Snake River Watershed Plan

Pennsylvania Mine, Peru Creek

Prepared on Behalf of:

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Prepared by:

Blue River Watershed Group
In cooperation with the
Snake River Watershed Task Force

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Executive Summary

The Snake River is the primary eastern tributary to the Blue River in Summit County Colorado. Much of the eastern edge of the Snake River watershed is along the west side of the Continental Divide. The Snake River watershed drains a heavily mineralized part of the central Rocky Mountains, an area that was heavily mined in the late 1800's and has had some ongoing mining related activities since then. The Snake River and several of its tributaries are on the Colorado 303(d) listing as streams that do not meet water-quality stream standards due to low pH and high concentration of four trace metals: dissolved cadmium, copper, lead and zinc. Much has been done to study the problems in the watershed, beginning at least in the early 1970s. Most of this work has focused in the tributary Peru Creek, which is home to the largest, longest serving mine in the watershed, the Pennsylvania Mine. This Mine has been targeted as the largest source of anthropogenic pollution in the watershed since the early-1970s studies. The Snake River Watershed Plan has been developed in an attempt to put the overall problem in some context, to summarize both the problems that exist and the work that has been and is being done to solve the water-quality problems in the watershed, to identify and prioritize the numerous sources of water-quality degradation and to study what successful remediation of the "most significant" water quality degrading sites might mean for the watershed.

The relevant watershed data indicate that the water-quality problems in the basin are a combination of natural "acid-rock drainage" and anthropogenic, mine related water-quality degradation. Parts of the upper watershed, particularly the upper Snake River and Cinnamon Gulch and Warden Gulch (tributaries of Peru Creek) are heavily impacted by natural water-quality degradation associated with the geology of the subwatersheds. The available data are not sufficient to definitely determine the relative contribution of the natural and anthropogenic sources watershed wide. A pending report, "Estimating instream constituent loads using replicate synoptic sampling, Peru Creek, CO by Robert Runkel, et al adds to our knowledge of the relative contributions and confirms that the Pennsylvania Mine is an important factor in Peru Creek. Furthermore, this issue is complicated by recent water-quality data that show higher levels of trace metals in the water at most of the sampling sites in the watershed (post 2006). Interpreting this increase in metals concentrations is one of the ongoing projects in the watershed. Resolving and understanding this increase is critical to implementation of this Plan, because if the basin water quality is deteriorating naturally, for some yet undetermined reason, implementation of this Plan to remediate the most damaging man-made mining related sites, will not have as much impact as this Plan suggests. A recent publications by Andrew Todd, et al "Climate-Change-Driven Deterioration of Water Quality in a Mineralized Watershed" adds to the understandings concerning the natural degradation of water quality in the Snake River watershed competing with the restoration activities underway.

This Plan identifies ten "Priority One" potential remediation-project sites that are significantly degrading the water-quality in the watershed. At each selected site, an estimate was made of the contribution of annual zinc load from that site. The Plan then proposes Best Management Practices (BMPs) at each of these sites and estimates the level of removal of zinc that might be possible if remediation were implemented. The estimated reduction in dissolved-zinc loads is about 18,900 lbs/y through implementation of these Priority One remediation projects. Three of the Priority One remediation projects have been partially implemented. These are the Silver Spoon Mine, the Delaware Mine and the Cinnamon Gulch realignment. The word partially is included here because water treatment per se was not included at any of the sites due to the liability issues associated with the Clean Water Act. Work has also been ongoing at the Pennsylvania Mine. The Plan then calculates the potential water quality improvement that might occur at key stream locations in the watershed. The results of this assessment indicate that even if these ten sites were remediated, water-quality standards in the Snake River at Keystone, the end point for purposes of this Plan, would not be attained. However, water quality standards (in terms of zinc concentrations) would be nearly met. Overall improvement in the lower portions of the watershed would be significant and might lead to improvement in the fishery in the lower basin above the confluence with the North Fork Snake River (NFSR). The Snake River above the NFSR and below Peru Creek does not sustain fish at this time.

This Plan should be considered a dynamic, working document with anticipated future revisions and enhancements. Consider it housed in a three-ring binder, so it can be modified as more data are collected, more data-assessment studies are completed, and initial remediation activities occur. The Plan has taken the available data and used it to the maximum to attempt to help understand the relationship between natural and anthropogenic sources. The remediation designs inherent in the analysis carry considerable uncertainty. More water-quality data are needed watershed wide, particularly tied to flow measurement to allow a better understanding of loading levels. The U.S. EPA has collected significant new data since 2009 in the watershed and Colorado River Watch has collected monthly data since 2009 on the Snake River at the River Run area at the Keystone Ski area. Expectations need to be tempered until the watershed is better understood and some remediation has occurred. Nevertheless, there are a number of projects that need remediation and will have a positive impact on water-quality. Currently, those professionals that are involved in the watershed to improve its water-quality, and there are many, need to continue their investigations, in order to better characterize the watershed, along with the implementation of initial remediation projects.

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ARD	Acid Rock Drainage
BRWG	Blue River Watershed Group
BMP	Best Management Practices
CDOW	Colorado Division of Wildlife
CDPHE	Colorado Department of Public Health and Environment
CDRMS	Colorado Department of Reclamation, Mining and Safety
CWA	Clean Water Act
D-Zinc	Dissolved Zinc
GPM	Gallons Per Minute
MOS	Margin of Safety
NFSR	North Fork Snake River
NPDES	National Pollutant Discharge Elimination System
NWCCOG	Northwest Colorado Council of Governments
QSP	Quartz-Sericite-Pyrite
SRWTF	Snake River Watershed Task Force
TMDL	Total Maximum Daily Load
TU	Trout Unlimited
TVS	Table Value Standards
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service

USGS	United States Geological Service
WLA	Waste Load Allocation
WQCD	Water Quality Control Division

1 Introduction

The Snake River Watershed Task Force (SRWTF) was established in 1998 to address water-quality problems in the Snake River watershed. The SRWTF has overseen and/or contributed to numerous study efforts on the Snake River, Peru Creek and other key tributaries in the watershed, primarily focusing on the pollution problems stemming from historical mining in the Peru Creek subwatershed. This small tributary drainage of the Snake River watershed is adversely impacted by numerous abandoned mines, some of which are causing serious water-quality problems, not only in Peru Creek but also downstream in the Snake River. The rest of the Snake River watershed has significant, but fewer, abandoned-mine problems. However, in some areas of the Snake River watershed, more natural water-quality problems occur due to the geology of those areas.

Over the past thirty years or so, numerous studies have been conducted by the U.S. Geological Survey (USGS), the U.S. Forest Service (USFS), the U.S. Environmental Protection Agency (USEPA), the state of Colorado's Division of Reclamation Mining and Safety (CDRMS, formally DMG), the Colorado Department of Public Health and Environment (CDPHE), the Colorado Geological Survey (CGS), the University of Colorado, the Colorado School of Mines (CSM), Northwest Colorado Council of Governments (NWCCOG), and various consultants hired by interested parties. Much of this work has been conducted in the past ten years and coordinated with the SRWTF. Appendix D summarizes most of these studies. Recent field investigations of streams in the watershed were conducted during the summers of 2006 through 2008 (CDPHE, 2008). Much of this work remains unpublished and focuses on the Pennsylvania Mine area. Additional work in this area is proposed for execution in 2009. The purpose of this Snake River Watershed Plan (Plan) is to summarize the major findings of these efforts, to document the major sources of water-quality degradation to streams of the watershed, to prioritize future water quality improvements through mining-related remediation and to estimate the anticipated benefits of near-term, high-priority remedial actions. In addition, recommendations are made for 2009 monitoring and data collection.

1.1 Watershed Description

1.1.1 Overview

The Snake River watershed encompasses approximately 78 square miles (mi^2) and is located east of Dillon Reservoir in Summit County, Colorado (Figure 1). It is part of the larger Blue River watershed. The eastern part of much of the Snake River watershed originates along the Continental Divide. The headwaters of the Snake River begin between the Continental Divide and Teller Mountain. A short distance below the upper valley, the Snake River is joined by Deer Creek, a tributary of nearly equal flow. This confluence occurs in a valley of wetlands, just above the town of Montezuma. As the Snake River flows through this upper valley, there are a number of leaking abandoned mine adits, many of which contribute flows, as well as regular seeps in the wetlands area. At the town of Montezuma, the tributary Sts. John Creek joins the Snake River. This tributary is also impacted by past mining activity. There are other leaking adits, old tailings piles and small tributaries as the Snake River flows past the Town of Montezuma. Not far below Montezuma is the confluence of the Snake River with Peru Creek. Peru Creek is one of the larger tributaries of the Snake River and begins in the high elevation southern slopes between Gray's Peak and Mt. Edwards immediately west of the Continental Divide. It has been heavily impacted from past mining activity (NWCCOG, 2006).

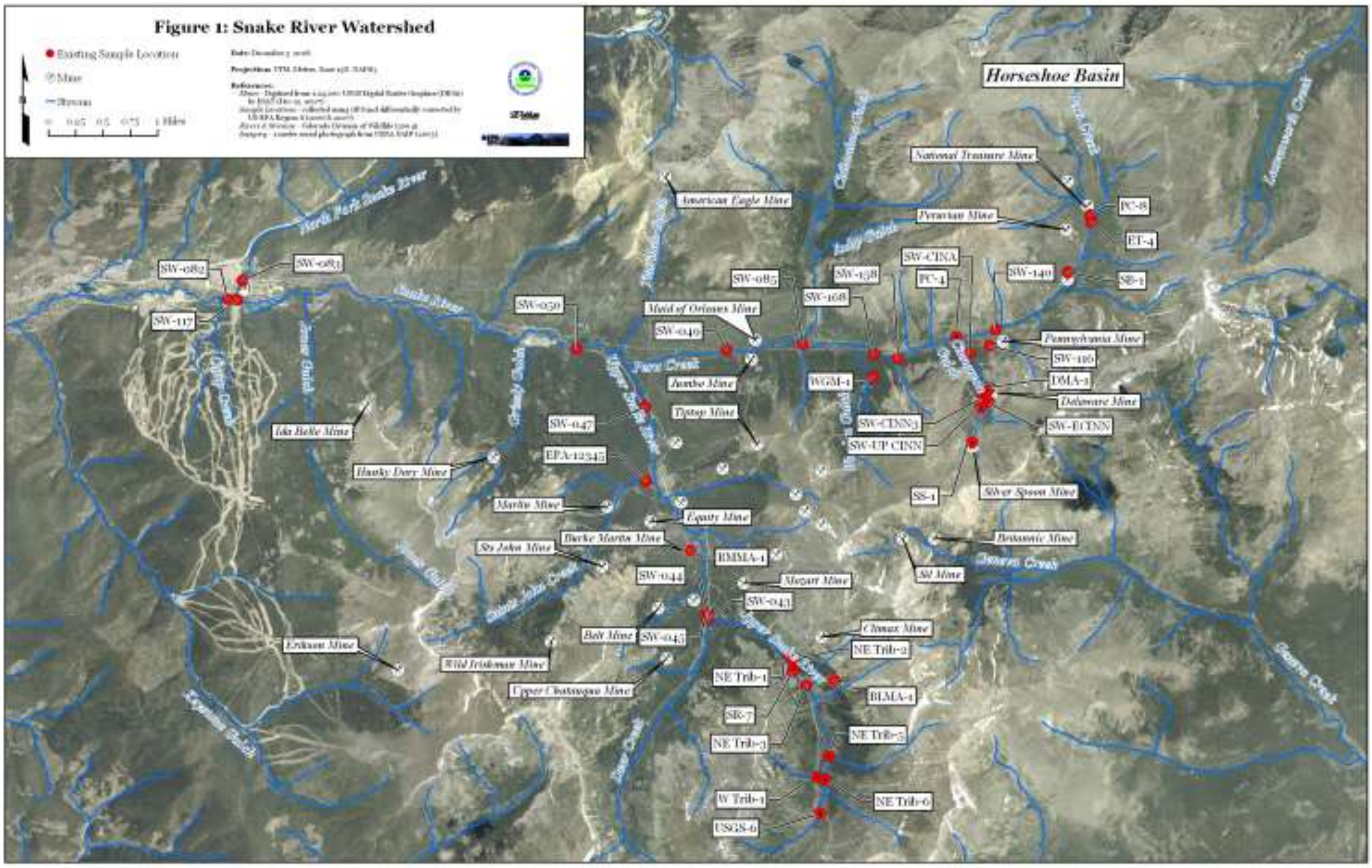

Figure 1. Snake River Watershed Map

There are few new water-quality related impacts as the Snake River flows below its confluence with Peru Creek towards Keystone. Thurman Gulch, Grizzly Gulch, Porcupine Gulch and Jones Gulch flow into the Snake River along this stream reach. Finally, in the area of the River Run development near the Keystone ski area, the North Fork Snake River (NFSR) joins the Snake River. Just below this confluence is a long-term USGS streamflow-gauging station. This Plan uses this stream location as the endpoint of the contributing watershed area.

Appendix A provides a detailed description of each of the sub basins in the Snake River watershed and a description of the Snake River itself. These descriptions identify the major factors affecting the water quality in each of the subbasins. The water quality in most of the basin is affected either by past mining activity or by mineralization in the basin which is naturally affecting water quality. The upper Snake River and Peru Creek are significantly impacted and are on the state's 303 (d) list of water quality impacted streams due to heavy metal contamination. Peru Creek tributaries Cinnamon Gulch and Warden Gulch are also heavily impacted.

Approximately 3,000 people live year-round in the Snake River watershed, though at peak times during the winter ski season, there may be as many as 20,000 residents--primarily at the Keystone Ski Resort. The Town of Montezuma is the only concentrated area of permanent habitation in the project area. There are an increasing number of cabins, mostly on old mining claims, that exist or are being constructed throughout the overall Snake River watershed. The Peru Creek subwatershed has a few summer cabins that are inhabited seasonally, although there are several undeveloped private properties stemming from old mining claims in this area. Federal lands, managed by the USFS, comprise 80 percent of the watershed. Summit County is the second largest landowner in the watershed providing additional recreational and open space terrain.

1.1.2 Geology

Morphology and surface deposition within the upper Snake River, including Peru Creek, has been dominated by glacial processes. Broad, U-shaped valleys that once held large masses of moving snow and ice, are now being downcut by snowmelt fed streams. Fluvial processes now drive erosion and deposition within the watershed. Hanging valleys that bound the main drainages feed snowmelt into the larger streams through large alluvial fans that formed at their outlets. Large talus and scree aprons surround many of the higher peaks and account for most of the colluvial material within the watershed. Large landslide and debris flow features have also been observed within the watershed, and appear to be associated with areas of extensive hydrothermal alteration.

Soil cover within the watershed is sparse to non-existent. Where existent, the soil is poorly developed and typically gravelly and sandy in texture with little organic material. Areas of thickest soil cover occur below timberline on heavily vegetated slopes. Areas of intense beaver activity within portions of watershed have resulted in moderate accumulations of sand, clay and organic material. Beaver dams have also acted as temporary holding ponds for much of the mine waste eroded by fluvial processes.

The drainage basins of the Upper Snake River are underlain by both metamorphic rocks of Precambrian age and tertiary igneous intrusives. Metamorphic rocks are made up of both the Idaho Springs Formation and the Swandyke Gneiss. Micaceous gneisses and schists compose the Idaho Springs Formation; whereas the Swandyke Gneiss is dominated by hornblende bearing gneisses. Swandyke Gneiss exposed in the western part of the upper Snake River headwaters is rich in both calcium, magnesium and iron, which does not appear to negatively affect water quality of streams in this area. The eastern area of the upper Snake River subwatershed exposes mostly Idaho Springs Formation, which is rich in both aluminum and silica, and appears to host much of the hydrothermal alteration that adversely affects water quality (Lovering, 1935 and Theobold, 1963).

Tertiary intrusion within the watershed is dominated by the Montezuma Stock, a large emplacement of quartz monzonite. Smaller dikes and plugs of varying composition, but mostly monzonite, are distributed throughout the watershed and appear tied to areas of mineralization (Lovering, 1935). The Montezuma Stock outcrops along Peru Creek and its confluence with the Snake River and is part of a voluminous suite of porphyries that was emplaced along the north-central Colorado Mineral Belt from Empire to Climax (Wood, 2005). Intrusion of the Montezuma Stock and associated smaller intrusions appears to have resulted in fracturing of the overlying metamorphic rocks which provided pathways for subsequent circulation of hydrothermal fluids.

Circulation of hydrothermal fluids through fractured rock resulted in both localized high grade mineralization and widespread country rock alteration. Both propylitic and quartz-sericite-pyrite (QSP) alteration account for most of the regional alteration. Propylitic alteration results in mineral assemblages not typically associated with poor water quality; whereas QSP alteration products are most often tied to natural degradation of water quality. An area of pervasively altered QSP rock is mostly concentrated south of the Montezuma Stock in the vicinity of Red Cone at the headwaters of the upper Snake River. A zone of extensively QSP altered rock extends along the continental divide in the eastern part of the watershed affecting four different drainages: upper Snake River, Peru Creek, Geneva Basin and Handcart Gulch (Church and others, 2008). Water quality in the areas of QSP appears to be consistently poor. Large ferricrete deposits are also found in portions of the upper Snake River and surrounding drainages. Ferricrete deposits, precipitated and cemented iron oxides, are common in areas underlain by and peripheral to QSP altered rocks.

Elevations range from about 9,500 feet above mean sea level (ft MSL) at the confluence between the Snake River and the North Fork of the Snake River to over to 14,000 feet MSL at the summit of Grays Peak, one of the peaks defining the headwaters of Peru Creek. The headwaters of the upper Snake River are bounded by peaks and ridges over 13,000 feet MSL.

A geology map of the area is provided by Stan Church of the USGS' Geological Division (Appendix B). Also given in Appendix B is a map of the areas with significant hydrothermal alteration (Church and others, draft 2008).

1.1.3 Hydrology

Stream gradients in the Snake River watershed are variable. The streams can be very steep with rapid stream flow rates or very flat in valley wetland areas with very slow flow rates. There is considerable variation in flow volumes between low-flow and high-flow regimes (see Appendix G).

The nearest stream gage with a long-term flow record is located on the Snake River near Keystone Resort; USGS gage 9047500, "Snake River near Montezuma." Stream flows throughout the watershed are typical of high-elevation mountain streams, as shown in Figure 2, with the majority of runoff and predominate peak flows occurring from springtime snowmelt. Smaller peaks are noted from summer thunder storms. Gage records indicate an average annual stream flow of 63.6 cubic feet per second (cfs) with spring snowmelt peaks varying between approximately 100 cfs to 900 cfs for the period 1995-2005 (http://waterdata.usgs.gov/nwis/nwisman/?site_no=09047500&agency_cd=USGS). Monthly water quality sampling has been conducted at this site for many years. The large variability in flow measurements between wet and dry years makes some of the water quality investigations in the upper basin more difficult to interpret. Average stream flows at selected sites are summarized in the Snake River Quality Assessment (Steele and Wyatt, 2004). A subtask of the 319 grant that provided the funds to do the remediation work at the Delaware Mine, the Silver Spoon Mine and the Cinnamon Gulch reroute was to update the quality and flow data in Peru Creek. "Trace-Metal Loads Assessment, Peru Creek Subwatershed and the Snake River above/below the Peru Creek Confluence Summit County, Colorado", by Tim Steele. Updated flows can be found in Appendix G.

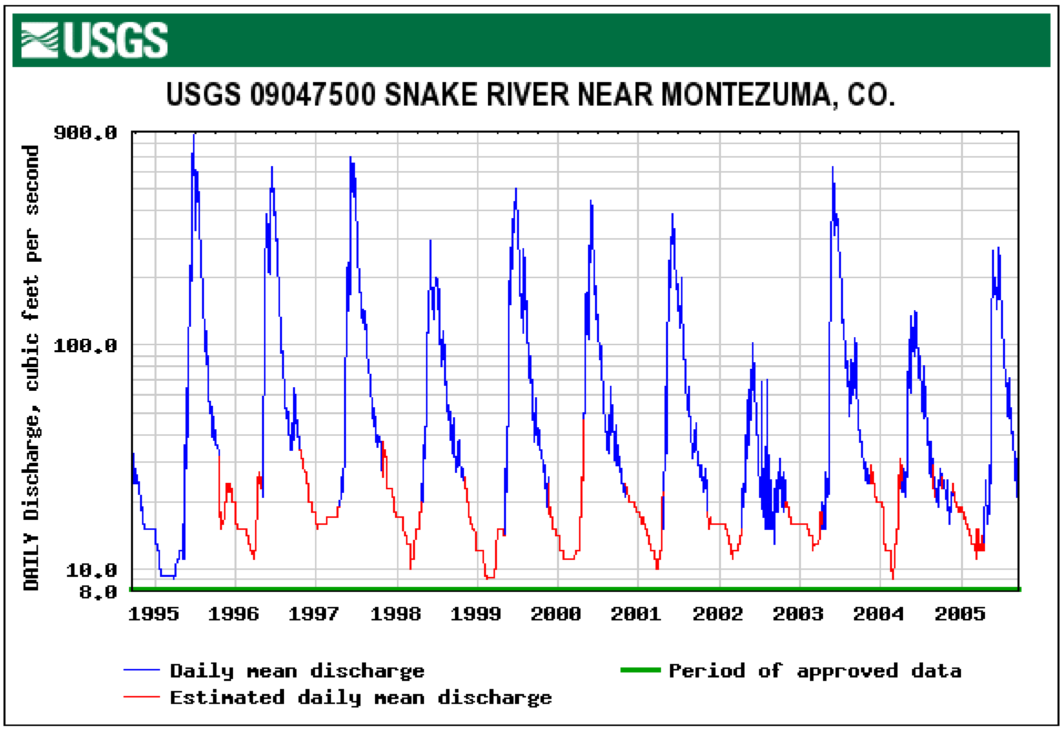

Figure 2. Seasonal and Multiyear Streamflow (X-axis in water years) Variations, Snake River near Keystone (SW-082)

The Vidler Tunnel in the very upper part of the Peru Creek subwatershed is a transbasin diversion into the Clear Creek watershed to the east. Historical diversions of the Vidler Tunnel Collection System from upper Peru Creek are 454 acre-feet, 590 acre-feet, and 509 acre-feet for dry, wet and average year hydrology, respectively (BoR, undated). An Environmental Assessment (EA) was initiated to increase these diversions. However, the City of Golden has indicated it does not intend to significantly increase these diversions at this time (personal communication, Lane Wyatt with Anne Bierle, 8/2006).

Other than the Vidler Tunnel diversions, there are no other significant natural or man-made hydrologic modifications in the Snake River watershed until its reach near the North Fork Snake River confluence. Keystone Resort makes water diversions of the Snake River for snow-making in late fall and early winter seasons just downstream from this confluence.

Arapahoe Basin Ski Area makes a diversion from the North Fork Snake River for snow making during the same time periods. The Snake River terminates at Dillon Reservoir.

1.1.4 Historical and Present Land Use

Mining began in the Snake River basin in the late 1860s and peaked in the 1890s. The Pennsylvania Mine, located in upper Peru Creek, operated over 70 years, finally closing in the 1940s. This mine was a lifeline to economically-depressed Summit County during its leanest years and was Summit County's most profitable mine (Gilliland, 1999). Along Peru Creek ran the famous Argentine Pass road which was one of the first and most treacherous roads crossing the Continental Divide. A former toll road, it connected the mining areas of Summit County to Georgetown and ultimately to Denver. A very detailed description of mining history can be found in "Mine Site History and Watershed Characterization of the Cinnamon Gulch Area, Dillon Ranger District, White River National Forest, Summit County, Colorado" by the Colorado Geological Survey (Wood and others, 2005; Gilliland, 2006). The Webster Pass in the upper Snake River area provided another travel passage from this area to the east.

According to a 2002 study prepared by American Geological Services (AGS, 2003) for Summit County, there are approximately 250 mine sites in the Peru Creek watershed with a patented mining claim (McKee, 2006), although no active mining in the watershed exists today. There are also many old mines in the upper Snake River, Deer Creek, Saints John Creek and along the Snake River above Peru Creek. Today, the Snake River watershed is mostly recreational land serving the needs of both ski-resort and cross-country/showshoe/ski-mobile visitors, summertime hikers and local residents. Popular activities include cross-country skiing, motor sports both summer and winter, hiking, mountain biking, and camping. Because most of the Snake River watershed's water quality in streams does not support fish, fishing is not a significant part of the recreation opportunities in the Snake River watershed.

1.2 *Impaired Waters*

1.2.1 Water Quality Standards and 303(d) Listing

The best discussion of applicable water-quality standards for the Snake River watershed is found in the TMDL document prepared by the CDPHE's Water Quality Control Division (WQCD) (CDPHE, 2008). The discussion and numerous tables below are extracted from that study document. The entire TMDL document is available from the CDPHE (and provided in Appendix F).

Different stream segments have been identified in the basin. Refer to Figure 1 to see the different segments. Blue River stream segment 6a is the mainstem of the Snake River, including all tributaries and wetlands from the source to Dillon Reservoir, except for specific listings in Segments 6b, 7, 8 and 9. Blue River Segment 6b includes the mainstem of Camp Creek, including all tributaries and wetlands from the source to the confluence with the Snake River. Blue River stream segment 7 is the mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8. Segments 6a and 7 have a use-protected (UP) designation. Blue River stream segment 8 is the mainstem, tributaries, and wetlands of the following streams: Keystone Gulch, Chihuahua Creek, Jones Gulch, and the North Fork Snake River. Stream segment 8 is generally of good water quality and uncontaminated by trace metals. Blue River stream segment 9 includes the mainstem and tributaries to Deer Creek.

In Colorado, stream segments are classified for their potential uses, and stream standards are assigned that are protective of those uses. Segments 6a, 6b, 7, 8, and 9 in the Blue River sub-basin are use classified as Aquatic Life Cold 1. Segments 6a, 6b, 8 and 9 are also classified as Recreation E; while Segment 7, Peru Creek and its tributaries, is classified as Recreation N. Similarly, the Snake River segments 6a, 6b, 8 and 9 are also use classified as water supply and agriculture. In parts of the mainstem and in several tributaries, elevated levels of heavy metals cause the streams to exceed the Aquatic Life use based standards, while other uses are attained.

The Colorado Basic Standards and Methodologies for Surface Water, Regulation 31, identify standards applicable to all surface waters statewide (WQCC, 2006a). The specific numeric standards assigned to the Snake River and its tributaries are contained in the Classifications and Numeric Standards for the Upper Colorado River Basin and North Platte River and contain standards for ammonia and ten heavy metals (WQCC, 2006b). In addition, a new, more stringent cadmium standard went into effect in 2008 at the Upper Colorado Basin Hearings. The pollutants that exceed water-quality standards (also called pollutants of concern) in the Snake River watershed are pH, dissolved cadmium, dissolved copper, dissolved lead, and dissolved zinc).

The relevant trace-metals' standards vary based on hardness. Because hardness generally tends to fluctuate seasonally, standards are developed by the CDPHE-WQCD on a monthly basis (WQCD, 2008) using the average hardness for each month to calculate the standard. In addition to the variation in stream hardness, flows also vary seasonally because of runoff and the dilution factor of the metals is seasonally affected. This seasonal flow variation is also accounted for by monthly standard values.

Water bodies that do not meet applicable water-quality standards are required to be placed on Colorado's "impaired" waters list, which is required by Section 303(d) of the Clean Water Act (CWA). The Snake River and Peru Creek were designated on this list due to exceedances of stream standards protective of the Aquatic Life classification.

Table1. Designated uses and impairment status for Segments 6 and 7, mainstem of the Snake River, Saints John Creek, and Peru Creek mainstem.

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COUCBL06	Mainstem of the Snake River, including all tributaries and wetlands from the source to Dillon Reservoir and Saints John Creek.	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Water Supply: Not Impaired Agriculture: Not Impaired
COUCBL07	Mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8.	Aquatic Life Cold 1: Impaired Recreation P: Not Impaired

This listing for the mainstem Snake River as an impaired water body also creates complications for expanded use of the water resource for activities such as snowmaking (less water for dilution). Both existing and future activities on public and private lands in the Snake River watershed are impacted by the degraded water quality. Specific actions to reduce metals pollution will help restore the overall health of the watershed.

1.2.2 Pollutants of Concern

The pollutants that exceed water quality standards in the Snake River watershed are pH, dissolved cadmium, dissolved copper, dissolved lead, dissolved manganese and dissolved zinc. However, the overall water quality picture is more complicated.

There is one minor permitted discharger into the Snake River associated with site construction (Table 2), and there are no permitted dischargers into or to Peru Creek. Consequently, the majority of the trace-metals loads to the Snake River and Peru Creek are contributed by natural geologic and non-permitted point sources (primarily draining adits from old mines) rather than permitted point source dischargers.

Table 2. Permitted dischargers in 303(d) listed segment of the Snake River.

	Dischargers	NPDES ID	SIC DESC	Design Capacity, mgd
Segment 6	Keystone Base 1 (River Run)	COG070488	heavy construction	0.050

The water-quality problems in the Snake River watershed involve a combination of natural acid rock drainage from heavily mineralized areas and anthropogenic (or man made) conditions associated with historic mining activities. These problems consist of leaking adits, waste-rock piles, tailings piles and other disturbed areas, including roads. The best summaries of the water quality conditions in streams of the Snake River watershed are currently found in the TMDL report (CDPHE, 2008) for the watershed and the draft Use Attainability Analysis(Wyatt and Steele, 2008). A number of data sources exist for the watershed and these were combined in the water-quality assessment (Steele and Wyatt, 2004). The following table from the TMDL report (CDPHE, 2008) summarizes those sources, some of which were used for that water quality study. Recently, additional data collection has occurred. Some of these more recent data were used by Dr. T.D. Steele for use in this Plan (Section 6.11 and Appendix G). The best update of this is the report mentioned above by Dr. T.D. Steele for the 319 grant to do remediation in the Cinnamon Gulch area.

Table 3. Sources of water-quality data for 303(d) listed stream segments in the Snake River watershed

Sources of water quality data for Snake River watershed
American Geological Services
Arapahoe Basin Ski Resort
Colorado Department of Public Health and Environment
Colorado Division of Wildlife River Watch
Colorado School of Mines
Colorado State University - Department of Fish, Wildlife & Conservation Biology
Denver Water Board
Hydrosphere Resource Consultants
Northwest Colorado Council of Governments
Summit Water Quality Committee
University of Colorado Institute for Arctic and Alpine Research
U.S. Environmental Protection Agency
U.S. Geological Survey
Colorado River Watch

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One of the most heavily naturally contaminated areas is the upper Snake River above Deer Creek(Boyer and others, 1999; Belanger, 2002; Tokash, 2003; Steele and Wyatt, 2004). The flows from the Montezuma Shear Zone and the disseminated pyrite in the rocks of the eastern upper basin result in a low pH, high metal concentration water quality. The following chart, taken from the TMDL report (CDPHE, 2008) summarizes the water quality problems for that part of the upper Snake River subwatershed upstream from Deer Creek.

Table 4. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above Deer Creek. Concentrations are given as 85th% values.

	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	52	6.5-9.0	3.9	0.26	3.7	5.1	28.8	1.2	0.0	71.2	848.1
Feb	54	6.5-9.0	3.9	0.27	4.5	5.3	28.6	1.3	2.0	73.5	751.2
Mar	55	6.5-9.0	4.0	0.27	3.8	5.4	28.9	1.3	2.0	74.7	831.0
Apr	52	6.5-9.0	3.7	0.26	4.0	5.1	20.6	1.2	1.8	71.2	681.3
May	36	6.5-9.0	3.7	0.20	2.2	3.7	18.0	0.8	1.3	52.0	458.3
Jun	26	6.5-9.0	3.8	0.15	2.3	2.8	14.5	0.6	0.8	39.4	338.9
Jul	32	6.5-9.0	3.8	0.18	3.4	3.4	19.4	0.7	1.0	47.1	626.2
Aug	32	6.5-9.0	3.8	0.18	4.4	3.4	21.7	0.7	0.7	47.1	488.4
Sep	39	6.5-9.0	3.9	0.21	3.5	4.0	24.0	0.9	1.0	55.7	721.2

Oct	47	6.5-9.0	3.7	0.24	3.2	4.7	18.4	1.1	1.0	65.3	683.8
Nov	48	6.5-9.0	3.8	0.24	4.6	4.8	19.7	1.1	1.7	66.5	888.4
Dec	50	6.5-9.0	3.8	0.25	4.9	5.0	22.8	1.2	0.7	68.8	809.6

Source CDPHE, (2008)

Deer Creek provides relatively good water quality to the Snake River (Steele and Wyatt, 2004, Appendix B). There is considerable precipitation of aluminum just below the confluence (Theobold, 1963) as Deer Creek water increases the pH of the Snake River (Steele and Wyatt, 2004, Table 1), resulting in the precipitation of aluminum. Below Deer Creek the Snake River flows through an upper valley above the town of Montezuma. There are numerous seeps and a few old adits that flow into the stream. The water quality from most of these adits is relatively good. At the lower end of Montezuma, Sts. John Creek flows into the Snake River. Just below this confluence there are other adit flows and seeps from contaminated tailings areas. Nonetheless, in the area above Peru Creek's confluence and below the Deer Creek confluence is one area of the Snake River where fish have been found in recent years (See section 1.2.4 for a complete discussion on fish surveys within the project reach). The following chart from the TMDL report (CDPHE, 2008) summarizes the Snake River water quality just above the Peru Creek confluence. The best update of the upper Snake River is the report cited above by Andrew Todd, et al.

Table 5. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above Peru Creek. Concentrations are given as 85th% values.

Current TVS Standards and Ambient Water Quality for Snake River above Peru Creek											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	62	6.5-9.0	6.3	0.27	1.5	6.0	9.0	1.5	0.0	74.7	483.9
Feb	59	6.5-9.0	5.7	0.26	1.6	5.7	7.9	1.4	0.0	72.4	490.9
Mar	65	6.5-9.0	5.4	0.29	1.8	6.2	7.2	1.6	0.0	80.4	531.3
Apr	57	6.5-9.0	5.2	0.26	1.4	5.5	6.6	1.4	0.0	71.2	634.9
May	43	6.5-9.0	5.3	0.22	1.8	4.4	7.9	1.0	0.7	59.3	844.5
Jun	33	6.5-9.0	5.9	0.16	0.8	3.5	1.5	0.7	0.0	42.0	250.0
Jul	42	6.5-9.0	5.7	0.18	1.0	4.3	1.8	1.0	0.0	47.1	275.4
Aug	53	6.5-9.0	5.7	0.19	2.0	5.2	5.8	1.3	0.0	50.8	469.1
Sep	54	6.5-9.0	5.5	0.22	2.2	5.3	9.3	1.3	0.0	60.5	498.8
Oct	60	6.5-9.0	5.4	0.25	1.6	5.8	5.0	1.4	0.0	67.7	505.6
Nov	56	6.5-9.0	5.2	0.26	1.7	5.5	7.6	1.3	0.0	71.2	436.2
Dec	57	6.5-9.0	5.8	0.25	1.9	5.5	9.0	1.4	0.0	70.0	456.0

Source CDPHE, (2008)

Peru Creek, one of the larger tributaries, also has significant water-quality problems. These problems are a combination of natural and anthropogenic impacts related to the mineralization of the area. The largest "point" source (considered from a regulatory standpoint currently as a nonpoint source) is the flow from the old Pennsylvania Mine adit (NWCCOG, 2006). Non-point source contaminated inflow into the stream occurs at the Pennsylvania Mine site and at a number of other mined areas. The Jumbo Mine (Figure 1) also provides significant point source flow. Two tributaries, Cinnamon Gulch and Warden Gulch (Figure 1) also provide metal-contaminated flow into Peru Creek. The following chart from the TMDL report (CDPHE, 2008) summarizes the Peru Creek water quality entering the Snake River.

Table 6. Current TVS and ambient water quality for 303(d) listed segment on Peru Creek. Concentrations are given as 85th% values.

Current TVS Standards and Ambient Water Quality for Peru Creek										
	pH Std	Observ pH	Cd-D TVS	Cd-D µg/L	Cu-D TVS	Cu-D µg/L	Pb-D TVS	Pb-D µg/L	Zn-D TVS	Zn-D µg/L
Jan	6.5-9.0	-	0.28	-	5.6	-	1.4	-	78.1	-
Feb	6.5-9.0	4.9	.029	5.2	5.9	60.3	1.4	7.2	81.6	1398.2
Mar	6.5-9.0	5.6	0.29	5.3	5.8	69.7	1.4	4.3	80.4	1640.0
Apr	6.5-9.0	5.9	0.29	5.5	5.9	64.3	1.4	5.9	81.6	1397.5
May	6.5-9.0	5.0	0.24	5.2	4.8	69.4	1.5	6.1	66.5	1264.0
Jun	6.5-9.0	5.1	0.2	6.3	3.7	102.0	1.5	7.1	52.0	1487.5
Jul	6.5-9.0	4.7	0.23	5.7	4.4	167.0	1.5	6.0	61.7	1508.5
Aug	6.5-9.0	5.1	0.22	3.4	4.2	56.6	1.5	4.8	58.1	955.0
Sep	6.5-9.0	4.7	0.28	4.6	5.5	108.6	1.4	6.0	77.0	1290.0
Oct	6.5-9.0	4.3	0.27	7.3	5.3	230.3	1.4	7.5	73.5	1700.0
Nov	6.5-9.0	5.4	0.28	5.7	5.7	75.5	1.4	5.8	79.3	1369.7
Dec	6.5-9.0	5.0	0.27	4.4	5.5	60.0	1.4	4.0	75.8	1300.0

Source CDPHE (2008)

Peru Creek's flow into the Snake River further degrades the water quality of the Snake River. The flows are approximately equal and the low quality of Peru Creek is easily seen in the water quality of the combined streams. The following chart, from the TDML report (CDPHE, 2008), summarizes the water quality of the Snake River below its confluence with Peru Creek.

Table 7. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites below Peru Creek. Concentrations are given as 85th% values.

Current TVS Standards and Ambient Water Quality for Snake River below Peru Creek											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	77	6.5-9.0	7.3	0.35	2.0	7.2	7.3	1.9	0.0	99.5	666.5
Feb	74	6.5-9.0	7.0	0.34	2.7	6.9	9.0	1.8	0.0	96.2	829.8
Mar	71	6.5-9.0	6.8	0.33	3.1	6.7	10.0	1.7	0.0	92.8	916.9
Apr	57	6.5-9.0	6.9	0.28	2.7	5.5	10.2	1.4	0.0	77.0	942.0
May	43	6.5-9.0	6.5	0.22	2.1	4.4	10.4	1.0	0.2	60.5	1000.6
Jun	39	6.5-9.0	6.6	0.21	2.0	4.0	5.9	0.9	0.1	55.7	499.4
Jul	49	6.5-9.0	6.4	0.25	2.5	4.9	10.0	1.2	0.0	67.7	621.9
Aug	51	6.5-9.0	6.5	0.25	2.4	5.0	18.4	1.2	1.2	70.0	742.4
Sep	63	6.5-9.0	5.4	0.30	2.8	6.0	32.1	1.5	2.6	83.8	829.6
Oct	63	6.5-9.0	5.9	0.30	2.9	6.0	33.8	1.5	0.0	83.8	860.8
Nov	70	6.5-9.0	6.2	0.32	2.0	6.6	4.0	1.7	0.0	91.7	675.6
Dec	72	6.5-9.0	7.0	0.33	2.1	6.8	8.1	1.8	0.0	93.9	658.5

Source CDPHE, 2008

The TMDL report (CDPHE, 2008) also summarized the problems by tributary for a number of the tributaries. This summary is useful in looking to areas to seek improvement.

The following table from the TMDL report (CDPHE, 2008) shows the problem areas.

Table 8. Current TVS and ambient water quality for tributaries to the Snake River and Peru Creek. Concentrations are given as 85th% values.

Snake River Tributaries								
	Deer Creek		Saints John Creek		North Fork Snake		Keystone Gulch	
Pollutant	TVS Standard	Ambient Conc.** µg/L	TVS Standard	Ambient Conc. µg/L	TVS Standard	Ambient Conc. µg/L	TVS Standard	Ambient Conc. µg/L
Hardness	-	36	-	69	-	38	-	34
pH	6.5-9.0	6.6	6.5-9.0	6.7	6.5-9.0	7.4	6.5-9.0	6.5
Cd-D	0.2	0.02	0.3	0.8	0.2	0.0	0.2	0.3
Cu-D	3.7	1.7	6.5	0.0	3.9	1.5	3.3	15.6
Mn-D	-	-	-	-	-	-	-	-
Pb-D	0.6	0.1	1.7	3.0	0.9	0.0	0.8	0.0
Zn-D	52.0	41	90.6	392.0	54.5	7.8	49.6	15.7

Peru Creek Tributaries						
	Cinnamon Gulch		Warden Gulch		Chihuahua Gulch	
Pollutant	TVS Standard	Ambient Conc. µg/L	TVS Standard	Ambient Conc. µg/L	TVS Standard	Ambient Conc. µg/L
Hardness	-	48	-	61	-	36
pH	6.5-9.0	3.7	6.5-9.0	3.8	6.5-9.0	6.9
Cd-D	0.2	9.0	0.3	37.6	0.2	0.0
Cu-D	4.8	223.1	5.9	61.6	3.7	0.0
Mn-D	1291.8	3170.0	1399.2	7749.5	1173.8	5.2
Pb-D	1.1	47.8	1.5	1.2	0.6	0.0
Zn-D	66.5	1770.0	81.6	11481.5	52.0	0.8

** Ambient concentration calculated from 1989-2006.

There are no significant sources of poor water quality to the Snake River below Peru Creek. There are a number of smaller tributaries, such as Grizzly Gulch, Thurman Gulch, Jones Gulch and a couple of un-named gulches, but all have relatively low flows compared to the Snake, have no significant sources of anthropogenic pollution, and have different geology resulting in no significant natural acid rock drainage. The next major water quality issue is the confluence with the North Fork of the Snake River. The North Fork is also a large tributary of clean mountain runoff of high water quality.

The following two charts, from the TMDL report, summarize Snake River water quality above and below the confluence of the Snake River and the NFSR.

Table 9. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above North Fork Snake River. Concentrations are given as 85th% values.

Current TVS Standards and Ambient Water Quality for Snake River above North Fork											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	66	6.5-9.0	6.8	0.31	2.0	6.3	5.4	1.6	0.0	87.2	694.2
Feb	62	6.5-9.0	6.4	0.29	2.2	6.0	4.9	1.5	0.0	82.7	733.6

Mar	60	6.5-9.0	7.1	0.29	2.0	5.8	4.3	1.4	0.0	80.4	648.6
Apr	58	6.5-9.0	7.0	0.28	2.2	5.6	4.8	1.4	0.0	78.1	672.1
May	45	6.5-9.0	6.7	0.23	2.2	4.5	6.0	1.0	0.6	62.9	687.0
Jun	37	6.5-9.0	6.8	0.20	1.8	3.8	5.9	0.8	0.0	53.3	454.8
Jul	43	6.5-9.0	6.7	0.22	2.4	4.4	9.0	1.0	0.0	60.5	548.6
Aug	49	6.5-9.0	6.6	0.25	2.7	4.9	8.9	1.2	0.0	67.7	643.9
Sep	59	6.5-9.0	6.6	0.28	3.5	5.7	14.0	1.4	0.0	79.3	845.8
Oct	50	6.5-9.0	6.5	0.25	2.8	5.0	9.8	1.2	0.0	68.8	776.8
Nov	56	6.5-9.0	6.6	0.27	2.5	5.5	8.0	1.3	0.0	75.8	678.4
Dec	64	6.5-9.0	6.8	0.30	2.1	6.1	7.0	1.5	0.0	85.0	609.0

Source CDPHE, 2008

Table 10. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites below North Fork Snake River. Concentrations are given as 85^{th}% values.

Current TVS Standards and Ambient Water Quality for Snake River below North Fork											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	56	6.5-9.0	6.8	0.27	1.6	5.5	2.9	1.3	0.0	75.8	434.5
Feb	52	6.5-9.0	6.7	0.27	1.6	5.1	2.8	1.2	0.0	74.7	388.9
Mar	55	6.5-9.0	6.7	0.27	1.3	5.4	2.1	1.3	0.0	74.7	512.0
Apr	56	6.5-9.0	6.9	0.27	1.3	5.5	5.5	1.3	0.0	75.8	355.7
May	43	6.5-9.0	6.9	0.22	1.4	4.4	5.4	1.0	0.0	59.3	427.8
Jun	32	6.5-9.0	7.0	0.18	1.0	3.4	5.7	0.7	0.5	48.3	296.9
Jul	40	6.5-9.0	7.0	0.20	1.6	4.1	8.0	0.9	0.0	54.5	325.1
Aug	49	6.5-9.0	7.1	0.24	2.1	4.9	6.2	1.2	0.0	64.1	408.5
Sep	47	6.5-9.0	7.0	0.25	2.0	4.7	6.1	1.1	0.0	70.0	510.3
Oct	51	6.5-9.0	6.9	0.26	2.3	5.0	6.1	1.2	0.5	72.4	508.5
Nov	52	6.5-9.0	7.0	0.26	1.7	5.1	3.2	1.2	0.0	72.4	417.7
Dec	58	6.5-9.0	6.5	0.26	1.3	5.6	3.0	1.4	1.9	72.4	392.0

Source CDPHE, 2008

Water quality problems still exist below the confluence for all of the four trace metals of concern for which the Snake River is on the 303(d) listing (and manganese in Peru Creek). The following table, also taken from the TMDL report (CDPHE, 2008), provides some guidance on how to prioritize remedial actions for some of the identified problems. Although this summary is useful, the values given for Warden Gulch and Cinnamon Gulch have issues associated with them. Most of the Cinnamon Gulch data came from a study during very low flow (Wood and others, 2005). More recent data, such at that from the USEPA 2007 sampling program, show that the Cinnamon Gulch drainage is contributing more than shown in the TMDL table. Further, an overall review of the Warden Gulch drainage data for this Plan, suggest a much smaller zinc contribution from that drainage.

Table 11. Annual cadmium, copper, lead and zinc total maximum daily load contributions for the Snake River and Peru Creek tributaries. Stream loads are given for dissolved cadmium, copper, lead and zinc.

	Snake River				Peru Creek		
	Deer Creek	Saints John Creek	North Fork Snake River	Keystone Gulch	Cinnamon Gulch	Warden Gulch	Chihuahua Gulch
Pollutant	Load Contribution, lbs/y	Load Contribution, lbs/y	Load Contribution, lbs/y	Load Contribution, lbs/y	Load Contribution, lbs/y	Load Contribution, lbs/y	Load Contribution, lbs/y
Cd-D	1.1	3.7	0.0	1.0	0.9	170.7	1.1
Cu-D	97.5	0.0	78.3	49.6	22.0	279.3	0.0
Pb-D	5.7	13.6	0.0	0.0	4.7	5.4	0.0
Zn-D	2350	1780	410	49.8	174	52050	0.1

Source CDPHE, 2008

1.2.3 Overview of TMDL Assessment Methodology

When stream segments are listed as impaired on the 303(d) list the State of Colorado is required to develop a Total Maximum Daily Load (TMDL) assessment. A TMDL is comprised of the load allocation (LA), which is that portion of the pollutant load attributed to natural background or the non-point sources, the Waste Load Allocation (WLA), which is that part of the pollutant load associated with point source discharges, and a Margin of Safety (MOS). The TMDL is the sum of the LA, WLA, and MOS and is typically expressed as pounds of metal per day.

$$\mathbf{TMDL = WLA + LA + MOS}$$

The WQCD has completed a TMDL report for the Snake River watershed (CDPHE, 2008) following a 319 grant to the NWCCOG which summarized much of the data needed for the TMDL effort (Wyatt, 2008). The vast majority of the metals load resulting in impaired water quality is attributed to natural and non-regulated point sources (primarily leaking adits from old mines). All of these leaking adits are point sources in violation of the CWA, but no action has been taken since current owners had nothing to do with the creation of the problem. In the TMDL report (CDPHE, 2008), the WQCD has estimated the metals load that would result in achieving compliance with the table value standards (TVS). That load is then compared to the existing ambient stream load for each metal to determine the load reduction necessary to meet stream standards. These charts are all taken directly from the TMDL report (CDPHE, 2008). Zinc is used here to illustrate the scope of the problem. The reduction required to meet the standards are very high, frequently in the 90+% range. Therefore, it is unlikely that even if all of the anthropogenic sources are remediated, the level of cleanup will be sufficient for the existing water-quality standards to be met. However, the reductions possible are large and could result in turning much of the Snake River below Deer Creek into a fishery.

One comment to keep in mind regarding these charts, extracted from the Snake River TMDL (CDPHE, 2008) is in order. The "Average Stream Load" column shows a total at the bottom of the column. This total is not an average daily stream load that can be multiplied by

365 to reach an annual load. Rather, this total is the sum of the monthly average loads. In order to more accurately calculate the average annual loads, it is necessary to multiply each monthly average daily load by the number of days in that month and sum the totals for all 12 months. Furthermore, because of the methodology used by the state in calculating these loadings (specifically TMDL loads were calculated with 85th percentile concentrations and chronic low flows (30E3) by USEPA DFLOW software; whereas, stream loads were calculated from average concentrations and median monthly flows), they are greater than the dissolved zinc loads calculated from the historical data in this report (Section 6.11 and Appendix G).

Table 12. Zinc total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Dissolved Zinc						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Avg. Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	2.29	2.04	0.25	-	-	-
Feb	2.39	2.13	0.26	45.48	43.09	95%
Mar	2.35	2.10	0.26	53.34	50.99	96%
Apr	2.39	2.13	0.26	53.86	51.48	96%
May	2.16	1.92	0.24	143.05	140.88	98%
Jun	2.32	2.06	0.26	522.92	520.60	100%
Jul	2.60	2.32	0.29	237.86	235.26	99%
Aug	2.31	2.06	0.25	82.51	80.20	97%
Sep	3.06	2.72	0.34	83.59	80.53	96%
Oct	2.66	2.36	0.29	90.56	87.90	97%
Nov	2.67	2.38	0.29	57.74	55.06	95%
Dec	2.37	2.11	0.26	50.11	47.73	95%
Annual Load	29.58	26.32	3.25	1421.01	1393.72	98%

Source CDPHE, 2008

Table 13. Zinc total maximum daily load allocations for the portion of Segment 6, the upper portion of Segment 6, from the headwaters of the Snake River to immediately above the Peru Creek confluence. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Dissolved Zinc						
Snake River above Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	1.63	0.0	1.63	15.41	13.78	89%
Feb	1.58	0.0	1.58	10.93	9.35	86%
Mar	1.76	0.0	1.76	14.85	13.10	88%
Apr	1.56	0.0	1.56	16.67	15.11	91%

May	1.59	0.0	1.59	75.54	73.95	98%
Jun	1.89	0.0	1.89	116.12	114.23	98%
Jul	1.95	0.0	1.95	70.40	68.45	97%
Aug	1.92	0.0	1.92	38.50	36.58	95%
Sep	2.29	0.0	2.29	29.42	27.13	92%
Oct	2.18	0.0	2.18	24.74	22.56	91%
Nov	2.04	0.0	2.04	18.37	16.33	89%
Dec	1.75	0.0	1.75	16.48	14.73	89%
Annual Load:	22.14	0.0	22.14	447.43	425.29	95%

Source CDPHE, 2008

Table 14. Zinc total maximum daily load allocations for the portion of Segment 6, the Snake River below the Peru Creek confluence. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Dissolved Zinc						
Snake River below Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	6.23	0.0	6.23	50.74	44.51	88%
Feb	6.02	0.0	6.02	58.40	52.38	90%
Mar	5.81	0.0	5.81	69.52	63.71	92%
Apr	4.82	0.0	4.82	96.77	91.95	95%
May	4.42	0.0	4.42	294.59	290.18	99%
Jun	6.20	0.0	6.20	593.83	587.63	99%
Jul	7.01	0.0	7.01	339.38	332.37	98%
Aug	6.72	0.0	6.72	195.32	188.61	97%
Sep	8.04	0.0	8.04	146.83	138.79	95%
Oct	7.08	0.0	7.08	120.44	113.36	94%
Nov	7.04	0.0	7.04	72.60	65.56	90%
Dec	6.49	0.0	6.49	60.66	54.16	89%
Annual Load:	75.87	0.0	75.87	2099.07	2023.20	96%

Source CDPHE, 2008

Table 15. Zinc total maximum daily load allocations for the portion of Segment 6, the Snake River below Peru Creek and above North Fork Snake River. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Dissolved Zinc						
Snake River above NFSR Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	2.76	0.0	2.76	34.51	31.75	92%
Feb	2.62	0.0	2.62	31.42	28.80	92%
Mar	2.54	0.0	2.54	27.36	24.82	91%
Apr	2.47	0.0	2.47	43.18	40.71	94%

May	2.57	0.0	2.57	280.91	278.34	99%
Jun	3.99	0.0	3.99	430.59	426.60	99%
Jul	4.12	0.0	4.12	258.50	254.38	98%
Aug	4.14	0.0	4.14	131.61	127.46	97%
Sep	4.85	0.0	4.85	108.96	104.11	96%
Oct	3.51	0.0	3.51	75.89	72.38	95%
Nov	3.35	0.0	3.35	48.40	45.04	93%
Dec	3.18	0.0	3.18	36.27	33.09	91%
Annual Load:	40.11	0.0	40.11	1507.59	1467.48	97%

Source CDPHE, 2008

Table 16. Zinc total maximum daily load, waste load allocation, and load allocations for the portion of Segment 6, the Snake River below the North Fork Snake River to the confluence with Dillon Reservoir. Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Dissolved Zinc						
Snake River below NFSR Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	3.81	0.030	3.78	34.37	30.57	89%
Feb	3.75	0.030	3.72	26.76	23.01	86%
Mar	3.75	0.030	3.72	29.61	25.86	87%
Apr	3.81	0.030	3.78	36.65	32.84	90%
May	3.84	0.030	3.81	229.08	225.23	98%
Jun	5.74	0.030	5.71	409.96	404.22	99%
Jul	5.88	0.030	5.85	241.24	235.36	98%
Aug	6.23	0.030	6.20	125.80	119.57	95%
Sep	6.80	0.030	6.77	108.82	102.02	94%
Oct	5.86	0.030	5.83	78.79	72.93	93%
Nov	5.08	0.030	5.05	47.56	42.48	89%
Dec	4.30	0.030	4.27	36.66	32.36	88%
Annual Load:	58.86	0.37	58.49	1405.29	1346.43	96%

Source CDPHE, 2008

As these previous tables indicate, the amounts of reduction in the trace-metal loads to meet the table value standards are significant, even downstream from the confluence with the NFSR (see Section 6.11 and Appendix G). Although there are as many mines contributing a significant amount of zinc, cleaning up these sources will not attain compliance with targeted stream standards. The natural sources of metals in this watershed will preclude compliance with table value standards. However, that does not mean that the improvements to water quality in the lower portions of the basin are not worth the effort. It is likely that the lower portions of the basin will support fish such as brook trout if the Priority-1 sites were successfully remediated. The Todd et al report makes the long term issue of water quality more difficult to predict as the natural sources seem to be getting worse.

1.2.4 Impacted Species

Despite the magnitude of water-quality data gathered for both the Snake River and Peru Creek, there have been few recent aquatic life surveys. This summary is taken from a previous water-quality assessment (Steele and Wyatt, 2004) and the TMDL report (CDPHE, 2008), which provide the best summaries of this aspect of watershed conditions. Reference also is made to information reported by Todd and others (2004).

Chadwick and Associates completed an initial characterization of benthic invertebrates for the Snake River in 1985. The mean density and diversity of benthic invertebrate populations increased in a downstream direction along the Snake River, in conjunction with increasing distance from the Peru Creek confluence (Chadwick & Associates, 1985a). In a follow-up study on trout populations, no fish were found at sites sampled on the Snake River upstream of Deer Creek, or just downstream of Peru Creek (Chadwick & Associates, 1985b). In addition, no fish were found at a Peru Creek site above the Pennsylvania Mine, despite the presence of relatively good macrohabitat (Chadwick & Associates, 1985b). Brook trout were the most abundant fish species collected in the lower Snake River, and sizeable populations of brook trout existed in the lower NFSR and Deer Creek. According to this study, trout were not present in the upper NFSR due to a physical barrier and not ARD.

Chadwick and Associates performed another biological investigation on the Snake River watershed in 1995. They concluded that resident fish do not occur in the mainstem of the Snake River between where Peru Creek and the NFSR tributaries enter); moreover, stocking provides the majority of fish biomass downstream of the NFSR (Chadwick & Associates, 1996). Similar to previously conducted studies, density and diversity of benthic macro-invertebrates were both significantly reduced in the Snake River upstream of the NFSR and below Peru Creek. The USEPA performed macro-invertebrate surveys within the Snake River and Peru Creek in 2001. Preliminary results demonstrate a pronounced lack of taxa in both the Snake River and Peru Creek. A report documenting these results is still pending.

In-situ caged rainbow trout studies demonstrated significant mortality (99 percent over 10 days) in the Snake River below Peru Creek and above the NFSR (Todd and others, 2007). Trout mortality was positively correlated with concentrations of metals approaching or exceeding conservative toxicity thresholds (Cd, Cu, Mn, and Zn) (Todd and others, 2006). Further, limited caged trout mortality was observed (21 percent over 10 days) in the Snake River below the NFSR. All caged rainbow trout placed in the NFSR drainage, which is known to support a self-sustaining, healthy brook trout fishery, survived through the duration of this study.

In September 2006, a visual habitat characterization was performed as a part of the UAA (Wyatt, 2008) by Walsh Aquatic Associates, Inc. to determine if the high level of metals in the Snake River and Peru Creek were the limiting factors for healthy trout populations or if there was simply no adequate habitat for fish. They concluded that abundant macrohabitat exists to support healthy trout populations in the Snake River (Walsh, 2007, see Appendix E). Consequently, if water quality were to be improved, the physical macrohabitat is judged to potentially support a healthy and sustainable trout population based upon this latest evaluation.

The Colorado Division of Wildlife (CDOW) and volunteers conducted limited electro-fishing during July and August 2007, and again in August 2008, to determine whether fish were present or absent in the mainstems of the Snake River and Peru Creek. Stocked populations of rainbow trout and resident populations of brook trout were found in the Snake River below North Fork Snake River. Brook trout were also found in the Snake River directly above Peru Creek and in Saints John Creek. Fish were absent in the Snake River below Peru Creek and directly above the North Fork Snake River as well as throughout Peru Creek, including both above and below the Pennsylvania Mine. Andrew Todd in his presentation February 13, 2013 to the Snake River Watershed Task Force presented fish populations in the Snake River above Peru Creek for 2008, 2009, 2010 and 2012 which showed significant declines each year.

USFS biologists also undertook macro-invertebrate sampling during July and September 2007 on the mainstem Snake River and Peru Creek along with the corresponding tributaries. Diversity (Shannon index) and number of taxa of macro-invertebrate populations on the mainstem of the Snake River were greatest below the North Fork Snake River and upstream of Peru Creek. Tributaries to the Snake River (NFSR, Saints John Creek, and Deer Creek) demonstrated high diversity numbers and an overall healthy number of taxa during the July sampling event. Peru Creek upstream of the Pennsylvania Mine demonstrated the highest number of taxa and diversity in macroinvertebrate assemblage of all of the Peru Creek mainstem sites during the July sampling event, although these sites too were pretty degraded. The metrics for all sites sampled in July and September on both Peru Creek (SW-049, PC-4, SW-140) and 2 out of 3 sites on the Snake River (SW-47, SW-082) showed a sharp decline in September samples due to adverse impacts from a large rainfall event. SW-50 had pretty low metrics in both months.

Additional studies are underway and planned. There has been a general recognition that more biological data were needed in the basin and a number of USEPA, USFS, USGS and Colorado state agency funded efforts are working to fill this void.

2 Watershed Partnerships and Efforts

2.1 Stakeholders

The SRWTF is a voluntary collaborative effort initiated by those concerned about water quality of the Snake River watershed to gather more information regarding sources of water quality problems and identify opportunities to improve water quality in the watershed. This stakeholder group has been coordinated by the Keystone Center since its inception in 1998. The SRWTF's focus has been on identifying and evaluating opportunities to reduce heavy metal concentrations of concern primarily in Peru Creek. Recent efforts have expanded the area of concern to the entire Snake River basin. Membership has been voluntary and active involvement from some entities has fluctuated over the years. A list of SRWTF members is given in Appendix C. Current core members of the SRWTF include the following: NWCCOG, USEPA, USFS, USGS, CDPHE, CDRMS, Trout Unlimited (TU), Blue River Watershed Group (BRWG), Summit County Open Space, Keystone Resort, and Arapahoe Basin Ski Area.

2.2 Public Outreach Activities and Technical Assistance

Since its inception in the late 1990's, the primary role of the SRWTF has been to provide information outreach and coordination on technical activities and studies underway in the Snake River basin. The Task Force meets irregularly about an average of three times per year primarily to provide updates, coordinate various activities and seek input. Informal subcommittees organize agendas and presentations as well as being the focal point for developing work plans for activities within the watershed. Much of the technical work that has been performed in the watershed is done by SRWTF members. The Keystone Center and the BRWG are working to make some of the public-outreach efforts associated with the development of this watershed plan be conducted in association with SRWTF meetings, so much of the talent working in the watershed will be available to deliberate and to answer questions at the meetings.

The BRWG has been working since receiving the grant to keep the people of Summit County informed of the activities underway in the basin. The Snake River Watershed Plan development was discussed at a March, 2008 Summit Water Issues class held at the Colorado Mountain College campus in Breckenridge. The Plan development was again discussed at the "State of the River" meeting held in June, 2008. This update will be discussed at the "State of the River" meeting May 8, 2013. The Plan was also discussed at the June, 2008 "Future of Water" forum held by the BRWG and Our Future Summit. In July, 2008, at the awards presentation held by the Summit Foundation to award its second half of 2008 grants, the plan was again discussed as the BRWG was asked to be the environmental awards recipient speaker. In August, 2008, the BRWG had a booth at the Continental Divide Land Trust annual meeting, where the plan development was displayed. Finally, in September, 2008, the Plan development and status were again discussed at the Patagonia Film Festival. This update will also be discussed at the SRWTF meeting May 29, 2013.

The BRWG had four mailings to water interested parties in 2008 which is designed in part to keep citizens informed of the development of the Snake River Watershed Plan. These mailings were sent in April, August, September and December, 2008. These newsletters discussed the progress of the plan development.

During the summer of 2008, the development of the BRWG website was finalized. This site provides up to date information on the plan development including the interim report filed in September, 2008. All of the events sponsored by the BRWG are also described on the web site. The actual Plan will be placed on the site once it is approved.

On December, 4, 2008 a public meeting to discuss the water-quality issues leading to the development of the Plan was held in Frisco, CO. The discussion at the meeting outlined the issues that have been addressed, different prioritization methodologies, the tradeoffs that need to be made, and the challenges associated with Plan development. A second public meeting was held on March 19, 2009. This meeting was held to discuss the specific elements of the Plan and the implementation challenges. The meeting was structured to first put the problems in context and then to discuss the potential solutions outlined in the Plan.

2.3 Hydrologic/Water-Quality Monitoring Program

Monitoring of this watershed's streams is ongoing and is coordinated by the SRWTF. The USEPA (in collaboration with CDPHE-HMWMD) has taken the lead in add-on water-quality monitoring surveys over the past three years. For the future, a systematic, technically sound water-quality monitoring plan is an essential component to the characterization of water-quality changes and, in turn, to the evaluation of the watershed management decisions and environmental alterations that cause those changes. To date, data collection efforts in the watershed have focused on compiling an extensive set of water-quality data, for ambient characterization and future changes due to remediation but regular water quality monitoring programs have not been established. Once cleanup projects are underway, a more formalized monitoring plan will be required in order to evaluate the effectiveness of remediation. The most important monitoring site is on the mainstem Snake River near Keystone, below the confluence with the NFSR. Since 2006, the BRWG and River Watch have collected water-quality data at this site for a suite of water-quality parameters on a monthly basis. Flow is measured at a USGS monitoring station at this site except during the winter (since 2005) when ice covering the stream channel makes flow measurement difficult. Nutrient and macroinvertebrate sampling has also occurred at this site about every other year since 2009.

The map below (Figure 2a), was taken from the Steele and Wyatt (2004) water-quality assessment of available historic and recent water quality data in the Snake River watershed. This map shows the locations of numerous monitoring sites for which data were used in that study. Since then, additional work has been conducted and other data sources have been found. Although there are many available data, they are from different times, many sample results have no flow measurements, many samples were collected and analyzed differently and resulted data cannot readily be combined to provide better confidence in the resultant information that the data provide.

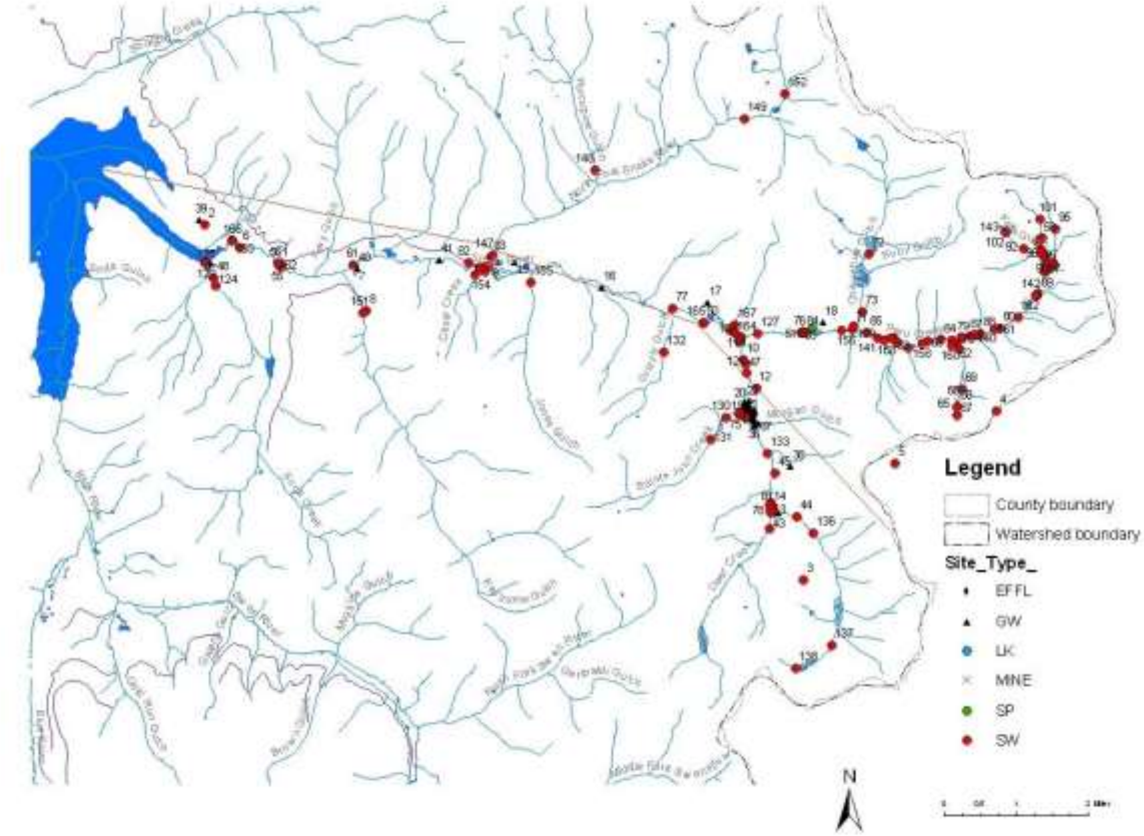


Figure 2a. Historical Water-Quality Monitoring Stations in the Snake River Watershed

The following table shows most of the major sites that have been sampled through USEPA and CDPHE investigations during the previous three years and provide important recent ambient data. Many of these sites have had data collected in previous studies as well (Steele and Wyatt, 2004).

Table 17. Recent Water-Quality Monitoring Sites, Snake River Watershed

Site Designation	Site Description
Snake River Monitoring Sites (downstream to upstream)	
SW-082	Snake River downstream of the North Fork Snake River at the current USGS Stream flow gage. From large parking lot, drive toward the resort and turn left at the River Lodge sign. Pass the first set of condos, turn right and drive across a large parking lot with telephone poles. This is a key site recommended for further monitoring.
SW-117	Snake River upstream of the North Fork Snake River. From Montezuma Road, turn right on Hunki Dori Road. Drive to the end and turn right into Hunki Dori parking lot. Sample sire is upstream of walking bridge at the base of the gondola.

SW-050 Snake River downstream of Peru Creek. Site is approximately ¼ to ½ mile upstream of EPA site 39355710553. Sample upstream of where Montezuma Road crosses the Snake at the concrete blocks. This is about ½ mile below where the Montezuma Road crosses the Snake River at the Peru Creek access parking lot. This is a key site selected for further monitoring.

SW-047 Snake River upstream from Peru Creek. Site is just upstream from the Montezuma road crossing at the Peru Creek parking lot. This is a key selected site for continued monitoring.

SW-045 Snake River downstream of Deer Creek confluence. Sample at USGS staff gage downstream of the road. Make sure the sample is well mixed.

SW-044 Snake River upstream of Deer Creek confluence. Sample at the USGS staff gage.

Snake River Tributaries (downstream to upstream)

SW-083 North Fork of Snake River upstream of the confluence with Snake River. Sample site is where Montezuma Road crosses the stream near the large Keystone parking lot.

EPA-12345Saints John Creek just upstream of the confluence with the Snake River.

EPA-SJA2 Saints John Mine adit just upstream of confluence with Saints John Creek. Sample sire is at road crossing downstream of where the adit flow combines with clean-looking seep water.

EPA-SJA Saints John mine adit as it comes out of the ground. Drive upstream through the old town of Saints John, take a left where the road forks, cross the private property boundary, and park at the top of the mine dump.

EPA-SJ2 Saints John Creek upstream of confluence with adit flow at road crossing. Sample site is across from a cabin called "The Berry Home-1869".

SW-043 Deer Creek upstream of confluence with Snake River. Sample in wooded area near the USGS gage about 100+ yards upstream of confluence.

BLMA-1 Blanche Mine adit. When heading up Webster Pass from Montezuma, take a left on a 4 wd road just before crossing the Snake River. Road will continue to the sampling site. Samples are collected at the mine portal.

Peru Creek (downstream to upstream)

SW-049 Peru Creek ½ mile upstream of confluence with the Snake River. Sample site is where Peru Creek road crosses the creek at the former University of Colorado (USGS supported) stream gage. Same location as EPA site 39355710551. This is a key site recommended for further monitoring.

SW-085 Peru Creek upstream of Chihuahua Gulch confluence. Access site at the new 1-room cabin that is on the right side of the road going upstream. Sample site is beside the old mine building and upstream of the waterfall.

SW-158 Peru Creek midway between Warden and Cinnamon Gulch. Sample just upstream of the "canyon" waterfall area where creek is beside the road. Sample downstream of the beaver ponds. This is a key site recommended for further monitoring.

PC-3 Peru Creek immediately downstream of the lower most fork of Cinnamon Gulch. Sample site is at the old mine building on stream right.

PC-4 Peru Creek downstream of Pennsylvania Mine discharge and upstream of Cinnamon Gulch confluence. Access site approximately 200+ meters upstream of an old mine shack on stream right. This site is immediately downstream of a beaver dam with a 4-ft waterfall.

SW-140 Peru Creek upstream of confluence with Pennsylvania Mine discharge. Sample site is upstream of road crossing.

PC-6 Peru Creek upstream of confluence with Shoe Basin and Pennsylvania Mine discharges. Sample where stone house is located beside the road.

PC-8 Peru Creek upstream of Shoe Basin Mine and ET-4 at road crossing. Sample upstream of culvert under the road.

Peru Creek Tributaries (downstream to upstream)

SW-Chi Chihuahua Gulch upstream of confluence with Peru Creek. Sample downstream of Peru Creek road crossing.

SW-168 Warden Gulch upstream of confluence with Peru Creek. Access site beyond the grave and where the power poles cross the road. Look for a flat area just downstream of the "canyon" that has lots of rocks/scree alongside the road. Park here and walk downhill to the site.

WGM-1 Warden Gulch Mine. First draining mine on left side heading up Warden Gulch Road. Old wooden frame here with beautiful ferricrete.

Cinnamon Gulch (Downstream to upstream).

SW-Cina Cinnamon Gulch upstream of confluence with Peru Creek. Access site by driving Penn Mine road past the concrete house and settling ponds. Stop at the first stream crossing and hike uphill past the Brittle Silver mine dumps and sample upstream of the flow split at the top of a rocky section of hill.

DMA-1 Delaware Mine adit as it emerges from the tunnel. Access site near the steel blue box-like structure and sample the adit at the tunnel with the fallen tree. Sample upstream of the pond.

SW-UpCinnCinnamon Gulch upstream of Delaware Mine adit. Site is downstream of SW-ECinn that enters on stream right but about 100 yards upstream of old cribbing across the creek and further upstream of the pond at the Delaware Mine adit.

SW-ECinn East fork of Cinnamon Gulch just upstream of confluence with Cinnamon Gulch. Site is just upstream of where the road crosses Cinnamon and is about 100 yards upstream of the mine cribbing/dam structure. Flow enters Cinnamon on stream right.

SW-Cinn3 Cinnamon Gulch upstream of the confluence with the East Fork of Cinnamon.

SS-2 Silver Spoon mine adit approximately 150 meters downstream of where it comes out of the ground. Sample downstream of the tailings piles.

SS-1 Silver Spoon Mine adit as it comes out of the ground. Site is located at the top of Cinnamon Gulch Road and serves as the headwaters to Cinnamon Gulch.

What is needed now is a more systematic monitoring program, continuing sample surveys at a few selected key sites over a period of time and combined with field measurements and streamflow data. As indicated above (Table 17) the most important monitoring sites for continued monitoring are SW-47 (the Snake River above Peru Creek), SW-49 (Peru Creek above the confluence with the Snake River), SW-50 (Snake River below Peru Creek) and SW-82 (Snake River below NF confluence). Although there is an argument for adding the Snake River above the NFSR confluence to this list, it is not being recommended at this time because the dilution provided by the NFSR is relatively consistent and the results above the dilution can be reasonable accurately calculated from the data from SW-082 and monitoring funding is limited. In addition, because the initial remediation work is planned for the upper Peru Creek area and Cinnamon Gulch, it makes sense to develop one upper Peru Creek monitoring site where regular (systematic) data can be collected. The two most logical sites are PC-3 and SW-158. The site PC-3 is the site just downstream of the Cinnamon Gulch confluence and site SW-158 is the site at the upstream end of the “canyon” just upstream of the Warden Gulch confluence. Both sites have existing data and both sites should help to characterize improvements to Peru Creek’s water quality from remediation activities in Cinnamon Gulch. A site in lower Cinnamon Gulch does not make sense, because the channel is proposed for realignment. Data collection at either of these sites can begin now and continue beyond the channelization, where any other site will be affected by the cleanup activity. Access is much easier at SW-158 and there is a good site to measure flow. The best site to add to the monitoring plan in Peru Creek is SW-158. Key monitoring sites are shown below in Figure 2b.

It is recommended that these 5 key recommended sites should be monitored at least eight times per year. This would include 4 times during high flow season (monthly during May through August) and 4 times during low flow (bimonthly from October through April). Flows should be measured whenever possible. It may not be possible to measure flow during some of the low flow, winter season due to thick ice and snow cover. A suggested sampling frequency for each monitoring (calendar) year is February, April, March, June, July, August, October and December. As discussed previously, River Watch is currently monitoring site SW-82 monthly and flow is measured by the USGS' stream gage located at this site (note that this is seasonal; it is not operational during winter months). For this proposed continuing monitoring program, the BRWG is willing to collect the samples for analyses and to measure field variables (flow, water temperature, specific conductance, pH, and dissolved-oxygen concentration). River Watch has agreed to do the metals analyses until alternative arrangements can be made. The EPA has monitored key sites since 2009 about three times per year. The report by Dr. Steele mentioned above for the 319 report for the Cinnamon Gulch remediation is the best summary of the new data.

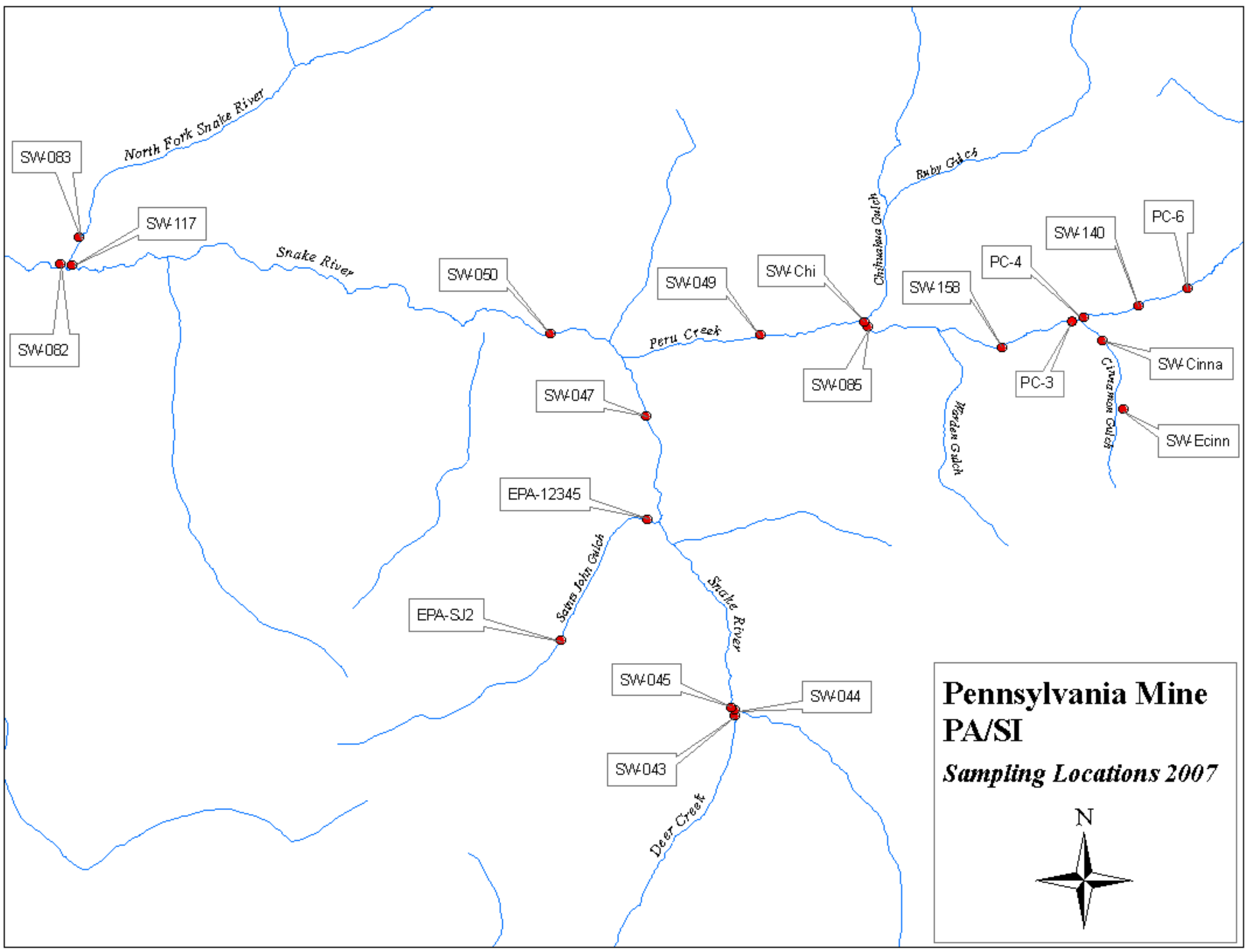


Figure 2b. Selected Monitoring Sites for Future Monitoring (Source Healy, 2008)

3 Water Quality Analysis and Characterization

3.1 Water Quality Data Analysis Review

The Snake River watershed has been the site of extensive environmental research in the past two decades. Much of the water quality data collected over the years was compiled in spreadsheet format and analyzed (Steele and Wyatt, 2004). This database forms the basis of much of the ongoing water quality assessment including the WQCD's TMDL analysis and efforts to predict improvements from remedial projects (CDPHE, 2008). In general, the report indicates that trace metals in certain stream segments significantly impair water quality and that the Peru Creek watershed is the most heavily impacted by anthropogenic sources and is a large source of potentially correctable water-quality problems that adversely impact downstream water quality of the Snake River. The Runkel, et al (2013) report adds to the existing data base.

Water-quality issues within the Snake River basin impact numerous users and present complex policy issues. Much of the research has been focused on the upper tributary basin of Peru Creek, which has been identified as a major contributor of metal solutes and acidity to the Snake River watershed through the processes of acid-rock-drainage (ARD). The Peru Creek subwatershed contains several moderately-sized historic narrow-vein silver/base metal mines that have been identified as discrete sources of metal loading. All of these mines are currently inactive. Water quality in Peru Creek is also affected by zones of diffuse and perhaps less well-documented naturally occurring ARD related to extensive alteration of country rock directly associated with the ore deposits. These natural water quality issues also affect the upper Snake River watershed. Anthropogenic impacts can also be found in Deer Creek, Saints John Creek, and Grizzly Gulch.

Initial environmental research centered on the Pennsylvania Mine, the largest producing silver-lead-zinc mine in the Peru Creek subwatershed, because early studies identified the Pennsylvania Mine as the largest point source of contamination. Investigations were later expanded to include basin-wide and watershed scale sampling initiatives and abandoned mine inventories. The initial efforts led to more targeted site assessments utilizing seasonal and synoptic constituent water sampling, streambed sediment analysis, and increased site mapping. In recent years research has included the use of chemical tracers to help understand the complex interplay between anthropogenic and naturally occurring ARD on Peru Creek water quality. All of these studies have shed important additional light on seasonal fluctuation in metal loading dynamics that are central to understanding the Snake River basin as a whole. In addition, chemical tracer studies have provided some additional insight into effects of multi-year climatic fluctuations on discharge and metal loading from Peru Creek into the greater Snake River watershed. Longer term monitoring at selected sites with flow measurement is needed. Existing data has a number of conflicts in metals loading, presumably caused by fact that most loading calculations are currently done by using flow data from downstream stations transposed on upper monitoring locations. There simply have not been enough flow measurements in upper basin sites. There has also not been enough sampling in the winter low flow conditions. Monitoring to help solve these problems is addressed in this Plan. (Section 2.3) The three new studies, Todd et al, Runkel et al and Steele confirm much of what has been known and adds new elements to be considered. The Todd el al adds considerable uncertainty as to how to predict the future metals concentrations.

3.2 Past Investigations/Mine Inventories/Site Assessments

There has been a considerable amount of research on the water quality problems of the Snake River basin and the causes of those problems. Appendix D provides a summary of that research. The list of studies is extensive. A recent attempt to quantify the amount of money spent in the basin showed that at least an estimated $630,000 have been spent, not including considerable staff costs from a number of agencies or labor costs for the many graduate students who have done research in the area. What the data have shown is that the water-quality problems in the Snake River watershed are a combination of natural and anthropogenic or man-made sources. Cleaning up the anthropogenic problems will not solve all of the water-quality issues in the watershed.

The studies have shown that natural acid rock drainage creates the water quality problems in the upper Snake River subwatershed above Deer Creek. Although there are a few man made issues in that part of the basin that can be addressed, the major problems are natural and will not be fixed when the few mines in that area are addressed.

Deer Creek, in general, has good water quality. There are several mine related issues that can and should be dealt with, and might lower metal loads in Deer Creek, the overall water quality will not change much when these issues are addressed.

Sts. John Creek has good water quality in the upper part of this tributary basin, but is degraded by the Sts. John Mine and the waste rock and tailings from that mine. The overall water quality at the confluence is not bad, but can be improved when the Sts. John mine and other, less critical mining issues are addressed.

The Snake River downstream of Deer Creek and above Peru Creek (e.g. the intervening area that includes the Sts. John Creek inflows) has a number of anthropogenic sources. There are flowing adits, waste rock and tailings issues, all of which are impacting water quality.

Below the Peru Creek confluence, water quality in the Snake River is impacted by the problems of Peru Creek. Most of the research has been conducted on Peru Creek, but much of what that research tells us is applicable throughout the overall watershed.

Flow into Peru Creek, and the other streams, is a combination of lateral inflow in wetlands and point source discharges from mines. Snowmelt in the basin tends to go into the unconsolidated rocks of the high slopes and move as ground water to lower elevations. Where the steep slopes form benches, or where they form wetlands near the bottom of the steep slopes, water comes out as seeps or springs. Depending on the geology of the area, the resulting water seeps can be of high quality, as we see in upper Deer Creek and Sts. John Creek or of low quality as we see in Cinnamon Gulch and Warden Gulch.

During the spring runoff, flow from the adits can be high, flushing metals from the mine. At the same time, there is considerable dilution from the snowmelt. During the late fall and winter, there is less flow from the mines and seeps, but it can be of worse water quality (higher concentrations of metals) because there is no snow melt to dilute the contaminated water.

It is always difficult to determine the actual impact of waste rock on water quality. Studies in Cinnamon Gulch have shown that most of the waste piles are potential problems. “Based on analytical data from these waste source areas, all sources are considered to be acid generating and contain high levels of metals. Future efforts to reduce loading to the watershed should start first with moving source areas out of, and away from contact with water and erosional migration (Rudolph, 2008).” This is likely to be true in other parts of the basin as well. Although each individual waste rock piles contribution is small, the accumulation of the impacts on water quality of all of the sites can be significant.

3.3 Evaluation of Physical Habitat

During 2006, Dr. William Walsh provided a qualitative assessment of the physical habitat in the Snake River watershed for aquatic life (Appendix E). General basic physical habitat variables will translate into biological diversity in stream communities with no other limiting factors or stressors. In specific terms of trout, the physical components of in-stream trout habitat typically includes pools, riffles, and cover in the form of aquatic vegetation, woody debris, undercut bank, and overhanging vegetation, in addition variables such as water quality, temperature, and stream discharge. These variables will affect the abundance and distribution of a trout population.

Dr. Walsh found Peru Creek to be heavily impacted from poor water quality conditions which will prohibit a trout population. However, if water quality conditions improved significantly in this stream abundant physical habitat would be available in the form of riffles and high gradient riffles with associated plunge pools. A similar conclusion had been made in a 1985 study (Chadwick, 1985b).

Dr. Walsh’s conclusion, based on a visual evaluation of the Snake River watershed including Peru Creek, was that there are abundant habitat types that would be excellent for a trout population. If water quality conditions in the watershed were improved to within the tolerance limits of trout, even on a seasonal basis, then one would expect to see trout population.

4 Best Management Practices (BMPs)

This section describes BMPs that are applicable to the treatment of inactive or abandoned mines. The following information is based on the informational booklet *Best Practices in Abandoned Mine Land Reclamation: The Remediation of Past Mining Activities* produced by the State of Colorado Department of Natural Resources, Division of Minerals and Geology (2002). The *Best Practices in Abandoned Mine Land Reclamation* booklet provides more detailed information for each BMP, including advantages, disadvantages, initial cost estimates, and maintenance considerations.

4.1 Overview

BMPs are management strategies implemented in an effort to control, mitigate, or reclaim degraded environments. The BMPs presented here present a diversity of potential solutions to mine site reclamation in the Snake River watershed. Due to the complexity of mine reclamation, including the need to address waste rock and tailings, surface water, groundwater, sediments, and safety hazards, no "silver-bullet" technology currently exists to remediate all mines in the same manner. Rather, a collection BMPs are generally applied simultaneously or in series to complete remediation of a site. Additional research into the specific hydrology, contamination type, and contaminant transport pathways of each site will necessary before embarking on a cleanup project. Effectiveness is also, to a degree, site specific. In most situations, it is as difficult to determine the exact contribution of a site to stream degradation as it is to determine the improvement created by implementation of a specific BMP.

Reclamation and treatment methods presented in this Plan include the following:

1) Surface and Subsurface Hydrologic Controls. These are generally preventative measures intended to inhibit the processes or acid formation or toxic metal dissolution by minimizing or eliminating the contact of water with mine wastes, particularly sulfide minerals. Surface hydrologic controls include surface and groundwater diversion features, mine waste removal, consolidation, and stabilization, capping, and revegetation.

2) Passive Treatment. Passive-treatment techniques refer to a range of low maintenance drainage treatment strategies. Passive-treatment BMPs include anoxic limestone drains, settling ponds, sulfate reducing wetlands, oxidation wetlands, aeration, and neutralization systems.

4.2 Mining BMPs

This section describes numerous mining-related BMPs that commonly are implemented as remedial actions for pollutant reductions from anthropogenic-related mining impacts in the Rocky Mountain region.

4.2.1 Surface and Subsurface Hydrologic Controls

4.2.1.1 Waste-Rock/Tailings Consolidation, Removal, and Stabilization

Waste-rock or tailings removal and consolidation, often aided by stabilization in the form of cribbing, cementation, or riprap cover, serves to move the reactive mine wastes away from areas of possible contact with water. This preventative measure tends to be effective in areas where there are several small waste piles near one another, or where waste piles are in direct contact with surface water.

4.2.1.2 Waste-Rock/Tailings Regrading

Regrading of waste-rock and tailings piles to a gentle slope (generally, a ratio of three feet horizontal to one foot vertical) reduces erosion of the piles by water, wind, frost, and animal action. Erosion reduction, in turn, promotes vegetation growth and decreases the transport and spread of waste materials.

4.2.1.3 Waste-Rock/Tailings Capping

Capping of waste-rock or tailings piles refers to covering the consolidated, regraded piles with a protective layer of clean, non-acid generating soil. This protective layer prevents or reduces water infiltration into the reactive mine waste materials, thereby slowing the processes of acid generation and metal leaching. In addition to clean soil, which reduces infiltration and promotes vegetation growth, caps may consist of synthetic filter fabrics, geotechnical materials such as clay liners, and acid neutralization materials such as limestone gravel.

4.2.1.4 Vegetation

Hardy vegetation growing on waste rock or tailings piles helps to protect the pile from erosion and reduces water infiltration into the pile. In addition, vegetative covers improve underlying soil by adding nutrients, providing wildlife habitat, and in some cases they may improve the aesthetics of any given site.

4.2.1.5 Bulkhead Seals and Plugs

Bulkhead seals and plugs are closure structures that seal off open mine portals through which mine waters flow. Following closure, the mine workings behind the seal or plug flood with mine water. If the mine workings completely fill with water, oxygen is no longer available and chemical reactions that produce acidity and dissolved metals are stalled. Bulkhead seals generally refer to closures structures that allow managers to open or close a portion of the seal, allowing mine water to flow out of the mine in a controlled manner. Plugs, on the other hand, simply block all mine waters into the workings and do not allow for the controlled release of water.

4.2.1.6 Diversion Ditches

Diversion ditches channel clean surface water around the source of contamination, or intercept shallow groundwater that may interact with mine workings or mine wastes. These ditches are applicable in situations where rainwater, snowmelt, or other surface or subsurface flow is degraded by flowing over or through mine workings or mine wastes.

4.2.2 Passive Water Treatment Techniques

4.2.2.1 Chemical Amendment

Chemical amendments may be used, generally in conjunction with other BMPs, to control the acidity of mine drainage or clean water that infiltrates into acid-generating waste piles or mine workings. Generally, chemical amendments involved adding a basic (high pH) material such as lime to the water. Lime may be added directly to the water, or may be introduced indirectly as reactive limestone gravel.

4.2.2.2 Anoxic Limestone Drains

Acidic mine water may be routed through an anoxic limestone drain (ALD) in order to reduce acidity and remove metals from the system by precipitation. A method of chemical amendment, ALDs are ditches lined with limestone to neutralize the mine water, and buried in order to block oxygen from the atmosphere from interacting with the water.

4.2.2.3 Aeration and Settling Ponds

Water aeration and subsequent settling in a pond is a two-part system to reduce the dissolved metal content of mine water. Aeration, which is often accomplished by routing the mine water over a series of small waterfalls, increases the oxygen content of the water. When this water is then captured in a quiescent settling pond, metals can precipitate out of the water solution as solids that accumulate on the floor of the pond. This method generally requires that the mine water is low in acidity. This BMP may need to be combined with chemical amendments such as lime addition that decrease acidity.

4.2.2.4 Sulfate-Reducing Wetlands

Sulfate-reducing wetlands rely on common bacteria found in decomposing organic material to remove metals from mine water. Sulfate-reducing bacteria (SRBs) utilize oxygen in the water for metabolism, initiating chemical reactions that lead to the precipitation of toxic metals in the water as metal sulfides. Wetlands stocked with organic materials such as compost or manure promote the healthy growth of a SRB community, which aids in maintaining the function of the system. Advanced systems referred to as sulfate reducing bioreactors act in the same way, but utilize less space. Sulfate reducing bioreactor efficiency in a particular application is site specific. However, effectiveness in metals removal has been above 90% in certain applications (Leviathan Mine, 2006).

5 Watershed Management Action Strategy and Remediation Priorities

The following sections discuss in some detail the problem sites in each subbasin that need attention. Focus is on the anthropogenic sites which can be improved with remedial actions, as opposed to the natural problems where no actions are generally appropriate.

5.1 Snake River

The problems in the Snake River begin at its headwaters. The Cashier Mine, high on the western edge of the drainage basin presents the first water quality problems in the basin. The mine has considerable waste rock that is eroding and is exposed to runoff. However, the slopes are so steep that doing anything to the waste rock, or revegetating it will be difficult. There is flow from the area of the adit. However, the adit area is normally covered with snow making it difficult to tell if the flow from that area is from the adit or the snow melt. In either case, flow occurs most of the non-freezing time of the year and typically runs over and down waste rock. It would be possible to channel this flow to an area where it would be in contact with less waste rock. Figure 3 shows the Cashier's Mine. Note the snow over the adit.

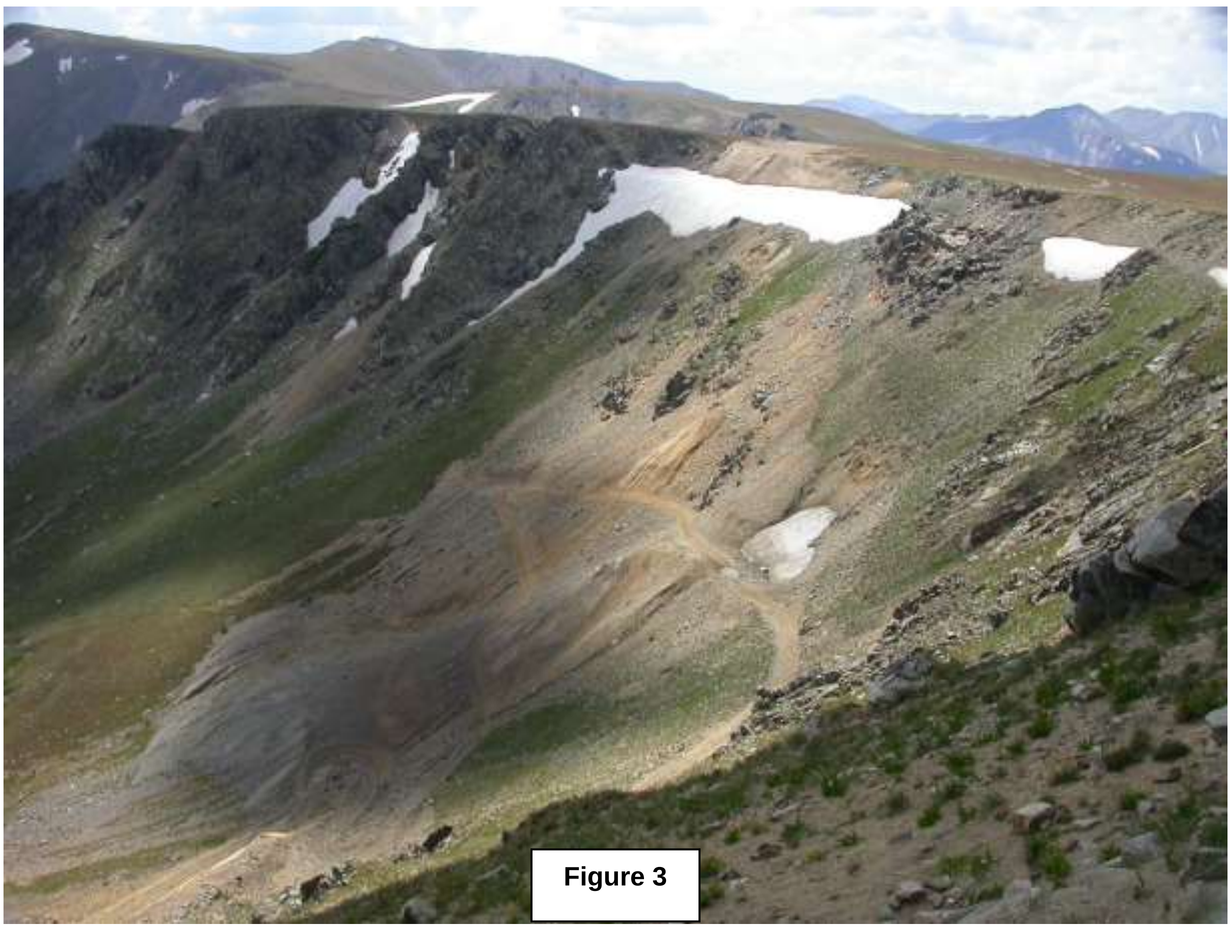


Figure 3

The next man-made problem in the upper Snake River basin is an old mine just south of the area where the Webster Pass road crosses the stream at the head of the valley. There is a waste rock pile near where flow from the unconsolidated area at the south end of the drainage flows into the Snake. This natural flow is of low quality water which is acidic. This low quality water comes into contact with the waste rock pile, which is right adjacent to the stream. Figure 4 shows this waste pile.

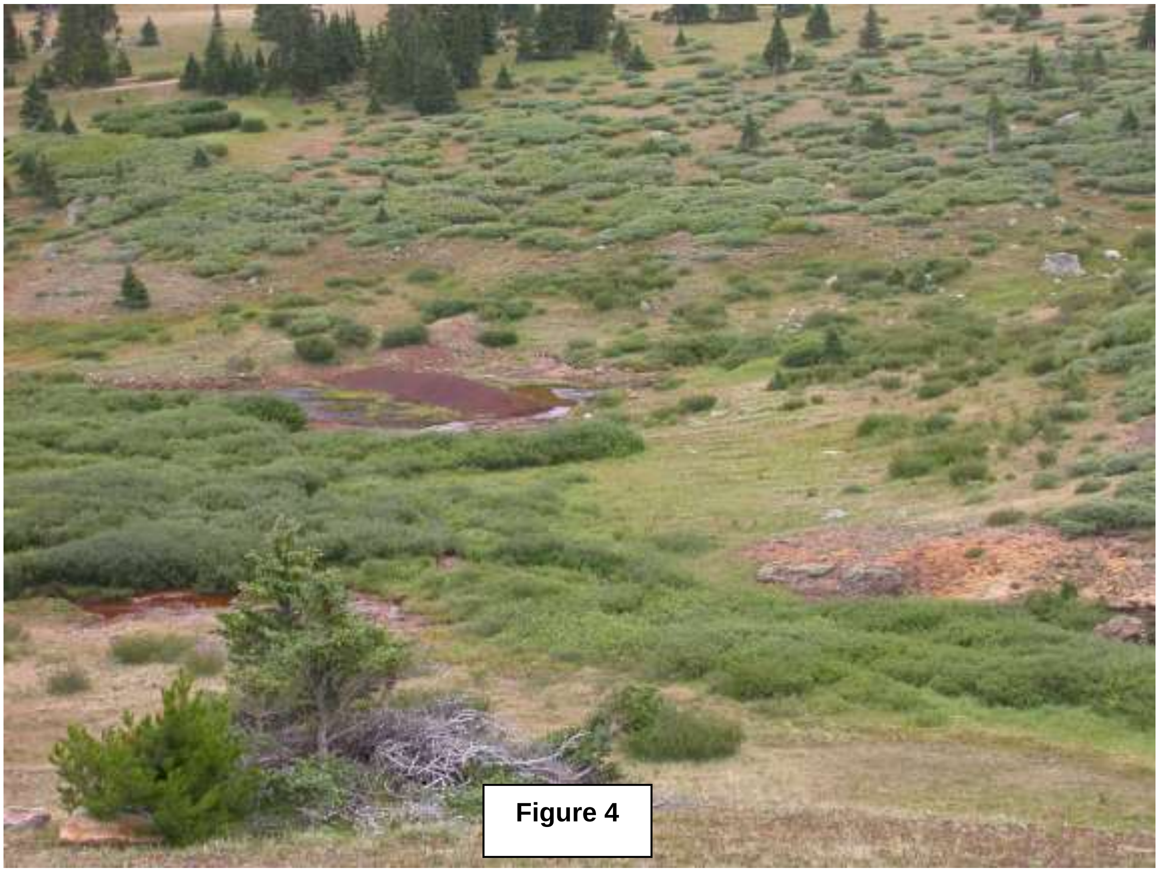


Figure 4

Not far from the mine in Figure 4, on the eastern side of the mainstem, are several areas that were disturbed during exploration for minerals. These areas show clear marks of dozer work. No revegetation has occurred in the many years they have been denuded. Flow from seeps in the area flows across these areas much of the time. The water from the seeps is acidic and metal laden. Water flowing across these areas does not look good. Figure 5 shows one of these areas.

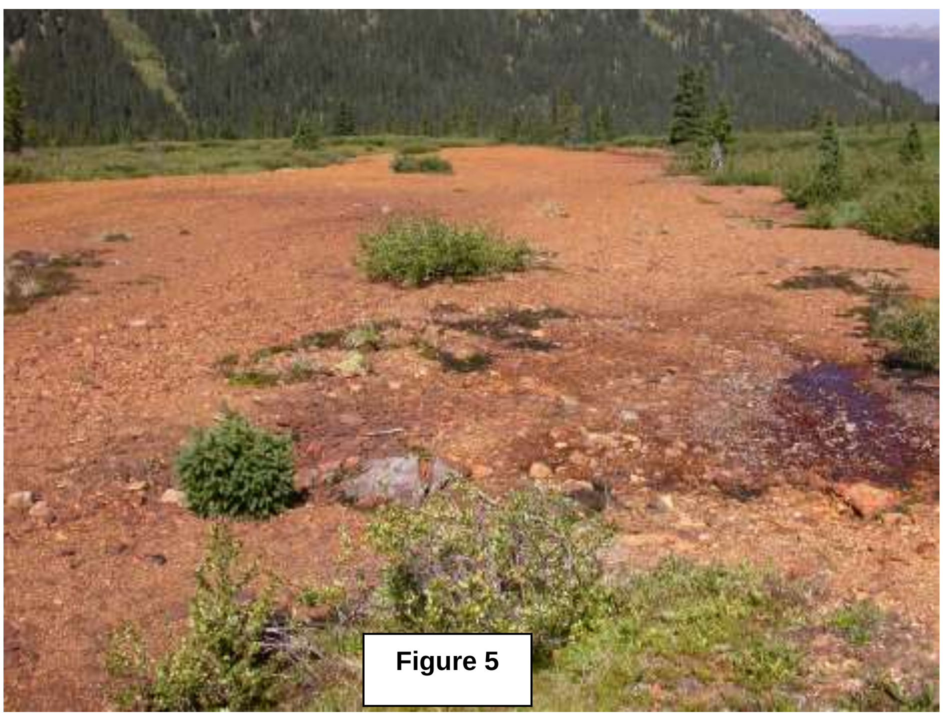


Figure 5

The next problem in the basin is an old mine. The name of the mine is in question, but has been referred to by the team working in the area as the Blanche Mine. It is located up an old road that takes off just before the Webster Pass road crosses the Snake River at the northern end of the upper Snake River valley and wetlands. The mine has a leaking adit which flow year round. During the summer much of the flow is down the road, reaching the Snake River in 2007. The remainder of the flow is across the parking area and down waste rock. In high flow periods, there is evidence of the flow going down the waste rock in several places. This mine, because of its access and the large flat, "parking area" around the mine will be a relatively easy clean up project. The waste rock can be easily pulled back to the natural slope and covered and revegetated. The flow from the adit needs to be directed to a passive treatment sulfate reducing bioreactor. There is room for such a facility below the

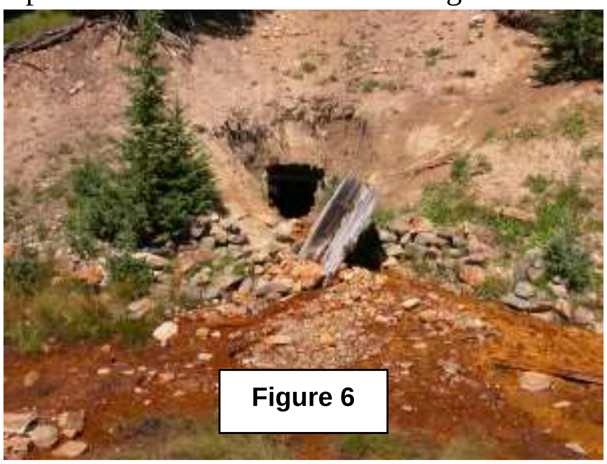


Figure 6

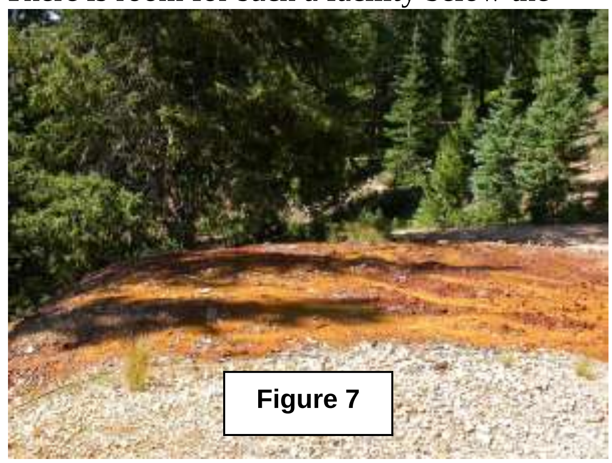


Figure 7

adit and waste rock. Figure 6 shows this mine site. Figure 7 shows the portion of the flow that goes over the waste rock.

As the Snake River leaves the upper valley and heads downstream, there are two tributaries that flow into the Snake on the eastern side. These are not shown on the USGS Montezuma, CO topo map (1958), but are roughly below the Climax Mine, which is shown on the map. Also shown on the map are a number of old mine sites. Each of these sites has waste rock associated with it. At least one was flowing in August, 2007 and at least one has

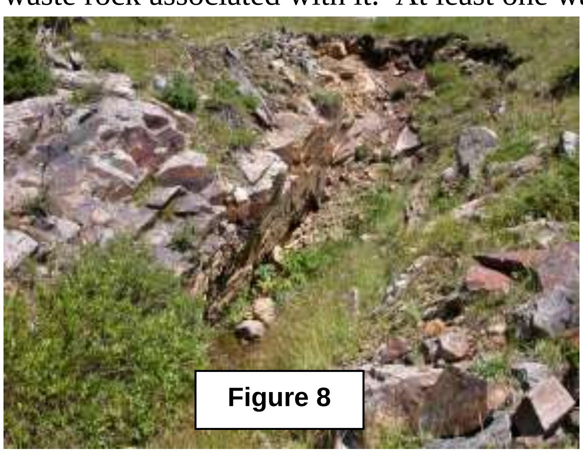


Figure 8


Figure 9

flow in contact with waste rock. Figures 8 and 9 show adit flow and waste rock contact.

From these tributaries the Snake drops rapidly to the flat, wetlands area just below the confluence with Deer Creek. At this point there are three leaking adits which flow into the Snake River from the west side. All three flow in just below the confluence with Deer Creek. Flow from the upper of the three does not always reach the stream directly, seeping into the ground and flowing into the stream via the wetlands rather than directly. The other two flow directly into the stream. Figures 10 and 11 show these two mines. In addition to the flowing adit, the upper mine has eroding waste rock issues. There is room to deal with the

Figure 10

Figure 11

waste rock issues at the upper mine. Treating the water in either case will be difficult, because they are so close to the river. Water quality is not bad. The flowing adit a few hundred vertical feet above these mines would be easier to treat. It does not always reach the stream directly, but flow from it does during the runoff season.

Not far below these mines, high on the western hillside is a flowing adit. Flow from the adit goes down a steep drainage that is highly eroded. Most of the flow enters the ground and flows into the Snake via seepage in the wetland below.

Further downstream, just before the town of Montezuma is the Burke-Martin Mine. This mine has been "worked" recently. The owner still lives on site. He has worked this property since 1948. There are extensive problems on the site. Waste rock and tailings are relatively adjacent to the stream. A flowing adit is piped to a point where it drops directly upon the waste rock. Drainage from this and much runoff goes across old tailings. Figures 12 and 13 show these problems. In figure 13 the adit flow is shown, but it is hard to see at the distance shown in the photo. The property is privately held and the owner has chosen to not be cooperative with the watershed plan development. This area is believed to be causing water quality degradation. The tailings need to be removed or isolated in some way. The flowing adit is not believed to be a significant problem, but no data have been collected on its quality. However, the adit flow needs to be directly routed to the stream and taken off of the waste rock. Drainage in the entire area needs to be addressed. In addition, just north of the Burke-Martin Mine is another mine. This mine too has a draining adit, but flow is low. There are also waste rock issues at this mine. There are a number of natural seeps in this area and some of that flows over waste rock and tailings. There are wetlands between this mine and the Snake River.

Figure 12

Figure 13

Figure 14

This mine north of the Burke-Martin Mine is shown in figure 14. The drainage shown is not from the mine, but from a seep in the mine area.

Not far below the confluence of Sts. John Creek, in the town of Montezuma, there was once a mill. Tailings from this mill affect a large area just below town. This area has considerable private property and some of the tailings have been moved around for house and road construction. Other large pockets of tailings remain. The tailings are in a wetlands area, making their impact worse. Further, on the east side of the stream, just below town is another old mine with a leaking adit. As with the Burke-Martin Mine, this adit flow has been captured and is routed directly onto waste rock, which it flow down on its way to the Snake. Further, the wetlands area below the old mine/draining adit have been contaminated with tailings and waste rock. Some of this has eroded closer and closer to the stream and some remains in dams and piles. Figure 15 shows some of these tailings and figure 16 shows the draining adit. The flow is difficult to see from this distance, but is easily visible to anyone on the road.

Figure 15

Figure 16


Figure 17

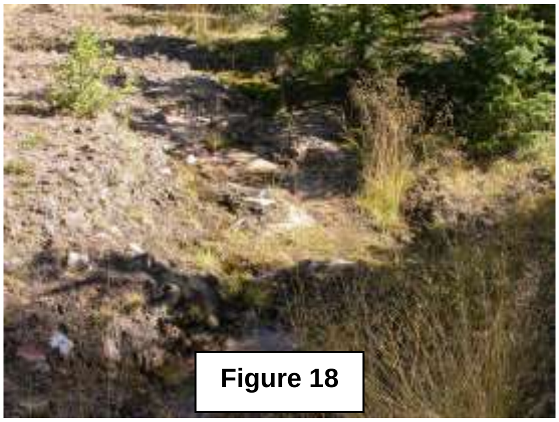


Figure 18

Figure 17 shows the lower end of this contaminated wetlands area. Figure 18 is flow from the contaminated area. This area is actively contaminating the Snake River.

On the eastern side of the Snake River, in Montezuma and high on the hills above Montezuma are several other problem areas. At the south end of Montezuma is the New York Mine. This has been closed and waste rock scattered over a fairly large flat area. The adit is draining and a pipe was set up to get the flow off of the waste rock. The adit flow goes down the side of an access road to the main Montezuma road, then down the ditch to a culvert and to the Snake River. Figure 19 shows this draining adit and Figure 20 shows the flow down the access road to the main road.


Figure 19


Figure 20

There are other waste rock piles around dry adits to the south of the New York Mine, on the eastern side of the Montezuma road. These waste rock piles are eroding from runoff.

To the east of Montezuma are a number of mines. Some have draining adits and some are dry. In general, the higher mines are dry. However, the series of waste rock piles around the Quail Mine are all in a drainage and erosion is inevitable. Lower, in the general area of the Morgan Mine are several dry adits with significant waste rock. The Morgan Mine has been closed, but is draining and there is a large waste rock area that is eroding significantly. There is room for a passive treatment system for the adit flow and reclamation of the waste rock may be possible with an organic/zeolites mixture.

Below the Morgan Mine, to the north, is another mine with a significantly draining adit. This mine has significant disturbance around it. There is room for a passive treatment system of the adit flow and to consolidate waste rock. There are seeps in the area and field measurements suggested their water quality to be low. This is an area where water quality improvements are possible.

Figure 21 shows one of the upper mines waste rock. Figure 22 shows the adit flow from the mine north of the Morgan Mine. Figures 23 and 24 show the closed Morgan Mine and the waste rock pile associated with it.


Figure 21


Figure 22

There are no other significant water quality issues affecting the Snake River below


Figure 23


Figure 24

where the Montezuma road crosses the Snake River near the Peru Creek parking lot. There are a few seeps or adit flows just above this point, but these flows are very small and there is considerable private property in the area. Peru Creek affects the water quality, but it is addressed separately in this report.

5.2 Deer Creek

Deer Creek water quality at its confluence with the Snake River is generally good. This reflects different geology than the upper Snake River and a relatively small amount of anthropogenic sources of water quality degradation. Still, there are areas worth considering for improvement.

On the east side of the basin are a number of old mines. The state has closed several adits from these mines. Most are dry, especially the higher ones, but some still have small flows from the old adits, even when closed. There is considerable waste rock, including some that is eroding. However, most of the mines on the east side are high enough, that waste rock flow is still, like most flow, seeping into the ground on benches and actually flowing into the creek via seeps and wetlands flow near the actual stream. Figure 25 shows an adit still flowing some after closure and Figure 26 shows some of the waste rock high on

Figure 25

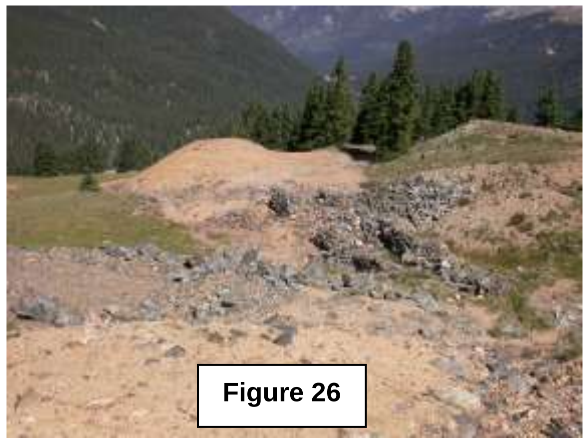


Figure 26

the eastern side of the basin.

Still on the eastern side, but further south is the Upper and Lower Radical Mines. These are below an upper lake on a small bench. What flow there is from this lake is toward these mines. These are dry and so isolated that it is difficult to see how much can be done to lessen their impact on water quality. Figure 27 shows the old adit and Figure 28 some of the waste rock.

Figure 27

Figure 28

On the western side of the basin is the Upper and Lower Chatauqua Mines. Both have significant waste rock piles that are eroding. The Lower Chatuaqua Mine   has a draining adit that has water flowing over waste rock. Both are relatively easily accessible and moving waste rock from flow areas is possible. Figure 29 shows the Lower Chatauqua Mine adit flow. Figure 30 shows the eroding waste rock at the Upper Chatuaqua Mine.

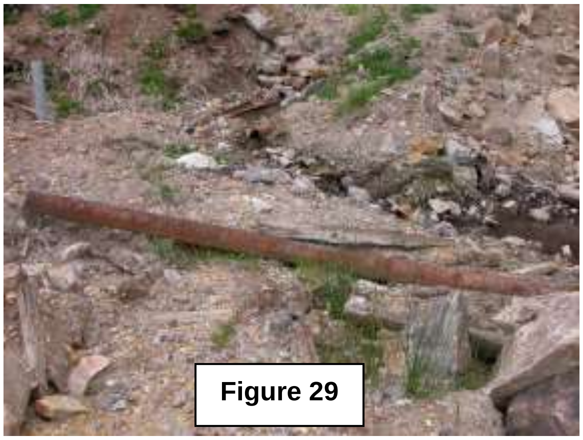


Figure 29

Figure 30

About one quarter mile from the confluence there is another draining adit. This adit is on private property and some efforts have been made to keep the flow on the property. The efforts are somewhat successful late in the season. However, flow from the adit goes directly into the stream in the early summer runoff season. Just down the road from this mine is another draining adit that flows directly out from the bottom of a waste rock pile. Flow is then down the west side drainage ditch of the road and directly into the Snake River. Figure 31 shows the draining adit and Figure 32 shows the flow from the bottom of the waste

Figure 31

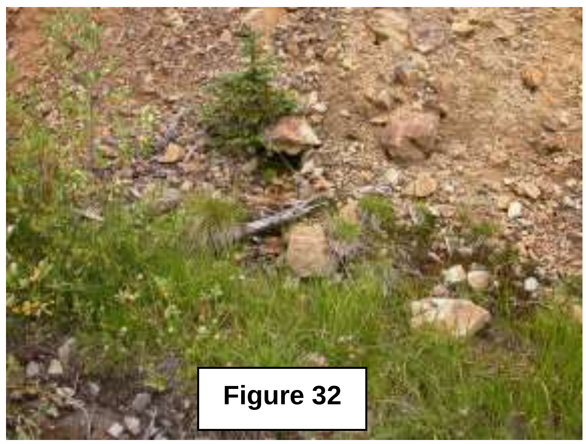


Figure 32

rock pile. The flow in Figure 32 was significant in both 2007 and 2008. Figure 33 shows the flow just before it enters the Snake River as it crosses the road to the Superior Mine complex.

Figure 33

5.3 Sts. John Creek

There are a number of old mines with significant waste rock in the upper eastern reaches of Sts. John Creek. The adits are all dry and the waste rock erosion small. Lower, the Wild Irishman mine has a draining adit and significant waste rock. The flow from the adit is along the north side of the waste rock. Figure 34 shows the lower half of the upper waste piles and Figure 35 shows the Wild Irishman Mine adit flow. In figure 34 the Wild Irishman Mine is the lowest waste pile shown. Figure 36 shows the flow of the adit on the north side of the waste rock pile.

Figure 34

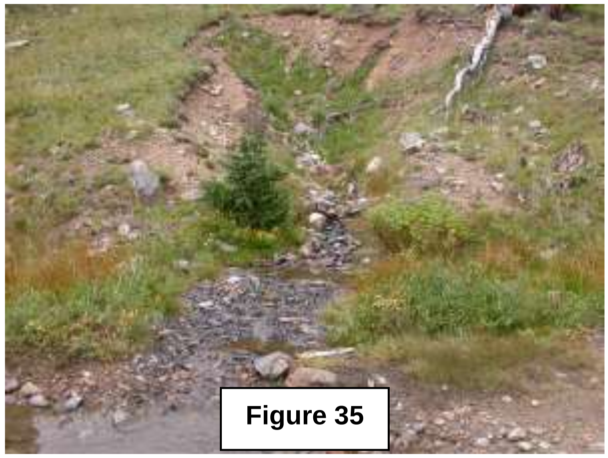


Figure 35

Figure 36

Slightly lower in the basin, just before the road to the Wild Irishman Mine crosses the mainstem, another road takes off to the west to another old mine. This mine has a slightly draining adit which goes directly into the stream. The flow is constant, but relatively low. The adit has been closed. The flow could be treated in a passive treatment system, although the benefits from doing so would be small.

There is a road to the east that takes off about half the way up the main part of the drainage. It serves an old mine with a draining adit. The area around the mine is privately owned and a cabin of sorts has been built below the mine area. This mine is actually just north of the Wild Irishman Mine in a sub-drainage that starts only a few hundred yards north of the Wild Irishman Mine. Figure 37 shows this draining adit. There is considerable waste rock in the area. Flow is across the waste rock and then down to an eastern tributary.

The waters of Sts. John Creek are good to just above the Sts. John Mine. The impacts from the mines discussed to this point are very small on the water quality of Sts. John Creek.

Only a few hundred yards from where an eastern tributary discussed above flows into Sts. John Creek is the Sts. John Mine and Mill site. This is one of the major problems in the Snake River Basin. The mine has a significantly draining adit, which is flowing across waste rock and tailings on its way to the stream. Further, water is seeping from the stream into areas disturbed by milling and the tailings from the mill contaminate the stream for hundreds of yards below the mine area. Major cleanup of the site is needed. Waste rock needs to be consolidated. The waters leaking from the stream need to be captured and channeled back into the stream before heading into a tailings area. The adit flow needs treatment. The tailings in the area of the mine need to be removed or consolidated and covered.

Figure 37

The Colorado Department of Reclamation Mining and Safety (CDRMS) is in the middle of a project to make significant impacts at the Sts. John site. The water seeping from the stream into disturbed areas is being collected in a large french drain and prevented from seeping into disturbed areas. The tailings are being collected and removed to a dry area on site consolidating all of the tailings into a single area. The wetlands area where much of the tailings resided prior to removal is being restored to a functioning wetland without tailings. Figure 38 shows the Sts. John Mine adit. Flow splits, with the majority going north and the rest heading across waste rock to the south. Figure 39 shows the north flow and Figure 40 shows the south flow. Figure 41 shows the north flow near its confluence with Sts. John Creek in August, 2007. The remediation work provides a better course for the adit flow.

Figure 38

Figure 39

Figure 40

Figure 41

Figure 42 shows the seepage from the stream. This seepage goes on into an area of considerable tailings and eroded waste rock. This is shown in Figure 43.

Figure 42

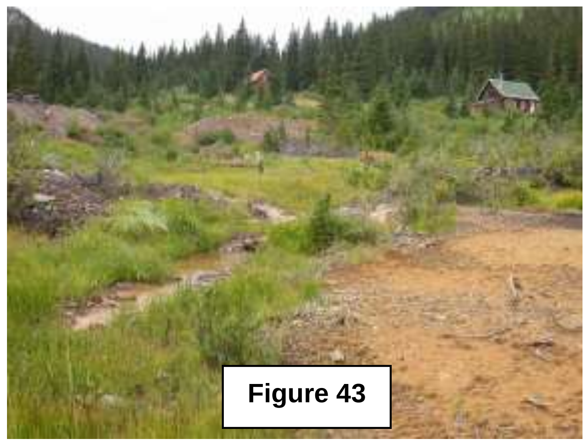


Figure 43

Not far below the Sts. John Mine, the creek enters a wide meadow. On the west side of the meadow is the Marlin Mine, with a draining adit and eroding waste rock. In the meadow, the creek meanders through significant tailings. Figure 44 shows the Marlin Mine and figure 45 shows some of the tailings in the meadow.

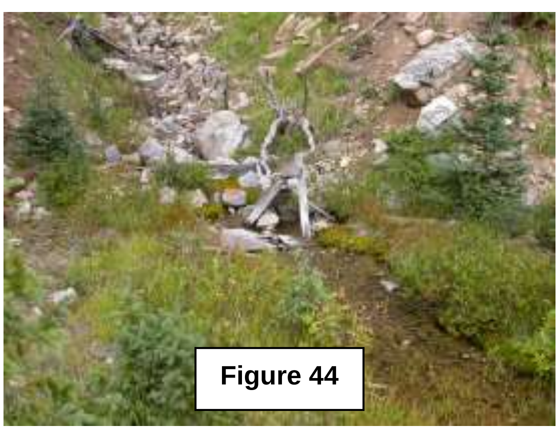


Figure 44

Figure 45

From the meadow, Sts. John Creek drops rapidly to confluence with the Snake River in the town of Montezuma.

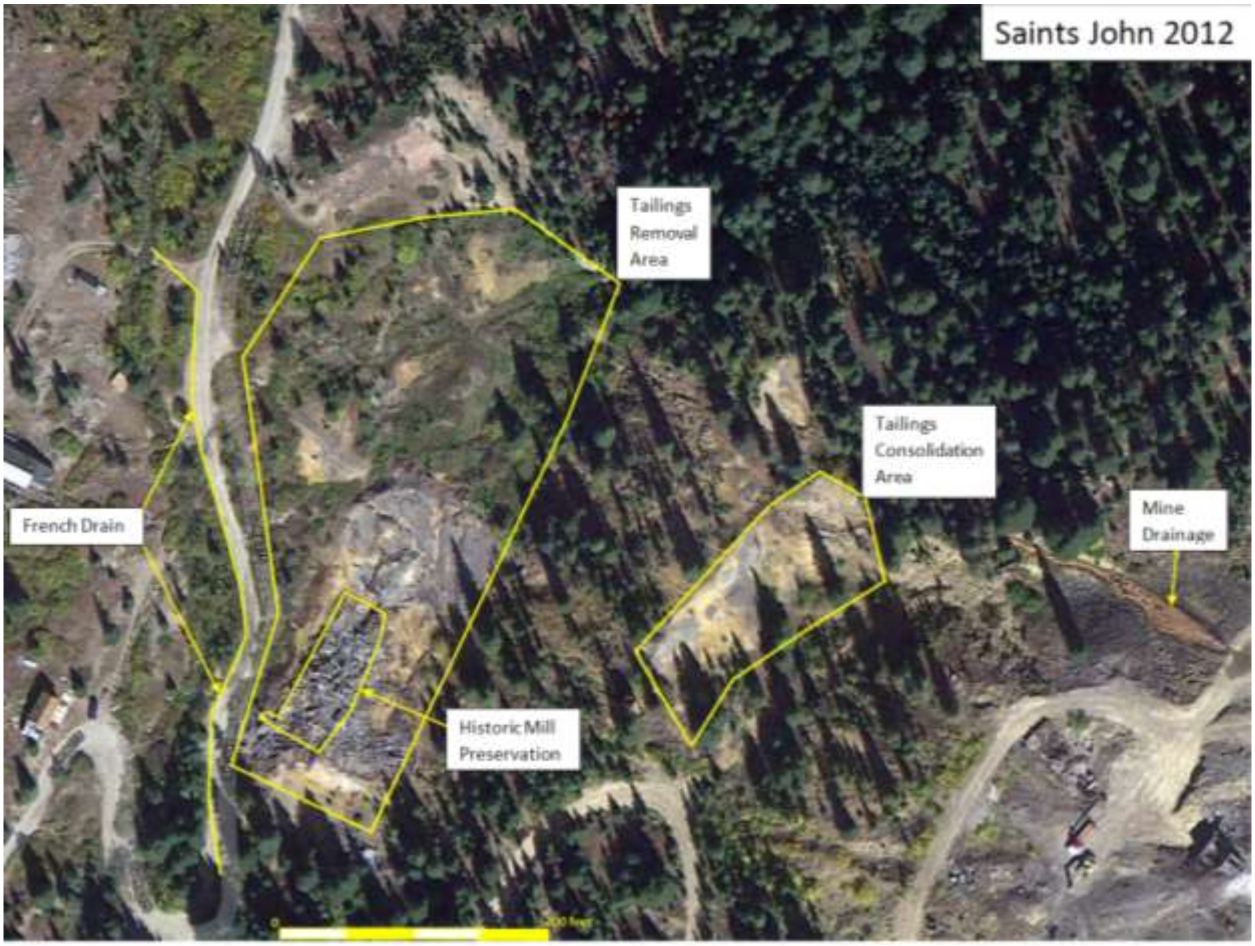


Figure 39 B

Figure 39 B shows the remediation plan for the Saints John mine and mill complex. The north area of the tailings removal area is the principal wetland area to be restored. The tailings consolidation area is shown. It was a dry upper tailings area thus allowing the consolidation. The area of the french drain is also shown. This project is expected to be largely completed in the summer construction season of 2013. While this project will not affect directly the water quality of the flowing adit, it will improve stream water quality by controlling the flow of water over tailings and the flow input from the tailings contaminated "wetland" area that is being restored. The project goal is a reduction of three pounds per day of zinc going into Sts. John. While this will be difficult to measure immediately after the project is completed, it is a good example of how water quality can be improved without active treatment of adit flow.

5.4 Peru Creek

The first problem in Peru Creek is near the headwaters in Horseshoe Basin. There are several piles of waste rock. At least one is draining. Figures 46 and 47 show this leaking adit and the associated waste rock. Not far from this point, just below the lake shown in figure 47

Figure 46

Figure 47

the stream goes by the toe of a waste rock pile. This is shown in Figure 48. A few hundred yards below this point, just below what appears to be one of the Vidler Tunnel diversions is the Paymaster Mine. This mine has considerable waste rock that is eroding. It is in this area that one of the western tributaries emerges and when it joins the mainstem, aluminum precipitation begins. There is also an open shaft just tens of feet south of the Paymaster Mine waste rock (Figure 49). The open shaft is shown if Figure 50. It is surrounded by a man-made rock wall.

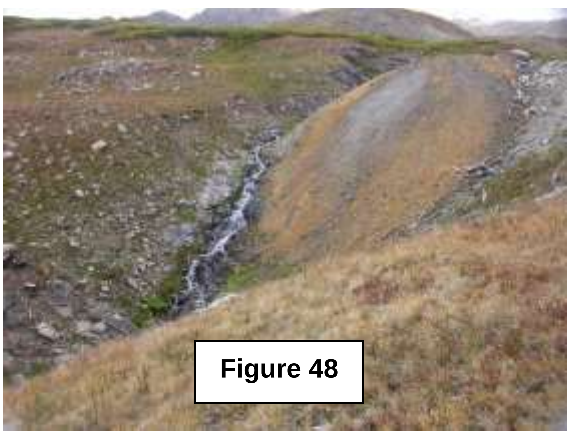


Figure 48

South of the Paymaster Mine, on the western hills of the drainage, are two flow channels. The north one, Falls Gulch on the map, has a small waste rock pile along the flow channel. The southern channel was not flowing in September, 2008 but has more significant waste rock in the flow channel. Figure 51 shows the Falls Gulch flow channel.

Figure 49

Figure 50

The other flow channel is just to the south of what is shown in this picture.

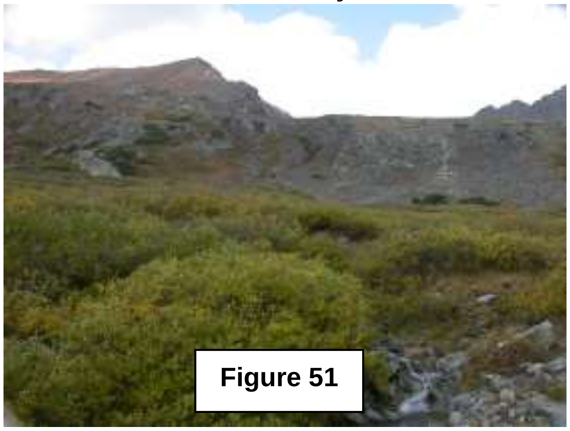


Figure 51

Just below this point in the stream, near where the road crosses Peru Creek, is another old mine with waste rock and an open shaft. The waste rock is spread over a large area and is eroding. The shaft appeared to be dry, but is a physical hazard. The waste rock is shown in Figure 52 and the shaft is shown in Figure 53.

Above this mine, on the western hills just south, are three old mines shown on the map as the Peruvian Mines. The northern most mine has two shafts, one with water and evidence of flow, although it was not flowing in September, 2008 and one grated shaft that appeared dry. The higher southern mine had an adit with evidence of flow, but that was not flowing in September, 2008. The lower southern waste pile had a draining adit and evidence of regular flow. All three waste piles were on relatively steep slopes and showed significant erosion. Erosion was all the way down to the wetland area above the road.

Figure 52

Figure 53

Just downstream from the Peruvian Mine is the Shoe Basin Mine. This area was reclaimed by Summit County. However, because of the potential liability associated with the CWA, the flowing adit was not dealt with. It is directed down a rock channel above the reclaimed waste rock and then down a natural area to the road. It flowed down the road until it seeped into the ground in September, 2008. Figure 54 shows the adit flow from the mine. Since the Plan was developed there has been additional vegetative reclamation across from the mine site. Heavy flow during runoff limited the effectiveness of the revegetation, but much of the site has been successfully reclaimed.

On around the hill downstream from the Shoe Basin Mine (the stream flow here changes from south to west) there are a number of old waste rock piles. Some are in natural drainages and have expected erosion associated with them. The adits in most appear dry, although there is one, to be discussed later well down the basin with a draining adit. Figure 55 shows one such waste rock pile.

Figure 54

Figure 55

The next issue in Peru Creek is the Pennsylvania Mine. It has been recognized since the 1970's as the largest single point source problem in Peru Creek. There is extensive data on the mine effluent and a good understanding of the problems associated with the waste rock. However, there are still many questions about the adit flow. Work is underway in 2008 and planned in 2009 to better understand this serious problem. In addition to the adit and waste rock at the main level F opening, there are serious issues associated with the tailings from the mill at the site. The milling was several hundred vertical feet lower and west of the now flowing adit. Just above the mill was the level C opening. This area has significant waste rock issues, as well. The tailings have been sluiced and/or eroded into a major wetlands area. This wetland was shown in the 1980's to be heavily polluted. Work was underway in 2008 to better understand the impact flow from the tailings area has on the stream. Figure 56 shows the current Pennsylvania Mine flow into Peru Creek and Figure 57

Figure 56

Figure 57

shows an aerial view of the waste rock area. Also shown in Figure 56 is some of the waste rock from the area above the mill near the level C opening. Figure 58 shows more of this level C waste rock and figure 59 shows the Pennsylvania Mine adit flow.


Figure 58


Figure 59

Downstream from the Pennsylvania Mine about a half mile, on the northern slope is another old mine (Rothschild Tunnel). This mine has significant waste rock issues and a draining adit. It is the waste pile discussed earlier concerning numerous waste rock piles on this northern slope. Figure 60 shows the adit and Figure 61 some of the waste rock.

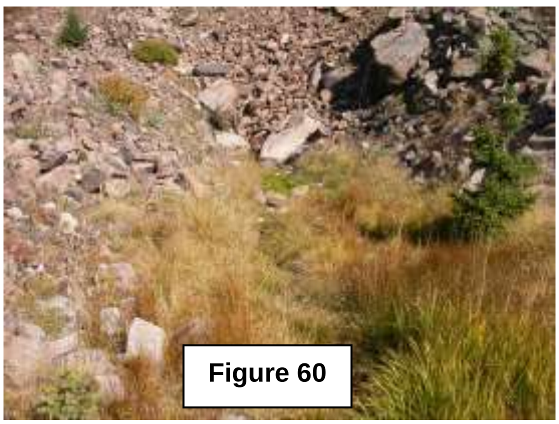


Figure 60

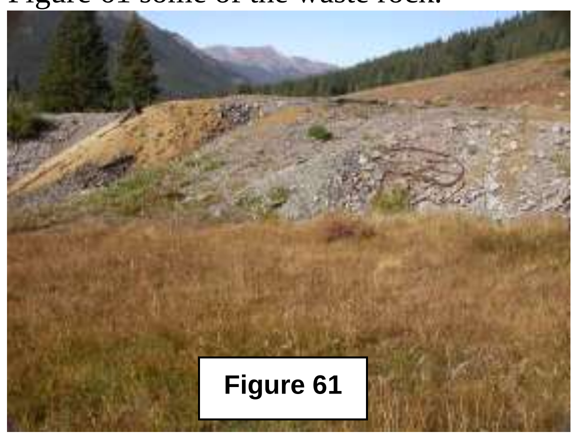


Figure 61

On downstream, there continues to be old mines on the north slope. Figure 62 shows one of these, the Silverlode Mine. Figure 63 shows another one, just west of the Maid of Orleans Mine. The Maid of Orleans Mine has been listed as having a draining adit in past studies (Munroe, 1999). The owners have allegedly closed the adit. A small spring remains. This is an area of private property.


Figure 62

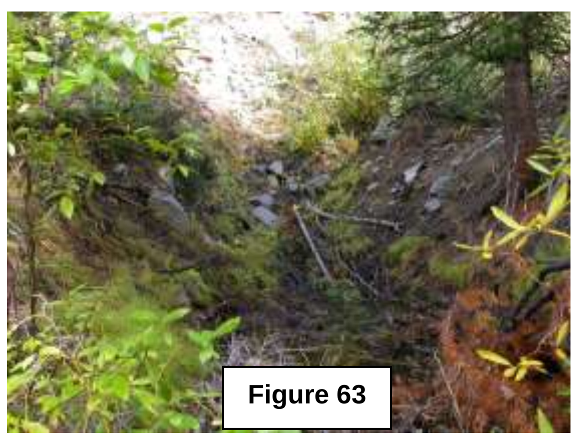


Figure 63

On the south side of the stream, just upstream from where the road crosses Peru Creek, about one mile from the parking lot and about one mile from the confluence with the

Snake River, is the Jumbo Mine. This mine has significant waste rock. The adit is draining and in September, 2008 there was flow from the bottom of the waste rock pile. Figure 64 shows the flowing adit and figure 65 shows some of the waste rock. Waste rock from this mine is just a few tens of yards off of the stream.

From the road crossing just below the Jumbo Mine, Peru Creek drops through a canyon to its confluence with the Snake River. There are no other anthropogenic issues with Peru Creek in the last half mile.

Figure 64

Figure 65

5.4.1 Pennsylvania Mine Clean up

The Pennsylvania Mine consists of a large area of disturbance. The Pennsylvania Mine was one of the largest and probably had the longest life of any Summit County mine. It has been viewed since 1979 as the largest single point source problem in the Peru Creek drainage (Holm, 1979). It has been the focus of cleanup efforts in the area since then. Much of the work of the SRWTF has been related to the problems caused by this mine. A major feasibility study of the mine and how to clean it up was completed in 2006 by the NWCCOG. The draining adit is a major source of contamination to Peru Creek. However, the Pennsylvania Mine, as a water quality problem, is much bigger than just the draining adit. The problem area consists of the area around the draining adit, which also has waste rock piles and tailings from previous milling. Figure 66 shows the adit itself. Note the manhole in the picture. In the 1990's flow from the adit was collected and flowed down this manhole to a treatment facility that was used to test various treatment schemes. The drain is now plugged. Figure 67 shows the flow from the adit, as it flowed in 2007, across waste rock just below the adit. The flow was directed in 2008 to flow more in a channel than across the waste rock piles. However, the waste rock piles are still a problem. Figure 68 shows more of the waste rock in this area.

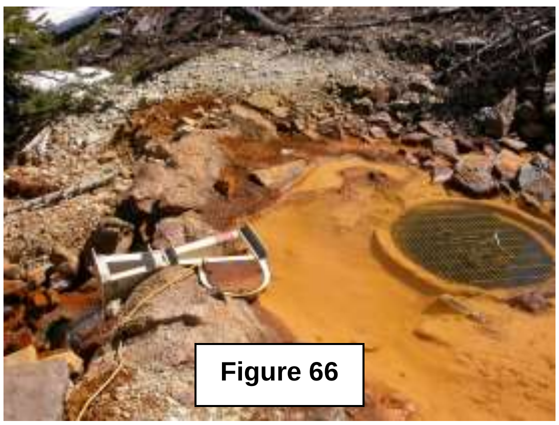


Figure 66


Figure 67


Figure 68

The waste rock in this area should be removed to a repository and not consolidated on site. There are serious questions about the level of contact with water from the adit and the waste rock below the surface. This is not a good site for on site treatment.

To the west of the area of the flowing adit is the major milling site for the complex. Some of the mill building remains. Adjacent to the old mill is the area where treatment of the adit was explored in the 1990's. There is a concrete building, a settling pond, and two small constructed wetland ponds. Down gradient from the mill is a large wetland area which is contaminated with tailings from the mill. Figure 69 shows this area from the road to the north of the mill.

Figure 69

Above the mill is another old adit opening. This adit is dry on the surface, but in a 2008 attempt to enter this adit, water was seen in the adit. It is not know if that adit, on what was called level C is connected to the level F of the mine, which is the level from which flow is now coming from. One of the plans in 2009 is to see if this can be determined. There is considerable unconsolidated rock above the level C adit. If this level is connected to level F, this area could be the source of much of the water that is leaking from the mine.

The area above the mill has considerable waste rock and some old structures. There are still cables that were used for the old tram between the opening and the mill lying on the ground. This, too, will be a difficult area to deal with the waste rock in place. It would be best if the waste rock could be removed to a repository. Figure 70 shows some of the waste rock in this area. Figure 71 shows more of the waste rock, but it also shows in the distance the disturbed area around the draining adit.

Figure 70

Figure 71

The waste rock and tailings area are believed to be important contributors to the metals contamination of Peru Creek. It will not be enough to just treat the draining adit, which has been the focus of most past work. The recent report on the area prepared by the CDPHE states “Based on analytical data from these waste source areas, all sources are considered to be acid generating and contain high levels of metals. Future efforts to reduce loading to the watershed should start first with moving source areas out of, and away from contact with water and erosional migration (Rudolph, 2008).”

Concerning the tailings area the report states: “The second area in the lower Cinnamon Gulch drainage is represented by mine tailings, waste rock and contaminated wetlands comprised of saturated tailings and organic matter originating from the El Jebel Mill Site. The upgradient portion of this area is comprised of waste rock and tailings which have eroded into the lower downgradient wetlands. Numerous water drainages occur through the upper waste rock and tailings. The lower wetlands are completely saturated and, based on preliminary ground water results discussed in Section 4.0, Ground Water Pathway, are highly contaminated and appear to contribute substantial contaminant loading to Peru Creek (Rudolph, 2008).”

Concerning the draining adit the report states: “The Pennsylvania Mine adit discharge has been frequently sampled by USEPA as part of the ongoing water quality monitoring conducted in 2006 and 2007. Data prior to 2007 indicated that the Pennsylvania mine discharge varies in flow rate from around 20 to 40 gallons per minute (gpm) in the winter to a peak flow of 150 to 300 gpm during spring runoff. The Pennsylvania mine portal is a source of perennial contaminated drainage that discharges to Peru Creek. The discharge ranged from 0.33 to 0.36 cfs (148 to 162 gpm) measured by CDMG in June and July of 1978. The pH ranged from 3.0 to 4.85, and conductivity ranged from 1,400 to 1,525 µS/cm. An additional potential major contaminant source is the infiltration through waste-rock dumps and tailings in the alluvial wetlands along Peru Creek. Combining the surface areas of all the waste rock dumps and tailings piles in the Pennsylvania Mine area gives a cumulative surface area of approximately 70,000sq ft. Assuming 36 inches of annual precipitation, it is possible that over 2 gpm is infiltration through the dumps and tailings located immediately down gradient of the portal and leaching contaminants to the alluvial groundwater and Peru Creek (Wood, 2005)” (Rudolph, 2008).

The USEPA has a contractor preparing a report on the options for treatment at the overall site. With questions remaining on where water is getting into the mine, what are the sources of the water, and how much flow from the mine is subsurface and not visible, more work is needed. Some of the additional study is planned for 2009 with additional USEPA funding.

Because of the size and complexity of the problems at the Pennsylvania Mine, the SRWTF is looking into whether placing the mine on the National Priority List as a Superfund site is appropriate. The weight of the evidence to date is beginning to suggest that the cost of treatment at this site might be high enough that other sources of funding (non Superfund) for cleanup might be inadequate.

A considerable amount of work has been done at the Pennsylvania Mine in a continuing effort to find the best way to remediate this area. Three holes were drilled to intersect the mine workings. Geophysical sonar surveys were conducted to better understand the workings and to determine the extent of the open cross cuts. Borehole camera inspections were conducted of the intercepted workings. In addition, two alluvial sampling wells were drilled.

The information from this effort has led to opening of both the F and C level portals. At each portal 11 foot diameter culverts were installed and the areas around the culverts backfilled and reclaimed. This has allowed the first actual underground investigation of the C and F levels. Underground investigation has provided the ability to find and sample inflow locations, quantities of inflow at different locations and the quality of the inflow water at different locations. This ability to go underground has also allowed the determination of areas requiring rehabilitation and the ability to investigate possible bulkhead locations.

Preliminary work to date indicates that perhaps as much as two thirds of the flow is water that has not been significantly contaminated. If that flow could be prevented from combining with the other waters in the mine, of very low quality, it would be much easier to treat the smaller flow. The strategic placing of a bulkhead underground might stop the higher quality water from flowing into and through the mine. In addition, it may be possible to capture some of the Level F flow higher in the mine. That is why the work has been conducted at Level C.

The current plan has eight phases. These include 1) improved site access; 2) underground rehabilitation and reconnaissance; 3) surface tailings consolidation and drainage improvements; 4) underground bulkhead #1; 5)sealing off Level C surface water pathways (if they are found in task 2); 6) underground bulkhead #2 (if needed); 7) passive treatment system for remaining contaminated adit flow; and 8) post removal site control. The proposed steps will be conducted step by step with appropriate modifications as new information is gained. The overall cost of the program will not be known until each step can be confirmed, but is likely on the order of three million dollars.

Figure 71b

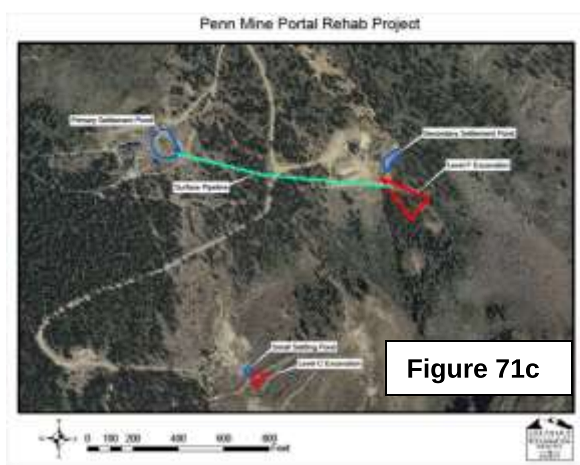


Figure 71c

5.4.2 Cinnamon Gulch

During most of the year, Cinnamon Gulch originates with flow from the Silver Spoon draining mine adit. Very shortly after the flow surfaces, it crosses waste rock. Drainage in the immediate area crosses waste rock. While the water from the mine is not good, the flow across the waste rock is making it worse. This waste rock is high in minerals as is almost all of the waste rock in the gulch as shown in the recent work by the CDPHE (Rudolph,2008). Figures 72 and 73 show the origination of flow and the above stream waste rock. Just below where the Silver Spoon Mine breaks through the waste rock, at an elevation of about 11,600 feet, is a series of adits. The adit adjacent to the road has been closed by the state. All that remains is a waste pile. The other adits in this series remain open and have been rated by the Colorado Geological Survey as environmental hazards. Some of these open adits flow continuously and some only part of the time. There are waste rock piles below the adits over which water from the adits flow. Figure 74 shows one of these open adits. Figure 75 shows the waste rock pile from the closed adit below the Silver Spoon.

Figure 72

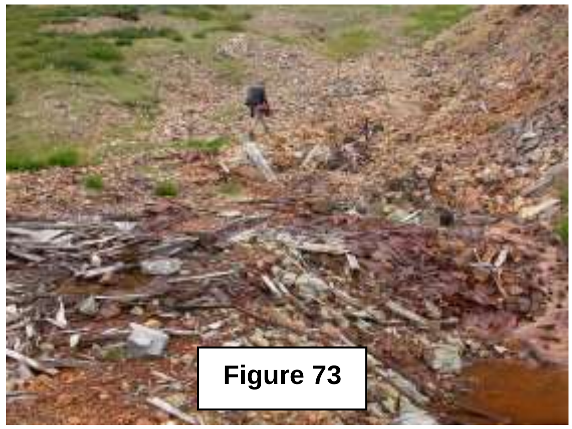


Figure 73

Figure 74

Figure 75

There are two Delaware Mine draining adits listed in previous work in Cinnamon Gulch (Wood, 2005). The "upper" one is near the lower end of the lower of two wetlands areas on the east side of the wetland. In addition to the draining adit, there is waste rock in contact with the adit flow. Figures 76 and 77 show two views of this area. The adit flow needs to be treated with a passive treatment system and the waste rock needs to be removed. This could be done in conjunction with the

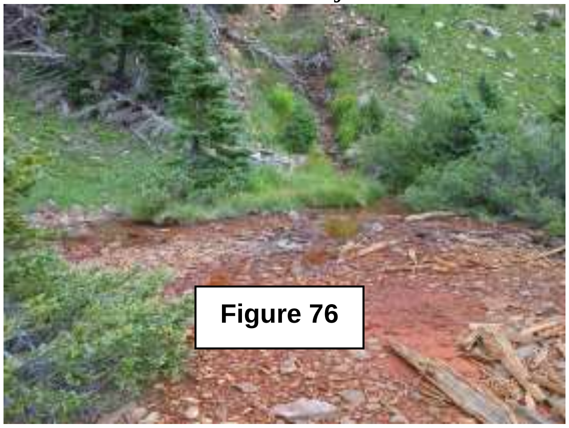


Figure 76

Figure 77

waste rock at the other Delaware Mine site.

The second Delaware Mine site has large waste rock disturbed area. The waste rock has been spread over a wide area by a dozer. Flow from the adit comes down an area by the waste rock. Some of the flow splits off and goes over the waste the rock. Some of the flow continues down a channel to a pond. Water from the pond seeps into the creek. Figures 78 and 79 show these problems.

Figure 78

Figure 79

The water from the adit needs to be treated in a passive treatment system. That will not happen until there is a change in the Clean Water Act. Therefore in the short term it would be better to clean up the waste rock and clean out the pond and use the pond for oxidation and settling. The pond can be removed when a water treatment system is finally built.

On the west side of the drainage, approximately across from the Delaware Mine is another draining adit. This adit has some waste rock issues, as well. The adit is still open and presents a physical hazard. Figure 80 shows this adit.

Figure 80

From a point just below the Delaware Mine the stream gradient increases. The stream flows into a heavily timbered area. About 50 yards above the road that goes from the Pennsylvania Mill area to and by the Brittle Silver Mine, the stream breaks into three channels. All three channels cross this road and have independent pathways to Peru Creek. The western most of these three channels breaks at the road and flows down the road past the Brittle Silver Mine. The flow down the road leaves the road in different places depending on the flow rate and much of the flow feeds the Brittle Silver Mine tailings area which has become a wetland area. Cinnamon Creek needs to be channelized from this point 50 yards above the road to Peru Creek. The Brittle Silver Mine has draining adit, waste rock, and tailings issues which all affect water quality. The tailings area has not been assessed to date. Figures 81 and 82 show the road flow issue and the Brittle Silver Mine issues.

Figure 81

Figure 82

The 319 grant has led to work at three areas in Cinnamon Gulch. The first is at the Silver Spoon Mine (Figures 72 and 73 above.) At the Silver Spoon Mine the waste rock in the drainage channel was added to the waste rock not in the channel and the channel was lined with limestone. In impermeable liner was placed in the channel and the sides were riprapped. The waste rock pile was covered with limestone. The picture to the right shows Cinnamon Gulch at the Silver Spoon Mine. The gulch frequently only flows with mine effluent. Compare this to figure 72 above.

Figure 72b

Significant activities also occurred at the Delaware Mine. The effluent from the mine flowed to an old pond. The pond was cleaned out and the flow channel to the pond was lined with limestone. A new culvert was placed below the road to keep the water flowing to the pond. Waste rock was cleaned up from around the site and all of the waste rock was consolidated at the east end of the disturbed area and covered creating one onsite repository. The disturbed area was revegetated and large boulders were placed along the road to keep vehicles off the reclaimed area. Figures 78 and 79 above show the before condition. The two pictures below show comparable after

Figure 79b

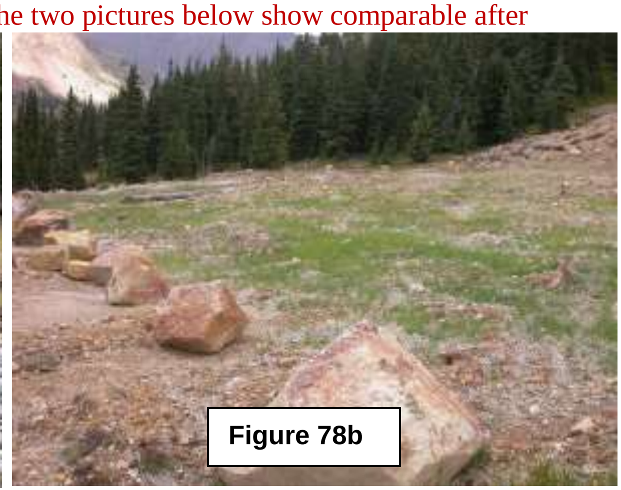


Figure 78b

pictures. Additional reclamation activities might be conducted in 2013 to further stabilize the disturbed areas.

Cinnamon Gulch split into three separate streams in the area where it crossed an old mining road. The western most "channel" ran down the road and ultimately across the tailings from the Brittle Silver Mine. See figure 81 above. Approximately 200 feet of Cinnamon Gulch was rerouted to the original channel along the old mining road. This prevents the stream from affecting the tailings area of the Brittle Silver Mine. The picture below shows the reroute.

Figure 81b

The changes will all positively affect water quality, even though none involve "water treatment" per se. The largest impact is likely to be the Cinnamon Gulch reroute, which will keep large volumes of water from flowing through the Brittle Silver Mine tailings area. Changes of this type are more difficult to measure at the water quality monitoring stations in use, because these flows are only a small part of what is measured at these sites.

5.4.3 Warden Gulch

At the headwaters of Warden Gulch is the Allen Emory Mine. This mine is on the steep slopes at the end of the cirque. There does not appear to be a draining adit. However, there is considerable waste rock that is eroding. Dealing with this waste rock at the existing slope angle will be very difficult. North of the main drainage origination, and lower in the basin, west of the main flow there are several waste rock piles. All appear to be dry and all are, to some extent, eroding. One the south side of headwaters area there is another mine, high on the steep slope with considerable waste rock. This mine is in an area of unconsolidated rock on the surface and expected high mineralization. Doing anything to this waste rock would be very difficult and would most likely gain little. Figure 83 shows the Allen Emory Mine. Figure 84 shows a typical example of the waste rock piles on the northwest side of the drainage. Figure 85 shows the mine on the high south slope.

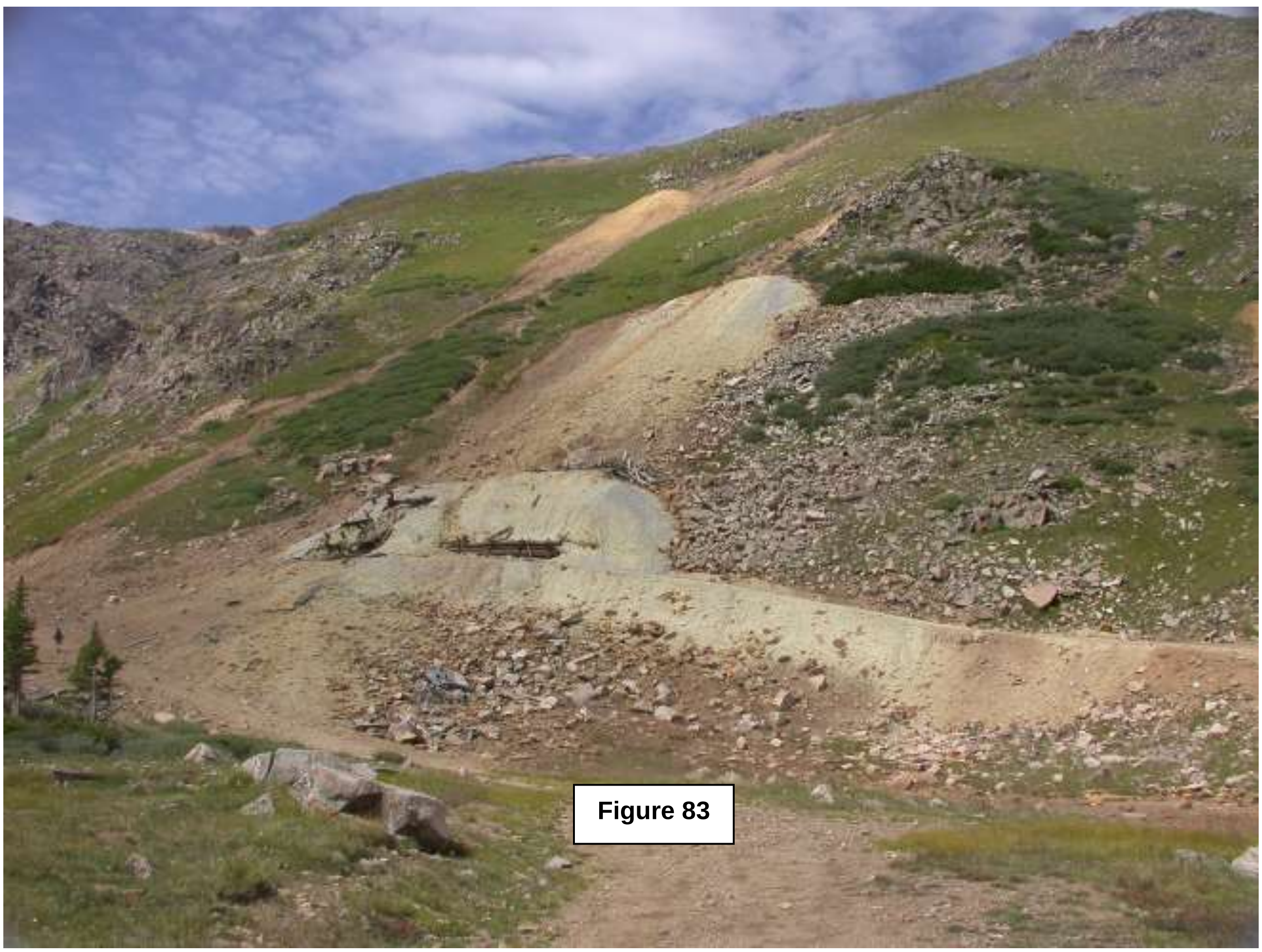


Figure 83

A few hundred yards above the confluence, where the road to the Allen Emory Mine approaches the stream is an old mine. The mine adit is draining and the water from the adit has created ferricrete deposits on the banks of the stream. There is room to the north to treat the adit flow with a passive sulfate reducing bioreactor. The waste rock and ferricrete need to be removed to a repository, although there might be enough room to consolidate them onsite and cover them. Figures 86 and 87 show two views of this mine.

5.5 Project Prioritization

There are many old mines located throughout the Snake River watershed that would benefit from remedial action. Not all can be done in a reasonable period of time. Therefore, some form of prioritization is needed. There are also two distinct types of problems that need to be addressed. One is the water from draining adits and the other is the problems associated with waste rock and tailings and water running across and through these piles. One is a point source and the other is a non-point source.

There is another distinct difference. Under current federal law, anyone cleaning up a draining adit may become liable for the pollution problems associated with that adit forever. There is no clear and easy way for a "Good Samaritan," one who voluntarily cleans up draining adit, to escape liability under all circumstances. A draining adit is a point source and requires a discharge permit under the Clean Water Act. This is currently not being enforced by USEPA or the state of Colorado. However, if someone were to put in a form of treatment plant, the requirement for a discharge permit could be enforced. The EPA changed the requirement for a discharge permit in these circumstances in 2012. This was announced in Summit County by Senator Udall in 2013. This is an important change, but it is not clear if it is enough of a change to entice "Good Samaritans" to begin cleanup. Further, any citizen is allowed under the Clean Water Act to sue the USEPA to require enforcement of the Act. So, even if USEPA and the state of Colorado were to not enforce the requirement for a discharge permit, any citizen could sue to require enforcement and the party responsible for the treatment plant would most likely be liable for bringing the treatment plant to a condition that any discharge would meet water quality standards in the receiving water body. Considerable time and effort has gone into finding a way to circumvent this problem. Although the ultimate solution is a legislative change, it is possible that under certain circumstances, a workable solution might be found that would reduce the residual liability to a point that some individuals or organization might be willing to be a Good Samaritan and clean up certain problems. Clearly, the EPA change in policy on the discharge permit is a step in the right direction.

Non-point source discharges do not have this problem. Grants are available under a variety of funding sources to fund cleanup of problems associated with the waste rock and tailings from past mining activity. This Watershed Plan is being developed under §319 of the CWA. This CWA section can also provide funding for actual clean up on non-point source mining related problems. However, funding from this source is limited. Further, in mine clean-up projects, the capital cost to implement a project is only one cost. The ongoing operation and maintenance costs are sometimes bigger issues to deal with when funding a project.

This distinction is important in the prioritization because most of the large sources of metal pollution into the streams in the Snake River watershed are point source discharges. The largest source and the one most intensively studied is the Pennsylvania Mine. It has been known to be the largest point source anthropogenic water pollution problem in the basin since the 1970's. This watershed-planning effort has confirmed that this is clearly the largest source of heavy metal pollution to the Snake River. However, there are other large point sources as well.

In the prioritization of the projects, the largest contribution of metals contamination is used as the principal variable in selection among projects. This means that the highest priority projects usually have a draining adit. A draining adit with a significant metals load is not the case in 100 percent of the top priority projects, but it is clearly the case in most of them.

Ranking projects beyond the main variable of metals contribution to the stream is more difficult. In general, tailings were viewed as a more serious issue than waste rock. Proximity to a stream was viewed as worse than a similar pile further from a stream. Physical hazards such as an open shaft or adit raised the priority of a project. Visible erosion of a waste rock pile raised the priority over waste rock not visibly eroding. Waste rock in a drainage channel was viewed worse that waste rock not on a steep slope or in a drainage area. The following table shows the projects ranked in three categories. Priority one is those projects with the highest contribution of metals to the stream. Priority two projects are contributing less pollution to the Snake River, but are still viewed as significant contributors. Priority three projects are generally smaller, more difficult to access, further from a waterway and most likely a smaller contributor. Table 18 shows the types of BMPs needed at each site. Detailed recommendations for Priority One sites are presented in Section 6.

Table 18. Snake River Watershed Prioritized Mine-Related Remediation Projects

Priority One

Pennsylvania Mine

- Waste rock/tailings consolidation, removal and stabilization
- Vegetation
- Chemical amendment
- Sulfate reducing wetland
- Possible underground seal or plug

Jumbo Mine

- Waste rock/tailings consolidation, removal and stabilization
- Vegetation
- Sulfate reducing wetland

Saints John Mine

- Waste rock/tailings consolidation, removal and stabilization
- Vegetation
- Chemical amendment
- Sulfate reducing wetland
- Hydrologic controls

Blanche Mine
- Waste rock consolidation and stabilization
- Vegetation
- Sulfate reducing wetland

Warden Gulch Mine
- Waste rock consolidation, removal and stabilization
- Vegetation
- Sulfate reducing wetland

Delaware Mine
- Waste rock removal or consolidation and stabilization
- Vegetation
- Sulfate reducing wetland

Brittle Silver Mine
- Waste rock/tailings consolidation, removal and stabilization
- Vegetation
- Sulfate reducing wetland

Silver Spoon Mine
- Waste rock consolidation or removal and stabilization
- Vegetation
- Sulfate reducing wetland

Channelize Cinnamon Gulch near confluence with Peru Creek
- Channelize lower portion of stream into single channel

Unnamed mine east of Montezuma
- Waste rock consolidation and stabilization
- Vegetation
- Sulfate reducing wetland

Priority Two

Burke-Martin Mine
- Waste rock/tailings consolidation or removal and stabilization
- Waste rock/tailings regrading and capping
- Vegetation
- Hydrologic controls

Unnamed mine just north of Burke-Martin
- Waste rock consolidation or removal and stabilization
- Waste rock regrading

- Vegetation

Mine north of Montezuma

- Waste rock consolidation and stabilization
- Adit flow channelization away from waste rock

Rich Ore Group

- Adit closure
- Waste rock consolidation and stabilization
- Vegetation

Peruvian Mines

- Waste rock consolidation and stabilization
- Waste rock regrading/capping
- Vegetation
- Sulfate reducing wetland (lower mine)

Little Nell Mine

- Adit closure
- Waste rock consolidation and stabilization
- Vegetation
- Possible sulfate reducing wetland

Morgan Mine waste rock/adit flow

- Vegetation
- Sulfate reducing wetland

Shoe Basin Mine adit flow

- Sulfate reducing wetland
- Vegetation

Priority Three

Allen Emory Mine

- Waste rock consolidation and stabilization (non steep areas)
- Vegetation
- Diversion ditches

Cashier Mine

- Waste rock stabilization
- Vegetation
- Diversion ditches
- Possible sulfate reducing wetland

Unnamed mine just south of Webster Pass upper road crossing

- Waste rock removal consolidation
- Vegetation

Horseshoe Basin leaking adit/waste rock

- Diversion ditch of adit flow around waste rock

Horseshoe Basin flow past waste rock

- Waste rock consolidation and stabilization
- Vegetation
- Diversion ditch (stream flow removed from waste rock erosion)

Lower Chatauqua Mine

- Hydrologic controls
- Waste rock consolidation and stabilization
- Waste rock regrading
- Vegetation

Sulfate reducing wetland

Paymaster Mine waste rock

- Waste rock consolidation and stabilization
- Vegetation

Wild Irishman Mine

- Waste rock consolidation and stabilization
- Waste rock regrading
- Sulfate reducing wetland

Unnamed mine ¼ mile due north of Wild Irishman

- Waste rock consolidation and stabilization
- Waste rock regrading
- Vegetation
- Sulfate reducing wetland

Marlin Mine waste rock

- Waste rock consolidation and stabilization
- Vegetation
- Channelization of adit flow

Hunki Dori waste rock(upper area)

- Waste rock consolidation and stabilization
- Waste rock regrading
- Vegetation

Leaking adit/waste rock north wall above Cinnamon Gulch confluence

- Waste rock consolidation and stabilization
- Waste rock regrading
- Vegetation
- Channelization of adit flow

Tailings just north of Montezuma

- Tailings removal and stabilization
- Vegetation

Tailings in Sts. John Creek in meadow

- Tailings removal and stabilization
- Vegetation

Superior Mine waste rock

- Waste rock consolidation and stabilization
- Channelization of adit flow (hydrologic controls)

Flowing adit ¼ mile up Deer Creek

- Sulfate reducing wetland

Denuded areas in upper Snake River basin

- Diversion ditches or hydrological control
- Waste rock stabilization
- Vegetation

Waste rock below Climax mine in early upper Snake River basin

- Diversion of flow around waste rock

New York Mine waste pile/adit flow

- Hydrologic controls
- Waste rock consolidation and stabilization
- Waste rock regrading
- Possible sulfate reducing wetland

Waste rock in Quail Mine area/waste rock slightly lower off same road

- Waste rock consolidation and stabilization
- Waste rock regrading
- Diversion of flow channel from waste rock
- Vegetation

Waste rock/open shaft just west of road crossing of Peru Creek near east trib.

- Waste rock consolidation and stabilization
- Vegetation
- Close shaft

Waste rock adjacent to avalanche chute above Decatur building

- Vegetation

Only Priority-1 projects are discussed in detail below in this current version of the plan. When viewing a Priority-1 or Priority-2 project, the water-quality improvements are judged to be more important than the historical values of the sites. For Priority-3 projects, there is more likelihood for differing opinions regarding the value of the historical site versus the benefits of the associated water quality improvement.

6.0 Pollutant Reduction

For purposes of analyzing the impact of implementing the plan as proposed, zinc is used as a surrogate trace metal for purposes of remediation loads-reductions assessment in this Plan. There is a high degree of uncertainly associated with the impacts of cleaning up certain problem areas. By focusing on this trace metal as an indicator water-quality indicator, more attention can be given to the range of alternatives. Similar results are expected from the other metals, (copper, cadmium, and lead – the other trace metals of concern) the concentrations which exceed current stream standards. Most treatment schemes contemplated remove some or most of all four key metals (zinc, cadmium, copper and lead). However, they do not necessarily treat all four metals to the same degree and will not treat manganese to the same degree. It is anticipated that some level of reduction in all metals of concern will occur as a result of the recommended treatments outlined below.

6.1 Pennsylvania Mine

This Mine is the largest point source and most likely the largest non-point source of anthropogenic heavy metals loading in the Peru Creek/Snake River watershed. Proposed remediation includes waste rock/tailings removal or consolidation and stabilization, revegetation, partial neutralization of adit flow, sulfate reducing wetlands, and possible flow control from the mine. Additional field work is needed before a final design can be completed for the entire site.

Considerable analysis and remediation design has been conducted at this mine site. The USEPA has funded many of the recent studies and design effort and has set aside funds for additional work next year. A feasibility study was also conducted by NWCCOG addressing the adit flows. This study is supportive of previous efforts, all indicating that a two-phased system is required for treating adit flows (NWCCOG, 2006). For effective implementation of a passive system such as sulfate reducing wetlands, iron and aluminum must be precipitated out before the adit flow can be treated for the other metals. The real issue is what flow to expect. There have been recent instances (2007) of higher flows than had been traditionally measured, although past flow measurements were generally not conducted during precipitation events. The high flows in 2007, which were associated with a precipitation event, may indicate changes in the hydrogeology underground and/or in the surrounding area. Efforts are underway by the USEPA to better define this. The CDRMS, with USEPA support, hired a contractor to attempt to enter level C, one of the higher levels within the Pennsylvania Mine, to see if this level was wet and if it was connected to level F, where the draining adit is located. This effort was unsuccessful due to collapsing of the attempted opening, but it did confirm there was water in level C. This is potentially important, because level C is covered in part with unconsolidated material and could be a source of significant water to the mine. Level C has now been entered and will be further studied underground in 2013.

Flow is an important consideration, because any treatment system has to be designed to treat all of the flow from the mine or have a way to divert higher flows. If higher flows are diverted, the amount of metals removed from the mine effluent will be less. Flow was first measured on a year-round basis during the winter of 1993-1994 (BIT, 1994). The estimate of zinc from the mine that year was 12,682 pounds of zinc. That study most closely correlated to the 1994 water year. An initial trace-metals loads-reduction assessment by Dr. Tim D. Steele for the UAA indicated that in that water year Peru Creek discharged an estimated 10,353 acre-feet of water into the Snake River (Wyatt, 2008). In the period of record, Peru Creek (flow data at site SW-049) discharges an estimated 12,843 acre-feet annually to the Snake River. Therefore, 1994 was a relatively low flow year. Adjusting the 12,682 lbs/yr of zinc estimated that year to a normal year results in an estimated contribution of 15,700 lbs/yr of zinc from the Pennsylvania Mine on the average. This analysis and that below assumes that the flow from the mine follows the general flow of the basin. That is a tenuous assumption, but the general flow pattern is similar, but delayed. That is peak flows occur later in the mine than in the stream, but there is a high flow and a low flow period at the mine as well.

If the Mine is discharging more now from a 2007 “blow-out” event, we can perhaps capture some of that from the two 2007 sampling events, although one occurred before the August, 2007 event. In July, 2007 the mine flow was an annual equivalent of 20,063 pounds of zinc. In September, 2007 the annualized discharge was 15,955 pounds of zinc. The issue is how to use this data to estimate annual discharge. Looking at the period of record of streamflow for the Snake River at the River Run USGS streamflow-gauging station,(just downstream of the confluence of the NFSR) it turns out that taking the July flow and the September flow and averaging them correlates to the annual flow with a factor of 1.34. That is the average of the July flow and the September flow is 1.34 times greater than the average flow for the year. Averaging these two annualized zinc loadings and correcting by 1.34 provides another estimate for zinc discharge for the mine of about 13,500 lbs/yr of zinc.

The TMDL report states that the Pennsylvania Mine is contributing 38,896 lbs/yr of zinc (CDPHE, 2008). The long-term average of zinc discharge from Peru Creek to the Snake River further downstream at SW-49 is calculated to be slightly over 24,000 lbs/yr (see Section 6.11.1 below). Because the constituent zinc in general tends to behave, for the most part, as a conservative trace metal in the Snake River basin, (that is at the pH levels of Peru Creek and the Snake River it does not generally precipitate out but is diluted as it approaches Dillon Reservoir) that estimate reported and used in the TMDL may be excessive.

A Colorado Geological Survey report suggests that the flow in the tailings area is 1.5 gpm and the flow through the waste rock piles at the mine is 2 gpm (Wood and others, 2005). If this level were accurate, and it needs to be acknowledged that much of the work for that report was in the drought period of 2002, and if the average level of zinc were similar to levels from the mine (40 mg/L) the contribution from the non-point sources at the mine would be on the order of 500 lbs/yr zinc.

Taking all of this into consideration, there is justification for estimating the contribution from the Pennsylvania Mine complex to Peru Creek as 15,000 lbs/yr of zinc. The USGS study by Runkel et al estimates the Pennsylvania Mine contribution at approximately 20,000 lbs/yr. for the adit flow only. Another approximately 10,000 lbs/yr is contributed from the inflow along the wetlands below the old mill site. The mine adit seems to be in the 12,500 lbs/yr range to around 13,500 lbs/yr. The 500 lbs/yr from the non-point sources is probably low and did not deal directly with the tailings area which we know is highly contaminated. Further, there is some concern that there may be high ground water flow in the adit area and from the mine workings that we have not yet measured. No remedial action (loads reduction) treatment scheme will be 100 percent effective in trace-metals removal and some sources may not be treatable at all. Although much of the waste-rock/tailings' contribution can be effectively treated, it is unlikely that a treatment scheme for the mine adit will be 100% effective. For purposes of this Plan, the assumption is that 80% removal is possible resulting in a reduction of 12,000 lbs/yr of zinc and a continuing contribution of approximately 3,000 lbs/yr.

The cost of treatment to this level is difficult to estimate at this time, because of the uncertainty associated with the rate of flow from the mine and the source of the water feeding the mine. Furthermore, although it will be best to move the waste rock to a central repository rather than deal with it in place, the availability of a repository is uncertain at this time. Nevertheless, the costs will be substantial. Treatment of the adit flow alone, on a present value basis for twenty years has been estimated at 2-3 million dollars in one unpublished draft study done for the USEPA and presented to the SRWTF. The treatment of the waste rock and tailings will raise this cost. As a result, there is discussion of placing the Pennsylvania Mine on the National Priority List and using Superfund dollars to pay for the cleanup. With the need to go underground to better understand the sources of contaminated water and to perhaps control the flow rate, it is possible cleanup could approach $4 million. What will be important in any cleanup effort is the goal to keep the area wild and open. Electricity should not be brought to the area. The area is not accessible during the winter except via skis, snow shoes or snow machines. Innovative schemes and passive technology need to be selected.

The work that has been done at the Pennsylvania Mine since the 2009 Plan was developed has led to the belief that trying to treat the entire flow is not the best approach. As discussed above the current consensus is that it may be possible to build one or more bulkheads in the mine to stop the flow from the Level F adit or to reduce it substantially such that treatment of the remaining stream is more feasible in a passive system. The eight elements of the current plan are discussed in Section 5.4.1.

6.2 Saints John Mine

This Mine is judged in this plan to be the second worst source of trace metals pollution to the Snake River. Proposed remediation includes waste rock/tailings removal or consolidation and stabilization, vegetation and a sulfate reducing wetland. As was the case with the Pennsylvania Mine, there is a leaking adit, waste rock infiltration, tailings with water flowing around and through them and seepage from Saints John Creek into the mine area and across waste rock and tailings. Flows from the adit are significant. There has been little study of the scope of problem or best remediation practices to use at this mine. In 2007 there were two water quality and flow samples taken. These two samples-- in July and September, 2007-- provide point source estimates of zinc discharge of 8,200 lbs/yr and 4,500 lbs/yr. An annual average can be calculated from the July and September data using the same procedure that was used for the Pennsylvania Mine (Section 6.1). This averaging technique results in a discharge estimate of 4,700 lbs/yr of zinc from the mine. The waste rock and tailings could be providing nearly the same 500 pounds of zinc as the Pennsylvania Mine. While the area is smaller, there is more miscellaneous flow at this site than at the Pennsylvania Mine. The combination of adit flow and non-point source flow suggests the contribution of zinc is on the order of $5,000^{+}$ lbs/yr of zinc. For this Plan's analysis, it is assumed that 4,000 pounds of zinc can be removed annually through treatment.

The Colorado Division of Reclamation Mining and Safety is in the middle of a program to cleanup much of the Sts. John site. The specifics of the plan are discussed in Section 5.3. The tailings are being consolidated on a dry on-site repository and the wetlands area that used to consist largely of tailings is being restored to a natural wetlands. In addition a french drain has been constructed along the stream to keep water from infiltrating into the disturbed area. The actual adit flow is not being treated, but has been rerouted to avoid contact with tailings and waste rock.

The cost of cleanup at this mine will also be high. The non-adit associated costs will be substantial because of the volume of waste rock and tailings to be dealt with. Once again, it will be better if there is an offsite repository where the waste rock and tailings can be taken. Based on the estimates from the Pennsylvania Mine, it could easily take more than $1 million to treat the adit flow from the mine over a twenty year period. With the significant waste rock and tailings in the area, overall cleanup costs could easily top $2 million. It is unlikely that additional work will be warranted at the site. While the adit flow is mineralized, the concentrations are relatively low and with the improvements to the overall site, treatment of the adit flow is probably not justified.

6.3 Jumbo Mine

This mine has not been studied to any significant degree. It was identified in the early 1990's Abandoned Mine Lands Inventory report and again mentioned in the Munroe report in 1999. One sample was collected in the fall, 2008 and analyzed by the USEPA. The effluent is clearly high in iron, as the channel is lined in red iron precipitate (1.5 mg/L total iron and 0.1mg/L dissolved iron). The flow rate is high. It appeared to be flowing in excess of 50 gpm in September, 2008, the low flow season. In addition there is flow directly from the waste rock toe to Peru Creek. This flow was low in September, 2008, but showed evidence of higher flow at other times. There was also evidence of waste rock flow on the eastern side of the waste pile. A flow rate of 100 gpm at 5 mg/L of zinc (the 2008 sample was 6.6mg/L) would provide on the order of 2000 lbs/yr zinc. A flow of 5 gpm of 20 mg/L zinc from the waste pile would represent another 400 lbs/yr of zinc. There is considerable uncertainty associated with this estimate due to the very limited data. For this Plan's analysis, it is assumed that 1500 lbs/yr of zinc could be removed from this source area. Proposed remediation includes waste rock removal and stabilization, vegetation and a sulfate reducing wetland.

Cleanup of this mine has several challenges. First, there is a private cabin with signs of temporary occupancy at the top of the waste rock area. The cabin would require relocation to allow removal of the waste rock. Second, due to the limited area at the site, the waste rock should be removed to a repository. Third, while passive treatment of the adit flow in a sulfate reducing wetland is preferred, the iron might prove an obstacle. If two stage treatment is needed, costs might be similar to the Pennsylvania Mine and Sts. John Mine costs in the $2 million range. If only a sulfate reducing bioreactor is needed along with the waste rock removal, costs might be closer to $1 million.

6.4 Blanche Mine

This Mine on the upper Snake River is another one with a significant draining adit. Remediation planned includes waste rock consolidation and stabilization, vegetation and a sulfate reducing wetland. There has only been one known water quality sample taken. That was in 2008. The zinc content was 1.1 mg/L. Flow is difficult to measure at this site due to the way the flow emerges from the adit. A Forest Service hydrologist estimated flow in July, 2007 at 50-75 gpm. Flow from the mine has been higher than it was that day. A 50 gallon per minute flow at the 1.1mg/L concentration would represent 216 lbs/yr of zinc. A flow of 75 gpm at that same concentration would result in a zinc load of 325 lbs/yr. Water is currently flowing over the waste rock potentially adding to the zinc load. For this Plan's analysis, a removal of 200 lbs/yr of zinc is assumed.

Treatment of the waste rock at this mine will be relatively easy. It should be able to be moved to an area against the mountain on the east of the flat pad the adit flow crosses and covered and revegetated for only about $50,000. The adit can be treated with a passive system near the wetland below for most likely a similar amount or slightly more.

6.5 Warden Gulch Mine

This Mine located on lower Warden Gulch contributes a modest, but steady adit flow and all flow occurs across waste rock. Remediation proposed includes waste rock removal, vegetation and a sulfate reducing wetland. Significant precipitation of iron has occurred creating ferricrete that the mine drainage flows across. Only one sample of the flow and concentration could be found. That sample was taken on September 26, 2007. Annualizing flow from that measurement suggests a zinc loading of 282 lbs/yr. Using the ratio of loading from the Pennsylvania Mine for July versus September shows a possible July flow of 355 lbs/yr. Annualizing a July/September reading as discussed for the Pennsylvania Mine above provides an estimate of zinc loading of 250 lbs/yr. For this Plan's analysis, a removal of 200 lbs/yr of zinc is assumed.

There is no good place on site for consolidation/stabilization of the waste rock. Movement to a repository would be best. There is a potential place for a passive treatment system for the adit flow. Because of the relatively small size of the disturbed area and the low flow from this Mine, remediation of this site might be accomplished for $100,000. Access is available via an old mining road.

6.6 Delaware Mine

There are two leaking adits that are from the old Delaware Mine. One is much more significant than the other. Both have waste rock issues, but again one is much more significant than the other. But, in both cases the flow from the adit is in contact with waste rock from the Mine. Remediation proposed includes waste rock consolidation/removal, stabilization, vegetation and a sulfate reducing wetland. The main Delaware Mine area is at the very lower end of Cinnamon Gulch, just before the creek drops steeply to the wetlands below. There are two 2007 samples of the flow and water quality. One is from the Pennsylvania Mine Site SI ARR (Rudolph, 2008) conducted by the CDPHE. That sample was taken on August 29, 2007. The other sample was taken on September 26, 2007. At both times the flow was about the same, 6.13 gpm verses 7 gpm. The zinc concentrations in the flow were very different. The CDPHE sample showed a concentration of 0.5 mg/L, whereas the USEPA sample showed a concentration of 4.88mg/L. The lower concentration would represent a loading of 12 lbs/yr whereas the higher concentration would suggest a loading of 135 lbs/yr. The second adit has lower flow and according to an August 29, 2007 sample collected by the state, lower zinc concentrations. This adit flow is most likely contributing only about one pound of zinc per year from the adit flow. In both adit areas, adit flow is in contact with waste rock. For this Plan's analysis, the assumption is that 100 pounds of zinc per year can be removed with complete cleanup of both sites. Because of the size of the waste rock at the lower site, it is possible that this estimate is low.

With the exception of the direct treatment of the adit flow, this mine has been successfully treated. The treatment is discussed in section 5.4.2 above. The waste rock has been consolidated on site and the disturbed areas revegetated. The adit flow channel has been riprapped and lined with geomembrane and covered with limestone rock. The adit flow under the road travels through a new culvert. The pond was cleaned out. As with the Sts. John mine, there is probably little reason to treat the adit flow directly, unless it were part of a test of new technology.

Costs to cleanup this area again involve both waste rock and adit issues. Direct costs to cleanup the waste rock problems at both sites has been estimated to be on the order of $115,000 for a 319 grant application. There is room to move the waste rock to a consolidated spot on site. It would probably be better if the waste rock were moved to a repository off site, but it is less important here than in other areas. The adit flow is low and a passive system could easily be built in the area. Considering indirect costs a reasonable estimate of cleanup might be $250,000.

6.7 Brittle Silver Mine

This Mine, located in the Peru Creek subwatershed, has more non-point source issues than adit issues. Remediation plans include waste rock/tailings consolidation, removal and stabilization, and a sulfate reducing wetland. There is a leaking adit which, based on the state's August, 2007 test (Rudolph, 2008) is contributing on the order of 10 lbs/yr if zinc, although the adit flow does not directly flow into the stream all year. There are significant waste rock and more importantly tailings issues. These could contribute on the order of 100 lbs/yr of zinc and are largely correctable. For this Plan's analysis, a removal of 100 pounds per year is assumed.

The most significant non-point source issue at the Brittle Silver Mine has been the flow from Cinnamon Gulch coming down the mining road and spilling across a tailings area. The channelization of Cinnamon Gulch in the area of the mining road has stopped this problem. The USGS study by Runkel, et al showed that this flow across the tailings area was one of the greatest sources of lead to Peru Creek. Future monitoring should check to see if this change reduces the lead contributions to Peru Creek. Section 5.4.2 addresses the Cinnamon Gulch channelization.

Costs to cleanup this site will be more than at other similarly sized sites because of the significant tailings contamination. A site like this also raises the question of water cleanup versus historical preservation. The water quality impacts appear to be significant enough to offset loss of a historical site. An estimate of $250,000 might be low.

6.8 Silver Spoon Mine

This Mine at the headwaters of Cinnamon Gulch has a draining adit and waste rock issues. Remediation planned includes waste rock consolidation or removal and stabilization, vegetation and a sulfate reducing wetland. The adit flow crosses waste rock as it flows down the gulch. There are three adit samples. Two were collected on the two USEPA sampling days of July 9 and September 26, 2007. The third was collected by the state on August 29, 2007 (Randolph, 2008). These three samples suggest zinc loading of 627 lbs/yr, 325 lbs/yr and 317 lbs/yr respectively. Taking the July and September (2007)loadings and correcting to an annual load as discussed for the Pennsylvania Mine (Section 6.1) suggests a loading of 355 lbs/yr from the adit. It is more difficult to estimate the waste rock additions. This will be a difficult flow to treat due to its location. For this Plan's assessment, a removal of 300 lbs/yr of zinc is assumed.

Simple treatment of the flow channel by removing the waste rock will be relatively inexpensive. To be effective all of the waste rock at the headwaters should be removed. This will cost more. The adit treatment at that site will be difficult because the area is avalanche prone. An estimate of $100,000 is judged to be reasonable.

6.9 Channelize Cinnamon Gulch

The stream coming out of Cinnamon Gulch drainage branches into three separate channels about 50 yards above the road from the Pennsylvania mill to the Brittle Silver mine. The western most channel generally flows down (west) this road across the lower portion of the Brittle Silver Mine before dropping down gradient to the north toward Peru Creek. As it seeps and runs to the north is generally goes right through and over the tailings from the Brittle Silver mill. Some flow from the middle channel is also believed to end up crossing some of the tailings, although the area below the road is such a wetland that actual flow is difficult to ascertain. The tons that this project would remove are shown for the Brittle Silver Mine to avoid over counting cleanup effectiveness.

An estimate to channelize the lower portion has been developed for a future grant with a direct cost of $65,000. An estimate of $100,000 in total costs seems more reasonable to collect the flow high enough to prevent future splitting of the flow channel.

6.10 Unnamed Mine East of Montezuma

There is at least one old mine on the hill east of Montezuma that is still flowing a considerable amount. There are others with less flow. Remediation proposed is waste rock consolidation, stabilization and vegetation and a sulfate reducing wetland. There has been no flow measurement at this adit, but there has been one quality sample. Unfortunately, that sample had a problem with the zinc analysis. The total metal analysis for zinc was 11.7 mg/L whereas the dissolved zinc level was only 0.01mg/L. It is not possible to say with certainty which is correct. However, the iron was 5 mg/L and the manganese was 17 mg/L. There is considerable staining on the rocks along the flow channel. The pH was about 4 su from the adit and a number of seeps in the area. A zinc concentration of around 10 mg/L seems more likely. At a flow rate of 25 gpm and a concentration of 10 mg/L would represent a zinc load of about 1,000 lbs/yr. This Plan's assessment assumes a reduction of 500 lbs/yr.

This mine is more difficult to reach, but can be accessed by a small road that is going right past a new house being built directly adjacent to the road. There are areas on site where waste rock could be consolidated and the adit flow treated. Cleanup at this site might be accomplished for $100,000.

In summary, the reductions in zinc loading for the Snake River in this Plan are based on the above-estimated and assumed reductions (see Sections 6.1 through 6.10). Clearly, clean-up of the projects in Priority-2 and Priority-3 will also have a positive impact. How much is even more difficult to forecast than it is for the Priority-1 projects. This Plan will assess in detail the potential improvements to the water quality in the Snake River from these projects. Further improvement of the Snake River water quality can be qualitatively estimated following the Priority-1 analysis.

6.11 Pollutant Characterization and Removal Impacts

In this section, a detailed characterization of hydrologic and water-quality (using zinc as an indicator) conditions is shown. Given the estimates of pollutant-removal quantities above (see Sections 6.1 through 6.10 above, given in lbs/y of zinc), a simple loads-reduction spreadsheet "model" (Excel files) developed earlier for the watershed (Steele and Wyatt, 2004) and modified for the UAA (Wyatt, 2007) was applied to assess the potential benefits of these reductions, in terms of reduced zinc loads and concentrations at key selected downstream stream-monitoring sites. These sites are located on the Snake River and Peru Creek (upstream-to-downstream order) as follows:

Site SW-047, Snake River just upstream from Peru Creek confluence.
Site SW-049, Peru Creek near its confluence with the Snake River,
Site SW-050, Snake River just downstream from the Peru Creek confluence,
Site SW-117, Snake River just upstream from the North Fork Snake River confluence, and
Site SW-082, Snake River just downstream from the North Fork Snake River confluence (USGS gaging-station 09074500).

Locations of these sites are given in this Plan's Figure 2b. This assessment strategy is intended to provide useful information relative to both ambient (pre-remediation) conditions and remediation-impacted benefits. It is provided as Snake River profiles, using spreadsheet-model analysis results for four of the five monitoring sites. The fifth monitoring site on Peru Creek (SW-049) is used to characterize directly this major tributary relative to the remedial actions anticipated in this Plan.

It is recognized that focus of this aspect of the Plan is on the "Priority-1" proposed projects for remediation. As remedial actions are developed in more detail and are implemented, the estimates herein may be changed to reflect actual values of reduced zinc loads. Also, lower-priority projects over time may be designated and funded for remediation. Accordingly, it is recommended that this aspect of the Plan be updated and revised as projects are completed and new information is provided. The spreadsheet model applied to this watershed is designed to facilitate these enhancements, as updated completed projects and associated data and information are available in the future.

6.11.1 Ambient Conditions

This section provides a summary overview of ambient (pre-remediation) hydrologic and water-quality (in terms of the indicator dissolved zinc) characteristics of streams of the Snake River watershed at the key monitoring sites indicated. These conditions (averages for the 1994-2008 water-year period of record) are summarized in Table 19 *(values are rounded to three significant figures)* and are described in some detail herein and in more detail in Appendix G. Because zinc readings have been higher basin wide in the time period 2006-2008, the table shows the averages for both 1994-2005 and for 2006-2008.

These higher zinc concentrations in the 2006-2008 time frame present some challenging issues which needs to be addressed (and are planned to be addressed in the §319 grant that has been applied for to initiate remediation activities in Cinnamon Gulch). The basic question is whether the increase is a result of differences in laboratory methods or whether it represents a fundamental change in the water-quality characteristics of the watershed. If it is the latter, it may have profound significance on remediation success in the watershed.

Table 19 – Streamflow and Water-Quality Conditions at Selected Monitoring Sites, Snake River Watershed

Site	*SW-047*	*SW-049*	*SW-050*	*SW-117*	*SW-082*
Avg Flow, cfs	21.1	18.0	40.2	41.8	64.4
Avg Flow, ac-ft	15,300	13,000	29,300	30,300	46,600
TW D-Zinc conc., ug/L	377/476	985/1149	691/693	479/570	316/329
QW D-Zn conc., ug/L	103	231	178	135	84.0
D-Zinc load, lbs/y	12,800	24,100	42,200	31,500	31,700

Notes: TW = time-weighted (1994-2005 vs. 2006-2008); QW = discharge-weighted, see Appendix G.

The following characteristics are noteworthy:

The cluster of monitoring sites around the Peru Creek confluence seem realistic, in terms of the upstream sites' (SW-047 & SW-049) characteristics matching those for the downstream site (SW-050, see Figure 2b). This particularly is the case for streamflows; the downstream flow volume is about 1,000 ac-ft greater than the sum of the two upstream sites.

The zinc concentrations for this same cluster appear realistic as well. The ambient sample analyses for D-Zn available at the three sites are interpolated between sample Julian dates, in order to provide relatively unbiased averages. This methodology has been applied in several other Colorado watersheds (Steele, 1999; TDS Consulting Inc., 2008) and is judged to improve upon simple averaging of sample results staggered randomly throughout the year (and also with several months without data values).

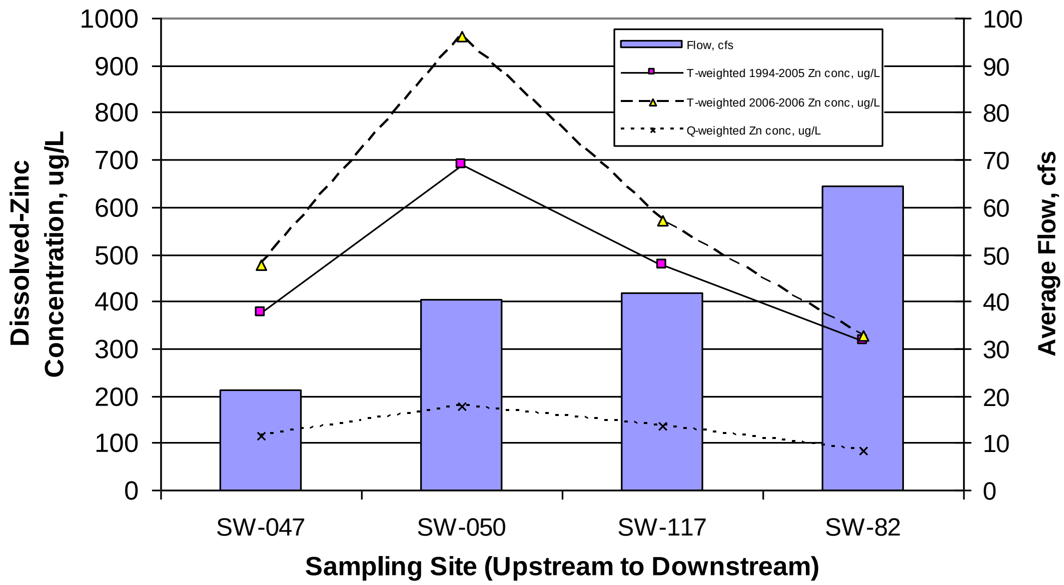
The ambient zinc load for the Snake River below Peru Creek (SW-50) may be biased high (see also below). The sum of average Zn loads for the two upstream sites is 36,900 lb/y, about 13 percent less than the load estimated for the downstream site (42,200 lbs/y) While the site (SW-50) is about ½ mile below the confluence, field work showed no other sources of contamination in this stretch. There is little flow data at this site. This downstream site had relatively few sample analyses (N=9 during 1990, 1998, and 2001; N=14 during 2002, a extremely dry year excluded from the data set; and N=14 during 2006-2008, when USEPA analytical results are suspected to be biased high). This anomalous estimate of Zn loads at this site for a shorter period of record also was noted in the earlier water-quality assessment (estimated to be 55,100 lbs/y in Steele and Wyatt, 2004, Table E-2).

Downstream in the Snake River, streamflows increase appreciably, as would be expected. The increase in Snake River flows is minimal between Peru Creek and the NFSR but flow increases significantly due to NFSR inflows (see differences between Qs at sites SW-117 upstream versus SW-082 downstream).

Although average flows change little in the Snake River between Peru Creek and the North Fork Snake River, zinc characteristics do change appreciably (lower concentrations and reduced loads). Due primarily to NFSR inflows, D-Zn concentrations at SW-082 (USGS stream gage) decrease by more than half compared to just below the Peru Creek confluence(178 down to 84 ug/L Q-weighted D-Zn). Zinc loads are significantly less than estimated for upstream just below Peru Creek. D-Zn inflows from the NFSR are negligible (about 150 lbs/y). At the furthest downstream monitoring site (SW-082), D-Zn loads are estimated to total 31,700 lbs/y. The number of sample D-Zn analyses for this lower monitoring site is quite high – much greater than the number of data values at upstream sites. Hence, the mass balance of D-Zn loads for this lower Snake River monitoring-site cluster is quite good and better when compared to the situation for Peru Creek versus Snake River above vs. below Peru Creek.

A stream-profile of ambient (e.g., pre-remediation project) D-Zn concentrations for the Snake River is given in Figure 88. For this depiction of ambient conditions, time-weighted values are used, and D-Zn concentrations for two periods are separated (due to the pending issue of 2006-2008 analyses).

Figure 88 -- Snake River Flow and Zinc-Concentration Profiles



6.11.2 Remediation Beneficial Impacts

This section describes the potential reductions in zinc loads resulting from various remedial actions outlined above in Section 6. The various Priority-1 projects (details provided previously above in Sections 6.1 through 6.10) are summarized below in Table 20 and distinguish between those located in the upper Snake River subwatershed and those in the Peru Creek subwatershed. The anticipated zinc-loads' reductions in these two subwatershed areas are 4,700 lbs/y and 14,200 lbs/y, respectively. Hence, downstream from the Peru Creek confluence, zinc loads removed will not exceed 18,900 lbs/y, as a result of implementation and completion of these projects.

Table 20 – Summary of Estimated Zinc-Loads Reduction (lbs/y)

Project Description	***Est. Reduction***	***Project Description***	***Est Reduction***
Pennsylvania Mine	12,000	Saints John Mine	4,000
Jumbo Mine	1,500	Blanche Mine	200
Warden Gulch Mine	200	Unnamed Mine	500
Delaware Mine	100	*(east of Montezuma)*	
Brittle Silver Mine	100		
Silver Spoon Mine	300		
Totals:	**14,200 lbs/y**		**4,700 lbs/y**

Source: see Plan Sections 6.1-6.10 above

As mentioned previously, the potential beneficial impacts described herein may be changed, once projects are completed and post-project monitoring confirms the effectiveness of various treatment technologies applied to each project. Also, other projects may be designated for remediation over both the near- and long-term. Both of these factors may significantly alter the loads reductions (hence, beneficial impacts) of those projects initially identified for consideration in this assessment. The Excel spreadsheet "model", results of which are provided in the following sections, also can be used to evaluate these future changes and enhancements.

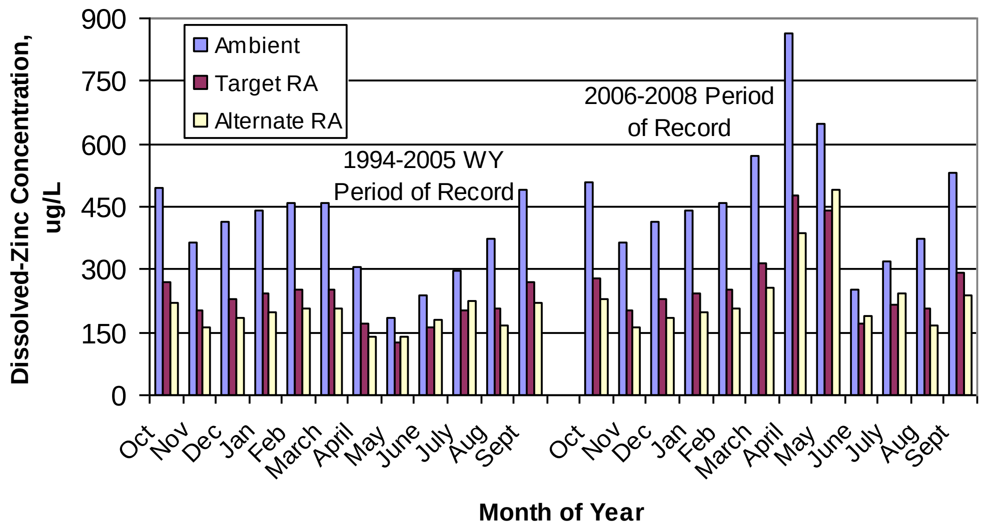
This model allows for ***monthly*** estimates of loads-reduction efficiencies to be provided as input. Realistically, this capability is important because it is envisioned that treatment effectiveness will tend to be lower during high flows (May through July in the assessment described for this Plan) and higher during low flows. In this preliminary loads reduction assessment, a simple form of sensitivity analysis was used to demonstrate this model capability. Caution is given that concentration changes are comparing ambient time-weighted concentrations with post-project discharge-weighted averages (always lower than time-weighted averages). This comparison is due to the fact that the reduced loads are used to convert back to post-remediation concentrations, and the spreadsheet does not calculate ambient (pre-project) discharge-weighted concentrations. Therefore, graphics showing these comparisons give the indication that reduction efficiencies are greater that actual in the case of concentration changes.

6.11.2.1 Snake River above Peru Creek

As indicated above, a total of 4,700 lbs/yr of zinc is estimated to be removed from three remediation projects located in the upper Snake River subwatershed. For this assessment, it was assumed that the entire 4,700 lbs/y of zinc loading was removed at the downstream end of this subwatershed. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from nearly 12,900 lbs/y down to about 8,050 lb/y. The assumed treatment effectiveness to achieve this reduction in loads was either 45/32 percent for low/high flow seasons or 55/24 percent for these seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall effectiveness of 37 percent (on an annualized basis). The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.1).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average discharge-weighted Zn concentrations are reduced from 377 ug/L (time-weighted ambient, pre-project) down to 215 ug/L (discharge-weighted post-project) for the 1994-2005 period. For the more recent 2006-2008 period, these values are 476 ug/L (time-weighted ambient), going down to 279 ug/L. On a monthly basis, these beneficial impacts of loads reductions for these two periods are depicted in Figure 89. Although these reductions are significant, they are not sufficient to meet TVSs.

Figure 89 -- D-Zinc Concentration Reductions, Remedial Actions, Snake River above Peru Creek (SW-047)



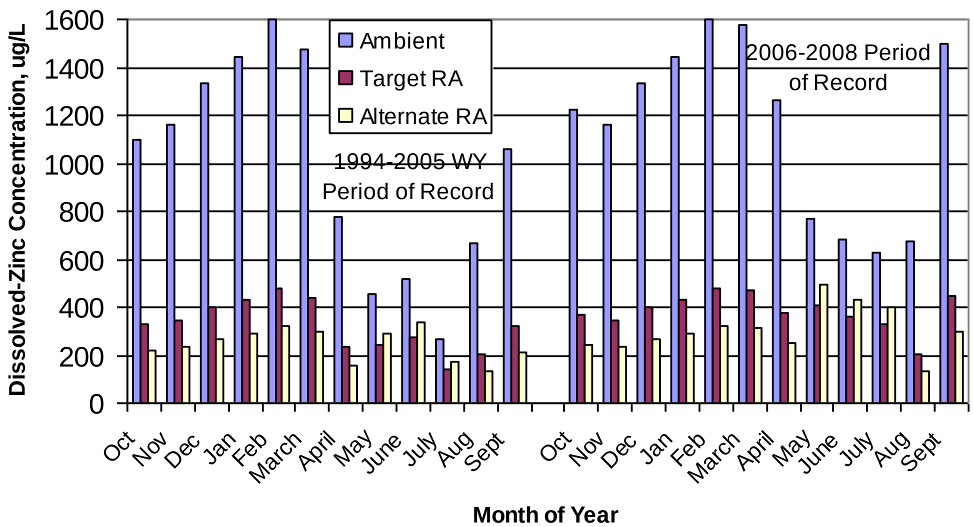
Notes: Monthly ambient (pre-project) concentrations are time-weighted; whereas target or alternate remedial-action (RA) monthly concentrations are discharge-weighted. See Appendix G

6.11.2.2 Peru Creek

As indicated above, a total of 14,200 lbs/yr of zinc is estimated to be removed by six remediation projects located in the Peru Creek subwatershed. For this assessment, it was assumed that the entire 14,200 lbs/y of zinc loading was removed at the downstream end of this subwatershed. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from nearly 24,100 lbs/y down to nearly 9,900 lb/y. The assumed treatment effectiveness to achieve this reduction in loads was either 70/47 percent for low/high flow seasons or 80/36 percent for these seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall effectiveness of 41 percent (on an annualized basis). The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.2).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average discharge-weighted Zn concentrations are reduced from 985 ug/L (time-weighted ambient, pre-project) down to 320 ug/L (discharge-weighted post-project) for the 1994-2005 period. For the more recent 2006-2008 period, these values are 1149 ug/L (time-weighted ambient), going down to 385 ug/L. On a monthly basis, these beneficial impacts of loads reductions for these two periods are depicted in Figure 90. Although these reductions are dramatic, they are not sufficient to meet the underlying stream standards (TVSs).

Figure 90 -- D-Zinc Concentration Reductions, Remedial Actions, Peru Creek near Snake River Confluence (SW-049)



Notes: Monthly ambient (pre-project) concentrations are time-weighted; whereas target or alternate remedial-action (RA) monthly concentrations are discharge-weighted See Appendix G.

6.11.2.3 Snake River below Peru Creek

As indicated above, a total of 18,900 lbs/yr of zinc is estimated to be removed by a total of nine remediation projects located in both the Peru Creek and upper Snake River subwatershed. For this assessment, it was assumed that the entire 18,900 lbs/y of zinc loading was removed at the downstream end of this subwatershed. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from nearly 42,200 lbs/y down to nearly 23,200 lb/y. The assumed overall treatment effectiveness by the nine remediation projects to achieve this reduction in loads was either 61/36 percent for low/high flow seasons or 68/32 percent for these seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall effectiveness of 45 percent (on an annualized basis). The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.3).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average discharge-weighted Zn concentrations are reduced from 691 ug/L (time-weighted ambient, pre-project) down to 320 ug/L (discharge-weighted post-project) for the 1994-2005 period. For the more recent 2006-2008 period, these values are 963 ug/L (time-weighted ambient), going down to 385 ug/L. On a monthly basis, these beneficial impacts of loads reductions for these two periods are depicted in Figure 91. Although these reductions are significant, they are not enough for the water quality to meet the underlying stream standards (TVSs).

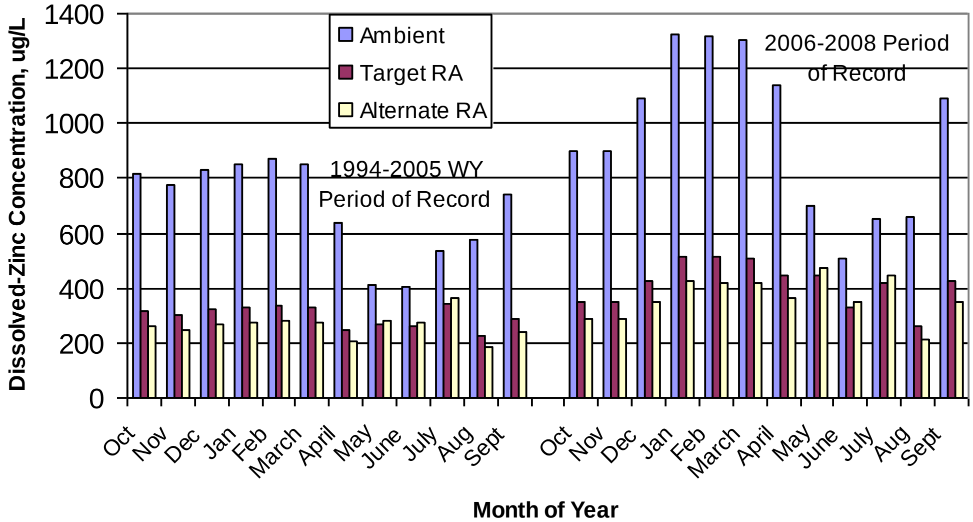


Figure 91 -- D-Zinc Concentration Reductions, Remedial Actions, Snake River below Peru Creek (SW-050)

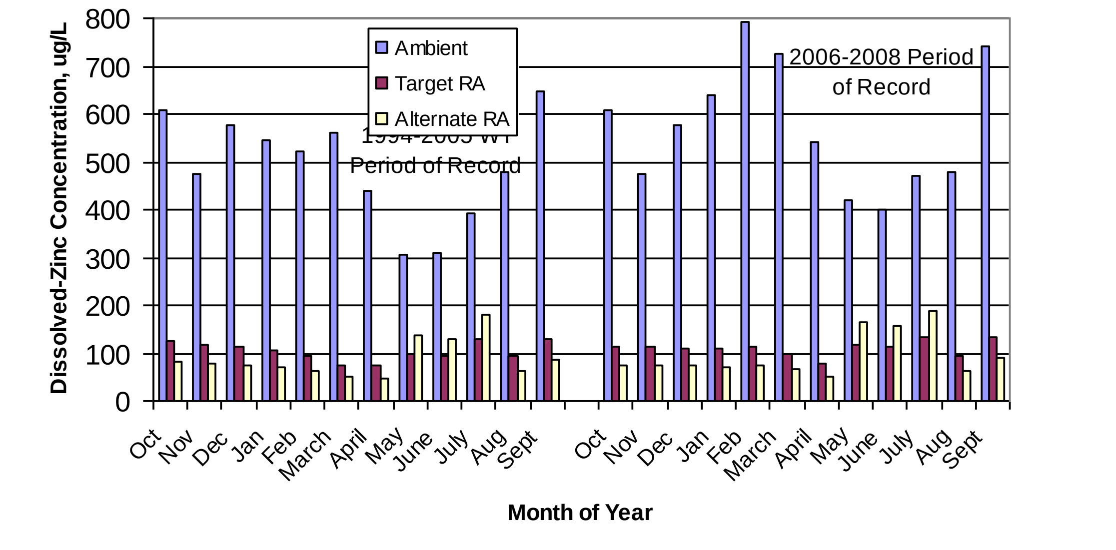
Notes: Monthly ambient (pre-project) concentrations are time-weighted; whereas target or alternate remedial-action (RA) monthly concentrations are discharge-weighted See Appendix G.

6.11.2.4 Snake River above the North Fork Snake River

As indicated above, a total of 18,900 lbs/yr of zinc is estimated to be removed by a total of nine remediation projects located in both the Peru Creek and upper Snake River subwatershed. For this assessment, it was assumed that the entire 18,900 lbs/y of zinc loading was removed at this downstream stream location. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from about 33,200 lbs/y down to approximately 14,700 lb/y. The assumed overall treatment effectiveness by the nine remediation projects to achieve this reduction in loads was either 67/30 percent for low/high flow seasons or 80/35 percent for these seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall effectiveness of 56 percent (on an annualized basis). The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.4).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average discharge-weighted Zn concentrations are reduced from 480 ug/L (time-weighted ambient, pre-project) down to about 210 ug/L (discharge-weighted post-project) for the 1994-2005 period. For the more recent 2006-2008 period, these values are 570 ug/L (time-weighted ambient), going down to 254 ug/L. On a monthly basis, these beneficial impacts of loads reductions for these two periods are depicted in Figure 92. As significant as these reduction are, they are not sufficient to allow the stream water quality to meet the underlying stream standards (TVS).

Figure 92 -- D-Zinc Concentration Reductions, Remedial Actions, Snake River above North Fork Snake River (SW-117)

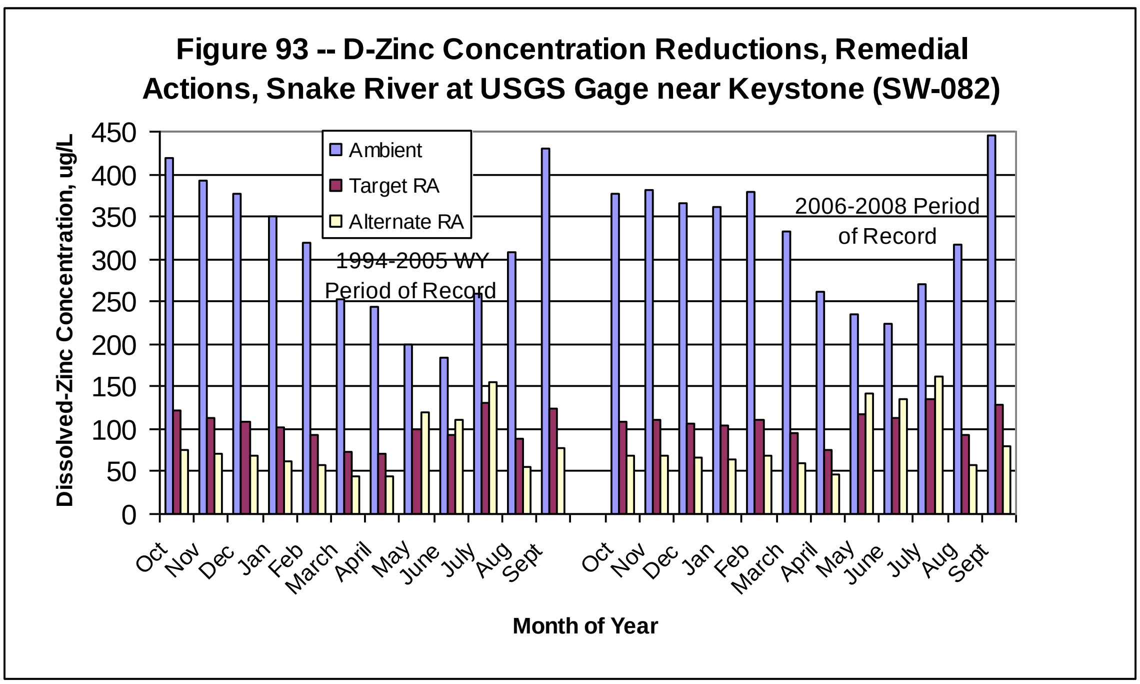


Notes: Monthly ambient (pre-project) concentrations are time-weighted; whereas, target or alternate remedial-action (RA) monthly concentrations are discharge-weighted. See Appendix G.

6.11.2.5 Snake River below the North Fork Snake River (near Keystone and at USGS gage)

As indicated above, a total of 18,900 lbs/yr of zinc is estimated to be removed by a total of nine remediation projects located in both the Peru Creek and upper Snake River subwatershed. For this assessment, it was assumed that the entire 18,900 lbs/y of zinc loading has been removed at the downstream end of the Snake River watershed at this location. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from nearly 31,700 lbs/y down to slightly over 13,200 lb/y. The assumed overall treatment effectiveness by the nine remediation projects to achieve this reduction in loads was either 70/50 percent for low/high flow seasons or 80/30 percent for these seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall effectiveness of 59 percent (on an annualized basis) [Note: This effectiveness is higher that upstream at SW-050, because of the calculated loss of Zn loads between these two sites]. The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.5).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average discharge-weighted Zn concentrations are reduced from 316 ug/L (time-weighted ambient, pre-project) down to 104 ug/L (discharge-weighted post-project) for the 1994-2005 period. For the more recent 2006-2008 period, these values are 329 ug/L (time-weighted ambient), going down to 111 ug/L. On a monthly basis, these beneficial impacts of loads reductions for these two periods are depicted in Figure 93. Although these reductions are significant, they do not allow the underlying stream standards (TVS) to be met for zinc. However, at this site, the remaining non-compliance is minimal. The average zinc TVS is on the order of 60-70u/L; whereas the projected concentration after cleanup is on the order of 100ug/L.



Notes: Monthly ambient (pre-project) concentrations are time-weighted; whereas target or alternate remedial-action (RA) monthly concentrations are discharge-weighted See Appendix G.

There are at least four messages that should be taken from this analysis. First, this modeling is taking a limited amount of data and using it to the maximum to try to help understand what implementation of significant clean-up of anthropogenic sources of water pollution in the basin might accomplish. As such, it must be used with caution and always within context. There are significant uncertainties in the estimates of clean-up at each mine, in the ongoing natural sources of contamination, in weather events that scour areas with significant exposed metal sources and so on. Second, the analysis shows that cleaning up the most significant anthropogenic sources will not allow the TMDL's to be met or for existing water quality standards to be met. However, third, the analysis shows that significant improvement is possible. While this improvement will not necessarily show up high in the basin, it should show up in the middle to lower portions of the basin in the Snake River. That is, it might allow fish such as brook trout to move up the Snake River, above the confluence with the North Fork of the Snake River, where they do not like to go now. Finally, fourth, this analysis does not deal with issues such as further diversions from the basin. If, for example, the Vidler tunnel should decide to increase diversions from the upper Peru Creek drainage, there would be less clean water available for dilution and an increase in the concentration of metals above that projected by the model. Any other diversions of "clean" water would have the same effect if it were to occur.

6.11 Pollutant Characterization and Removal Impacts

In this section, a detailed characterization is provided for hydrologic and water-quality (using zinc as an indicator) conditions at key monitoring-site locations in the Snake River watershed. Given the estimates of pollutant-removal quantities above (see Sections 6.1 through 6.10 above, given in lbs/y of zinc), a simple loads-reduction spreadsheet "model" (Excel files) was developed initially for this watershed (TDS Consulting Inc. and Wyatt, 2004), modified for a draft use-attainability analysis (UAA) (Wyatt, 2007), and more recently included in the original Plan. This methodology was applied to assess the potential benefits of these reductions, in terms of reduced trace-metals loads and concentrations at key selected upstream stream-monitoring sites (TDS Consulting Inc., 2013). These latter results for dissolved zinc (D-Zn) are combined in this Plan update along with two lower mainstem Snake River monitoring sites. The sites included for this update are located along the Snake River (four sites) and the farthest downstream site on Peru Creek; these five sites are the following:

Site SW-047, Snake River just upstream from Peru Creek confluence,
Site SW-049, Peru Creek near its confluence with the Snake River,
Site SW-050, Snake River just downstream from the Peru Creek confluence,
Site SW-117, Snake River just upstream from the North Fork Snake River confluence, and
Site SW-082, Snake River just downstream from the North Fork Snake River confluence (USGS gaging-station 09074500 and SEO gaging-station SNAKYO).

Locations of these sites are given in this Plan's Figure 2b. This assessment strategy is intended to provide useful information relative to both ambient (pre-project) conditions and remedial-action projects resulting in trace-metals (TMs) load reductions in the upper Peru Creek subwatershed. It is provided as Snake River profiles, using spreadsheet-model analysis results for the four mainstem Snake River monitoring sites of the five sites considered in this assessment. The fifth monitoring site on Peru Creek (SW-049) is used to characterize directly conditions for this major tributary relative to ambient characterization and the specific project remedial actions described in a separate 319-Grant report (TDS Consulting Inc., 2013, p. 15).

This aspect of the Plan thus focuses upon two of the "Priority-1" proposed projects for remediation identified in the original Plan. Additional remedial actions and projects have been and no doubt will be identified, developed in more detail, and eventually implemented. Also, post-project monitoring at key watershed sites will help to assess loads reductions. As a result, estimates of benefits (in terms of load reductions) included herein may be changed to reflect more realistic values of reduced zinc loads (and for other TMs, if added later in future investigations). Lower-priority projects over time may be designated for remedial-project funding. Accordingly, it is recommended that this aspect of the Plan continue to be updated and revised as projects are completed and new information is provided. The spreadsheet model applied to this watershed is designed to be used to facilitate these changes and enhancements, as updated completed projects and associated data and information are available in the future.

6.11.1 Ambient Conditions

This section provides a summary overview of ambient (pre-remediation) hydrologic and water-quality (in terms of the indicator dissolved zinc) characteristics of streams of the Snake River watershed at the key monitoring sites indicated. These conditions (averages for the 2004-2012 water-year period of record) are summarized in Table 19 *(values are rounded to three significant figures)*. The rationale for selecting this period of record for the baseline comparing ambient conditions with estimated load and concentration reductions has been provided elsewhere (Steele and others, 2010; TDS Consulting Inc., 2012; Todd and others, 2013). In essence, there had been a time-trend of increasing concentrations, especially in comparing recent years data with earlier data. Whether or not this has been a linear trend over time of a shift in conditions in recent years is subject to continued discussion and professional judgment. Accepting this observation derived from the available data, nonetheless, the 9-year recent period of record was selected for comparison of loads-reduction benefits. Results are given in more detail in a separate 319-Grant report for the upstream three sites (TDS Consulting Inc., 2013) and in this Plan's Appendix G for the two lower downstream Snake River sites. This update thus provides comparisons using an additional four years of record not available in the original Plan.

These higher zinc concentrations in the 2006-2012 time frame present some challenging issues which were addressed 319-Grant scope, considering initial remedial-action projects involving the Pennsylvania Mine and in nearby Cinnamon Gulch. The basic question is whether the increase is a result of differences in laboratory methods or whether it represents a fundamental change in the water-quality characteristics of the watershed. If the latter, it has profound significance on the ambient (baseline) period with which to judge remediation benefits.

Table 19 – Streamflow and Ambient Water-Quality Conditions at Selected Monitoring Sites, Snake River Watershed (2004-2012 Water-Year Period of Record)

Site	***SW-047***	***SW-049***	***SW-050***	***SW-117***	***SW-082***
Avg Flow, cfs	17.4	18.3	36.7	37.0	61.0
Avg Flow, ac-ft	12,600	13,200	26,600	26,800	44,200
TW D-Zinc conc., ug/L	667	1,870	1,110	727	416
QW D-Zn conc., ug/L	166	456	283	209	121

D-Zinc load, lbs/y	16,500	48,400	60,200	45,400	39,500

Notes: TW = time-weighted (2004-2012); QW = discharge-weighted, see TDS (2013) or Appendix G.

The following characteristics are noteworthy:

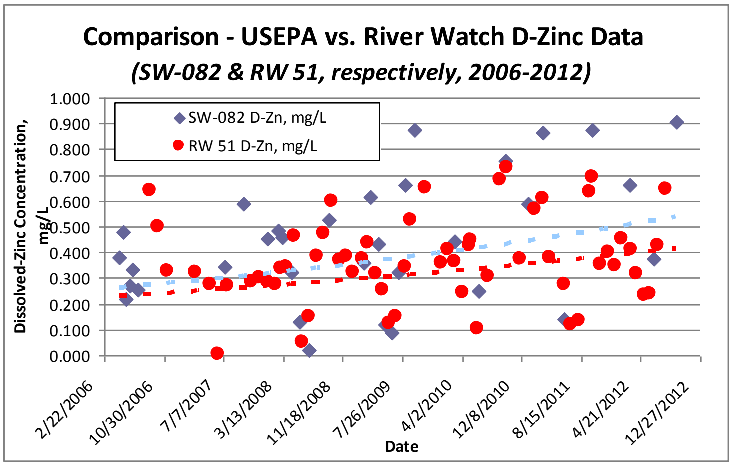
The cluster of monitoring sites around the Peru Creek confluence seem realistic, in terms of the upstream sites' (SW-047 & SW-049) characteristics matching those for the downstream site (SW-050, see Figure 2b). This particularly is the case for streamflows; the downstream flow volume is about 800 ac-ft (1.0 cfs, about 3 percent) more than the sum of the two upstream sites.

The zinc concentrations for this same cluster appear realistic as well. The ambient sample analyses for D-Zn available at the three sites are interpolated between sampling-survey Julian dates, in order to provide relatively unbiased averages. This methodology has been applied in several other Colorado watersheds (Steele, 1999; TDS Consulting Inc., 2012) and is judged to improve upon simple averaging of sample results staggered randomly or irregularly throughout the year (and also dealing with the problem of several months having no data values).

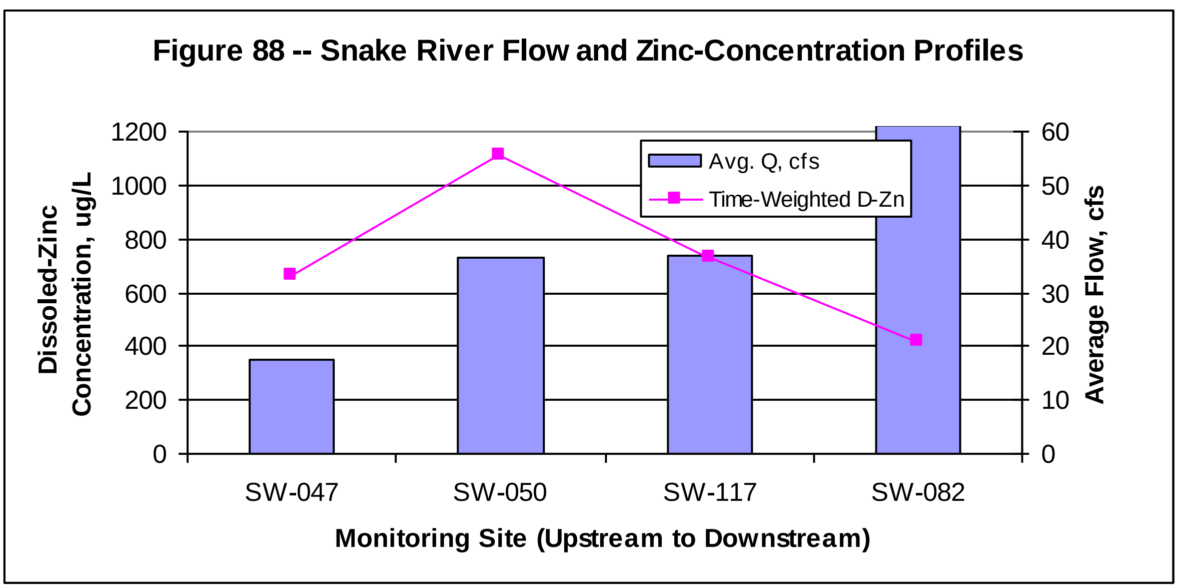
The ambient zinc load for the Snake River below Peru Creek (SW-50) is relatively high (see also below). The sum of average annual D-Zn loads for the two upstream sites is 64,900 lb/y, about 7 percent more than the load estimated for the downstream site (60,200 lbs/y), within the errors in the load-calculation methodology. Although the site (SW-50) is about ½ mile below the confluence, field work indicated no other major sources of contamination in this reach. There have been few flow measurements at this site. This downstream site had relatively few sample analyses (N=9 during 1990, 1998, and 2001; N=14 during 2002, a extremely dry year excluded from the data set; and N=14 during 2006-2008, the recent period when USEPA analytical results are higher than the historical data values). A relatively high estimate of D-Zn loads at this site for a shorter period of record also was noted in the earlier water-quality assessment (estimated to be 55,100 lbs/y; TDS Consulting Inc. and Wyatt, 2004, Table E-2).

Downstream in the Snake River, streamflows increase appreciably, as would be expected. The increase in Snake River flows is minimal between Peru Creek and the North Fork Snake River (NFSR) but flow increases significantly, due to NFSR inflows (see differences between Qs at sites SW-117 upstream versus SW-082 downstream).

Although average flows change little in the Snake River between Peru Creek and the North Fork Snake River, zinc characteristics do change appreciably (indicated by estimated lower concentrations and reduced loads). Due primarily to NFSR inflows, D-Zn concentrations at SW-082 (USGS stream gage) for the Snake River below the NFSR decrease by more than half compared to just below the Peru Creek confluence (727 down to 416 ug/L time-weighted D-Zn). Zinc loads at this downstream Snake River site are significantly less than estimated for the Snake River upstream just below Peru Creek. D-Zn inflows from the NFSR are negligible (averaging about 239 lbs/y). At the furthest downstream Snake River monitoring site (SW-082), D-Zn loads are estimated to total nearly 39,500 lbs/y. The number of sample D-Zn analyses for this lower monitoring site is quite high – much greater than the number of data values at upstream sites. Hence, the mass balance of D-Zn loads for this lower Snake River monitoring-site cluster tends to be quite good when compared to the situation for Peru Creek versus Snake River above vs. below Peru Creek. For the 2006-2012 WYs period (the last seven years of data available for this assessment), there is a complication regarding combining the two primary data sources – USEPA versus RiverWatch. A difference in average D-Zn concentration values seems to occur consistently throughout this period:



A stream-profile of ambient (e.g., pre-remediation project) D-Zn concentrations for the Snake River is given in Figure 88. For this depiction of ambient conditions, time-weighted values are used, and average D-Zn concentrations for the recent assessment period (2004-2012 WYs) are indicated for all four mainstem Snake River sites (with combined data for SW-082).



6.11.2 Remediation Beneficial Impacts

This section describes the potential reductions in zinc loads resulting from various remedial actions outlined above in Section 6. The various Priority-1 projects (details provided previously above in Sections 6.1 through 6.10) are summarized below in Table 20 and distinguish between those located in the upper Snake River subwatershed and those in the Peru Creek subwatershed. However, for purposes of this Plan update, only remedial-action projects are assumed for the Peru Creek subwatershed. Thus, the anticipated zinc-loads' reductions in this single subwatershed area are 10,500 lbs/y (TDS Consulting Inc., 2013). Hence, downstream from the Peru Creek confluence, zinc loads removed in the Snake River would not exceed approximately 10,250 lbs/y over the long term, as a result of implementation and completion of projects involving the Pennsylvania Mine and Cinnamon Gulch.

Table 20 – Remedial-Action Projects, Peru Creek Subwatershed, Zinc-Loads Reduction (lbs/y)

Project Description	***Est. Reduction***	***Project Description***	***Est Reduction***
Pennsylvania Mine	6,500	Cinnamon Gulch	4,000
Totals:	**6,500 lbs/y**		**4,000 lbs/y**

Source: see previous Plan Sections 6.1-6.10 and TDS Consulting Inc., 2013).

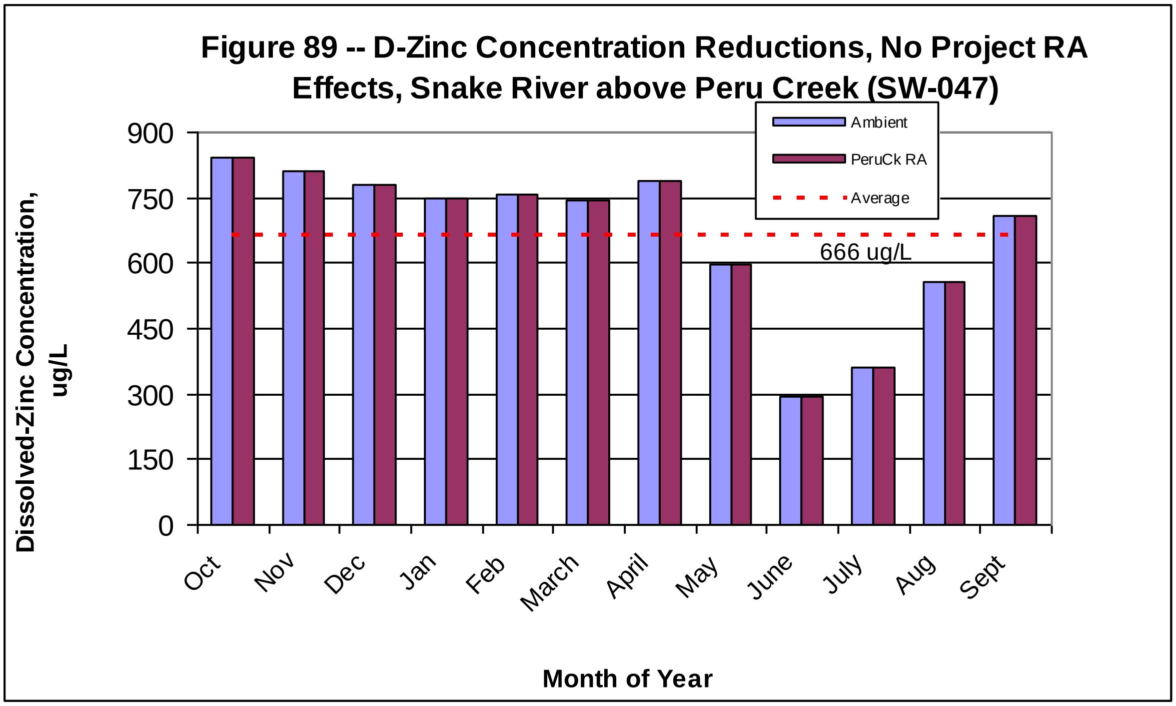
As mentioned previously, the potential beneficial impacts described herein may be changed, once these and future (yet-to-be-identified) projects are completed and post-project monitoring confirms the effectiveness of various treatment technologies applied to each project. Other projects than those identified and/or prioritized in this Plan may be designated for remediation over both the near- and long-term. Both of these factors may significantly alter the loads reductions (hence, beneficial impacts) of those projects initially identified for consideration in this assessment. The Excel spreadsheet "model", results of which are provided in the following sections, also can be used to evaluate these future changes and enhancements.

This model allows for ***monthly*** estimates of loads-reduction efficiencies to be provided as input. Realistically, this capability is important because it is envisioned that treatment effectiveness will tend to be lower during high flows (May through July in the assessment described for this Plan) and higher during low flows. In this preliminary loads reduction assessment, a simple form of sensitivity analysis was used to demonstrate this model capability. Caution is given that concentration changes are comparing ambient time-weighted concentrations with post-project discharge-weighted averages (always lower than time-weighted averages). This comparison is due to the fact that the reduced loads are used to convert back to post-remediation concentrations, and the spreadsheet does not calculate ambient (pre-project) discharge-weighted concentrations. Therefore, graphics showing these comparisons give the indication that reduction efficiencies are greater than actual in the case of concentration changes.

6.11.2.1 Snake River above Peru Creek

As indicated above and in accordance with the 319-Grant scope, remedial-action projects anticipated for load-reduction benefits are located only in the Peru Creek subwatershed. Thus, for purposes of this Plan update, no load reductions occur at monitoring site SW-047 characterizing this upper part of the Snake River watershed. The graphics and tables reflecting these ambient conditions are given in Appendix G (Figure G.1.1). With no

TMs load reduction at this site, the ambient average D-Zn concentration of 666 ug/L remains unchanged (Figure 89).

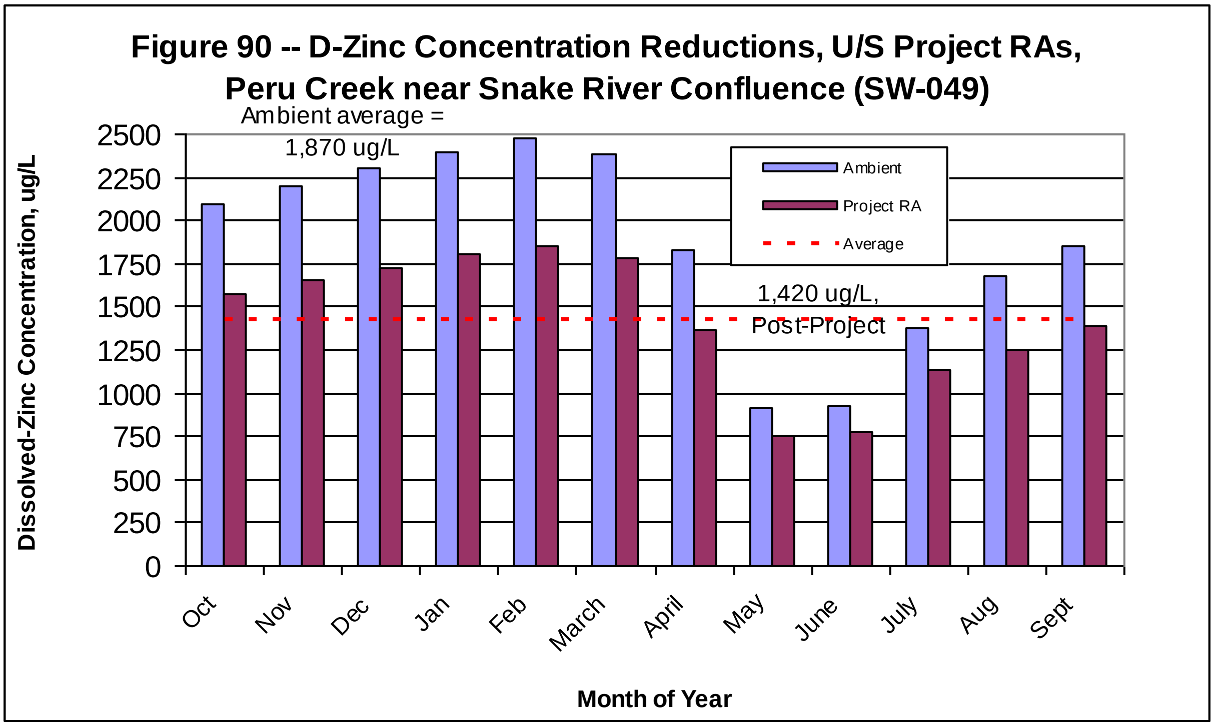


Notes: Monthly ambient) concentrations are time-weighted. See Appendix G Figure G.1.1

6.11.2.2 Peru Creek

As indicated above, a total of 10,250 lbs/yr of zinc is estimated to be removed by two remediation projects located in the Peru Creek subwatershed. This load reduction for zinc is reflected for post-remediation characterization at Site SW-158, located on the mainstem Peru Creek just below Cinnamon Gulch. For this assessment, it was assumed that the zinc load at the downstream-end monitoring point of this subwatershed (Site SW-049) would be reduced by this same amount. In reality, given water-sediment interactions along stream reaches, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads at Site SW-049 are reduced from about 48,400 lbs/y down to nearly 38,100 lb/y (TDS Consulting Inc., 2013). The assumed treatment effectiveness to achieve this reduction in loads was an estimated 26 percent on an annualized basis and 30/20 percent (low/high) on a seasonal basis. This latter form of sensitivity analysis was done to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall annualized effectiveness of 26 percent. The graphics reflecting these ambient and reduced zinc-load reductions are given in Appendix G (Figure G.1.2).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations in Peru Creek near its confluence with the Snake River. At this monitoring site (SW-049), average Zn concentrations are reduced from 1,870 ug/L (ambient, pre-project) down to 1,420 ug/L (post-project) for the 2004-2012-WYs period (Figure 90). Although these reductions are dramatic, they are not sufficient to attain the targeted stream standards (TVSs).



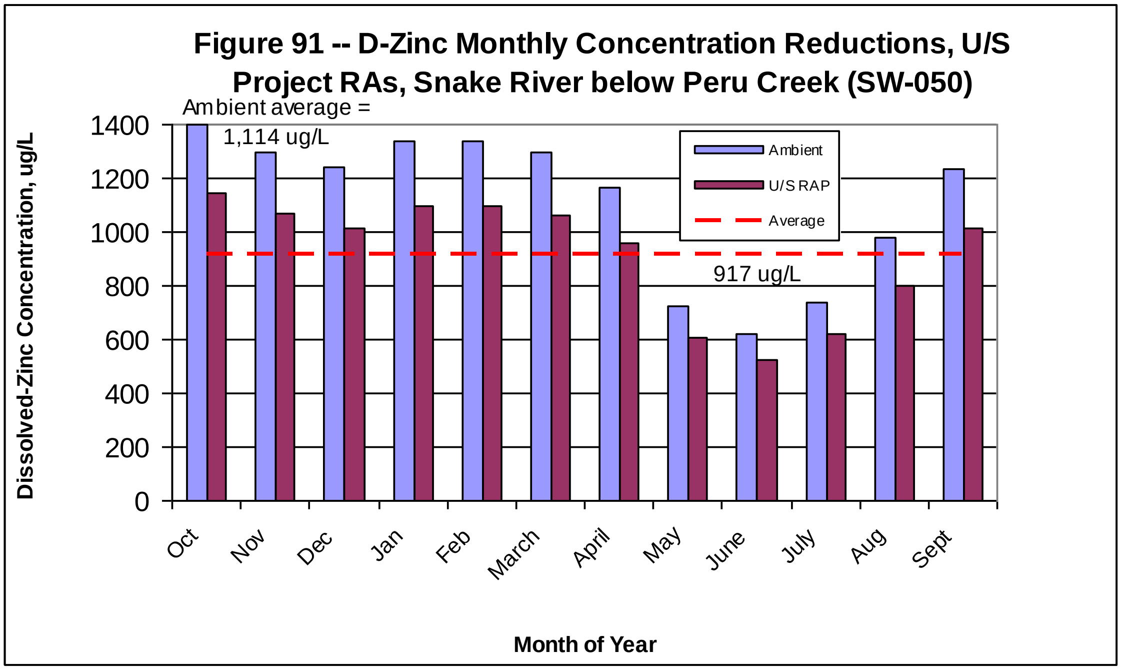
Notes: Monthly ambient (pre-project) and post-project concentrations are time-weighted. See Appendix G.

6.11.2.3 Snake River below Peru Creek

As discussed previously, a total of 10,250 lbs/yr of zinc is estimated to be removed by remediation projects located in the upper part of the Peru Creek subwatershed. However, separate assessment of downstream conditions indicated the sum of upstream D-zinc loads at sites SW-047 and SW-049 exceeded that estimated for Site SW-050 on the Snake River just below Peru Creek. Nonetheless, for purposes of this Plan update, it was assumed that the entire 10,250 lbs/y of zinc loading removed upstream would be reflected at this downstream monitoring location along the Snake River (TDS Consulting Inc., 2013). Given water-sediment interactions along stream reaches and added processes adding to or reducing TMs, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from nearly 60,200 lbs/y down to almost 50,000 lb/y. The assumed overall treatment effectiveness by the remediation projects to achieve this reduction in loads was 17 percent on an annualized basis and 18/16 percent for low/high-flow seasons. This latter sensitivity analysis again was to simulate conditions where more efficiency in loads reduction might be achieved during low flows and less during high flows – still achieving the load-reduction target overall annualized effectiveness of 17 percent. The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.3).

Perhaps of equal or greater interest are the estimated beneficial impacts on Zn concentrations. For this monitoring site, average D-Zn concentrations are reduced from

1,110 ug/L (ambient, pre-projects) down to 917 ug/L (post-projects) for the 2004-2012 WYs period. On a monthly basis, these beneficial impacts of loads reductions are depicted in Figure 91. Although these reductions are significant, they are not sufficient for water quality (in terms of D-Zn concentrations) to attain the underlying (targeted) stream standards (TVSs).



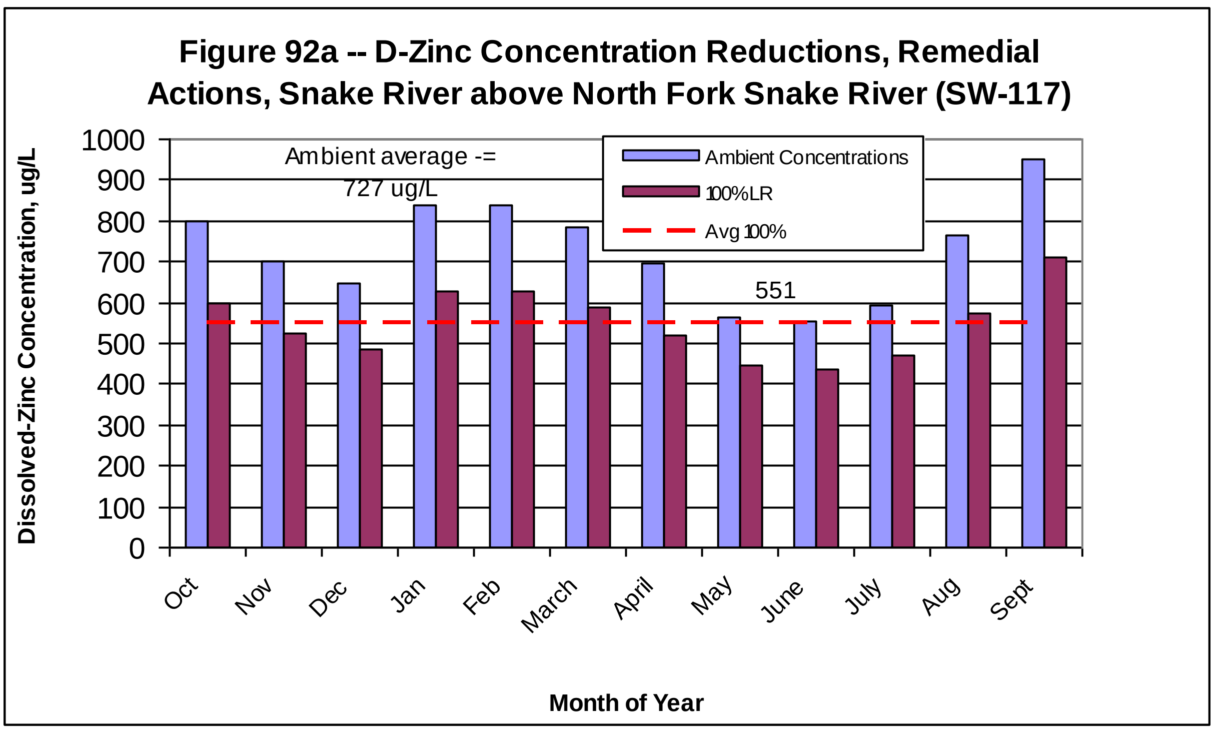
Notes: Monthly ambient (pre-project) and post-project concentrations are time-weighted. See Appendix G.

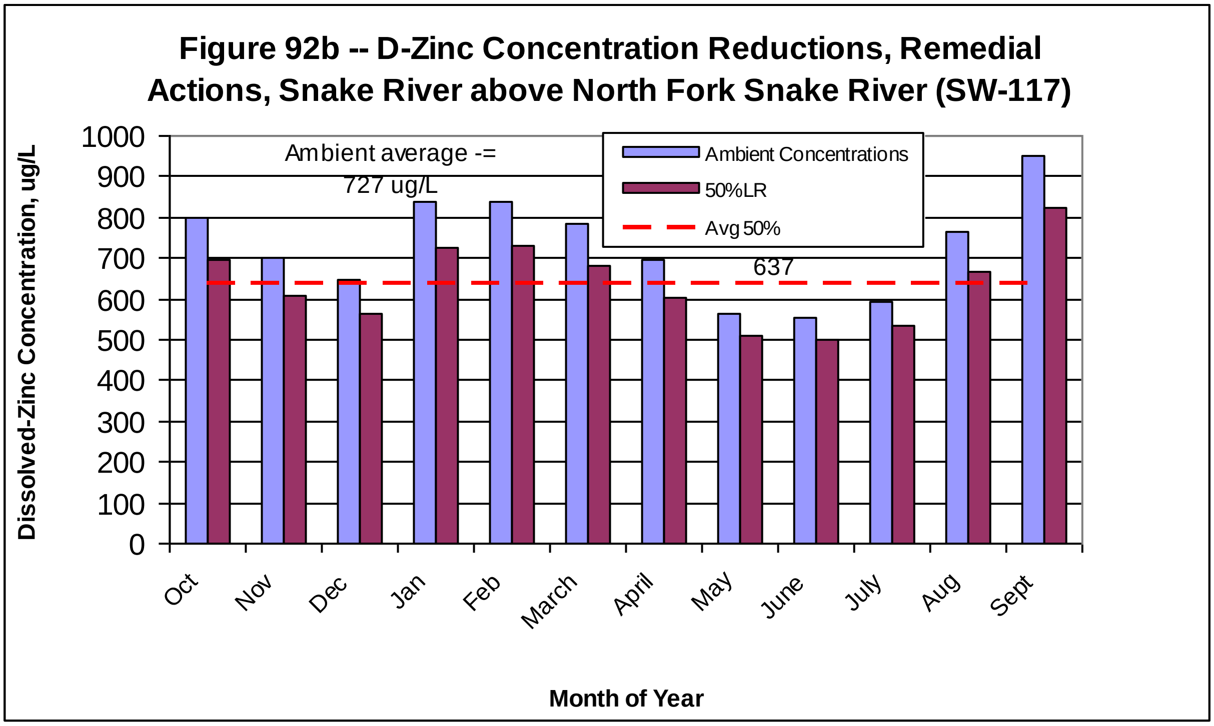
6.11.2.4 Snake River above the North Fork Snake River

The entire 10,250 lbs/yr of zinc is estimated to be removed by a Peru Creek remedial-action projects may or may not be reflected in post-project conditions in the lower Snake River. For this assessment, it was assumed that the entire (100-percent) zinc-loading reduction or only half (50-percent) of this reduction would be reflected in post-project conditions at this downstream stream location (Site SW-117). In reality, given water-sediment interactions along stream reaches and other sources/sinks of TMs, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from about 45,400 lbs/y down to approximately 35,400 lb/y. *[It is noteworthy that the ambient (pre-project) D-Zn load at this downstream location is substantially less than that (60,200 lbs/y) estimated for upstream Site SW-050. This situation promoted the alternative less-optimistic case resulting in less effective load reductions downstream in the lower reaches of the Snake River.]* For the 100-percent case, the assumed overall treatment effectiveness by the remedial-action projects to achieve this reduction in loads was 22 percent on an annualized basis or 25/20 percent for low/high-flow seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall annualized effectiveness of 22 percent. The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.4). For the assumed (less optimistic) 50-percent load-reduction case, the assumed overall treatment effectiveness by the remedial-action projects to achieve this reduction in loads was 11 percent on an annualized basis or 13/10 percent for low/high flow seasons. In this case, loads were assumed to be reduced from 45,400 lbs/y to 40,400 lbs/y.

Perhaps of greater interest are the estimated beneficial impacts on D-Zn concentrations. For this monitoring site and assuming the 100-percent load-reduction transport scenario, the average D-Zn concentration is reduced from 727 ug/L (ambient, pre-project) down to about 551 ug/L (post-project) for the 2004-2012 WYs period. For the less-optimistic (50-percent) load-reduction scenario at this location, the resultant D-Zn concentration is not as low (as would be expected) and is 637 ug/L (post-project). On monthly and annualized bases, these beneficial impacts of loads reductions for the two scenarios are given in Figures 92a and 92b, respectively. As significant as these reduction continue to be from the upstream remedial-action projects, they still are not sufficient to attain the stream water-quality targets (in terms of D-Zn concentrations) to meet the underlying stream standards (TVS).

It should be kept in mind that this site (SW-117) on the Snake River does not benefit from the dilution effects of low TMs concentrations that characterize the North Fork Snake River. Regression analysis of paired streamflow measurements at this site with the daily records provided by the stream gages below the confluence of this major tributary indicate that 39 percent of the downstream Snake River flows are contributed by the NFSR. This flow allocation is supported as well by the distinctive water-quality conditions at these two sites when compared with the downstream Site SW-082 where flows are combined in the Snake River and enter Dillon Reservoir downstream.





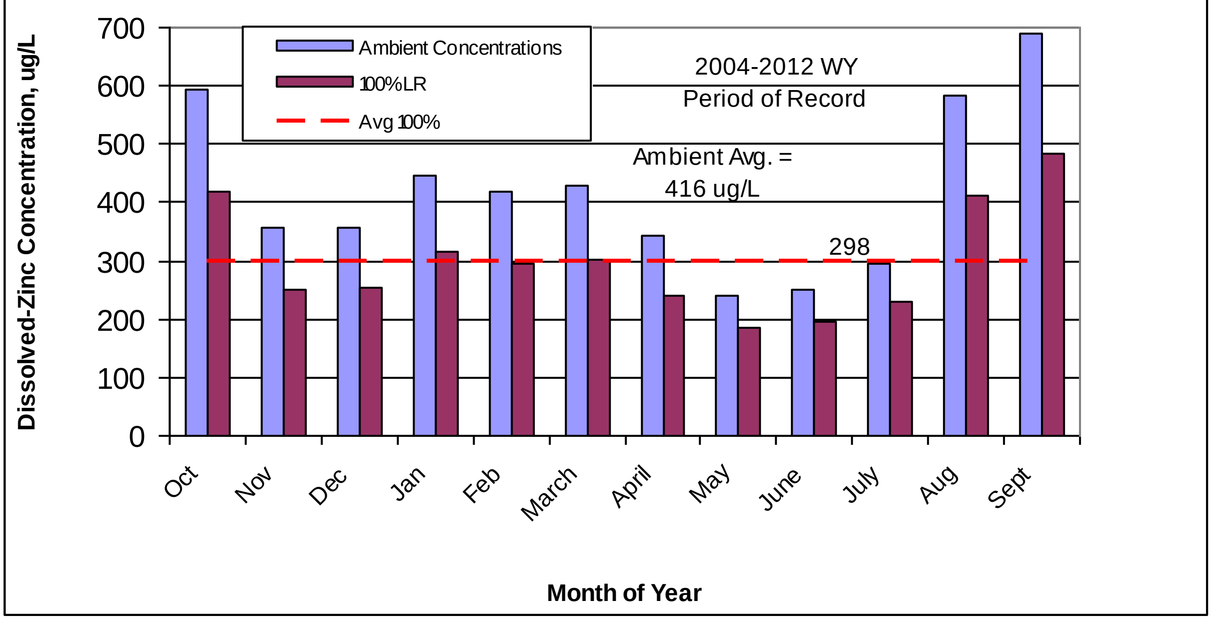
Notes: Monthly ambient (pre-project) concentrations and post-project (assumed 100-percent and 50-percent effective load reduction are time-weighted. See Appendix G.

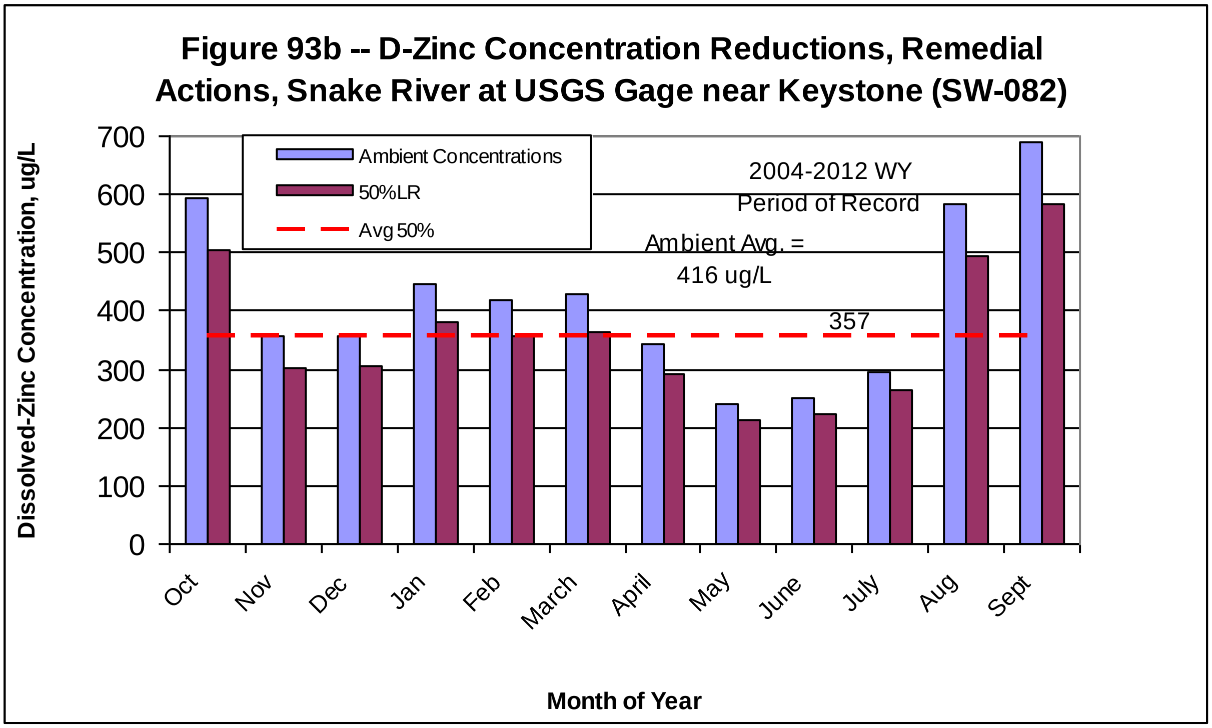
6.11.2.5 Snake River below the North Fork Snake River (near Keystone and at USGS/SEO stream gages)

As discussed in the previous section, the entire 10,250 lbs/yr of zinc estimated to be removed by a Peru Creek remedial-action projects may or may not be reflected in post-project conditions in the lower Snake River. For this assessment, it was assumed that the entire (100-percent) zinc-loading reduction or only half (50-percent) of this reduction would be reflected in post-project conditions at this downstream stream monitoring site (SW-082) located downstream from the NFSR. In reality, given water-sediment interactions along stream reaches and other sources/sinks of TMs, it should be recognized that it may take several years for trace metals-laden sediments to be transported downstream after the identified sources are treated. For this case, the D-Zn loads are reduced from about 39,500 lbs/y down to approximately 29,400 lb/y. *[It is noteworthy that the ambient (pre-project) D-Zn load at this downstream location is substantially less than that (60,200 lbs/y) estimated for upstream Site SW-050 and also less that that (45,400 lbs/y) estimated for the Snake River just upstream of the NFSR. This situation promoted the alternative less-optimistic case resulting in less effective load reductions downstream.]* For the 100-percent case, the assumed overall treatment effectiveness by the remedial-action projects to achieve this reduction in loads was 31 percent on an annualized basis or 30/22 percent for low/high flow seasons. This sensitivity analysis was to simulate conditions where more efficiency in loads reduction could be achieved during low flows and less during high flows – still achieving the load-reduction target overall annualized effectiveness of 31 percent. The graphics reflecting these ambient and reduced loads reductions are given in Appendix G (Figure G.1.5). For the assumed (less optimistic) 50-percent load-reduction case, the assumed overall treatment effectiveness by the remedial-action projects to achieve this reduction in loads was 13 percent on an annualized basis or 15/11 percent for low/high-flow seasons. In this case, loads were assumed to be reduced from 39,500 lbs/y to 34,300 lbs/y.

Perhaps of greater interest are the estimated beneficial impacts on D-Zn concentrations. For this monitoring site and assuming the 100-percent load-reduction transport scenario, the average D-Zn concentration is reduced from 416 ug/L (ambient, pre-project) down to about 298 ug/L (post-project) for the 2004-2012 WYs period. For the less-optimistic (50-percent) load-reduction scenario at this location, the resultant post-project D-Zn concentration is not as low (as would be expected) and is 357 ug/L (post-project). On monthly and annualized bases, these beneficial impacts of loads reductions for the two scenarios are given in Figures 93a and 93b, respectively. As significant as these reduction continue to be from the upstream remedial-action projects, they still may not be sufficient in attaining the stream water-quality targets (in terms of D-Zn concentrations) to meet the underlying stream standards (TVS).

Figure 93a -- D-Zinc Concentration Reductions, Remedial Actions, Snake River at USGS Gage near Keystone (SW-082)





Notes: Monthly ambient (pre-project) and post-project concentrations are time-weighted. See Appendix G.

There are at least four messages that should be taken from this load-reduction assessment resulting from remedial-action projects implemented in the upper Peru Creek subwatershed. First, this modeling is taking a limited amount of data and using it to the maximum extent in an attempt to help understand what implementation of significant clean-up of anthropogenic sources of water pollution in the basin might accomplish. As such, it must be used with caution and always within the context of the assessment. There are significant uncertainties in the estimates of clean-up at each mine site or mineralized area, in the ongoing natural sources of contamination, in weather events that scour areas with significant exposed metal sources, etc. Second, the analysis indicates that the degree of remediation of the anthropogenic sources identified for this assessment will not allow the TMDL's to be met or for existing water-quality standards to be met. However, third, the analysis shows that significant improvement is possible. Although this improvement will not necessarily benefit conditions in the upper part of the Snake River watershed, it should show up in the middle to lower stream reaches of the mainstem Snake River. That is, it might allow fish such as brook trout to migrate up the Snake River, above the confluence with the North Fork of the Snake River, where they do not like to go now due to ambient TMs levels. Finally, fourth, this analysis does not deal with issues such as further diversions from the watershed. If, for example, if water-rights holders using the Vidler tunnel should decide and successfully negotiate to increase diversions from the upper Peru Creek drainage, there would be less "clean" (low TMs concentrations) water available for dilution and a resultant increase in the concentration of metals above that projected by the model. Any other diversions of "clean" water would have the same effect if it were to occur.

In conclusion, this Plan-update section addresses loads reductions only for D-zinc. The accompanying 319-Grant technical report (TDS Consulting Inc., 2013) also evaluates load reductions for other TMs of interest (D-Pb, D-Cu, and D-Cd) in the upper parts of Peru Creek and Snake River subwatersheds. This assessment for other TMs included monitoring sites given in subsections above (SW-047, SW-049, and SW-050); however, it did not include the two monitoring sites (SW-117 and SW-082) along the lower reaches of the Snake River. It might be useful to extend this analysis to these lower-downstream sites. This would enhance the comparison with targeted stream standards (TVSs) for these other TMs. Finally, post-monitoring is key to assessing the estimated loads reductions summarized herein. This is recommended for key water-quality monitoring sites and for a sufficient duration to assess long-term benefits.

6.12 Implementation Schedule/Milestones/Criteria

The schedule for implementation of the Plan is unknown at this point in time. Certain projects, such as the cleanup of the waste rock at the Delaware Mine can be projected, based on a recent application for a 319 grant by the BRWG, NWCCOG, and TU, with technical support from the CDRMS. If that grant is awarded, the first cleanup projects will be implemented in the summer of 2010. However, the real issues are associated with the point source draining adits. With the possible exception of the Pennsylvania Mine and its potential listing on the National Priority List under Superfund, most adit cleanup must await Congressional action to amend the CWA to provide some form of liability relief to parties willing to tackle adit cleanup at these sites. It is not clear when such relief might be granted. All of the active participants in the SRWTF are working to find a more innovative solution to this liability problem that would not require new legislation. However, no clear solution to the problem has been found to date.

The single largest anthropogenic source of metals to the Snake River is the Pennsylvania Mine (Section 6.1). Cleanup at this Mine will have the largest impact in removing metals from the waters of the Snake River. At this time, it is not possible to determine exactly what the cleanup at that site might entail. As this Plan indicates elsewhere and as the recent feasibility study indicated, cleanup of the Pennsylvania Mine adit flow will most likely involve a two stage process where in the first stage the iron and aluminum are precipitated followed by a second stage where the other metals are treated, most likely in some passive form of sulfate reducing bio-reactor (NWCCOG, 2006). The USEPA is working on a definitive plan for the site. However, additional field work is planned in 2009 to better define the source and likely volume of flow from the mine. This work might require that the report that is being prepared be modified before final decisions on treatment can be made. At this point in time, it appears that the treatment needed at the site will be more expensive than any identified "Good Samaritans" are likely to be able to support financially. This has resulted in serious consideration being given to classification of the site as a Superfund site. This would open up funding sources that could deal with the costs projected for the site. If this were to happen, cleanup before the summer of 2011 is not likely and any schedule would be based on the availability of funding and could delay construction further. It is not clear if similar listing of sites such as the Jumbo Mine and the Sts. John Mine will occur. In these and perhaps other cases cleanup costs undoubtedly may. Nonetheless, this will be the preferred process to fund cleanup at these sites.

In the interim, monitoring flow and water quality at key sites, as discussed in the monitoring section of this report (Section 2.3), is important. There is not enough flow data correlated to quality data to have confidence in the estimates of annual loadings. If the monitoring program were implemented now, then enough data should be accumulated by the time any implementation occurs to be able to see the improvements. The sites chosen will allow improvement to be seen in different parts of the basin as cleanup is implemented. Cleanup effectiveness will be measured by the reduction of heavy metal loading in the Snake River and from Peru Creek. Although the key measurement point at SW-082 will indicate overall improvement for the watershed, the upper sites recommended in the proposed future monitoring will allow improvement to be assessed closer to the source of remedial-action improvements.

The other key schedule issue involves the USFS. Many of the sites are located on USFS property. Furthermore, the USFS manages the adjacent lands, even if the site itself is on private land from an old mining claim. The USFS has indicated that it might have some funds available for cleanup in the basin and might work with the other parties on a waste rock repository which is badly needed for effective cleanup at a number of site. However, the USFS has not shared with the SRWTF any definitive plans or schedule for their involvement in any specific site cleanup.

The implementation of this Plan, in total, is unlikely to change the water- quality problems in the upper Snake River subwatershed, Warden Gulch, and Cinnamon Gulch. Water-quality conditions in these areas are generally mostly natural in origin and not significantly affected by the projects proposed in this Plan. It is expected that the TMDL standards (targets) will not be fulfilled (CDPHE, 2008). Although a watershed plan is expected to address TMDL targets, there are simply not enough anthropogenic-driven targets to allow this to be accomplished. Stream water quality standards, if based on table value standards for aquatic life, will not be attained. What is needed is a more realistic set of water quality stream standards based on this Plan and reasonable expectations for an area heavily impacted by acid rock drainage. This area was mined heavily for a reason. The area is mineralized and the geology in areas of the basin results in acid rock drainage and heavy metal contamination of the waters. This can’t be changed. The anthropogenic (man-made) problems can be addressed and improvements made, but these changes will not solve all of the water-quality problems identified for this watershed. Efforts to modify the water quality standards to more realistic levels have been initiated and a draft plan developed. This effort is referred to as a Use Attainability Analysis (UAA Wyatt, 2007). Further expanded work along this line needs to continue.

What is needed is an appropriate monitoring plan, with flow measurements, which can better define metal loads in the stream and that can monitor these loadings over time as this plan is implemented. This Plan outlines recommended monitoring. This monitoring is being initiated by the BRWG in conjunction with River Watch and by the USEPA.

The other remaining question, which should be addressed is how the Plan will be implemented. That is, what organizational entity might or should take the lead in implementation. The SRWTF is a coordinating body and not an organization per se. The first actual cleanup in the basin was conducted by Summit County, through its Open Space Department. This cleanup was at the Shoe Basin Mine. Due to the liability issues associated with point source draining adits, the adit flow was not addressed in this cleanup. The second cleanup planned is via a 319 grant application submitted to the CDPHE in November, 2008. This plan is being submitted jointly by NWCCOG, the BRWG and TU. Key technical assistance and matching funding is to be supplied by the CDRMS. The institutional arrangement currently in place for the upper Clear Creek Basin, dividing responsibilities and remedial projects between the Upper Clear Creek Watershed Association (UCCWA, with a similar role to the SRWTF) and the Clear Creek Watershed Foundation (CCWF, overseeing a USEPA targeted-watershed grant and two 319 grants) might be considered (T.D. Steele, oral communication, November 26, 2008).

This model of cooperative behavior among the several groups with an interest in cleaning up the water quality problems in the basin may provide the best model for Plan implementation to proceed. Different groups bring different skills and interests to the cleanup. Collaborative efforts may be the best way to proceed. As mentioned above, the other key player in cleanup will be the Forest Service. The USEPA and National Priority Listing is the other unknown, but important implementation vehicle. As discussed above, this funding and implementation vehicle may be the best way to proceed on the more expensive cleanup sites.

As indicated in Section 1.2.3, this Plan extracts selective results of the CDPHE's TMDL assessment (CDPHE, 2008). In expanding upon these results and focusing upon Plan-developed targets for trace-metals loads' reductions -- which constitute a key aspect of this Plan -- a different assessment approach was used (see Section 6.11 and Appendix G and compare with Section *1.2.3).* It is believed for purposes of this Plan that this latter assessment -- developed specifically for this Plan -- represents a realistic, practical approach to the issue of loads-reduction targets and depicts a reasonable and technically sound conclusion regarding reduction effectiveness, based upon considering the current state-of-the-art mine-related remediation technologies applicable to conditions in this watershed (NWCCOG, 2006) as well as other watersheds with similar characteristics (the upper Clear Creek watershed in Colorado would serve as another example). In future (near-term) deliberations promoted by comparing these two assessment approaches, it is intended by this Plan to evaluate remedial-action effectiveness as projects are implemented and to note the extent to which loads-reduction targets are being attained.

7 Overview of Applicable Funding Sources

7.1 Clean Water Act §319

The 1972 Federal Water Pollution Control Act (the “Clean Water Act” or CWA) set the stage for state-enforced water quality remediation and protection. The 1987 Water Quality Act added §319 to the Clean Water Act, which created a national program to address nonpoint sources of water pollution such as mining and agricultural runoff (Ferrey, 2001). Section 319(h) provides for federal grants to state management programs which will “control particularly difficult or serious nonpoint source pollution problems, including, but not limited to, problems resulting from mining activities" and, "implement innovative methods or practices for controlling nonpoint sources of pollution." These grants to states consist of incremental funds, which are designated for development and implementation and implementation of the TMDL program, and base funds, which fund state management and staffing support of the Nonpoint Source Management Program. States may disperse incremental funds to state and local abandoned mine reclamation projects that are not covered under National Pollution Discharge Elimination System (NPDES) permitting, such as remediation of water pollution from abandoned mines, mapping and planning of remediation, monitoring for the design and effectiveness of implementation strategies, technical assistance, information and education programs, technology transfer and training, and development and implementation of policies addressing abandoned mine lands (EPA 1996).

Following the Federal mandates, the Colorado Nonpoint Source Management Program requires that all projects must be consistent with the Colorado Water Quality Control Division's efforts to meet §303(d) TMDL program requirements (Colorado Nonpoint Source Program, 2004). The Colorado Nonpoint Source program allots grants of up to $25,000 per project to allow stakeholder groups to develop watershed plans outlining prioritized implementation of BMPs to restore and protect water quality. This is the funding which was provided to Blue River Watershed Group (BRWG) in 2007 to develop the Snake River Watershed Plan. Further funding up to $250,000 is available to stakeholder groups to implement their watershed plans for nonpoint source activities within §303(d) listed waters. The Colorado Nonpoint Source program requires a 40 percent non-Federal funding match for §319 awards. This 319 grant has provided the most significant improvements and its projects provided the most input for this Plan update.

7.2 Brownfields Program

Enacted on January 11, 2002, the Small Business Liability Relief and Brownfields Revitalization Act (H.R. 2869) provides grants that enable stakeholders to work together to clean up and reuse Brownfields. Public Law 107-118 defines a Brownfield site as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant." The law includes "mine-scarred land" as an additional area to which the term "brownfield" applies. This act provides up to $200 million annually, through 2006, for grants related to site assessment or direct clean up, not to exceed $200,000 per site.

7.3 Targeted Watershed Grants Program

The EPA Targeted Watershed Grants Program (TWGP), formerly known as the Watershed Initiative or the President's Watershed Initiative, was funded by Congressional appropriations of $21 million in both 2003 and 2004. The TWGP encourages comprehensive, community-oriented, watershed-based approaches to the protection and restoration of water resources. In particular, grants are given to "studies of approaches that go beyond implementing separate, detached activities and will, instead, focus on the effectiveness of an integrated ecosystem-based approach to conservation and restoration throughout a watershed (Federal Register, 2003a)." The competitive granting process requires project nomination from governors or tribal leaders, who are each entitled to nominate two state or tribal watersheds. According to the 2004 Call for Nominations (Federal Register, 2003a), watershed nominations are evaluated and scored based on the criteria of innovation, measurement of environmental results, broad support, outreach, and financial integrity. Grant awards range from $300,000 to $1,300,000, depending on the size and need of projects. The lower Trail Creek (and other sites) in the neighboring upper Clear Creek watershed received a TWGP grant award last year.

7.4 Ecosystem Protection Regional Geographic Initiative

Established in 1994 in an effort address environmental issues not covered by existing national programs, the USEPA Regional Geographic Initiative (RGI) empowers each USEPA Region to address unique environmental challenges by helping to integrate local efforts in the application of modern, multi-media approaches to human health and environmental risks. RGI emphasizes a "holistic environmental approach" and grassroots, stakeholder partnerships in decision making that addresses multi-dimensional environmental problems (USEPA, 2003e). As outlined in the USEPA Region 8 Project Proposal Guidance (USEPA, 2003e), Region 8 distributes RGI funds to a diversity of projects that:

- Address problems that are multi-media in nature;
- Fill a critical program gap in the protection of human health and the environment;
- Address places, sectors;
- Demonstrate innovation;
- Demonstrate that they are based on a regional, state, tribal or other strategic plan; and
- Demonstrate state, local and/or other stakeholder participation.

USEPA Region 8's financial assistance normally ranges between $1,000 and $30,000, for projects of generally one or two years in duration.

7.5 Colorado Healthy Rivers Fund

The 2002 Colorado General Assembly established the Colorado Watershed Protection Fund (now called the Colorado Healthy Rivers Fund or CHRF) with the adoption of Senate Bill 02-087 (C.R.S. 02-087 §1, 2002). Financed by voluntary tax refund check-offs on Colorado individual tax forms, the CHRF provides money for a competitive grant program to help grassroots watershed protection groups restore and protect watersheds. The Colorado Water Conservation Board, in cooperation with the Colorado Water Quality Control Commission and the Colorado Watershed Assembly, will administer CHRF resources to support the planning and implementation of watershed restoration and protection projects (C.R.S. 02-087 §1, 2002). The maximum grant award for project planning grants is $25,000, whereas the implementation of projects may be awarded up to $50,000. The CHRF grants require a 20 percent in-kind or cash match.

7.6 USEPA Community Action for a Renewed Environment (CARE) Grant

An USEPA initiative, Community Action for a Renewed Environment (CARE), is designed to reduce local exposure to toxic pollution by establishing community-based and community-driven projects. In addition, the USEPA provides technical assistance to stakeholder groups to identify and address local sources of toxic pollution.

7.7 Other Funding Sources

In addition to these opportunities for the funding of mine site remediation, additional federal grant opportunities periodically arise. Any remediation efforts fundraising should also target private foundation grants, of which many are available.

8 Acknowledgements

The development of this Plan has been the work of a number of people, within and outside of the Blue River Watershed Group. While the principal author has been Jim Shaw, this plan would not have been possible without the assistance of co-authors Lane Wyatt, NWCCOG and Elizabeth Russell, Trout Unlimited. They were partners in the effort from the beginning. In addition, the input of Dr. T. D. Steele has been especially important. He has been assisting with the tough hydrologic and water quality issues in the watershed for the last several years. His inputs into this Plan allowed it to build on the significant body of research and investigations that have been conducted in the watershed in a most effective manner. Finally, the Snake River Watershed Task Force and its members have been very important. Many of its members have contributed directly to the development of this Plan. Essentially every request for assistance was met with eager enthusiasm. The following members need to be singled out for direct assistance. Lane Wyatt of the NWCCOG, Jeff Graves of the CDRMS, Andrew Todd of the USGS, Tim Steele of TDS Consulting, Inc., Jean McKenzie and Bill Schroeder of USEPA, Robyn Blackburn of the USFWS, Mark Rudolph of the CDPHE-HMWMD, Rebecca Anthony of the CDPHE-WQCD, Stan Church of the USGS-GD, Brian Lorch of the Summit County Open Space Department, Elizabeth Russell of Trout Unlimited, and Brian Healy of the USFS. Special thanks to Keystone Center's Jody Erikson and Nissa Erickson for their help are also in order. The collegial nature of the participants of the SRWTF, make working in the watershed a pleasant and rewarding experience.

This update would not be possible without the continuing support of key participants of the SRWTF. Lane Wyatt of NWCCOG, Jeff Graves of the CDRMS, Andrew Todd of the USGS, Tim Steele of TDS Consulting, and Ryan Dunham of the EPA have met every request for assistance with immediate help. Julie Annear of CDRMS provided the update on the Sts. John activities.

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Finally, Colorado River Watch, a program of the Colorado Division of Wildlife, should be recognized for their willingness to assist in the monitoring of the key sites until a §319 grant can be approved and funded to take over the monitoring. As the Plan discussed, this interim monitoring is very important and would not be possible without the assistance of River Watch.

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Appendix A

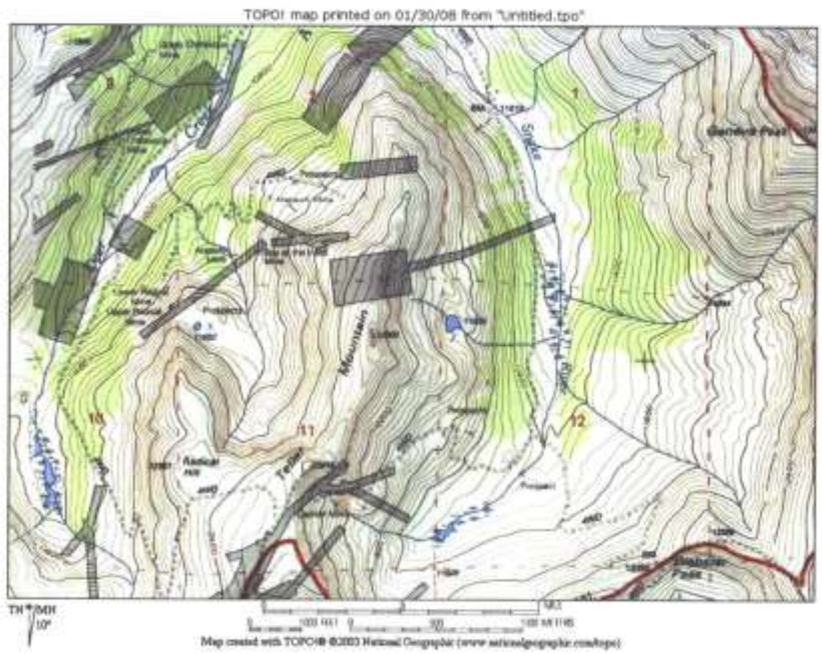
River Basin Descriptions

List of Figures

Appendix A

The Snake River

The Snake River originates high in the Rocky Mountains of Summit County. The basin is bounded on the south and east by the Continental Divide and by Teller Mountain on the west. Figure1is a topo map of the upper basin area.



The valley of the Snake River is little modified from the U-shaped form inherited from glacial occupation. The geology of the Montezuma quadrangle was mapped and described in detail by Lovering (1935)

The drainage basin of the upper Snake River is underlain by igneous and metamorphic rock of Precambrian age intruded by igneous rocks of Tertiary age. The metamorphic rocks greatly predominate over all the other rock types and, except for the southern part of a large quartz monzonite stock at Montezuma, are the only recognized and mapped in this area by Lovering (1935). The western part of the extreme headwaters of the Snake River is underlain by Swandyke Gneiss, a rock relatively rich in calcium, magnesium and iron. With this exception, the drainage basin of the Snake River above the junction with the first tributary, Deer Creek, is almost entirely underlain by the Idaho Springs Formation, a rock relatively rich in aluminum and silicon. In the upper part of the Snake River valley, a ½ square mile tract of bog-iron covers the valley from near the head of the stream to the lower ford on the Webster Pass road. The bog ore does not extend far to the west from the mainstream, but it extends well up the east slope of the valley.

Pyrite is a common accessory mineral in the veins and along the Snake River watershed from north of Landslide Peak to the vicinity of Webster Pass where it is disseminated in the older rocks. Though less concentrated, the total quantity of pyrite in the zone of dissemination is far greater than that in the veins. Extensive weathering over a long period of time beneath the Flattop Peneplane (possibly formed as early as Eocene time) has resulted in the oxidization of pyrite to limonite and hematite; releasing sulfur in acid, sulfate water to the drainage of the Snake River.

The actual flow in the Snake River originates in the western portion of the upper basin, below a bench, which has the Cashier mine at its headwall.(Figure 2). It has been difficult to determine if the adit is flowing because of a snow field that persists at the adit and does contribute some runoff that flows across waste rock and down the fall line to a bench and infiltrates into the ground water. Some of that flow might be from the adit.

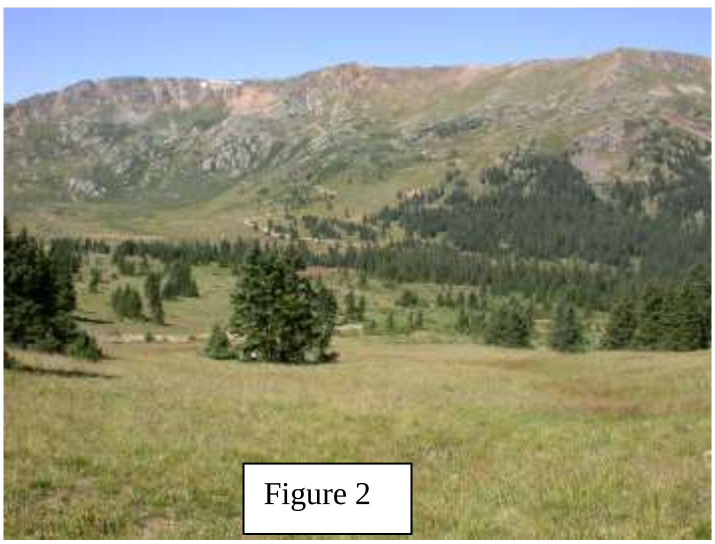


Figure 2

Figure 3

The flow that originates the stream is essentially seeps at the lower end of the "wall" below the upper bench. Figure 3 shows a typical seep that begins the stream in the upper western portion of the basin. Figure 4 shows the upper basin, below the wall of seeps, looking north. The river at this point is essentially a wetland of seeps and ponds. Not all of the seeps are of high quality. Figure 5 shows part of the flow from one seep that show considerable degradation.

Figure 4

Figure 5

The water quality in the upper Basin is not well documented. There is one data point, from 1966 which shows the pH to be 6.1 su. This is consistent with the geology of the western portion of the upper basin. The water quality quickly deteriorates when the stream hits the iron bog and the portion of the basin covered by the Idaho Springs Formation. The eastern/southern portion of the upper basin has been hydrothermally altered and is near the end of the Montezuma shear zone. This leads to acid rock drainage from the eastern side of the headwaters. Right in this area is waste rock from an old mine. As the stream flows on down the valley it crosses the Webster Pass road and is joined by the first majority tributary, which drains an area just north of Webster Pass. Figure 6 shows this tributary. The limited data on this tributary from the Tokash thesis (Tokash, 2003) suggests the pH is in the range of 4.5 and has high dissolved metal content. The tributary does cross the bog area near its confluence in a wetlands area.

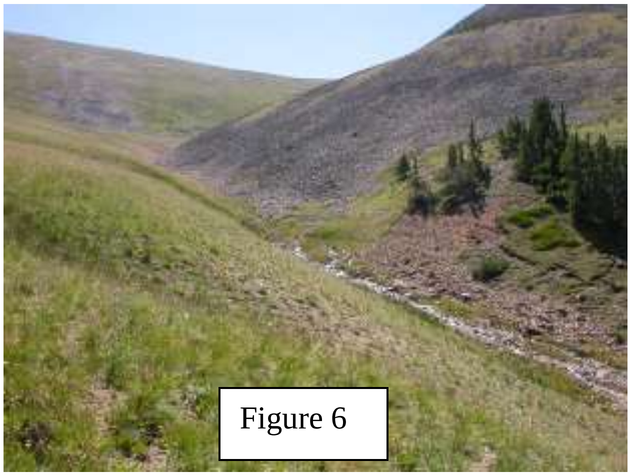


Figure 6

The area north of this tributary, before reaching the second tributary, appears to be one of the major areas of water quality degradation. Visually, it is difficult to separate the natural problems from those worsened by man. There is an upper bench, a sloping area and the wetlands below. In the lower portions of the sloping area there are many seeps. Some of these seeps immediately cross areas disturbed by past mining activity. Claim markers and exploration pits are visible in these denuded area. The average particle size of the rocks is very small. The minerals in the area are know to contain disseminated pyrite. Limited sampling in the eastern tributaries and an understanding of the geology of the area suggests that the water from the seeps is acid before reaching the disturbed areas. There is also every reason to believe the acid water flowing across the disturbed areas is further degrading the water quality. The flow between tributaries one and two on the east side appears to be as great as the flow in the two tributaries and appears to be of very low water quality. Figures 7 and 8 show two of the seep areas between the two tributaries. Figure 7 shows that the disturbed areas are quite large and significant water flows over them. This

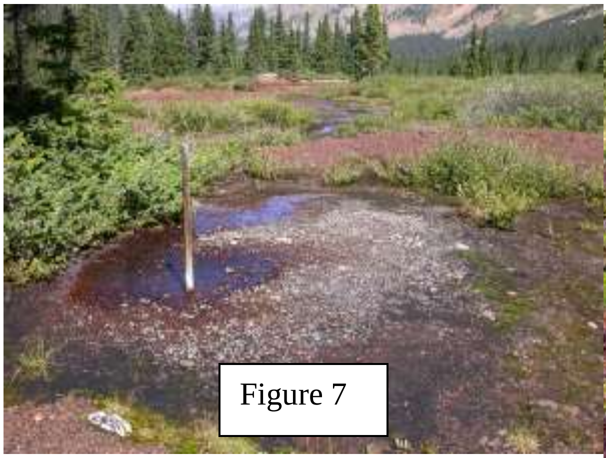


Figure 7

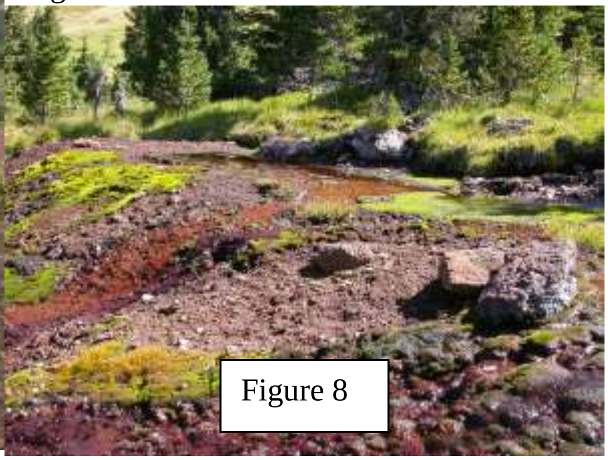


Figure 8

water is moving not as a tributary but through a series of seeps and overland flows into the wetlands area around the actual stream.

Tributary number two going north on the east side of the Snake, north of the area of seeps and visible water quality problems originates high on the continental divide. Figures 9, 10 and 11 show this tributary. Figure 9 shows the upper portion of the tributary. The flow originates around to the left of the grassy slope on the left of the

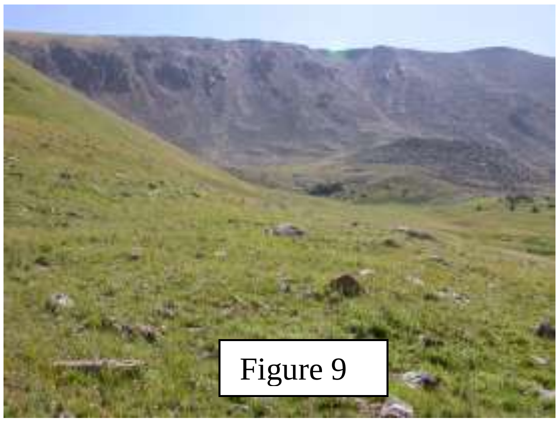


Figure 9

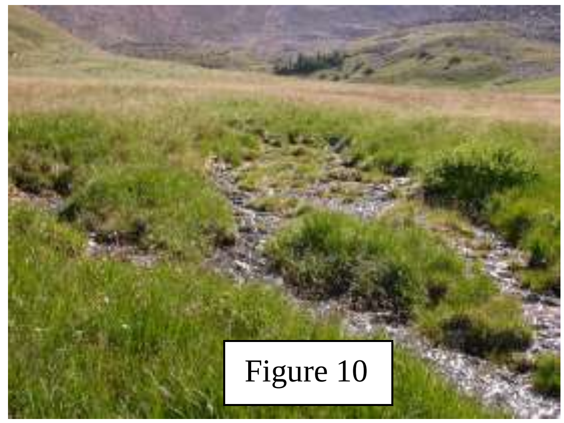


Figure 10

figure. Figure 10 shows a typical seep where the flow originates. At the top left of the photo you can see the slopes shown in Figure 9 and the center of the photo shows the bottom of the wall visible in Figure 9. Figure 11 shows the tributary as it heads toward the Snake. It will enter in the middle of the valley wetlands. The only known water quality data on the tributary is from the Tokash thesis (Tokash, 2003) which showed pH values from 3-4 SU.

Figure 11

There are two other eastern tributaries shown on the USGS topographic map for the area. Both originate from seeps, well below the continental divide. Figures 12 and 13 show the headwaters of these two tributaries. Figure 12 is the headwaters of tributary 3, counting from Webster Pass and Figure 13 is tributary number 4. Both of these tributaries enter the Snake in via the wetlands in the main valley. The Tokash thesis (Tokash, 2003) data again shows these two tributaries to have very low pH values which is consistant with the geology of the headwaters of these two tributaries.

Figure 12

Figure 13

Tributary 4 flows right past the one major man made water quality problem in the upper Snake River. Just to the north of the tributary is a major leaking adit. The evidence on the ground suggests that at times some of the flow from the adit enters tributary 4 in the wetlands area just before the tributary enters the Snake. Part of the flow from the adit goes down the access road to the mine and enters the Snake River at the point where the Webster Pass road crosses the Snake at the north end of the valley. There is considerable evidence of significant flow from the mine going directly west from the adit, over waste rock and to the wetlands, joining the flow from tributary 4. Figure 14 shows the leaking adit. Figure 15 shows some of the flow from the adit entering the Snake River after flowing down the access road.


Figure 14

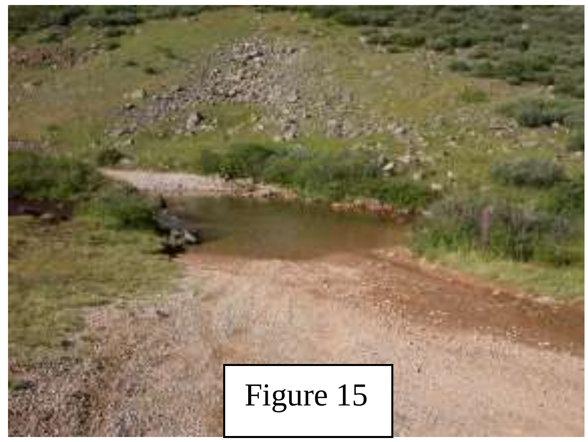


Figure 15

There are two other tributaries draining the eastern side that are not shown on the USGS topographic map. Both were flowing in the summer of 2007 and 2008. The northernmost of these two tributaries flows by and partially through some waste rock from previous mining activity. There is flow from under the waste rock that joins the tributary. Both tributaries start from seeps high above treeline. The flow increases from groundwater as they descend. The northernmost of the two tributaries crosses the Webster Pass road and disappears into a wetlands. There was no obvious point of entrance into the Snake River. The second unmarked tributary crosses the Webster Pass road about 150 yards south of the northernmost and does have a distinct entry point into the Snake. It too, however, crosses a wetland and passes through a small grove of trees with a distinct orange coloration. Figure 16 shows the headwaters of the northern most tributary and Figure 17 shows the headwaters of the one just south.

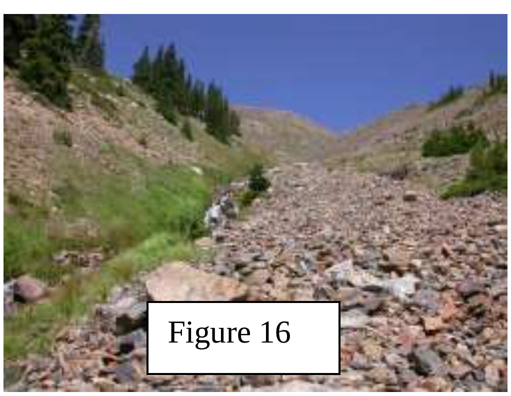


Figure 16

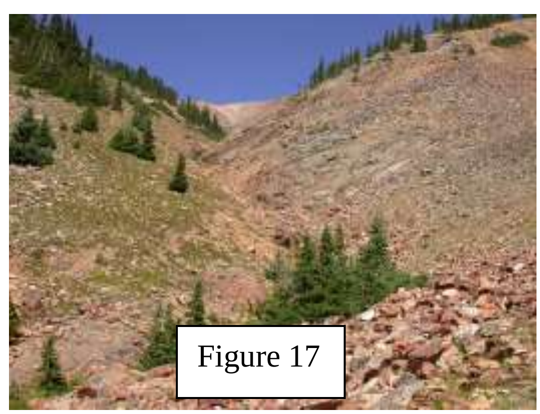


Figure 17

Figure 18

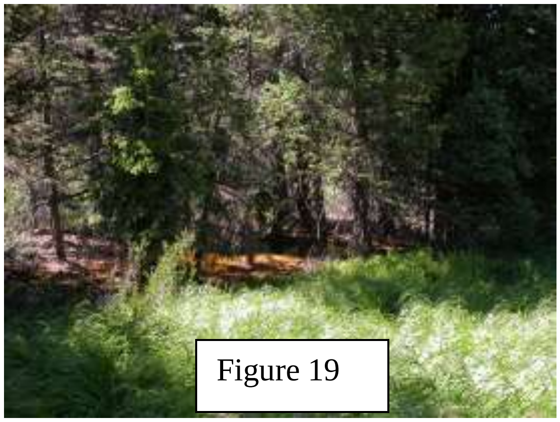


Figure 19

Figure 18 shows the northern most eastern tributary just west of the Webster Pass road crossing a wetlands on its way to the Snake River. Figure 19 shows the small tributary just to the south after it has crossed the wetlands, as it passes through some trees just a few yards away from entering the Snake River. Note the orange coloration of the water.

From here the Snake River passes through an area of some old beaver ponds where the flow is quite slow. Then, below the last beaver pond the stream drops rather rapidly and turns west as it drops to its confluence with Deer Creek, the first major tributary. There is at least one open adit in this stretch. Flow from the adit is very small, less that one gpm. There may be a second mine near the confluence, but the area consists of private property and has not been investigated. Deer Creek flows at approximately the same rate as the mainstem at their confluence and has a major influence on the water quality of the Snake River.

Snake River Below Deer Creek

The Snake River changes in water quality below its confluence with Deer Creek. The low pH in the upper Snake River has allowed the leaching of many metals. At the pH levels in the Snake, some iron has precipitated, but other metals, such as aluminum and manganese are soluble. In Deer Creek, at pH values in the upper 7's, none of these three metals are soluble. At the junction, the pH of the combined stream rises to the point that aluminum and manganese precipitate. Most visible below the confluence is white staining on the rocks from the precipitation of aluminum. This staining is visible for a considerable distance below the confluence.

Just below the confluence is a large, relatively flat area of significant wetlands. Two leaking adits with significant flow discharge into the stream and/or wetlands right below the confluence. Just above the northern most of these mines, shown as the Superior Mine on the USGS topo map is another leaking adit. Just north and slightly higher on the western mountains is a pipe sticking out of an old mine adit spewing water down an eroded drainage. The flow from these higher mines normally does not discharge directly into the stream. Rather the flow from these mines and several tributaries which flow higher on the western hills seep into the groundwater and enter the Snake via seeps in the lower wetlands. Downstream from these two leaking adits, there are a considerable number of small inflows through and across the wetlands. Figures 20 and 21 show examples of this. In the immediate area of this flow there were three others just like these two. As in the upper parts of the Snake and Deer Creek, much of the flow is entering the stream via seeps at the base of steeper areas and flowing via the wetlands into the main stream. Figure 22 is one example of many in this area.

Figure 20

Figure 21

Figure 22

Near the bottom of the wetlands is the town of Montezuma. Just before the town, on the west side of the stream is the Burke- Martin mine. This mine has significant disturbed areas and water

Figure 23

Figure 24

flowing out of a pipe onto tailings or waste rock and then across other disturbed land to the Snake River. The source of the water is an adit higher on the mountain. Figures 23 and 24 show some of the disturbed land and the discharge. Figure 24, which shows the discharge, is from a distance and makes the actual discharge from the pipe difficult to see. There is another mine, just to the north of the Burke Martin mine with a leaking adit. Flow from this adit is low and the water goes into the waste rock and ground water, not directly into the Snake River. Just south and west of Montezuma there are two other mines a few hundred yards above the stream. These are north of the Burke Martin mine, but south of town. One of these mines has significant disturbance of land in the area of the mine, but both mines were dry and no sign of flow in August, 2007.

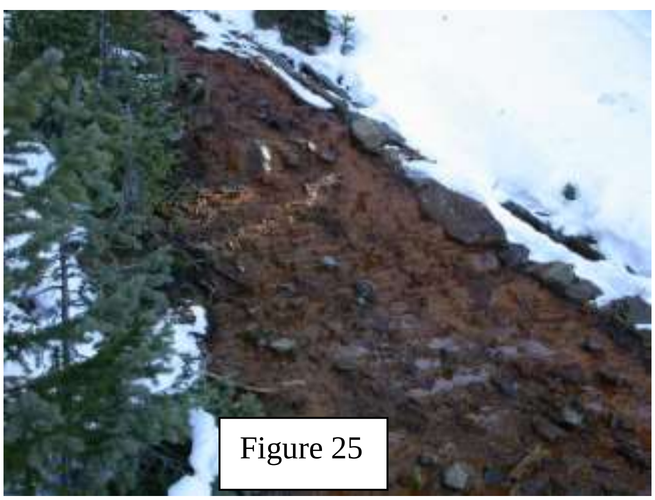


Figure 25

In the north end of the town of Montezuma, Sts. John Creek flows into the Snake River. There are several mines with discharge histories on the hills east of Montezuma. In August, 2007 none were flowing clear to the Snake River. However, one has significant flow and most of the flow crosses the waste rock and is a candidate for some cleanup. This mine is shown if Figure 25. There is another mine, higher and south of this one that has been closed by the state and still has some adit leakage, but not a significant flow. There are a few other mines with disturbed area, but only one high above the town in a drainage area that seems to need any attention at this time.

Below the town of Montezuma there are a number of problems. Just below the town there is an area of significant past mining activity. The only clear discharge is from a mine on the east side of the road just north of Montezuma. A house has been built on the old mine site and a pipe spews water onto waste rock just to the north of the house. This flow goes down the waste rock, across under the road and down across an old tailings pond area into the Snake. The overall area has considerable tailings and still some ponds. Much of the flow in this area is via shallow groundwater flow. This is the area water from the mine shown in Figure 25, usually as ground water, also flows toward the Snake River. Because much of the area was patented from mining claims there is considerable private

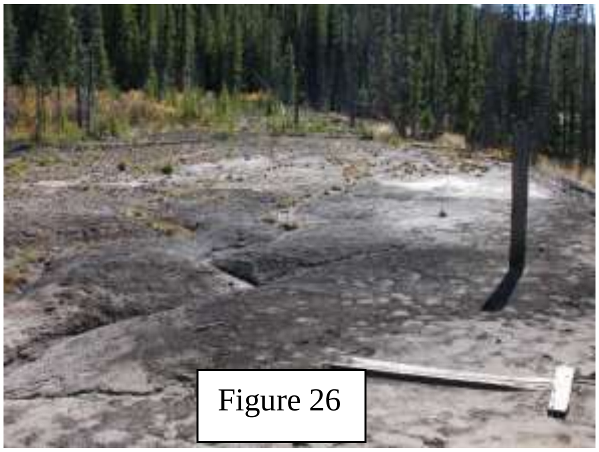


Figure 26


Figure 27

land and a number of houses have been or appear ready to be built in this general area. Figures 26 and 27 show this area. Figure 27, which shows the house and pipe discharge was taken from distance and does not clearly show the discharge. Anyone familiar with


Figure 28

the area has seen the house and the discharge. In this area there are a number of seeps on the west side of the stream and flow from one reasonable significant tributary. This area is below the road to the Hunki Dori mine as that road goes along roughly on contour around a ridge from Bear Mountain. There are a number of seeps and small flows that cross this road and flow down to the Snake in this area. Figure 28 shows one of the larger flows into the Snake in this area. There are several other smaller flows into the Snake. There are a number of small old mines in the area just above the road crossing by the Peru Creek parking lot with leaking adits. However, flows are very small.

.

Nothing happens to affect water quality from the road crossing at the Peru Creek parking lot to the confluence with Peru Creek. Peru Creek is the major tributary and its waters have a low pH and high metal concentrations. As with the confluence with Deer Creek, this confluence has signs of aluminum precipitation with the white staining on the rocks below the confluence. The Snake River is causing the pH to rise in the waters coming from Peru Creek resulting in the precipitation of aluminum. Figure 29 shows the confluence of Peru Creek and the Snake River and Figure 30, taken a few hundred yards below the confluence shows the aluminum precipitation with the white staining on the rocks. In this area below the confluence there are still seeps feeding the stream along the way as there were in the upper reaches of the Snake and its tributaries.

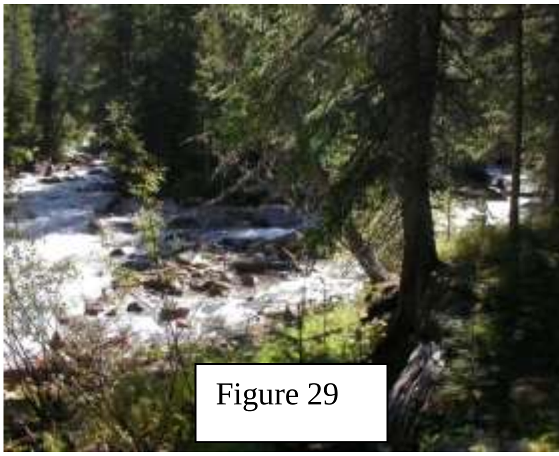


Figure 29

Figure 30

A few hundred yards further down the Snake is a major wetlands area on the east side of the road and flow from Thurman Gulch enters the stream. A few hundred yards further the Snake crosses under the Montezuma road and approaches the area where the Roberts Tunnel access portal is located. There are no water quality issues in this stretch of the river

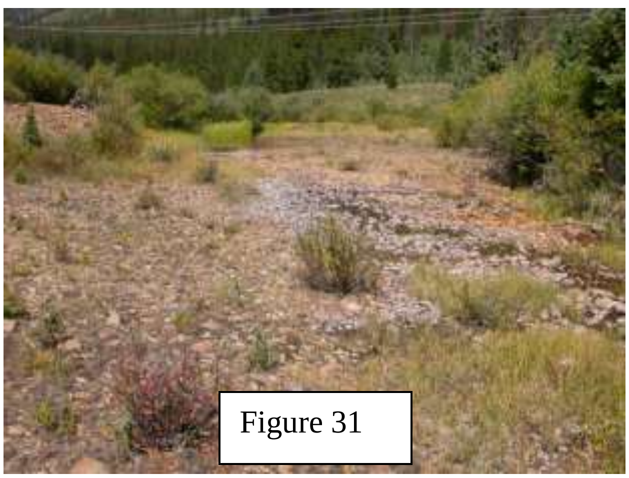


Figure 31

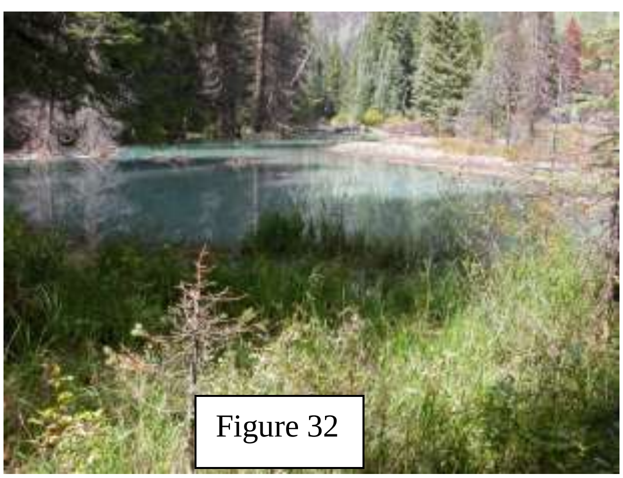


Figure 32

The area of the Roberts tunnel access is a large area that has been leveled. In this area there are a number of "drainage" areas that cross the area. One of them, at the west end, is Grizzly Gulch. At the far northwest end of this area the Snake River is affected by a dam or series of obstructions that act as a small, ineffective dam creating a pond. Figure 31 shows one of the drainage areas across this area and Figure 32 shows the pond in the stream. Much of the stream on the western edge of this flattened area is surrounded by wetlands.


Figure 33

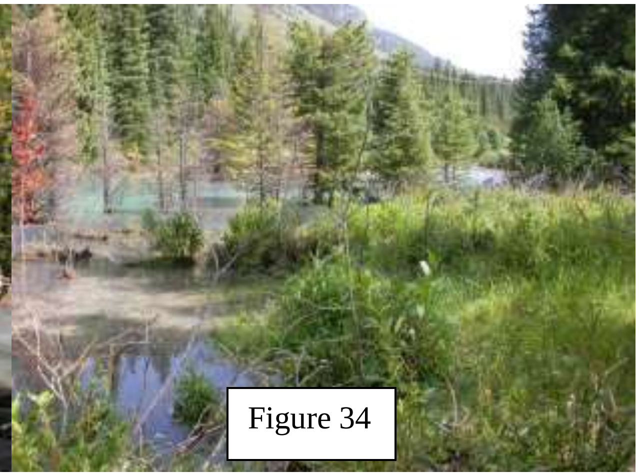


Figure 34

A few hundred yards below this pond stream flow from a tributary north of the Snake enters the river. This is flowing from a drainage east of Porcupine Mountain and crosses the Montezuma road in a culvert. Figure 33 shows this tributary entering the Snake River.

Not far below this small tributary obstructions have created another natural dam in the stream which has resulted in a number of dead trees. This is shown in Figure 34. This is just before the developed area of Keystone. A few hundred yards downstream there is a bridge at the entrance to Settlers Creek. Just below that flow from Jones Gulch enters the Snake. While there are mines in the upper Jones Gulch area, they appeared to be dry in September, 2007 with no sign of flow into Jones Gulch. Figure 35 shows the flow from Jones Gulch entering the Snake River in the Keystone area.


Figure 35

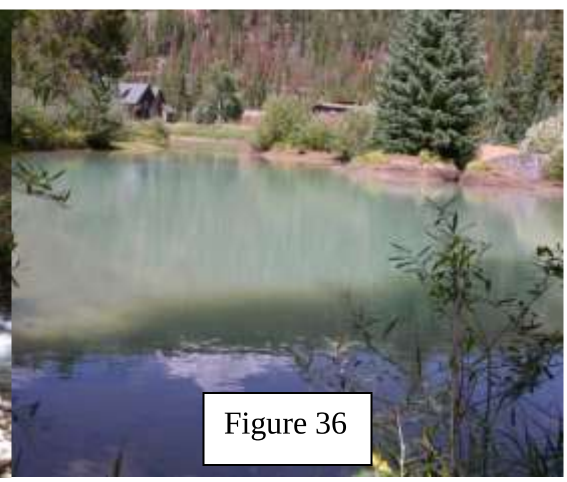


Figure 36

The stream in this area, as it flows through the developed area just west of the base of the ski area, flows through an area of significant wetlands. The river flows by a large pond to its north and through very heavy, undeveloped wetlands, on both sides of the stream. Figure 36 shows the pond and figure 37 shows some of the lower wetland area. These wetlands are practically impenetrable to foot travel, with very heavy willows and swampy footing.

Shortly below the wetlands the North Fork of the Snake River joins from the north. The North Fork has good water quality and significant flow, relative to the Snake itself resulting in the highest water quality of the Snake River from this point to its flow into Dillon Reservoir.

The Snake River just past the wetlands approaches the River Run area of the Keystone Resort. In this area it is joined by the North Fork of the Snake River. Just below the confluence is the flow and quality sampling station that provides the monitoring location to evaluate clean-up activities in the basin.

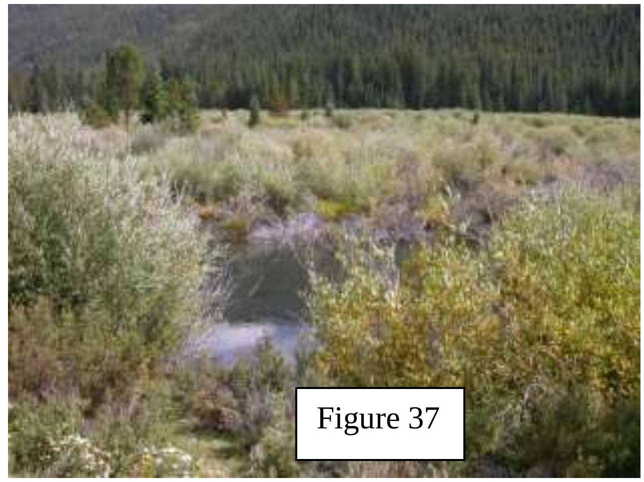


Figure 37

Deer Creek

The Deer Creek drainage originates just to the west of the upper Snake River drainage, separated by Teller Mountain. The creek originates from seeps below an upper bench, high above treeline. Figure 38 shows the upper portion of the drainage. Figure 39 is taken just to the right or west of Figure 38 and shows the first pond and the area of initial seeps in the flow of the creek. Looking further to the west, downstream is Figure 40. There was one waterfall on the north facing (left) slopes seen in Figure 40. As the stream flows from west to north, a lot of seeps in the treed areas on the south facing slopes feed the creek. In particular, as you come around Radical Hill, there are many seeps. The rocky area above the seeps infiltrate the water from melting snow and feed the seeps lower on the mountain.

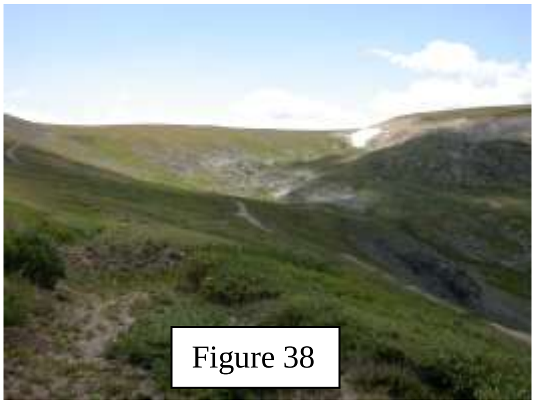


Figure 38

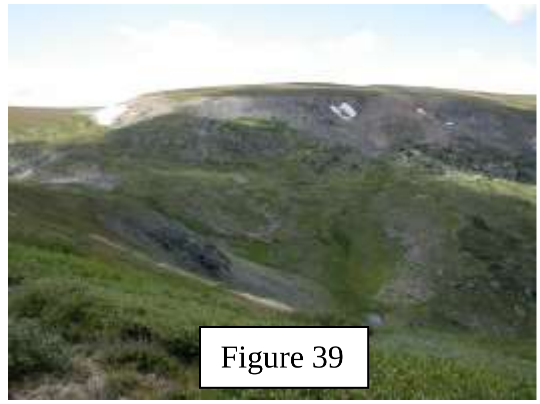


Figure 39

Figure 40

The valley of Deer Creek is underlain almost entirely by Swandyke Hornblende Gneiss, a rock relatively rich in calcium, manganese and iron. There are scattered veins of lead, zinc. And silver sulfide minerals on Teller Mountain. As a result, there are remnants of past mining activity on the entire east side of the drainage as it turns north flowing. There are fewer mines on the west side, particularly high.

In the summer of 2007, there was only one flowing adit from the old mines on the east flank of the drainage. That was at the old Arabelle Mine, which has been closed by the state of Colorado, but continues to leak slowly from the closed adit. While the leak is close to the only tributary on the east side of the drainage, it does not appear to flow into the drainage. Figure 41 shows the closed, but leaking Arabelle Mine adit and Figure 42 shows the eastern tributary nearby. While there are many mines on the eastern flank they are far removed from the stream, are basically dry, and pose no real water quality issues.

Figure 41

Figure 42

The west side of the drainage is very different. There are fewer mines, only two of significance, the Upper and Lower Chatauqua Mines. There is a large upper bench above treeline which accumulates snow melt, and considerable seeps along the lower, tree covered slope to the stream. Where the road to the Chatuaqua mines cuts areas of shallow groundwater, there is seepage flow onto and down the road cut. Much of the water enters the wetlands of the main channel via seeps and ground water flow. Figure 43 shows the upper bench, Figure 44 shows a typical road cut seep and flow and Figure 45 shows a view looking down the treed slope to the valley floor below. Figure 46 shows the minor flow from the Lower Chatuaqua Mine.

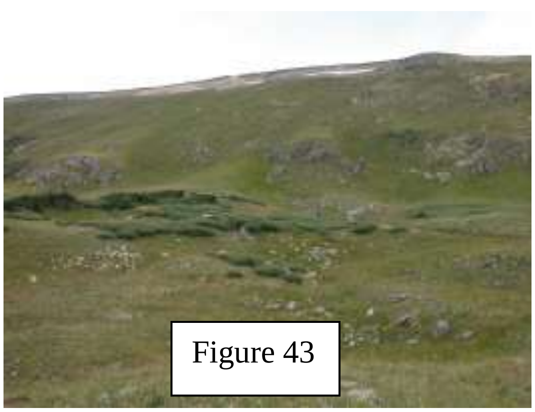


Figure 43

Figure 44

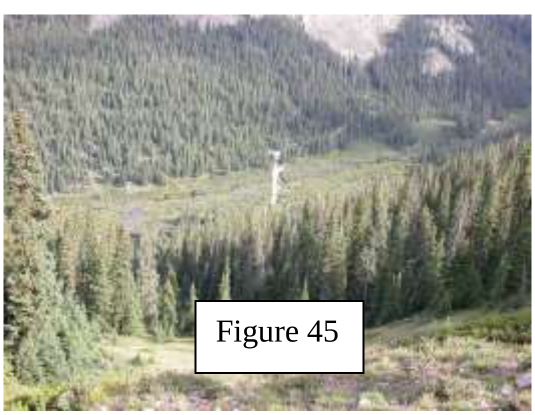


Figure 45

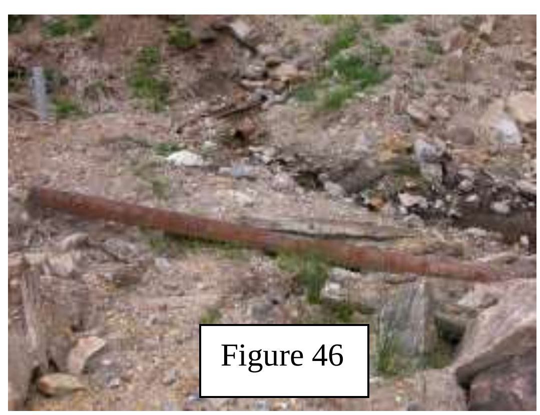


Figure 46

There are a number of other seeps and mine adit discharges in the lower portion of Deer Creek, from the west side. There are a number of areas of waste rock, with seepage coming out of the waste rock and flowing down the road. Figure 47 shows one example of this road flow and Figure 48 shows a leaking adit in the lower Deer Creek area. The flow from this adit goes through a series of man made ponds and does not flow into the creek via surface flow except in the spring runoff.


Figure 47


Figure 48

While not officially Deer Creek discharges, there are two leaking adits that enter the Snake River just below the Deer Creek confluence. These two both flow at relatively high levels of flow and both discharge into the Snake River, before there has been complete mixing with Deer Creek. The two leaking adits are only a few hundred yards apart. Figure 49 shows the southern most one and Figure 50 shows the northernmost one.


Figure 49


Figure 50

Sts John Creek

The Sts. John drainage originates just west of the Deer Creek Drainage, across Glacier Mountain. The west side of the drainage is a ridge between Keystone Mountain and Bear Mountain. Figure 51 shows a panorama of the upper basin and this ridge. While the topo map of the region shows the stream originating at approximately the middle of Figure 51, in August of 2007and 2008, the majority of stream flow was originating in a tributary to the east which joined the "mainstem" at approximately the point where the stream crossed the main road to the Wild Irishman mine. This eastern tributary had a number of sub tributaries. The road forks near where this eastern tributary crosses the road. The right or western fork of the road goes to a mine with a minor leaking adit which flows into the "mainstem" as shown on the topo map.

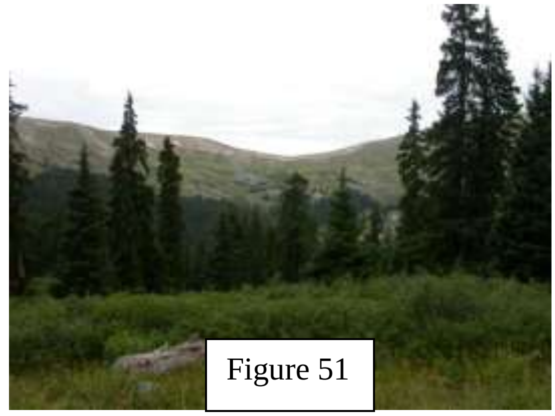


Figure 51

Figure 52 shows this leaking adit. The eastern tributary flows via a number of subtributaries from the higher bench south of the Wild Irishman Mine. This mine also has a leaking adit, but the flow does not appear to reach any perennial flowing tributary. The flow disappears into the ground and ultimately reaches surface flow via some seep or springs lower on the mountain. Figure 53 shows the flow from the Wild Irishman Mine. A third mine in the basin also has a leaking adit. It is north from the Wild Irishman mine and down a small subdrainage. This is one of the tributaries feeding the eastern tributary that is the majority of the flow of Sts. John Creek. This mine is shown in Figure 54. The General Teller Mine, above the Wild


Figure 52


Figure 53


Figure 54

Irishman Mine and near the top of the drainage was dry in August 2007and 2008. While there is considerable waste rock, there is so little water flow the waste rock piles do not appear to cause water quality degradation. While these three mines all have leaking adits, two were not directly entering the creek and the third had very low flow and was not a significant contributor to stream flow. However, the Wild Irishman mine and the one to its north both have adit flow crossing waste rock.

The geology of the basin appears to be similar to the geology of Deer Creek. Most of the basin is underlain by Swandyke Hornblende Gneiss. Like, Deer Creek, the water quality in the upper part of the Sts. John basin is good. There are limited water quality data from the upper basin, but the EPA has sampled Sts. John Creek just above the Sts. John Mine twice in 2006 and twice in 2007. The pH of these four tests ranged from 7.1 to 7.7. There were no significantly high metal values. Water quality in the upper basin appears to be very good.

About halfway down the drainage the stream comes to the old Sts. John mine site. There are a number of old mine buildings and several old cabins, at least one of which is

Figure 55

Figure 56

still used. This site changes the chemistry of the stream. The old Sts. John mine site has both leaking adit problems and tailings/waste rock contamination problems. EPA has sampled the adit flow twice in 2007. Flow was 0.68 cfs in July, 2007 and 0.38 cfs in September, 2007. The pH was 6.2 in July and 6.0

Figure 57

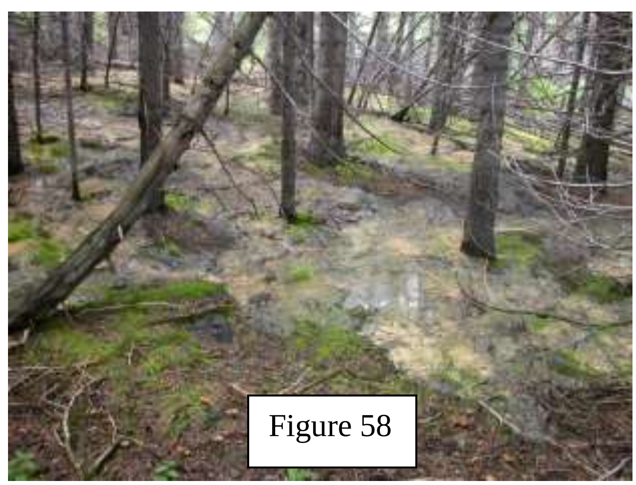


Figure 58

in September. Manganese was 12-16 mg/l and zinc was 6.5-8.4 mg/l. Figures 55 and

56 show the adit flow and some issues around the old mill site, where it appears that some flow from the stream is seeping into disturbed areas and affecting water quality. In addition to the two problems shown, there are a number areas where water flows across waste rock or old tailings. These issues too, need to be addressed. The adit flow splits near the adit, with a minor portion flowing south across disturbed areas and the majority flowing north, reaching the creek via a very circuitous path. Figures 57 and 58 show two

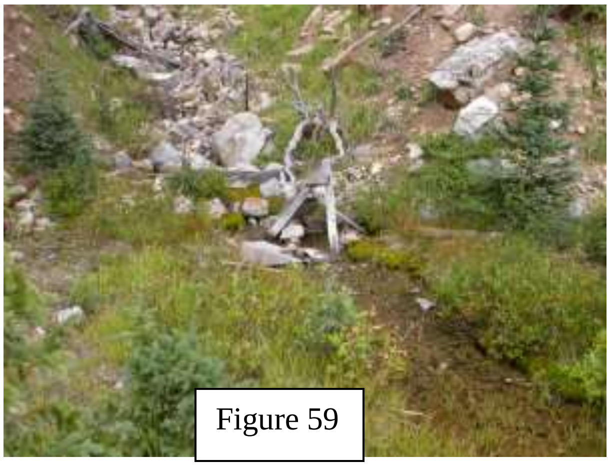


Figure 59

Figure 60

views of the northern route to the creek in August 2007.

The area just below the mill site has become a wetlands of sort, from seepage from the stream mainly and holds considerable tailings. This area needs to be addressed as well.

Sts. John Creek below the Sts. John mine flows into a large meadow that is filled with old tailings. To the west of the meadow is another mine, the Marlin Mine, with a leaking adit. At the north end of the meadow the stream crosses the road that goes to the Hunki Dori mine and Grizzly Gulch. The USGS sampled above and below this wetland in 2001. The pH both times was 6.6 su. The manganese increased from 0.286-0.728 mg/l and the zinc increased from 0.39-0.548 mg/l. Figure 59 shows the Marlin Mine leaking adit as it emerges and figure 60 shows the flow as it crosses a flat area and drops toward the stream. Figure 61 shows some of the tailings in the meadow.

Figure 61

From the north end of the meadow the stream drops quickly to its confluence with the Snake River in the town of Montezuma. There have been water quality measurements at this confluence from 1998-2003 by the Colorado Department of Public Health and Environment and by EPA in 2006 and 2007. The pH has ranged from 6.67-7.83. Flow has ranged from 1.37 to 17.9 cfs, with flow in July, 2006 and 2007 being about 8cfs. Manganese has been measured as high as 0.3 mg/l and zinc as high as 1.3 mg/l.

Peru Creek

Peru Creek originates high in the central rocky mountains of Colorado between Gray's Peak and Mount Edwards. There is a western and eastern "headwaters", with the eastern tributary shown on the USGS topo map as the mainstem, but the western tributary is larger and longer than the eastern one. There is a Forest Service road that goes nearly to the headwaters and in the upper basin, is on the divide between the eastern and western headwaters. Flow originates from two high lakes just east of Grays Peak. Flow from these upper lakes comes down a steep rock embankment to a high bench in what is called Horseshoe Basin. Figure 62 shows this embankment. The flow is coming down about where the shadow begins. There are other seeps and springs below the upper slopes. There are also flowing adits, as the one shown in figure 63.

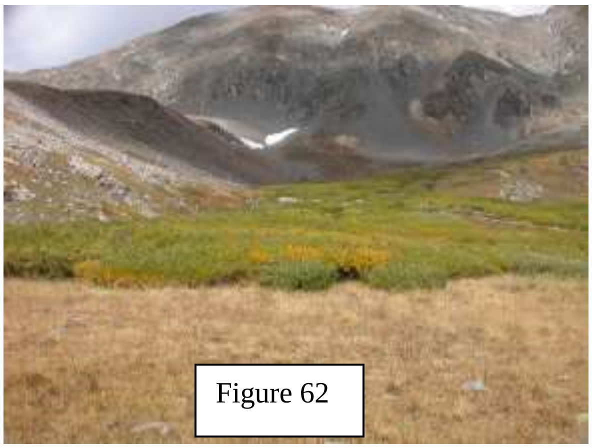


Figure 62

Figure 63

The waste rock from this adit is shown in figure 64 as is another lake, flow from which enters Peru Creek lower in the basin. Figure 65 shows the overall upper basin. There is flow down a number of channels on the right or west in the figure. There are also a number of old mines along the west side. The east side of the upper basin is best shown in Figure 66. In this photo the Vidler Tunnel, through which upper basin water is diverted to the eastern slope is clearly shown. Most of the flow in the upper eastern tributary is captured by the Vidler Tunnel diversion.

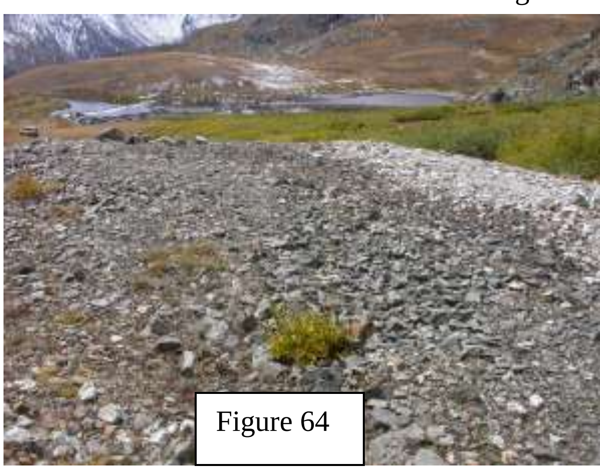


Figure 64

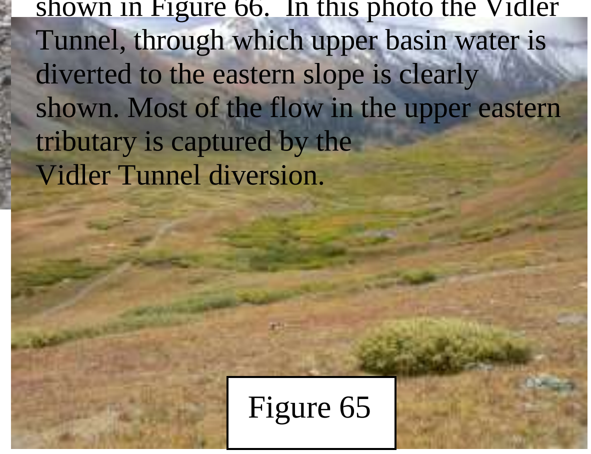


Figure 65


Figure 66

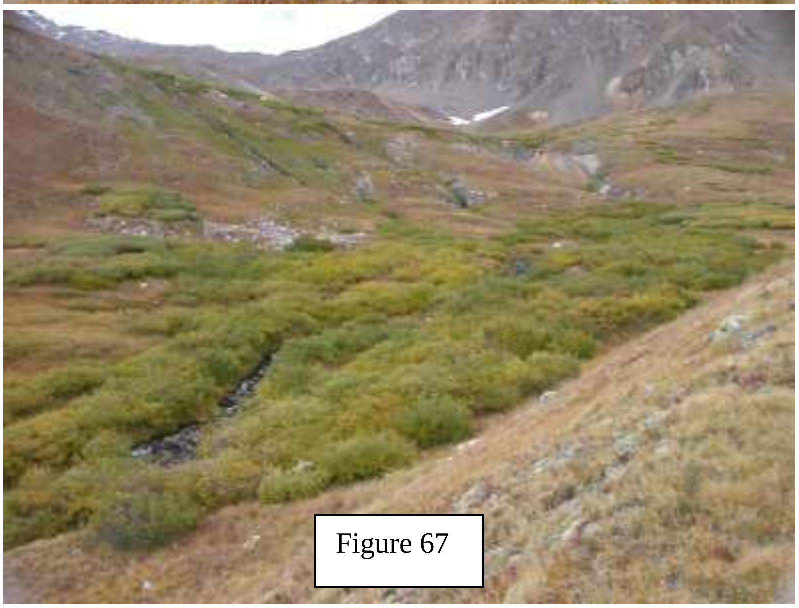


Figure 67

Flow down the upper portions of the western tributary is shown in Figure 6. Some flow is directly adjacent to waste rock while some is just down steep flow channels. Two significant tributaries from the west join the mainstem just below the stream as shown in figure 67. The upper of these two tributaries begins just below the Paymaster Mine. The second or lower of the two tributaries comes down Falls Gulch. As the first tributary joins the mainstem precipitation of aluminum begins. By the time the second tributary joins, precipitation is significant. The mainstem is largely white from this point until the ponds are reached in the area of the Shoe Basin Mine. A few hundred yards above the confluence of these two tributaries, just above where the creek crosses the road to the Paymaster Mine is a diversion structure which appears to be taking water to the Vidler Tunnel. Figure 68 shows the confluence of the lower of these two western tributaries. The upper tributary flows into Peru Creek only about ten yards above the confluence shown.

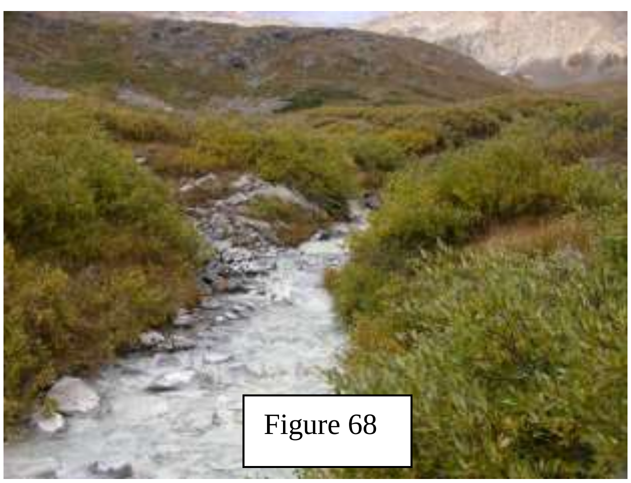


Figure 68

Peru Creek flows along the west side of the road until just below the closed National Treasury Mine and then crosses to the other side of the road. Shortly below this point the eastern tributary joins. Much of the eastern tributary is captured by the Vidler Tunnel diversion, so the tributary flows at much lower levels than it would otherwise. Just below the confluence of the two main forks of the stream, Peru Creek flows in a small

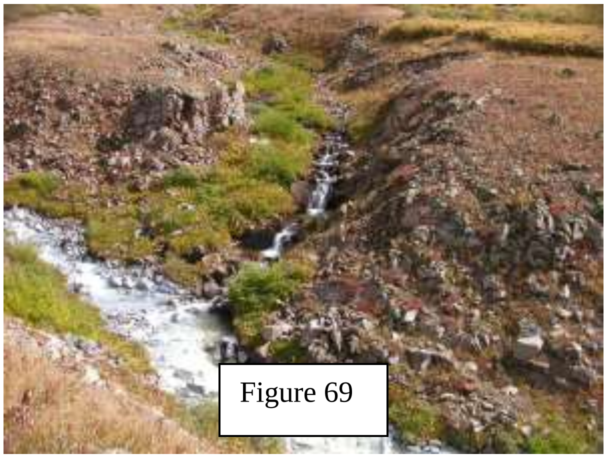


Figure 69

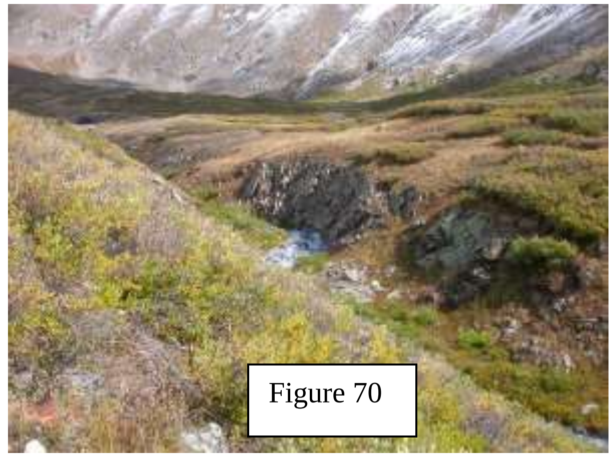


Figure 70

“canyon”. Figure 69 shows the confluence and Figure 70 shows the canyon. In all of this part of the stream the rocks are stained white from aluminum precipitation.

As Peru Creek approaches the Show Basin Mine the gradient lessens and the creek flows through a number of wetlands and beaver ponds. This is shown in figure 71.

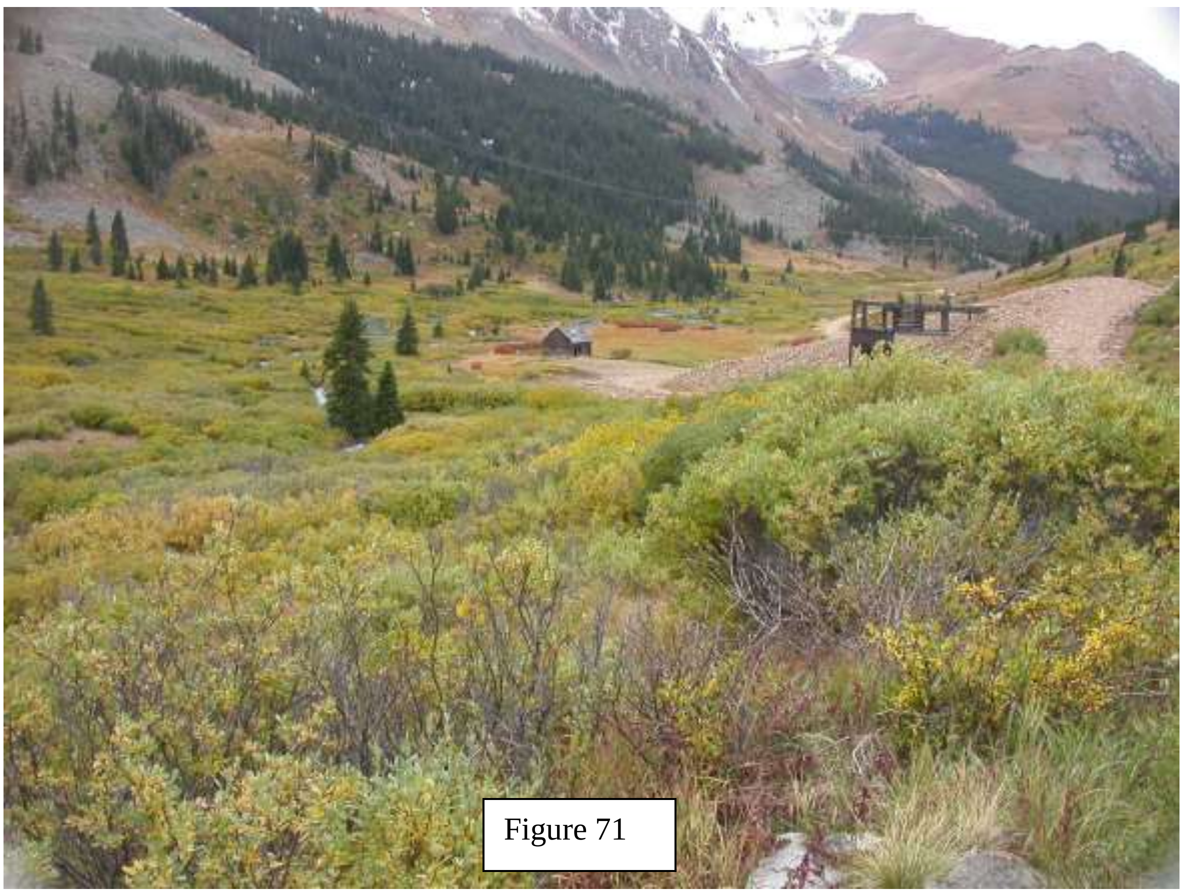


Figure 71

The Shoe Basin Mine site has been reclaimed by Summit County Open Space. However, due to restriction in the Clean Water Act the leaking adit was not addressed. The adit flows along a rock channel and then drops to the road where it flows along the ditch until it seeps into the ground. During periods of higher flow it will still reach the stream. Just below the Shoe Basin Mine, high above the road, is a waste rock pile. The stream gradient increases some, but there is still primarily wetland and beaver ponds. Figure 72 shows the stream a few hundred yards below the Shoe Basin Mine. In this general area there are seeps entering the creek from the south. The north side has steep slopes above the road with occasional waste rock piles. Some are in hazardous positions relative to avalanches and other sources of erosion inducing natural hazards such as the pile shown in Figure 73.

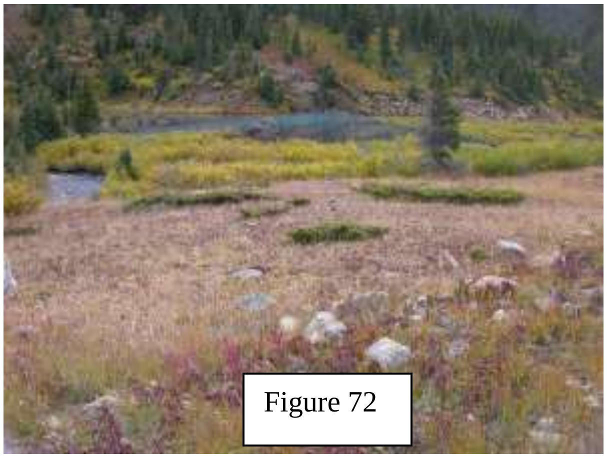


Figure 72

Figure 73

The stream gradient again lessens as the Pennsylvania Mine area is reached. Figure 74 shows the effluent from the mine reaching the stream. Just below this there are significant wetlands on both sides of the stream. The wetlands on the south contain the tailings from the Pennsylvania Mine milling activity. Figure 75 shows these wetlands.

Figure 74

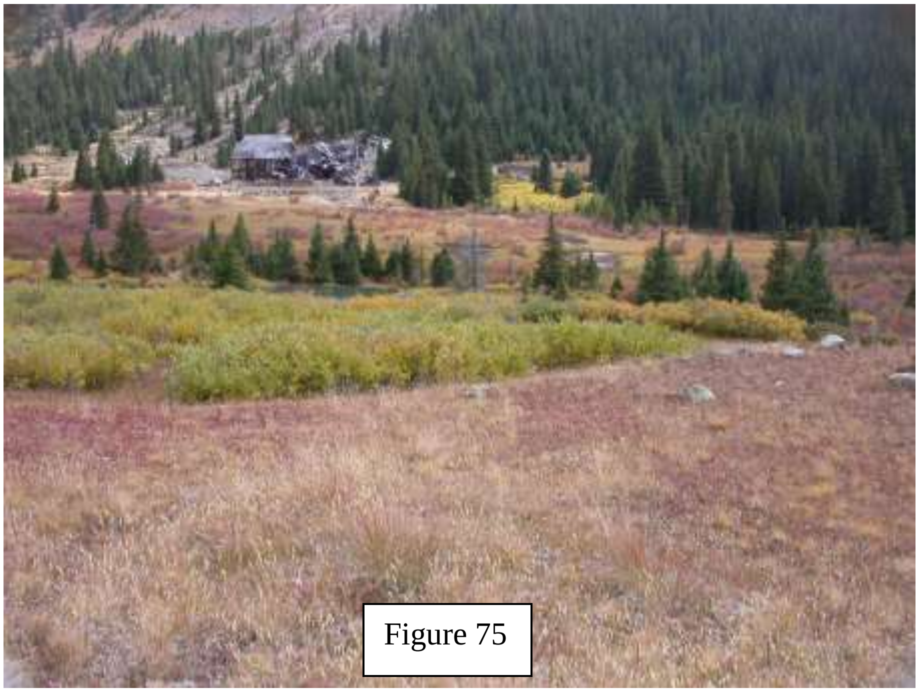


Figure 75

Just below this area Cinnamon Creek joins Peru Creek. In the lower part of Cinnamon Gulch the creek has divided into three separate flow channels. The first flow channel from the east gets close to some of the tailings. The middle channel seems to be the "main" channel. The western channel was created because Cinnamon Creek crossed an old road and part of the flow headed down the road, breaking off toward Peru Creek in the area of the Brittle Silver Mine and its associated tailings. Figures 76 and 77 show the middle and western confluence.

Peru Creek below this confluence continues through an area of significant wetlands. The steep slopes on both sides give way near the stream to wetlands that contribute to flow through seeps and springs. Figures 78 and 79 show the stream in this area. There are avalanche chutes on the north side and at least one leaking adit and significant waste rock pile. However, most of the flow is underground not surfacing until the wetlands area.

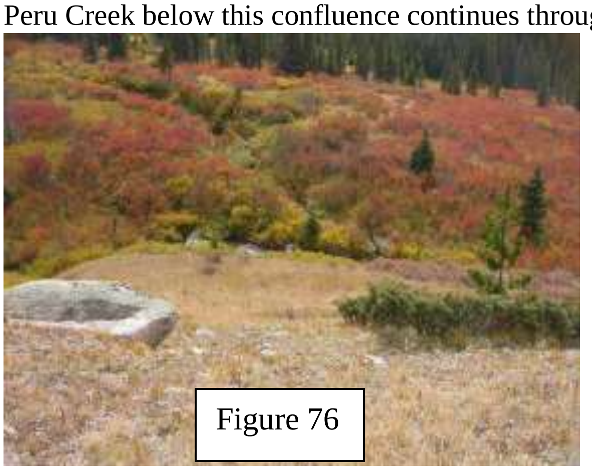


Figure 76

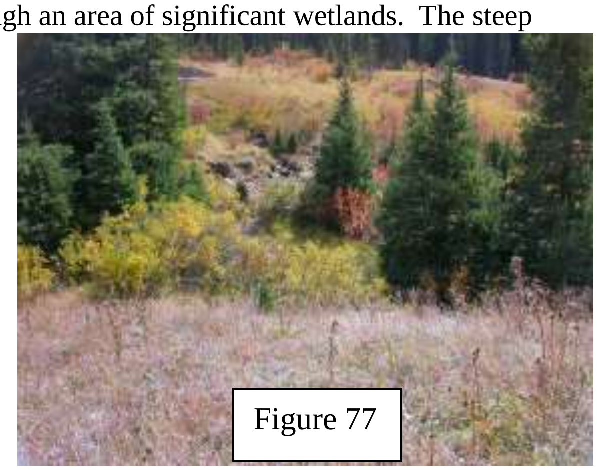


Figure 77


Figure 78

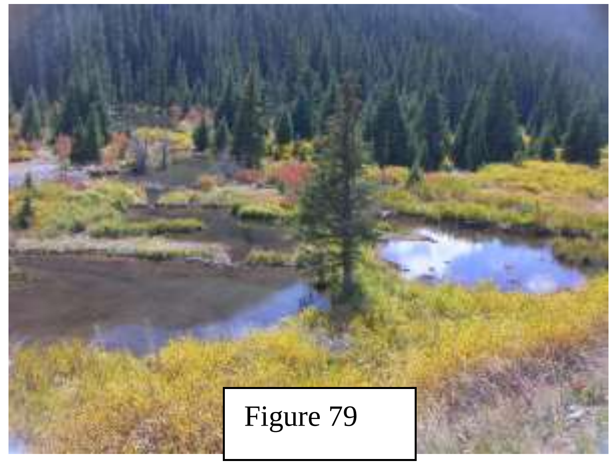


Figure 79

Below the wetlands area, Peru Creek heads into a canyon and the gradient increases. Along this canyon there are significant seeps into the creek on the south side of the stream. Figure80 shows the stream heading into the canyon and Figure 81 shows one of the seeps.

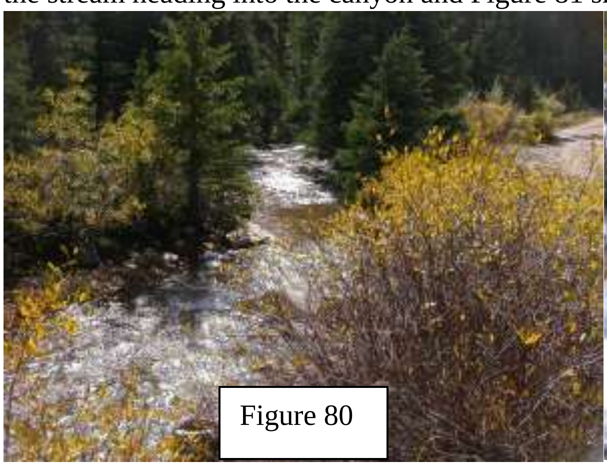


Figure 80


Figure 81

Below the canyon, Warden Gulch flow enters Peru Creek. Water quality is a problem with flow from Warden Gulch and iron staining is heavy just below the confluence for several hundred yards. Figure 82 shows the confluence of flow from Warden Gulch.


Figure 82

Peru Creek flows north for a short distance and then turns again west. Gradient again lessens and a generally flat area with wetland exists in the general area of the old town of Chihuahua. The road to Warden Gulch crosses the stream in this area. The creek again turns to the northwest briefly until the confluence of Chihuahua Creek. This water is of high quality and again creates precipitation of metals in the stream. Figure 83 shows the confluence of flow from Chihuahua Gulch and Figure 84 shows flow just below the confluence.


Figure 83


Figure 84

The south side of the creek has the normal steep slopes and wetlands areas at this point. The north side over the next quarter mile will have the same steep slopes/avalanche chutes and lower wetlands. Figure 85 shows the south side wetland area below an avalanche chute and Figure 86 shows the north side wetlands in the area of the Orleans Mine. There is a flowing adit just west of the Orleans Mine. That and seeps from the steeply sloped avalanche chute above provides flow that keeps the road permanently wet in this area.


Figure 85

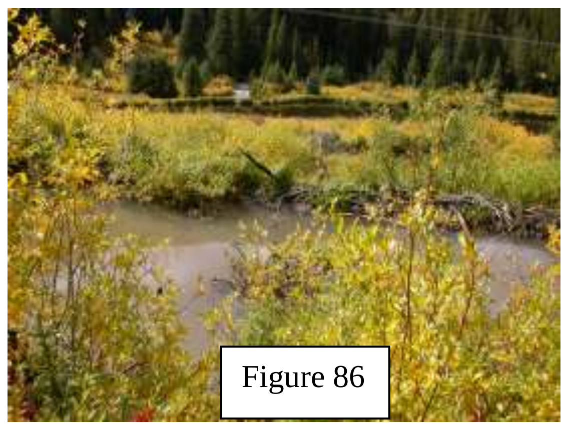


Figure 86

There are a number of seeps that flow down from the steep slopes on the north and go into the ditch on the north side of the road. This flow enters Peru Creek where the road crosses Peru Creek. Just before the end of the wetlands area and just a few hundred yards above the road crossing is the Jumbo Mine on the south side of the creek. This mine has significant waste rock and a flowing adit. The adit flow is along the west side of the waste rock. There is also flow from the toe of the waste rock and strong evidence of recent flow on the east side of the waste rock. The adit flow crosses the road to the mine and heads down a wetland area before tumbling down a steep cliff into Peru Creek.

Figure 87 shows the adit flow which flows down the west side of the waste rock and Figure 88 shows the significant pile of waste rock.


Figure 87

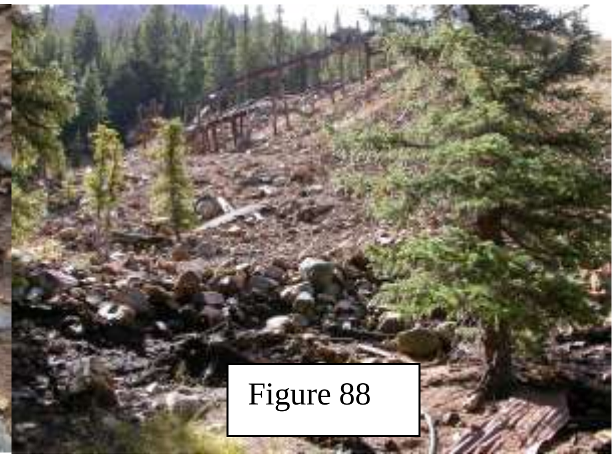


Figure 88

Peru Creek crosses the road just below where this mine effluents enters the stream. In the first quarter mile below the road, Peru Creek has significant wetlands on both sides of the stream. There are seeps and springs along and near these wetlands. Figure 89 shows one of these seeps on the south side of the stream. Figure 90 shows some old beaver activity in this same area.

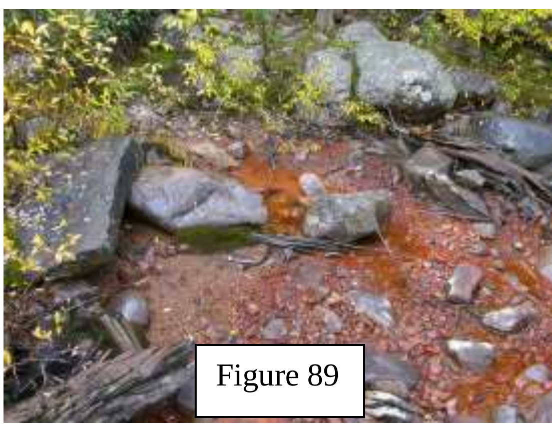


Figure 89

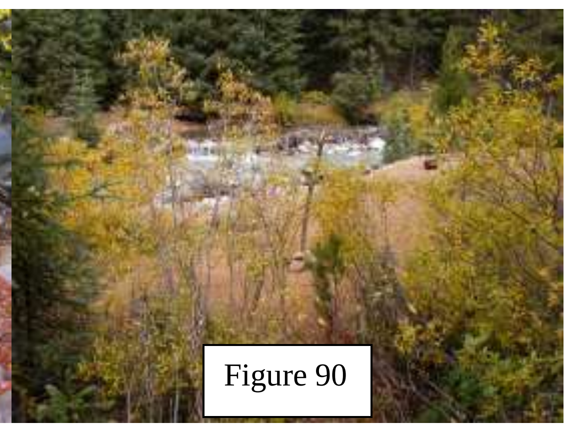


Figure 90

Below the wetlands, Peru Creek goes through a steep canyon with high walls on both sides. As the creek emerges from the canyon it comes to its confluence with the Snake River. Figure 91 is a view of the creek in the canyon and Figure 92 shows the confluence.

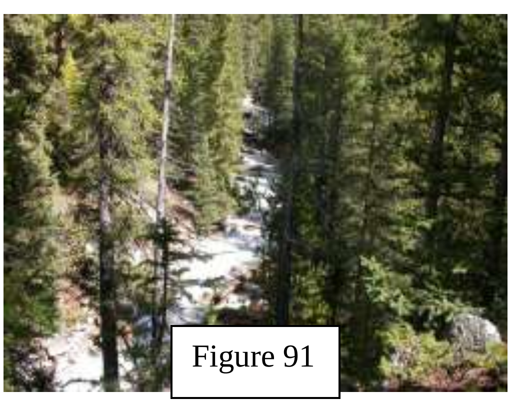


Figure 91

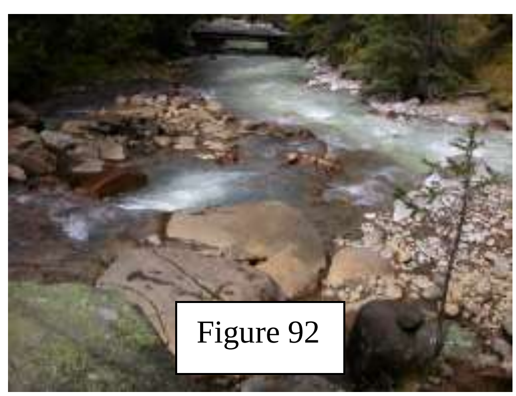


Figure 92

Cinnamon Gulch

Cinnamon Gulch is a tributary to Peru Creek in eastern Summit County. Cinnamon Gulch flows between Silver and Brittle Silver Mountains on the west and Revenue and Decatur Mountains on the east. Flow is primarily from the south to the north. Elevations range from about 10,800 feet above sea level at the confluence between the lower branch of Cinnamon Creek and Peru Creek, to 11,800 feet at the Silver Spoon Mine (apparent headwaters of Cinnamon Creek).

The main channel of flow comes from the saddle between Brittle Silver Mountain and Silver Mountain. However, most of the year, flow actually originates at the Silver Spoon Mine. Figure 93 shows this upper basin and the adit area of the mine. Flow from the adit nearly immediately flows across old waste rock on a level area below the mine. Figure 94 and figure 95 show waste rock piles from the mine where water flows through and around them. Figure 96 shows this same view from above. There is a flow channel to the east of the waste piles that also flows over mine waste and there are other waste piles just below the flow channel on the west side.


Figure 93

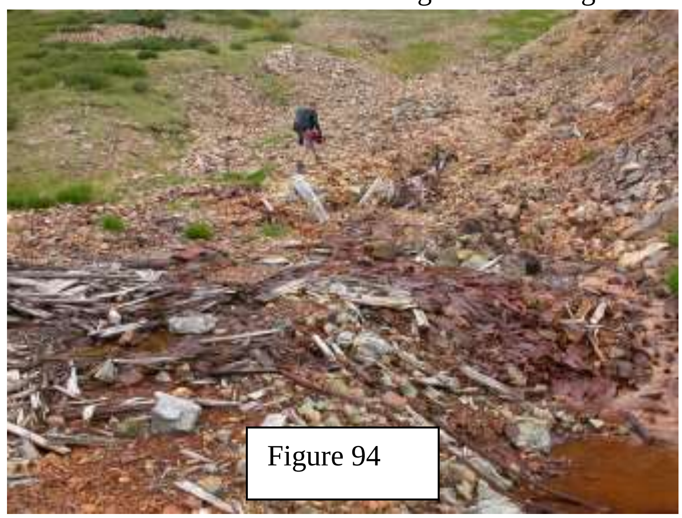


Figure 94

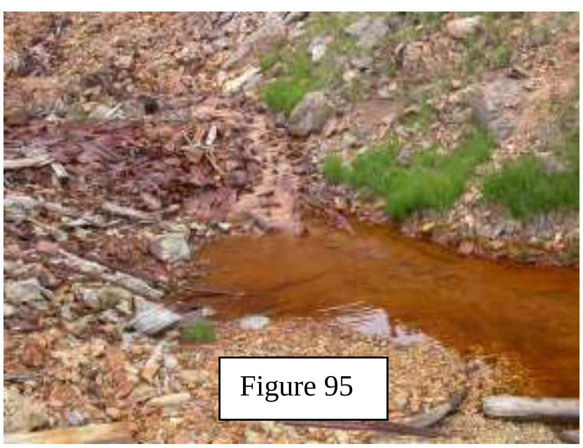


Figure 95

Just below the Silver Spoon mine is an area of old mines called the Rich Ore Group. These are a series


Figure 96

of mines at about 11,600 feet. These are discussed in detail in Wood, 2005. "Four separate adits discharge water along the Rich Ore Lode, including adits #100, #101, #103, and an adit that was not inventoried in 1993. In July of 2001, the combined flow from the four adits was measured at about 4.5 gpm. The pH ranged from 3.16 to 3.58, and conductivity ranged from 287 to 611 µS/cm. In October of 2001, only one of the four adits was flowing (adit #100), at a rate of about 1 gpm. Standing water was present at the other three. The pH ranged from 2.91 to 3.21, and conductivity ranged from 464 to 593 µS/cm." (Wood, 2005). Figure 97 shows the general area of these adits from the road. The photo is looking west. Figure 98 shows one of these adits, referred to in previous studies (Wood, 2005) as adit #103. Figure 100, from the Wood report, shows the schematic of the area downstream of adit #103. There is evidence of a state closed adit at about 11,600 feet elevation on the road to the Silver Spoon. The other adits, leading to #103 are at the same elevation moving off to the west. Figure 99shows the beginning of this trend along the main road. You can see a waste pile at the road. The others are around to the right or west. All were flowing or showed signs of recent flow in 2007. The lack of flow in 2001 was probably due to 2001 being the beginning of two low flow years. Water from a pool just inside the open adit flows onto the bench and down the southern side of the upper lobe of the waste-rock pile.


Figure 97


Figure 98


Figure 99

The Wood report stated: “Three of the five inventoried adits (#100, #101, and #103) along the Rich Ore Lode were assigned EDRs of 2, indicating “significant” environmental degradation. The remaining two were assigned EDRs of 4, indicating “slight” environmental degradation. Adits #100 through #104 were assigned physical hazard ratings of 3, indicating “potential danger.” The physical hazard ratings are based on the fact that these adits are partially to completely intact, and entrance is not impeded.”

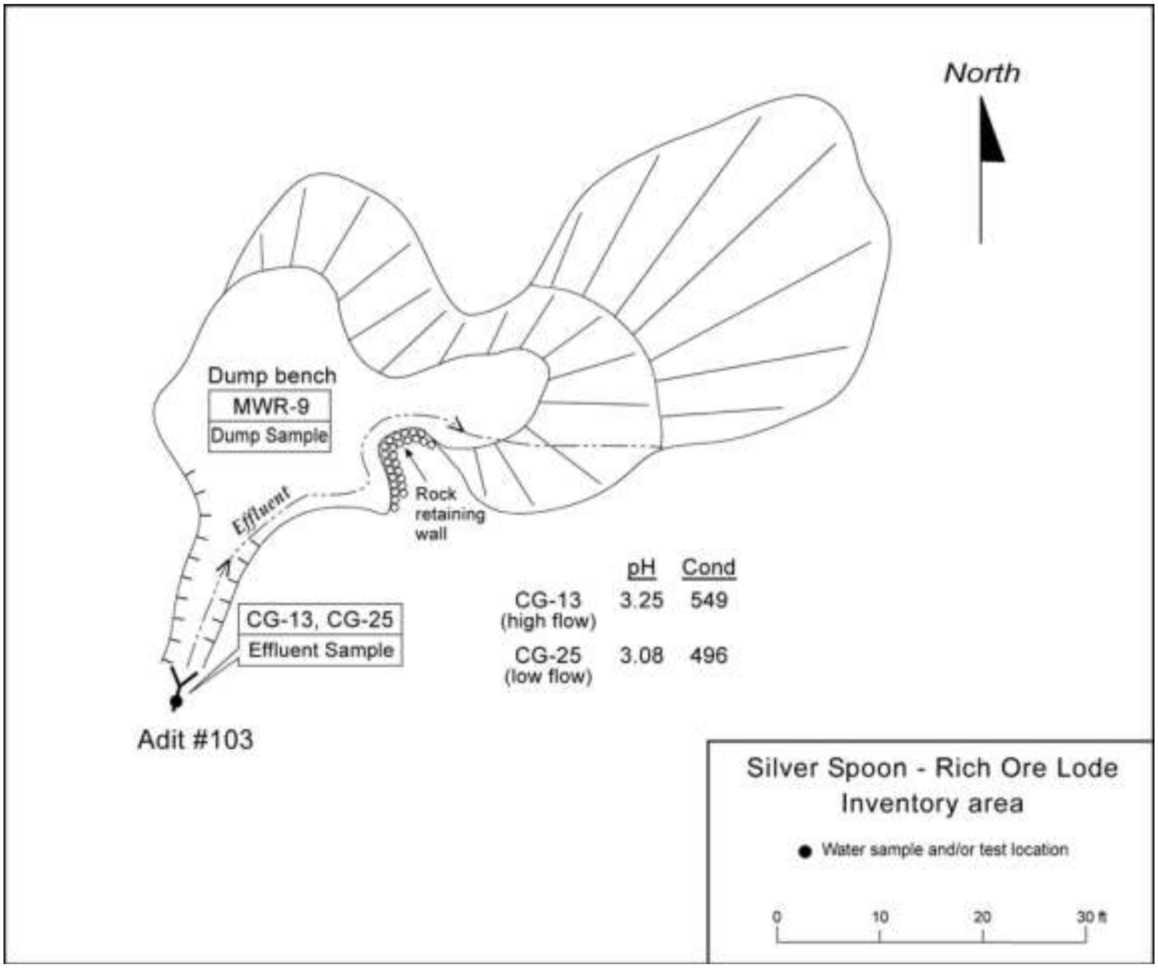


Figure 100

The flow in the “main channel” is mostly fairly straight down the drainage from south to north. In the middle of the upper portion of the gulch there is flow originating from a number of seeps along the eastern edge of the upper valley. Some are in areas where there appears to be waste rock. Others are just seeps at the bottom of a steep sloped area as we see in all of the Snake River basin. Above the eastern side of the basin is an area of highly altered rock and the zone referred to as the Montezuma shear zone. This area produced water of low pH and high dissolved metal content. Seeps have significant iron staining. The combined flows from the seeps and adits form an eastern tributary of Cinnamon gulch. Figures 101, 102, 103 and 104 show four of these “seep” or adit discharges. Several of the leaking adits on the east side flow through or directly adjacent to waste rock piles. Figures 105 and 106 give examples.

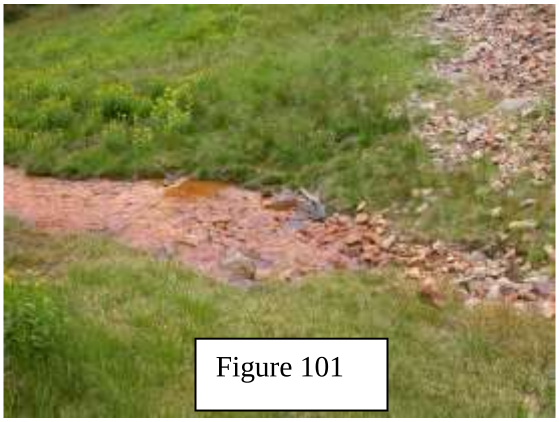


Figure 101


Figure 102

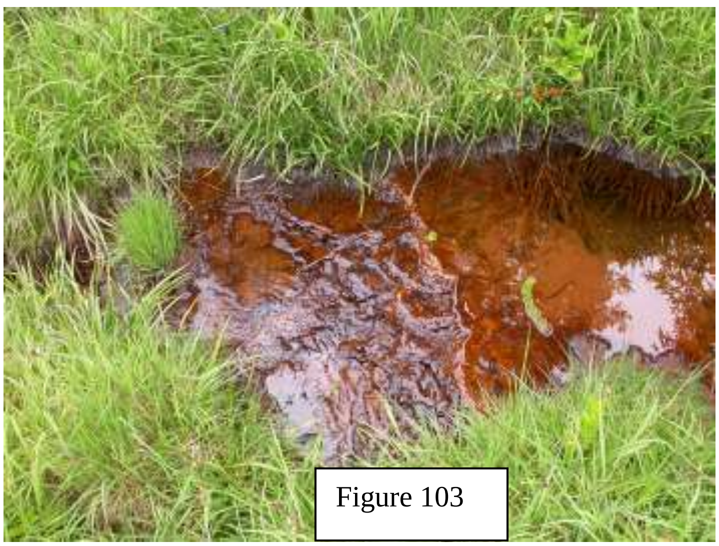


Figure 103

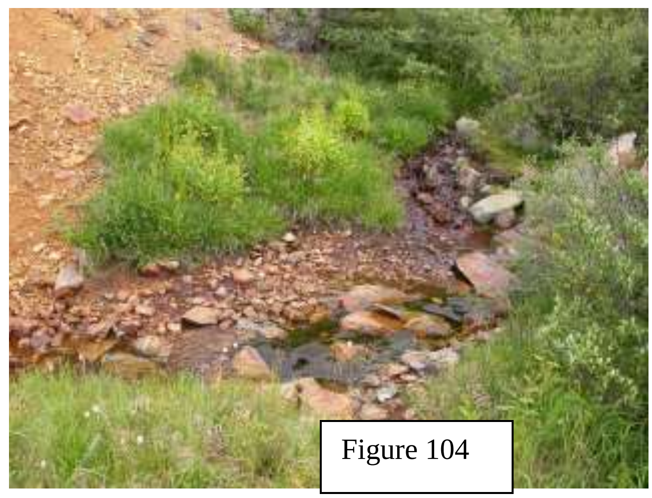


Figure 104


Figure 105


Figure 106

The eastern fork flows through a number of channels and some wetland areas before joining the mainstem near the bottom of the valley. Figure 107 gives a typical example of the flow. Shortly after joining the mainstem the creek goes through an old dam. Figure 108 shows this structure.

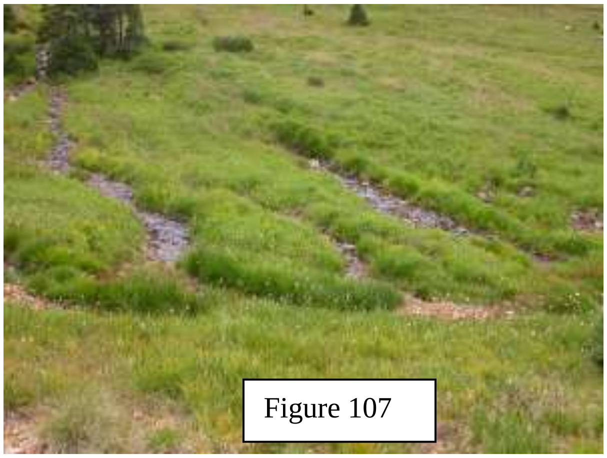


Figure 107

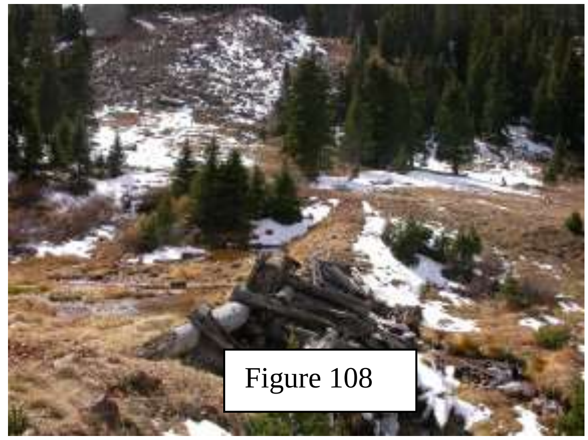


Figure 108

To the west of the dam, several hundred feet above the valley floor is another leaking adit (Little Nell). This adit is still open and the water from it flows over waste rock on its way down from the adit. Figures 109 and 1110 show this adit flow from the mine and down the rocky channel below.

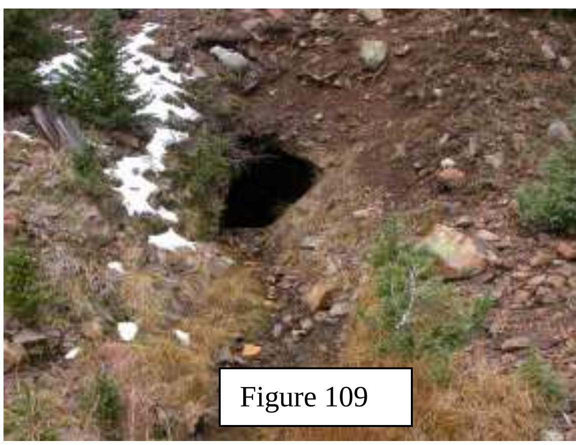


Figure 109

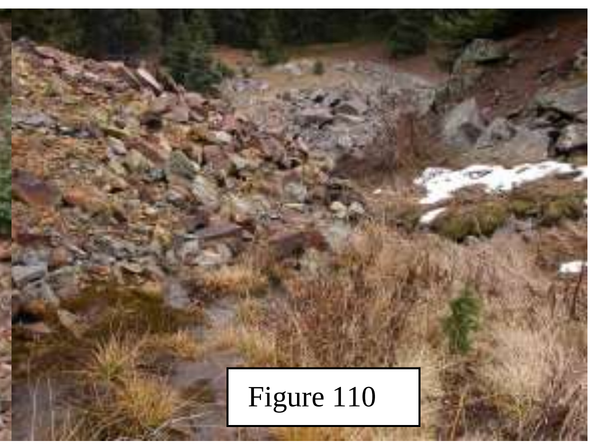


Figure 110

Just below the old dam, above the creek on the east side is the collapsed adit from the Delaware Mine. This adit is flowing and the waste rock from the mine has been spread over a fairly large area. Water from the adit flows partially down a channel and into a pond and partially over the waste rock. The pond itself may be on waste rock. There are several seeps into the stream below the pond. This site is one of the primary candidates for improvement. There is a zone of dead trees below the waste rock, indicating runoff from the pile is toxic to vegetation. Figures 111 and 112 show the adit of the mine and some of the waste rock.

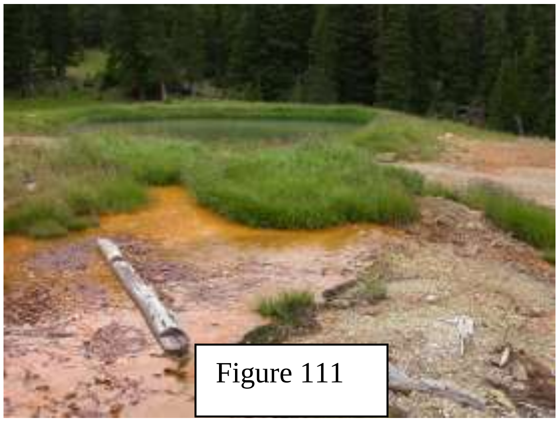


Figure 111


Figure 112

Below the Delaware mine the creek begins to drop at a more rapid pace. Over the next several hundred yards it crashes through timber and has made a number of channels. The flow in each channel varies by year. At least three separate channels emerge on the road that cuts across the channel near the Brittle Silver Mine. The road comes out of the old Pennsyvania Mine mill area. The western most channel ends up running down this road, below the Brittle Silver Mine most years. The flow down the road will break on down toward Peru Creek in different places, but ends up providing flow across the tailings from the Brittle Silver mill. Figure 113 shows the western most fork of Cinnamon Creek flowing down the road. Figure 114 shows some of the flow heading down from the road toward Peru Creek. Figure 115 shows the confluence of this western fork with Peru Creek.


Figure 113


Figure 114


Figure 115

The Brittle Silver Mine has a leaking adit, significant waste rock issues and significant tailings issues. The current flow of the western fork is making these problems worse. However, there are seeps in several areas in the mine waste rock area demonstrating the mine has problems of its own, not just those exacerbated by Cinnamon Creek.

Warden Gulch

Warden Gulch is a drainage originating between the Collier Mountains on the west and Silver Mountain on the east and emptying into Peru Creek. It is west of the drainage of Cinnamon Gulch and is the last significant Peru Creek southern tributary. It drains an area of heavy mineralization. The upper part of the basin has extensive hydrothermal alteration, which has adversely affected the natural water quality in the basin.

Flow in the upper part of the basin is shown on the USGS topo map as originating on the eastern part of the basin. This is not correct. Flow originates at the lower end of a western drainage below steep sides of a glacial valley. At the end of the valley is the Allen Emory mine. North of the end of the valley is a bench, below Morgan Peak, where there are a number of small waste rock piles at about 11,900 feet elevation. These were all dry in August, 2007. There is a road up to the Allen Emory mine. This road traverses south at about 11,600 feet elevation to about 11,800 feet elevation just below these mines as it approaches the end of the valley. Figure 116 shows the end of the valley and the Allen Emory mine and figure 117 shows one of the other waste piles. There are other waste piles along the road.

Figure 116

Figure 117

The Allen Emory mine is dry, but there are significant erosion issues. It is on such a steep slope that erosion will be difficult to stop. Snow melting in the area mostly goes into the ground. Flow in the drainage channel begins significantly below the mine, from seeps and springs as it does in all of the drainages of the Snake River basin.

The initial flow in August, 2007 began from a stream at the point where the picture in figure 116 was taken. Figure 118 shows this spring and figure 119 shows a spring just below, where flow in the channel actually begins.

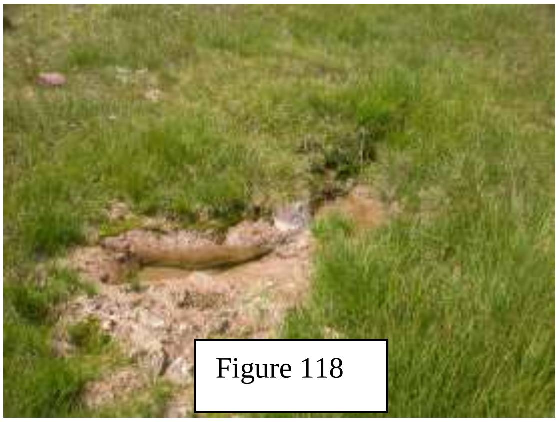


Figure 118

Figure 119

As the “stream” proceeds down the drainage there are many seeps and springs. Some are in the channel area and some are more at the base of the steep slopes on the south. In this part of the basin, which is very rocky, flow comes and goes from the surface. Figures 120 shows another typical spring and figure 121 shows the surface flow, coming and going in the rocks.

Figure 120

Figure 121

In the middle of this part of the drainage there is a mine high on the south slope. The waste rock is eroding significantly. However, like the Allen Emory mine, the waste rock is on such a steep slope that stopping the erosion would be nearly impossible. Snow melt in this area also tends to go straight into the rock. At the base of this area there is a significant seep or spring which flow alone for a while before joining the existing flow. As the drainage area approaches the place on the USGS topo map that shows an eastern trib, there are several flow channels and the stream takes on a look of flowing through wetland. This is an area where flow is increasing from the many seeps in the area. Figure 122 shows the mine on the south slope and figure 123 shows the flow coming from below the mine where the steep slopes meets the valley floor.

Figure 122

Figure 123

The wetlands in this area are quite lush and productive. From here the stream begins to drop at a much steeper grade. It crosses the road to the Allen Emory mine and drops into a canyon. Figure 124 shows the lush meadows and figure 125 shows the stream as it begins to drop into the canyon.

Figure 124

Figure 125

The stream flows down the canyon and is joined by an eastern tributary. This eastern tributary is draining an area of heavy mineralization and hydrothermal alteration. Water quality is naturally low. At the point this tributary joins the mainstem, there is also a significant spring that adds flow to the stream. Just below this point there is a seep of particularly bad water quality that has killed all the vegetation in the area of the seep. Figure 126 shows the eastern tributary and figure 127 shows the spring. Figure 128 shows the stream just below this confluence and the seep of particularly low water quality.

Figure 126

Figure 127

Figure 128

Just a couple of hundred yards below this confluence, where the Allen Emory mine road comes right to the edge of the stream is an old mine. This mine has a leaking adit, waste rock, and ferricrete deposits on the bank. It is a significant source of bad water to a stream with already low water quality. Figures 129 and 130 show this mine. Figure 131 shows the Warden Gulch sampling site just above its confluence with Peru Creek. This is about a quarter of a mile below the mine. Figure 132 shows the confluence of Warden Gulch flow with Peru Creek.


Figure 129


Figure 130


Figure 131


Figure 132

Grizzly Gulch

Grizzly Gulch drains an area between Independence Mountain and Bear Mountain, with flow basically south to north. The map shows the mainstem splitting into two tributaries, but in August 2007 and 2008, only the tributary shown on the map as the eastern tributary was flowing. Further, the map does not show the flow from the Hunki Dori mine, which was approximately equal in flow to the main tributary in the upper reaches in September, 2007. There was also flow from another small tributary draining a steep area off of Bear Mountain in September, 2007 and August 2008.

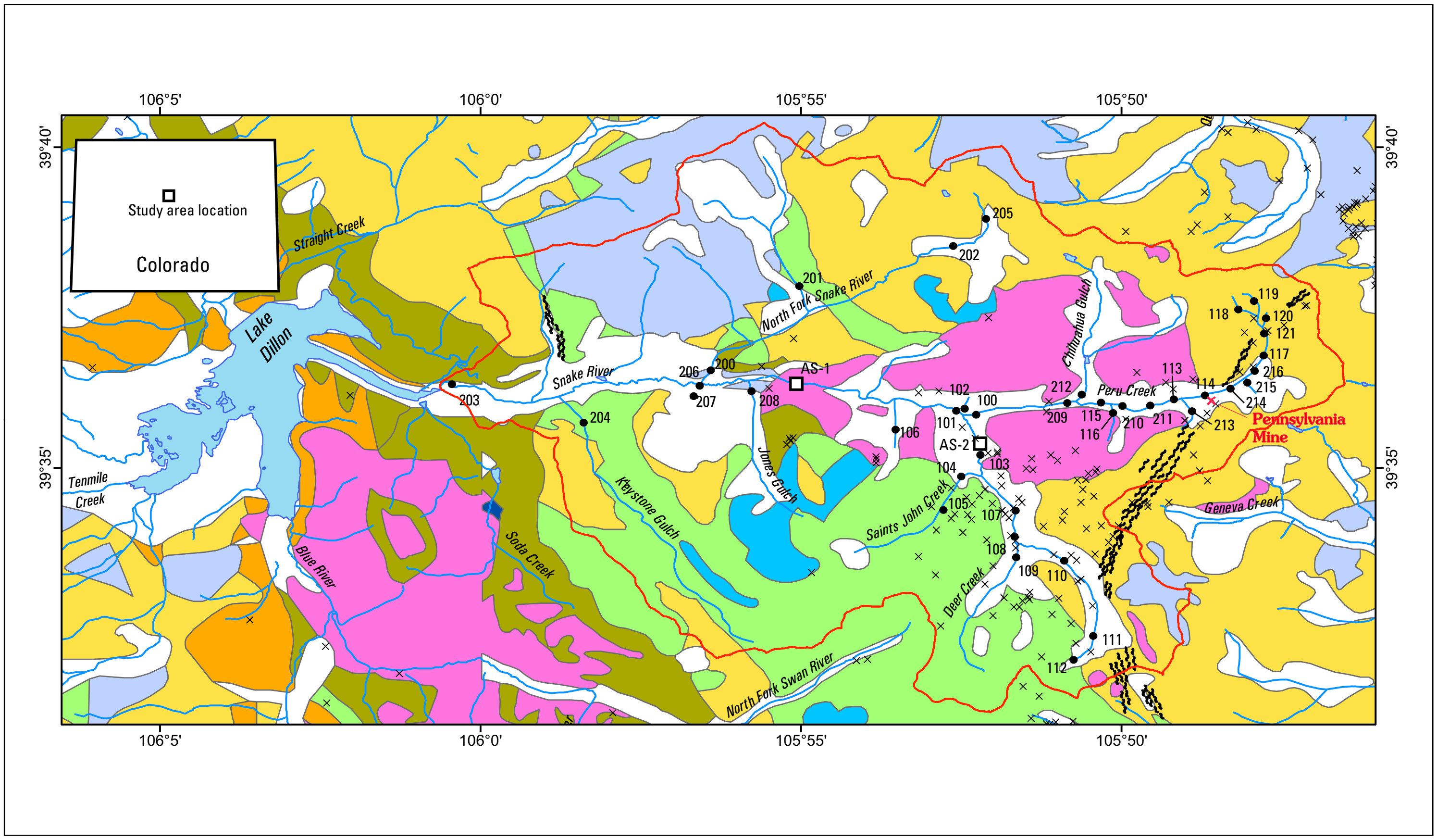
Flow originates from seeps in the area above the highest mining area just above the Hunki Dori mine. The upper mining area was dry in September, 2007. While there was some evidence of flow, it appears that the flow in the area is mainly snow melt. Figure 133 shows the origination of the flow in Grizzly Gulch. Flow picks up as you move down the drainage. In September, 2007 flow became noticeable at about the point on the topo map where the two

Figure 133

Figure 134

tributaries are shown coming together, although only the eastern one was flowing.

Shortly below this point is the Hunki Dori mine. That mine adit is flowing and constitutes a significant tributary in the gulch. Figure 134 shows the flow from the adit. The USGS sampled Grizzly Gulch in October, 2001. The pH was 6.6 and the metal content was generally low. A sample collected in 2008 and analyzed by River Watch confirms the quality is generally acceptable. As the flow proceeds downstream it joins an eastern tributary and then flows down the gulch. The flow from the gulch joins the Snake in the western part of the flat land associated with the Roberts tunnel access portal.



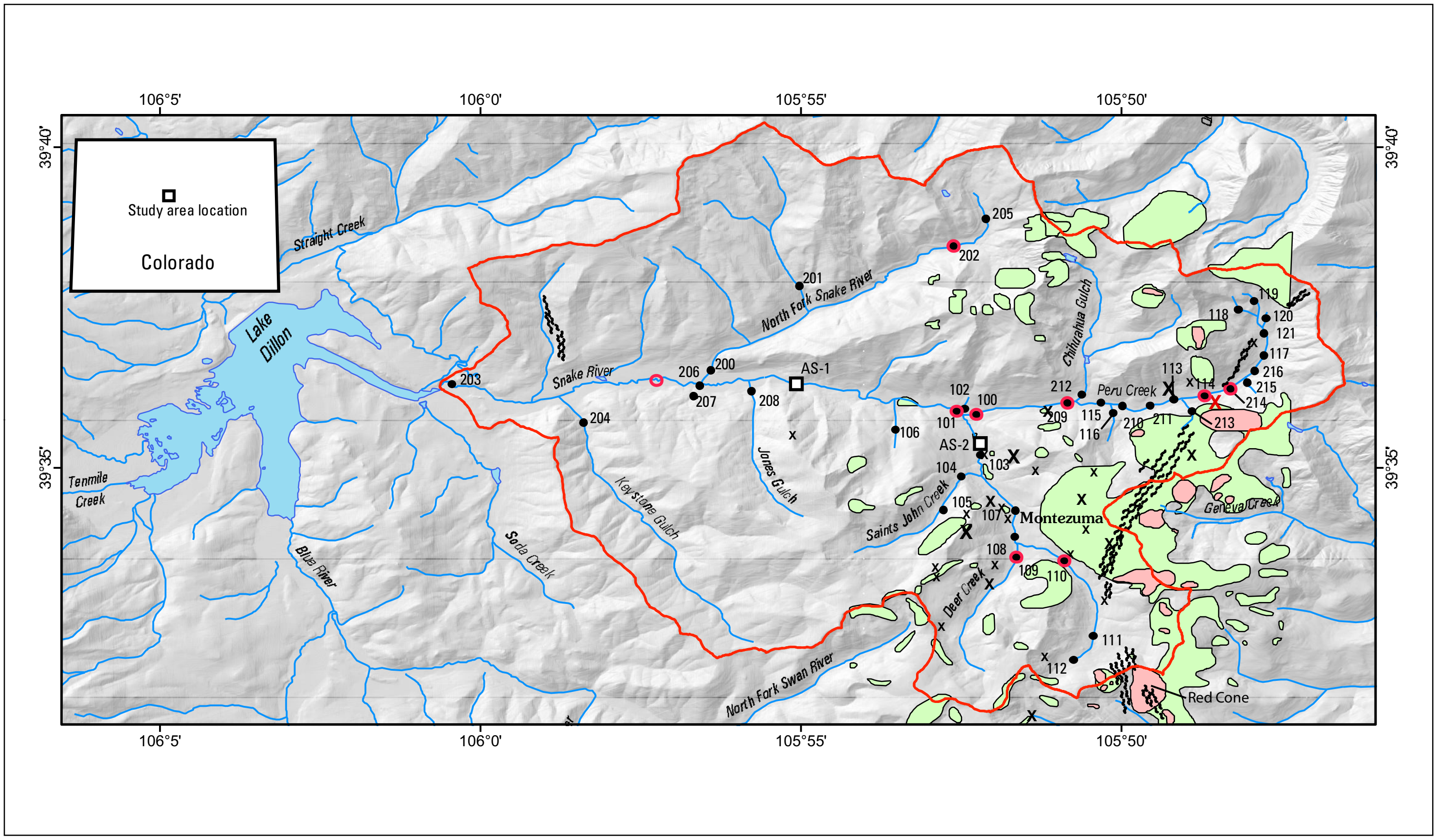
Explanation

Qal	Quaternary Alluvium
TKp	Tertiary - Cretaceous Plutons
Kbs	Cretaceous Marine Black Shale
PTsh	Permian - Tertiary Nonmarine Shale
PTss	Permian - Tertiary Terrigenous Sandstone
Pcp	Precambrian Plutons
Pcms	Precambrian Metasedimentary Rocks
Pcv	Precambrian Mafic Metavolcanic Rocks
Pcm	Precambrian Migmatites

- ● Sample locality, 2001 study
- □ Autosampler locality, 2001 study
- × Mine or prospect
- Shear zone
- Snake River watershed boundary

0 1 2 4 6 8 10 Miles

0 2.5 5 10 Kilometers



Explanation

Mine Production

- x < 500 (in short tons)
- x > 500 - < 5,000
- X > 5,000

- ● Sample locality, 2001 study
- □ Autosampler locality, 2001 study
- ○ Sample locality, 2004 - 2007 study
- Shear zone

0 1 2 4 6 8 10 Miles

0 2.5 5 10 Kilometers

Hydrothermal Alteration

- Propylitic
- Quartz Sericite Pyrite
- Snake River watershed boundary

Snake River Watershed Task Force
May 2013

The Snake River Watershed Task Force includes federal and state agencies, local government, nonprofit organizations, businesses, university faculty, elected officials, and planning commission representatives. Task Force meetings are open to the public. For more information on how to participate, please contact Julie Shapiro (jshapiro@keystone.org).

The following is a list of agencies and organizations that are currently involved in the Task Force's Core Group (the technical working group).

- Blue River Watershed Group
- Colorado Department of Natural Resources, Division of Reclamation Mining & Safety
- Colorado Department of Public Health and Environment
- Keystone Resort
- Northwest Colorado Council of Governments
- Summit County
- Trout Unlimited
- US Environmental Protection Agency
- US Fish and Wildlife Service
- US Forest Service
- US Geological Survey

Appendix D

Past Studies in the Snake River Watershed

There has been considerable study of the Snake River watershed. While most of the work has been done within the Peru Creek tributary, certainly not all of the work has been done there. One of the earliest studies is of the upper Snake River basin and Deer Creek, the upper most tributary. This work was done by P.K. Theobold. He documented the precipitation of aluminum at the confluence of Deer Creek with the Snake River and explained the water quality in both basins based on the geology of the basin. His 1963 paper was titled: The precipitation of aluminum, iron, manganese at the junction of Deer Creek with the Snake River in Summit County, CO.

Another early study was a 1971 cooperative study between the Colorado Water Quality Control Division and the U.S. Geological Survey. That effort was undertaken to determine the extent and magnitude of the effect of mine drainage on Colorado's streams (Wentz, 1974). The Snake River was one of the areas studied. In addition, both the Colorado Division of Wildlife (1974) and Trout Unlimited (1975) have conducted some testing in the area. In 1977, the U. S. Forest Service established a testing schedule for Peru Creek.[1]

In 1978, pursuant to Section 208 of the Clean Water Act, Colorado was doing water quality planning. In February, 1978, the Colorado 208 Water Quality Planning Agency held a non-point source workshop. There was wide agreement among those who attended the workshop that a demonstration project should be developed which would restore beneficial uses to a stream which were lost as a result of mine-related pollution. After some study, it was decided that Peru Creek met all of the criteria for a demonstration site and a vigorous water quality sampling program was initiated in the spring of 1978 on Peru Creek. [2]

The water quality sampling program was quite extensive, beginning in the very upper basin and including most of the major inflows into the creek from both natural sources and mine effluents. "Sampling stations were located to measure changed in stream quality attributable to obvious sources of mine drainage and tributary inflow."[3] Simultaneous collection of water quality samples together with flow measurements allows the calculation of metal loading simply by multiplying the observed concentrations by the flow. Transformation of the water quality data into loading figures allows comparisons to be made among sources and between in-stream sampling stations. The objective of the water quality survey was to determine the significant sources of acidity and heavy metals. Water quality samples and flow measurements were taken from each identified mining operation, which produced water.

The study showed that the Pennsylvania Mine is a major source of heavy metals in the Peru Creek drainage basin. "No other discrete source of mine drainage or tailings erosion in the Peru Creek system impacts water quality as severely as the Pennsylvania Mine complex. In fact, the combined metal loading contributed by all other point sources in the drainage does not add up to that contributed by the Pennsylvania Mine. Natural seepage also plays a major role in

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[1] Holm, J.David, The Restoration of Peru Creek, October, 1979
[2] Ibid
[3] Ibid

maintaining elevated metals levels in the stream. Obviously, there is no practical means of dealing with the natural seepage problem."[4] The abatement options quickly become narrowed to treating various aspects of the Pennsylvania Mine drainage problem.

"The ultimate questions to be answered by this (1979 Holm) study are what instream concentrations would result from removing the loading contributed from the Pennsylvania Mine and can Peru Creek be reinhabited by trout….If 100% of the metals contributed by the Pennsylvania Mine were removed from the system, trout that were bred to be tolerant of heavy metals might well be able to survive in the process."[5] A rehabilitation strategy was proposed for Peru Creek, which focused on abatement of mine drainage problems at the Pennsylvania Mine. The cost of the project would be approximately $166,000. The specific abatement measures would include infiltration controls, drainage diversion, sediment controls and revegetation measures.[6]

There was no apparent implementation of the recommendations from the report.

Keystone Property Owners Association

In 1981 the Keystone Property Owners Association hired James Montgomery to prepare a treatment study of the acid mine drainage from the Pennsylvania Mine. In that study Montgomery stated the "rate of flow from the Pennsylvania Mine measured in 1978 ranged from 170 gallons per minute (gpm) during mid-June to 45 gpm in October. He went on to claim: "Ground water is the source of drainage from the Pennsylvania Mine. An estimated 50 miles of tunnels exist as a result of mining operations. Groundwater flows into these tunnels and discharges at the abandoned mine adit. Drainage from the adit cannot be diverted nor can it be controlled simply by plugging the outlet because of the resultant hydrostatic head." No known followup exists to this report.

Huskie Thesis

The first major treatment project at the Pennsylvania Mine was conducted by a graduate student at the Colorado School of Mines, in cooperation with the Colorado Mined Land Reclamation Division. The student's name was William Huskie and the project was for him one step toward a Master degree. The treatment system was an experimental system built to determine if a natural wetland could be used in a passive treatment strategy without the input of outside power or chemicals. Passive treatment relies on natural geochemical processes for acid neutralization and metals removal. Biologic processes are also responsible for removal and fixation of metals in the wetland. This project was the third passive system constructed in Colorado. It was the first of its kind to use an existing natural wetland as a treatment medium on "high impact" mine drainage (effluents of greater than 100 gpm with total iron and manganese mass loadings of up to 18 and 8 kg/day respectively) from a hardrock metal mine in a high altitude, subalpine environment.[7]

[4] Ibid
[5] Ibid
[6] Ibid
[7] Huskie, William W. "The Pennsylvania Mine Drainage Diversion Study, Thesis, August 26, 1987

Historically the effluent from the collapsed adit had flowed down a steep rocky natural drainage. For this project a four-inch PVC pipeline was installed to convey the acid mine drainage from the collapsed adit to a leachline to distribute the effluent across the natural wetland. Drainage was routed into the pipeline for the first time in August, 1986.

The study for the first time revealed several important characteristics at the mine. The study showed that where a change in flow occurs, there is a corresponding change of pH in the opposite directions. That means that the discharge is worse at high flow rates. This flushing effect suggests that large volumes of water are in contact with the ore body in the mine and that dilution is unlikely. Most metal concentrations were fairly uniform, decreasing slightly from spring to fall. The initial peak in metals concentrations corresponded to the first high flow, or flushing, from the adit in late July. The next high flow event from the adit in late September did not cause an increase in metals concentration. This suggests that the spring flushing of metals may provide the heaviest loadings that any treatment system must accommodate. [8] These insights have proven to be largely correct.

The mine drainage collection and diversion system that was installed for this project worked very well at the collapsed adit of the mine. There were no other visible flows from the mine that could have been collected, though the results of this study indicate that mine water was leaking into the colluvium to surface later in and around the wetland. This too has been confirmed with water quality analysis in the stream. These so-called lateral discharges are a serious problem along Peru Creek.

It turned out that the study did not truly test the treatment capability of a wetland, because the wetland had been receiving mine drainage for decades and had been significantly disturbed by mining activities. What the study did show is the complexity of mechanisms and parameters which should be evaluated to design and understand a wetland passive treatment system. One important conclusion has been fully validated: The dynamic, non-equilibrium nature of mine drainage and wetland processes may mean that empirical studies will be most important in designing passive treatment systems which can be evaluated in detail.[9]

The results of the experiment to divert water from the mine adit to the wetland strongly indicated the need for pretreatment of the mine water (pH adjustment and iron removal) prior to secondary removal of trace elements such as zinc. While the wetland did remove much of the iron, it did not remove other metals. For a wetland to be effective the highly pH-sensitive geochemical removal mechanisms cannot be overloaded by low pH, iron laden waters. The study showed that the removal of iron and aluminum in the wetland overloaded its treatment capability. Pretreatment to remove the iron and aluminum would greatly enhance the effectiveness and longevity of a secondary treatment system such as a zeolite bed or constructed wetland.[10]

Colorado Mine Land Reclamation Division

The wetlands project was followed by the development of a comprehensive "Pennsylvania Mine Drainage Treatment Project" plan conducted by the Colorado Mined Land Reclamation Division. The plan was completed in April, 1989. In preparing this plan, the

[8] Ibid
[9] Ibid
[10] Ibid

CMLRD carefully evaluated the results of the natural wetland treatment plan and a number of other options.

Hydraulic Mine Drainage Treatment Controls

Bulkhead Seal The Pennsylvania Mine is the most extensive operation within the Peru Creek Basin. The mine was operated on six levels (A-F) which are separated by approximately 400 vertical feet. In the past, access into these levels was provided by adits into Level A, Level B, Level C and Level F. These adits have long been collapsed. There is a tremendous amount of colluvial material and rock talus which has covered these historic mine entries. Avalanches affect almost the entire exposed slope of Decatur Mountain each year, further covering the historic Pennsylvania Mine adits with hillslope materials. Placement of bulkhead seals in these collapsed workings is considered a low feasibility mine drainage abatement alternative, which could require refurbishment of at least the Level F and Level C adits for a considerable distance inside the mountain to a point where competent rock and appropriate geohydrologic conditions might be encountered.[11]

Run-on/run-off controls. Primary contamination of Peru Creek is caused by the Pennsylvania Mine drainage. Upland water diversions are proposed to protect the settling pond associated with the passive mine drainage treatment system from additional inflows. A diversion around an existing tailings pile is also proposed. Other run-on controls for mine waste are not considered cost effective.[12]

Mine Waste Removal. Tailings, which have been deposited in the wetland below the Pennsylvania Mine, were to be sealed during the construction of a wetlands for the mine drainage polishing purposes. These tailings which are currently subject to sheet erosion will be relocated to an existing tailing pile which is isolated from surface and ground water systems. That tailings pile is located immediately west of the existing mill building upland from the wetland.[13]

The actual system was a “passive hydropowered” chemical treatment system capable of removing heavy metals to near in stream standard levels. This project was funded on a demonstration basis through the Non-Point Source Program of the Clean Water Act (§ 319). The initial design specified the use of powdered limestone as a neutralizing agent delivered using a hydro-powered (mechanical drive) combination hopper and ribbon blender/chemical feeder. Limestone addition rate was intended to be normally set to be linearly related to mine water flow, however the turbine speed could be adjusted by a nozzle adjustment. The limestone-mine water mixture was designed to run out of the treatment building which housed the turbine and ribbon blender-feeder, through a sluice in the floor, pass down a 75-100 foot long rip-rap channel)to provide mixing and limited aeration), and then enter the settling pond for sludge removal.[14]

The system was constructed in 1990, but only operated for a short time due to chemical inefficiency, mechanical problems and materials of construction failures. The ribbon blender and limestone feeder was selected to also serve as a storage hopper, large enough to allow full winter

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[11] Pennsylvania Mine Drainage Treatment Project, Colorado Mined Land Reclamation Division, April 1989
[12] Ibid
[13] Ibid
[14] Pennsylvania Mine Drainage Phase I, Laboratory, Field Piloting and Acidic Mine Drainage Treatability Study, BIT 1994

operation without refilling. It held approximately six tons of powdered limestone. Upon initial filling the available power and gearing was insufficient to operate the internal ribbon blender. The limestone in the hopper could not be moved and the feeder would therefore not operate. The limestone was manually removed until the hopper was only approximately 25%-30% full, at which point the unit began to operate. Limestone was fed for a short time, but was found to be ineffective in significantly raising the pH, except at very high use rates. After being installed for less than one year, the water turbine was effectively destroyed by electrochemical acid attack and possible cavitation problems. The housing and pelton wheel and other metal parts were entirely corroded, the unit unsalvagable. The entire unit was constructed of either carbon steel with an epoxy coating or a specialty alloy selected by the manufacturer. The only surviving parts were two stainless steel pieces, believed to be Type 316L. They were the nozzle needle and a bushing. Later study showed that the storage and dosing systems were significantly undersized for limestone.[15]

Diane McKnight

In 1984 Diane McKnight and Kenneth Bencala did in Peru Creek, looking specifically at the chemistry of Iron, Aluminum and Dissolved Organic Material to better understand how watershed and in-stream processes affected these variables. The study focused on the upper reaches of Peru Creek and the area around the Pennsylvania Mine. The stream sampling station furthest downstream was above Warden Gulch, somewhat less that one mile below the Pennsylvania Mine discharge into Peru Creek. Their data confirmed the earlier work that abandoned mines are the principal sources of trace metals in Peru Creek. Their data also showed that pH dropped and concentrations of Fe, Al, Zn, and Mn increased below the Pennsylvania Mine effluent entrance into Peru Creek. The study also confirmed the differences between "conservative" and "reactive" solutes. The pH of Peru Creek is generally high enough that aluminum and iron precipitate out, while it remains low enough that metals such as zinc remain in solution and are transported significantly further downstream before precipitating out or diluted to levels with less concern. [16] Dr. McKnight has continued research in the Snake River basin publishing numerous reports on instream chemical processes. Her graduate students have conducted significant studies throughout the basin.

Boulder Innovative Technologies

The next major project at the Pennsylvania Mine was conducted by Boulder Innovative Technologies. It was a water quality baseline and design basis lab and field piloting program. The program began in March, 1993 and ran through early 1994. The overall program envisioned two subsequent phases. Phase II was to be a design and construction of the revised full-scale chemical pre-treatment and a polishing biological system. Phase III was to be the operational demonstration of the installed revised system.

The following description of the study was taken form the Executive Summary. During calendar years 1993 and 1994 a detailed investigation was conducted to fully characterize the chemistry and metal loading from this drainage and to conduct a comprehensive series of laboratory and field piloting treatability studies.

A very comprehensive water quality sampling, flow sampling and data interpretation of the Pennsylvania Mine drainage was conducted. Year round data collection provided a very good

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[15] Ibid
[16] Diane M. McKnight and Kenneth E. Bencala, USGS (December, 1990)

understanding of the seasonal variation in both flow and chemistry from the drainage. It was learned that the drainage is very responsive to the snowmelt, with both high flows (over 150 gpm) and the most degraded water quality occurring during June and July. Annual metal loadings are the highest during this period. Flows in the fall and winter diminish to 20-40 gpm or less. This major swing in seasonal loading has significant impact on the design and selection of treatment approaches and on forecasting of treatment costs.

Laboratory work during the late winter and spring of 1993 was conducted using samples of mine water. A series of screening chemical neutralization tests were conducted to define dose requirement to chemically precipitate the toxic metals from the acidic water. Characterization of the produced chemical sludge from these tests was also performed. Using both raw mine water and partially chemically neutralized mine water, a series of ion exchange polishing tests were performed using natural zeolites and Chabcarb, as combination natural zeolite-activated carbon ion exchanger.

Based on the laboratory screening studies, a field pilot treatability study was designed and equipment was procured, fabricated and installed at the mine site during June, 1993. The pilot operation consisted of a field camp, field laboratory and pilot plant sized for approximately 1 gpm flows. The field piloting program consisted of a series of chemical dosing and sludge characterization studies with selected neutralizing agents. Agents tested included lime, limestone, trona, calcined trona, soda ash, magnesium oxide, calcium polysulfides and Trapzene a proprietary calcium peroxide chemical. Several pieces of equipment were also tested for operational characteristics including the water powered Aquafix dry chemical feeder, and an Accurate volumetric dry chemical feeder.

A set of ion exchange experiments with the natural zeolite, clinoptilolite and Chabcarb was conducted using mine water which had been partially treated with various chemical neutralizers. The ion exchange tests were conducted in 1.5" diameter columns, with a single test conducted in 8" diameter columns.

Engineering interpretations of the data derived from the laboratory and field piloting resulted in recommendation for a treatment system to minimize the consumption of neutralizing chemicals and the resultant sludge. The recommended chemical for partial neutralization for this site was determined to be reactive grade magnesium oxide (MgO). While more expensive, MgO was found to produce a rapid settling dense sludge with only 25% settled volume compared to more traditionally used chemicals such as lime and limestone. This was determined to be a major factor in the secondary costs of sludge disposal and on constraints on the sludge settling pond.

Ultimately, the treatment system which was recommended for Pennsylvania Mine as a result of this study and a follow up conceptual sludge disposal feasibility study involves a partial neutralization with reactive grade magnesium oxide, settling of the sludges in a settling pond, followed by final treatment in sulfate reducing bacteria (SRB) beds. The partial chemical neutralization is projected to extend the operating life of the SRB system and improve its performance by a reduction in the influent loading of iron and aluminum, plus providing an influent with a pH more suitable for the optimal performance of the sulfate reducing bacteria. The selected chemical sludge disposal system for such a combined treatment system is pumping to bulkheaded portions of the underground workings of the Pennsylvania Mine.[17]

[17] Ibid

At the conclusion of this study, work commenced on the construction of the wetlands associated with the pre-treatment. A major project was established with Volunteers for Outdoor Colorado for the weekend of August 6-7, 1994. Meanwhile, on December 22, 1993 the EPA sent a letter to the state of Montana, which outlined the EPA policy on discharges from abandoned mines. Notwithstanding the fact that the Pennsylvania Mine discharge was dumping metal laced water into Peru Creek with no interest from EPA, this letter was interpreted to mean that if the state of Colorado began to treat the mine discharge, they would need to obtain an NPDES permit and could be responsible for the treatment of the waste stream in perpetuity. As a result of this potential liability, work on the treatment system was stopped.

In 1997 the Colorado Division of Minerals and Geology again moved ahead with actual design of a treatment system for the Pennsylvania Mine. A contractor was hired to do a final design of a treatment plant. In September, 1998 final design drawings and specifications for a treatment system were delivered to the DMG. The 1997 revised work plan included investigation of suitable areas at the Pennsylvania Mine project site for demonstration of a paste-backfill sludge disposal alternative. This new technology has been successfully used in Canada to safely and economically dispose of tailings material at abandoned mines. During summer 1997, an underground assessment of the accessible working of the nearby Shoe Basin mine was conducted. This mine is located on property owned by the Pennsylvania Mine owner, and is accessible via a locked portal closure. Underground work delineated potential paste disposal alternatives within these workings. The conditions were less than ideal, mostly because of limited storage capability within the workings, but this site was identified as a potential disposal alternative. A drilling project to investigate underground storage potential of the Pennsylvania Mine itself was developed for execution in 1998.[18]

Following additional study by state and EPA personnel, a demonstration project for sludge disposal was proposed. Both subsurface injection and "land-filling" scenarios were to be investigated. Plans were developed to:

A. Perform underground geotechnical assessment of the two potential on-site sludge disposal alternatives through drilling, and underground mapping. (August 1998)
B. Perform dye tracer tests of stopes and Pennsylvania Mine workings to assess groundwater systems and suitability of workings for injected amended sludge disposal (Sept-Oct. 1998)

These plans were put on hold in early summer 1998 due to lack of progress on the liability issue. With no resolution in sight for the liability issues, DMG closed out the Pennsylvania Mine project in their files on November 16, 1998.

Sullivan and Drever

Synoptic water sampling was performed in 1996 and 1997 at Peru Creek to investigate spatial and temporal variability in stream chemistry (Sullivan and Drever 2001). Over this two year study, significant changes in all measured solute concentrations were observed due to tributary inflow. The study documented summer increases in dissolved concentrations of metals by factors of 2 to 12 with decreasing flow and reduced dilution by snowmelt. These authors

[18] Closeout Report, Pensylvania Mine NPS project, November, 1998

reported that dissolved metal concentrations in Peru Creek increase by a factor of 10 immediately at and below the inflow from the Pennsylvania mine.

Laura Belanger

In 2000, a University of Colorado student, Laura Belanger, did a significant study of Peru Creek. Her study confirmed that much of the problem in Peru Creek is from so-called lateral flows or ground water seeping into the stream as opposed to discharged from old mine adits or from natural runoff in stream channels. "Precipitation in August, when lateral inflows were more prevalent was greater than in any other month. This data suggests that lateral inflows fluctuate in importance throughout the year at this confluence and other locations in the basin. The Snake River synoptic study captured a late season pulse of lateral discharge resulting from a month of above average precipitation. "[19]

"Lateral inflows are also of great interest in the vicinity of the Pennsylvania Mine in Peru Creek. In August, mine drainage discharge was only slightly greater than calculated lateral inflows between sites PR1 and PR2 with additional lateral inflows calculated downstream. A visible inspection of the Pennsylvania Mine and Cinnamon Gulch region provides evidence of the extent of lateral inflows with visible seeps along much of the reach." [20] She therefore concluded that a large percentage of metals from the Pennsylvania Mine enter the stream laterally.

US Forest Service

In the summer of 1999 the US Forest Service asked Erik Munroe to examine the old mines of the upper Snake River watershed and try to document the sources of metal contamination and help select those sources where passive treatment options might exist. His 1999 report identified 38 mine sites that had leaking adits. Nearly half of these leaking adits had water flowing across waste rock. An additional 45 sites had storm water runoff issues. Many sites offered the possibility adit effluent and storm run-on diversion away from waste rock piles.

Colorado Geological Survey

CGS revisited selected sites in the Peru Creek drainage both in July and October of 2001 in an attempt to document changes in discharge and water quality during high and low flow regimes. A total of 39 water samples were collected during this study (19 high-flow samples in July, and 20 low-flow samples in October), including some in stream samples collected to bracket selected mines or groups of mines. These samples were all collected from within Cinnamon Gulch and from Peru Creek both above and below the Cinnamon Gulch outflow. No new samples were collected from the Pennsylvania mine as extensive pre-existing data from CDMG were available and utilized (Wood et al. 2005).

Direct measurements of surface water discharge from Cinnamon Gulch into Peru Creek are complicated by numerous alluvial fan distributaries at the mouth of this reach. For this study discharge was thus calculated indirectly by measurement in Peru Creek both immediately above and below the confluence of the various outputs from Cinnamon Gulch. Total discharge estimated in this manor for Cinnamon Gulch ranged between 460 gallons per minute (gpm) at low flow to 1,920 gpm at high flow. In Cinnamon Gulch itself this study recorded only 8.4 gpm

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[19] Belanger (2002)
[20] Ibid

discharge of surface water during low flow from discrete anthropogenic sources (9 mine adits), and 3 gpm discharge of surface water during low flow from identified natural sources (seeps & springs). This suggests that the overwhelming majority (97% to 98%) of total discharge from Cinnamon Gulch into Peru Creek is gained from ground water inflow (Wood et al. 2005). Discharge from the Pennsylvania mine ranged from 148 gpm at 162 gpm when measured by the CDMG in June and July of 1978 (Holm et al. 1978). This was presumably a high flow event.

Throughout the Cinnamon Gulch watershed, pHs ranged from a low of 2.91 to a high of 5.42, and 18 of 33 samples had a pH below 4. Due to the combined inflows from Cinnamon Gulch, Peru Creek was observed to suffer a decrease in pH and an increase in dissolved concentrations of Al, Cu, F, Fe, Mg, Mn, Si, Na, SO_4, and Zn at both high and low flow regimes. At many sample sites there were generally higher concentrations of most ions at low flow than at high flow, reflecting the expected dilution from runoff at high flow. A few sites displayed the opposite (higher concentrations during higher flow), possibly reflective of dampened recharge in the unsaturated zone. As with discharge, total metal loading from Cinnamon Gulch was also determined by subtracting values of samples from above and below the inflow zone into Peru Creek, both at low and high flow. Cinnamon Gulch gains close to 400 gpm discharge during low flow in its lower portion that is not attributable to anthropogenic sources, suggesting that this reach is a groundwater discharge zone affected by hydrothermally altered bedrock. Metal loading calculations for both anthropogenic and natural sources indicate that discrete sources throughout Cinnamon Gulch account for only about 4% of total metal loading at base flow and 5-8% of total metal loading at high flow (Bird 2003). The small percentage of groundwater capture by the abandoned surface mine workings in Cinnamon Gulch presents numerous remediation challenges (Wood et al. 2005). It should be noted that the time frame of this study was during the initial part of a significant drought period and flows were lower than during other years.

U.S. Geological Survey

On October 9-12, 2001 the U.S. Geological Survey did a "Water and Sediment Study of the Snake River Watershed, Colorado." While this study looked at a number of metals, the results for zinc are particularly useful. "Peru Creek from Cinnamon Gulch downstream to the confluence with the upper Snake River exceeds the acute toxicity threshold for all trout species".[21] The report went on to state: "Peru Creek is affected by all the listed elements for all three species except lead where only the chronic toxicity threshold for dissolved lead is exceeded for Rainbow Trout."[22]

"Whereas concentration maps identify reaches with elevated water concentrations, load calculations provide a way to compare contribution from different sources in the watershed. Tributaries with high concentrations of metals may or may not have a major effect on the concentration of a trace element in the main stream. For example, the metal concentrations measured in Cinnamon Gulch were the highest in the study, and exceed toxicity standards by many times, but the discharge is only 0.0014 m^3/s, and so the load from Cinnamon Gulch cannot be significant enough to influence concentrations in Peru Creek in a major way (the discharge of Peru Creek near here was 0.121 m^3/s). The concentration of zinc and copper in Peru Creek rise dramatically between sites 114 and 113, as do the loads. Between sites 114 and 113, the zinc

[21] Fey et al (2002)
[22] Ibid

load in Peru Creek increases from 0.9 kg/day to over 18 kg/day and the copper load increases from 0.01 to 2.32 kg/day. The loads from Cinnamon Gulch are so small (0.23 and 0.03 kg/day respectively) that another source must be responsible for these increased metal loads. This is most likely drainage coming from the Pennsylvania mine area."[23]

Samantha Tokash

In 2001, CSM student Samantha Tokash studied procedures for evaluating natural background conditions, after mining has occurred, by investigating the Upper Snake River and Deer Creek. She found that "surface water samples from river reaches impacted by historical mining activities,as well as reaches with no observed upgradient mining activities, contain elevatedconcentrations of dissolved sulfate (up to 400 mg/l), Al (up to 25 mg/l), Mn (up to 9.8mg/l), and Fe (up to 36 mg/l). In many cases, the highest concentrations of these elements are found in reaches that are not associated with mining activities. Acidic waters (pH 3.5 to 5) in the upper Snake River of Summit County, Colorado result from interaction of ground water with disseminated pyrite in metamorphic rocks and alteration zones surrounding small rhylolitic to granitic intrusions. The Montezuma shear zone transects the area and may provide a conduit through which surface and ground waterflows, oxidizing subsurface disseminated pyrite and creating acidic water and ferricrete.

Sabre Duran

In late 2001 and through much of 2002 (11/01 – 9/02) Sabre Duren, another University of Colorado student, again studied Peru Creek. This time the research included a tracer study to attempt to better quantify metal loading sources. In this study, once again, "All of the other dissolved metal (with the exception of Pb) and sulfate loading curves appeared similar. The profiles exhibited a continual increase in instream loading along the upper 3600 m, and then reached a plateau after the confluence with Chihuahua Gulch."[24]

This study showed that the area around Warden Gulch was the major contributor to the metals loading of Peru Creek. However, it also identified the area around the Pennsylvania Mine and the area around Cinnamon Gulch as very important. Moreover, this study was undertaken in a very dry year and that most likely influenced the results. "Within the context of this study's findings, it is important to note that 2002 was not a regular hydrologic year; it was the year of the largest drought in over 100 years. With this the case, it is possible that under normal hydrologic conditions another area along Peru Creek may be a more important source of ARD. For example, maybe with more snow melt and overland flow occurring within the basin Pennsylvania Mine would contribute the majority of the metal loading to Peru Creek. If this were the situation, remediating Pennsylvania Mine would pose an ideal solution to improving the water quality of Peru Creek since it is a discrete source."[25]

A look at the water quality data from the Duren study compared to the data collected at other times reinforces this conclusion. The water quality normally is worse in the spring flush. The Duren study showed its worst water quality in a September sample. Further, the water quality from the Pennsylvania Mine during the spring and summer in 2002 was considerable

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[23] Ibid
[24] Duren (2004)
[25] Ibid

better than that measured at other times. For example, the 2002 measurements for Fe were in the range of 18-23 mg/l. The 1993 data showed spring time Fe concentrations of up to 114 mg/l. Similarly for Zn, the 2002 data ranged from 14-27 mg/l while the 1993 data showed levels as high as 59 mg/l. The hydrological conditions of 2002 were fundamentally different from a normal year due to the lack of moisture that year.

Andrew Todd

University of Colorado PhD student Andrew Todd also did work in the Snake River watershed in 2001-2002. In his thesis he looked at three issues. First he examined the problems acid rock drainage poses for western recreational economies. He then evaluated the spatial and temporal dynamics of water chemistry in the watershed noting the impacts were both natural and anthropogenic. His work showed snow-melt driven dilution to be the dominant driver of seasonal variation in stream metal chemistry. He also noted reactive metals like aluminum and iron precipitated at multiple confluences while less reactive metals like zinc were transported throughout the watershed. He also conducted in-situ caged rainbow trout toxicity tests and showed trout mortality was positively correlated with metals concentrations approaching or exceeding known toxicity levels. Overall the thesis showed how important ARD was in western communities.

URS/EPA Site Assessment

A Phase I site assessment performed by URS Operating Services consisted of a number of synoptic sampling events spanning Peru Creek from its upper basin (Shoe Basin) to its confluence with the Snake River. The initial sampling event occurred on September 24-25, 2001 and was originally designed to establish a baseline prior to the removal of water from the North Fork Snake River for snowmaking at Arapahoe Basin ski area. Calculated low flow daily loading rates at the mouth of Peru Creek were about 119 ppd Al, 0.3 ppd Cd, 5.3 ppd Cu, 15 ppd Fe, 0.5 ppd Pb, 59 ppd Mn, 0.5 ppd Ni, and 70.6 ppd Zn. This study also concluded that the majority of metal loading to Peru Creek occurs in the middle reach in the area of the Pennsylvania mine, Cinnamon Gulch, and from seeps along the creek downstream, including Warden Gulch. As in the CGS study, this first sampling event recognized a large contribution from non discrete sources in the Cinnamon Gulch area to total metal loading in Peru Creek. The study also determined that although there is some degradation in upper Shoe Basin, winter season flows are so small that impact on Peru Creek is minimal to non-existent.

Phase II synoptic sampling was conducted on May 21, 2002 and was designed to capture a snapshot of high flow conditions. Discharge in Peru Creek at its confluence with Snake River was double the winter flow, however; both the 2001 and 2002 sampling were conducted during the longest duration drought period in central Colorado in 100 years. Results confirm the initial findings that the majority of metal loading occurs in the Pennsylvania mine/Cinnamon Gulch area and that Peru Creek above this area is only slightly impacted. Metal loading for most constituents at the confluence of Peru Creek with the Snake River was significantly reduced during the high flow sampling event, except for Fe and Pb. This study also removes Chihuahua and Thurman Gulches from suspicion of environmental degradation. Indeed, water quality in Peru Creek consistently improves at and below the mouth of Chihuahua Gulch.

Summit County Open Space and Trails Department

In 2002, the Summit County Open Space and Trails Department contracted with American Geological Services to conduct an Environmental Assessment of the Peru Creek watershed. This study used an environmental-risk-based ranking system to distinguish the level of contamination at the various properties in the watershed. The ranking was from 1 to 5 and ranged from properties that were relatively free of contamination to those that have contaminated water discharges. In 2006, Summit County Government used this assessment and completed the remediation of the Shoe Basin Mine in upper Peru Creek. Due to liability issues associated with the Clean Water Act, the leaking adit was not addressed in the cleanup.

University of Colorado

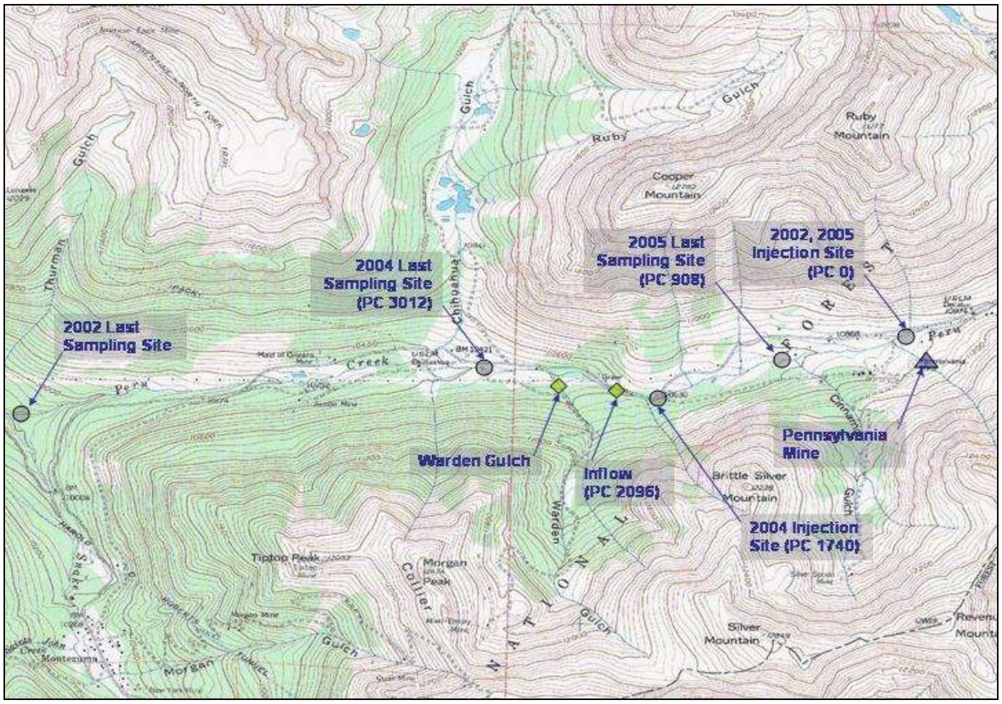
In the fall of 2003, an interdisciplinary team of students in a design class decided to study the Pennsylvania Mine. In essence they did an engineering feasibility study of what should be done at the mine to mitigate the mines impact to Peru Creek. The study concluded that a water treatment system consisting of a successive alkalinity producing system (SAPS), a settling pond, an anaerobic wetland, a manganese removal bed and a permeable reactive barrier (PRB) for the lateral inflows from the tailings area was best. While an SAPS system is not appropriate for situations like the Pennsylvania Mine due to the high iron and aluminum content, their overall concept was very similar to that designed by the state in the 1990's. That is, pretreatment of the iron and aluminum followed by an anaerobic wetland. The manganese bed and PRB were in addition to the state plan, but addressing serious issues. Overall, the students report was a credible response to the problems of the Pennsylvania Mine area.

Northwest Council of Governments/ Summit QQ Committee

Lane Wyatt, who has been the leader in coordinating activities in the Snake River basin since at least 2000, has led two 319 grants in the basin. The first grant summarized the existing water quality data in the basin and helped to pinpoint problem areas. The result was the widely used "Water Quality Assessment, Snake River Watershed, Summit County, Colorado" released September 21, 2004. The second study was designed to help with the process of developing TMDL standards for the basin. That study provided significant information and methodology to determine the impact of cleaning up the Pennsylvania Mine on water quality in the Snake River. A detailed model was developed which could forecast water quality in the lower Snake River based on projected metal removal from the Pennsylvania Mine. The report included a comprehensive feasibility study of removal options for the mine. The recommended design was developed by Dr. Linda Figueroa of the Colorado School of Mines.

University of Colorado

Since the Duren work, two additional tracer studies have been conducted by University of Colorado students. On July 10, 2004 Brendan Cusick conducted a three-hour tracer study in the Warden Gulch area. Flow rates in the stream were considerably higher than during the 2002 study. This tracer study identified several lateral inflows that were significant sources of contamination in the Warden Gulch area. The second study was conducted in the Pennsylvania Mine area. On July 31, 2005, Jeff Wong conducted a two-hour tracer experiment along the upper reaches of Peru Creek, adjacent to the Pennsylvania Mine. His injection site was the same site at the 2002 study. His last sampling site was located immediately downstream of Cinnamon Gulch. Flow rates during this study were again much higher than during the Duren 2002 study. The following map from a special report written by Jeff Wong for this feasibility study shows the injection areas from the tracer studies. [33]



The 2005 study did show significant differences from the low flow study of 2002. "Metal loading calculation for 2005 data show that the discrete tributaries from the Pennsylvania Mine was the chief contributor of mass loads for dissolved Cd, Cu, Fe, Mn, and Zn during a higher flow year in the first kilometer of the study reach"[26] The 2005 study goes on to state: "Loading data shows that Cinnamon Gulch is the major source of Pb contributions in the upper stretch of Peru Creek, regardless of flow conditions….Discrete tributaries in the upper reach of Peru Creek may have a larger influence on water chemistry during a higher flows year, when compared to a drought year"[27]

The Wong 2005 study was more consistent with past research and was for a more representative water year. What his report clearly shows is the discrete flows of the Pennsylvania Mine, Cinnamon Gulch and Warden Gulch are very important to the metals loading of Peru Creek. These flows are all influenced by mine drainage and mean that the discrete mine drainages need to be treated. His report also concludes, as have many studies in the area: "However, subsequent data from more representative hydrologic conditions show that the Pennsylvania Mine should remain a focus of remediation in Peru Creek"[28]

[26] Wong (2006)
[27] Wong (2006)
[28] Wong (2006)

Onging Work

Additional work has been conducted in 2007 and is underway in 2008. Most significantly, better effluent monitoring has been put in place at the Pennsylvania Mine adit discharge. This monitoring has shown that flow from the mine can be at much higher levels than had been measured or observed in the past. Further, there have been unusual fluctuations of flow levels during 24 hour periods and associated with precipitation events that have suggested that something is going on in the mine that makes it different that a typical leaking adit. Groundwater pools do not normally exhibit such behavior. An attempt will be made in 2008 to enter the C level of the Pennsylvania mine. This is the highest level and may be in contact with the surface somewhere and/or may be providing water to the lower levels of the mine. In 2009, an attempt is being planned to enter the F level, the level that the adit flow is from, to see if a better understanding of the flow sources can be found and to see if flow control may be possible. There is also concern that there may be significant ground water flow from the adit just below the surface. Efforts are underway to test for this as well. In addition, work is underway in 2008 to better understand water flow in the wetlands below the mine and mill area to see if this known source of contamination can in some way be controlled.

TMDL Analysis

In August, 2008 the Colorado Department of Public Health and Environment, Water Quality Control Division released a Total Maximum Daily Load Analysis of the Snake River and Peru Creek. Prepared by Rebecca Anthony, this report provides help and insight in two key areas. First, it is one of the best summaries of the water quality data as of its publication. Second, it shows that cleaning up the Snake River and Peru Creek to meet current water quality standards will not be possible. For water bodies and streams on the 303(d) list, a Total Maximum Daily Load (TMDL) is used to determine the maximum amount of a pollutant that a water body may receive and still maintain water quality standards. The amount of certain metal, like zinc that must be removed is frequently over 90%. The projects available are unable to remove that much of the zinc in the watershed.

UAA Report

Because of the how difficult it will be to clean up all of the Snake River basin to meet water quality standards, a draft Use Attainability Analysis has been prepared to help determine what water quality standards might be achievable. The model developed to do this analysis has been modified for use in the Snake River Watershed Plan. After the completion of the plan it should be possible to finalize this analysis and propose new water quality standards. The UAA report explains this issue: “This use-attainability analysis (“UAA”) is an assessment of the factors that influence water quality and aquatic life in Peru Creek and the Snake River below the confluence with Peru Creek (“study area”). It is primarily intended to assess whether a water-quality condition protective of aquatic life community is attainable, and to justify the recommendation of site-specific water-quality standards. A UAA is one method that can be used to support the adoption of site-specific standards that differ from existing table value standards. §31.7(1)(b)(iii).

Practically, a UAA addresses the following questions: (1) What are the stressors limiting the aquatic life use; (2) Is control of those stressors feasible; and, if so, (3) What is the resultant expected condition? This UAA responds to these questions and provides a recommendation to the CDPHE’s Water Quality Control Commission.” This draft analysis was prepared by Lane Wyatt of NWCOG and Summit Water Quality Committee with assistance from Dr. T.D. Steele.

U. S. Geological Survey

Andrew Todd and a number of other researchers in the Snake River published a paper entitled Climate-Change-Driven Deterioration of Water Quality in a Mineralized Watershed. This was the result of taking a hard look at the data that has been collected along the main stem of the Snake River over a number of years and trying to understand why some of the metals were increasing over time. There are not land disturbances in the watershed during the time of the data collection, about a thirty year period. The paper postulates that climate change might be the underlying cause of the metals increases. Clearly temperatures in the area have increased. "Consideration of potential specific causal mechanisms driven by rising temperatures suggests that melting of permafrost and falling water tables (from decreased recharge) are probable explanations for the increasing concentrations. The prospect of future widespread increases in dissolved solutes from mineralized watersheds is concerning given likely negative impacts on downstream ecosystems and water resources, and complications created for the establishment of attainable remediation objectives at mine sites. " The last point, that the apparent increase in metals concentrations naturally makes predictions of the impact of cleanup activities much more difficult.

Robert Runkel and a team of USGS personnel conducted a replicate synoptic sampling of Peru Creek in the summer of 2009. This study added to the overall knowledge of how best to create a program to document which source of several is causing a particular problem. While this was a one time (actually two with the replicate sampling) event, it provides perhaps the clearest example of how important the Pennsylvania Mine is to the effort to clean up Peru Creek. This study showed that the Pennsylvania Mine, the wetlands below the old mill that are where most of the old tailings reside and Cinnamon Gulch contribute 14%, 27% and 46% of the flow in Peru Creek at that point in the Creek. Further, the study showed that the metals loading in the creek is largely from the Pennsylvania Mine. While the mine is 14% of the flow, in provides more than 50% of the As, U, Fe, Co, Cu, Mn, Zn, and Cd. Using zinc as an example the study showed that 55% of the zinc in the stream was from the mine, 25% from the mines wetland and less than 20% was from Cinnamon Gulch. On the other hand, the study showed that Cinnamon Gulch was responsible for over 60% of the lead. Since this study was done before Cinnamon Gulch was channelized to stop a portion of the creek from flowing across the tailings area of the Brittle Silver Mine, there may be a dramatic decrease in lead concentrations in Peru Creek.

While this study addressed better than previous studies the specific contribution of the wetlands associated with the old mill tailings, it did not solve the issue of where the water in the wetlands was coming from and if flow could be reduced in some way. Some of the flow in the area might come from the mine, some from Cinnamon Gulch and some just from the normal flow of ground water from the adjacent mountain.

Northwest Council of Governments

NWCCOG was the lead in the 319 grant that did the work in Cinnamon Gulch. A part of the work was further water quality analysis by Dr. Tim Steele. This work involved a detailed data assessment for selected monitoring sites in a mining-and mineralized-impacted region of the Snake River watershed in Colorado. The assessment's objectives are (1) to characterize streamflow and trace-metals conditions at six key monitoring sites involving the Peru Creek subwatershed and (2) to use this characterization as a basis for evaluating potential benefits of future mining-related remediation projects. The specific focus of this assessment for remedial actions involves the Pennsylvania Mine adit discharge and BMPs installed in Cinnamon Gulch as part of a 319 grant. Cinnamon Gulch is a tributary of Peru Creek draining a mineralized area and old mine workings adjacent to the Pennsylvania Mine. The "tool" for assessing load-reduction impacts entails a simple spreadsheet "model" that has the capability of tracking impacts locally and downstream as well as over a period of several years to give the seasonal and year-to-year variations in streamflows and associated trace-metals' concentrations and loads. The spreadsheet model has the advantage of describing conditions and impacts on a site-by-site basis. The limitation is that the complex physical, chemical, and biological processes affecting trace metals in water are not captured by this tool. The application is two-fold: (1) to estimate load reductions and downstream water-quality improvement from the proposed projects, and (2) to evaluate through continued post-project monitoring the extent to which estimated water quality improvements and targets are being met.

Reductions in metal concentrations for Zn, Cd, Pb and Cu from potential treatment in Cinnamon Gulch and for the Pennsylvania Mine were postulated and the resulting concentrations were calculated for SW-50, a site just below the confluence of Peru Creek and the Snake River. While this model does not account for instream changes in concentration, it can be used to estimate potential concentrations at different sites.

Environmental Protection Agency

In 2012, Ryan Dunham of Region 8 developed a technical memorandum which used mass balance methods similar to those used by Dr. Steele above to illustrate the magnitude of the Pennsylvania Mine metals source and to provide a rough estimate of changes in downstream water quality that could occur if metal loads were reduced.

Memorandum

To: Lane Wyatt

From: William A. Walsh, Ph.D.

Date: 10/20/2015

Re: Snake River Visual Evaluation

In September 2006, a visual evaluation or semi-qualitative aquatic habitat survey was conducted on the Snake River, Colorado. This type of visual evaluation can provide a general picture of stream physical quality; however, a more comprehensive evaluation would need to be conducted to quantify physical habitat limitations.

The survey started at the confluence of the North Fork and Snake River and continued upstream to the confluence with Deer Creek. In addition, a survey was also conducted from the confluence of the Snake River and Peru Creek, upstream to the Pennsylvania Mine Site.

The overall objective of this survey was to determine if any broad scale physical habitat condition was present on the Snake River that would result in a limiting factor to a trout population. Due to the high levels of heavy metals occurring in both the Snake River and Peru Creek, water quality was not included as part of the physical habitat. Therefore, we assumed that if water quality was significantly improved in both systems was there any potential problems with physical habitat that would then exclude a potential trout population.

Typically, stream physical habitat structure includes all those structural attributes that influence or sustain organisms within the stream. Habitat assessments generally provide a critical understanding of a stream's ecology. Some common physical habitat attributes are stream size, channel gradient, channel substrate size and type, habitat complexity and cover, and riparian vegetation cover and structure.

In general basic physical habitat variables will translate into biological diversity in stream communities. In specific terms of trout, the physical components of in-stream trout habitat typically includes pools, riffles, and cover in the form of aquatic vegetation, woody debris, undercut bank, and overhanging vegetation, in addition variables such as water quality, temperature, and stream discharge will effect the abundance and distribution of a trout population.

The Snake River at the North Fork confluence (Figure 1) provides quality riffle habitat for both trout and macroinvertebrates. Trout will utilize these types of habitat for spawning, egg incubation, and initial fry rearing locations. Critical to any trout population is food available; typically, this type of riffle habitat (Figure 1) would be an ideal location for the production of a diverse and abundant community of macroinvertebrates, resulting in a significant food source for trout. During this visual survey, a number of trout were observed in the North Fork side of the confluence (Figure 2.); in the absence of poor water quality conditions in the Snake River side of the confluence, we would expect to have trout present also.

The Snake River from the North Fork confluence upstream to the confluence with Deer Creek provides a good mixture of runs and high and medium grade riffles (Figure 3). In addition, a number of pool habitats types were evident during the survey (Figure 4). Based on these limit visual surveys the Snake River provides good to excellent physical habitat for trout.

The only problem we noted on our survey was the culvert and associated habitat at the road crossing, just upstream of the Peru Creek confluence (Figure 5), maybe impassable to trout moving upstream. Due the narrow channel and high gradient in this stream section, it is probable that the culvert poses a potential barrier to trout movements. The overall height of the culvert from the stream bed and the lack of pool for fish to rest and jump from would result in trout not being able to freely move upstream during normal or low flow conditions. During high flows, the velocities inside the culvert may be extreme, thus inhibiting fish from swimming through the culvert.

Peru Creek is heavily impacted from poor water quality conditions which will prohibit a trout population for many years, if conditions improved significantly in this stream, and then abundant physical habitat would be available in the form of riffles and high gradient riffles with associated plunge pools (Figure 6).

In conclusion, based on our visual evaluation of the Snake River we found abundant habitat types that would be excellent for a trout population, particularly, in the stream section downstream of the culvert (Figure 5). If water quality conditions in this stream section were improved to within the tolerance limits of trout, even on a seasonal basis, then we would expect to see trout population. If conditions were greatly improved, then a sustaining trout population could be maintained in this section.

Figure 1. Excellent Riffle Habitat at the Snake River & North Fork Confluence.

Figure 2. North Fork at the confluence of Snake River.

Figure 3. Excellent Trout Habitat, Snake River.

Figure 4. Beaver Pond Pool Providing Cover Refugia For Trout .

Figure 5. Culvert Barrier on the Snake River

Figure 6. Typical Step-Pool or Plunge Pool on Peru Creek.

Total Maximum Daily Load Assessment
Snake River and Peru Creek
Summit County, Colorado

Colorado Department of Public Health and Environment
Water Quality Control Division

August, 2008

TMDL Summary	
Waterbody Description / WBID	Mainstem of the Snake River, including all tributaries and wetlands from the source to Dillon Reservoir, except for specific listings in Segments 7, 8, and 9, COUCBL06/ Mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8, COUCBL07.
Pollutants Addressed	pH, Dissolved Cadmium, Dissolved Copper, Dissolved Lead, and Dissolved Zinc
Relevant Portion of Segment (as applicable)	Mainstem of the Snake River, Saints John Creek in Segment 6; mainstem of Peru Creek and all tributaries in Segment 7.
UseClassification/Designation	Segment 6: Aquatic Life Cold 1, Recreation 1a, Water Supply, Agriculture / Use Protected Segment 7: Aquatic Life Cold 1, Recreation 2/Use Protected
Water Quality Targets (for dissolved fraction of metals)	see below
TMDL Goal	Attainment of TVS Standards for pH, cadmium, copper, lead, and zinc and manganese for COUCBL07.

Segment 6	Chronic	Acute
pH	6.5-9.0	6.5-9.0
Cd-D	TVS	TVS
Cu-D	TVS	TVS
Pb-D	TVS	TVS
Zn-D	TVS	TVS
Segment 7	**Chronic**	**Acute**
pH	6.5-9.0	6.5-9.0
Cd-D	TVS	TVS
Cu-D	TVS	TVS
Mn-D	TVS	TVS
Pb-D	TVS	TVS
Zn-D	TVS	TVS

EXECUTIVE SUMMARY

The Snake River watershed is part of the Blue River sub-basin in the Upper Colorado River basin (Figure 1). The mainstem of the Snake River, from the source to Dillon Reservoir, including Saints John Creek, and the mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River (except for specific listing in Segment 8) were placed on the Colorado 1998 303(d) list for non-attainment of dissolved cadmium, dissolved copper, dissolved lead, and dissolved zinc standards (Table 1) (WQCC 2006a). Both segments were also listed for pH on the 2006 303(d) list and Peru Creek, Segment 7 was also listed for dissolved manganese. The combination of low pH and high metals concentrations does not support the Aquatic Life Cold 1 classification. The high concentration of metals is primarily the result of the natural geology of the region and anthropogenic sources which include a mining boom in the 1880s, fueled by silver and gold discoveries in Colorado's interior.

The Snake River, Segment COUCBL06, is 25.1 miles long, terminating in Dillon Reservoir, a principle domestic water storage impoundment owned by the City of Denver. Peru Creek, Segment COUCBL07, is approximately 5.5 miles long, terminating at the confluence with the Snake River. About 3,000 people live year-round in the Snake River Watershed. Resort use, particularly in the winter, frequently swells that number to over 20,000.

Segment #	Segment Description	Portion	303(d) Listed Contaminants
Segment 6	Mainstem of the Snake River, including all tributaries and wetlands from the source to Dillon Reservoir and Saints John Creek.	all	pH, Cd, Cu, Pb, and Zn
Segment 7	Mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8.	all	pH, Cd, Cu, Mn, Pb, and Zn

Table 1. Segments within the Snake River watershed that appear on the 2006 303(d) list of impaired waters for excessive heavy metals.

The geology of the Snake River watershed, i.e. the composition of the rocks and minerals exposed in the surface and near-surface environment within the watershed, control the surface and groundwater chemistry through natural weathering processes. Historical mining activities in the watershed have greatly accelerated the relationship between pH and total metals, which are also a function of the mineral deposit characteristics (USGS, 1999). Due to abundant quantities of mine waste rock and the slow biogeochemical process of acid rock discharge, this pollution can continue to flow long after the mining ends (Todd, 2005). Both existing and future activities on public and private lands in the Snake River Watershed face constraints that could impact important social and economic development in the watershed. Specific actions to reduce metals pollution, restore fisheries, and protect water supplies in the Snake River watershed are critical to its future (Snake River Task Force, 2006).

I. INTRODUCTION

Section 303(d) of the federal Clean Water Act requires States to periodically submit to the U. S. Environmental Protection Agency (EPA) a list of water bodies that are water-quality impaired. A water-quality impaired segment does not meet the standards for its assigned use classification. This list of impaired water bodies is referred to as the “303(d) List”. The List is adopted by the Water Quality Control Commission (WQCC) as Regulation No. 93.

For water bodies and streams on the 303(d) list, a Total Maximum Daily Load (TMDL) is used to determine the maximum amount of a pollutant that a water body may receive and still maintain water quality standards. The TMDL is the sum of the Waste Load Allocation (WLA), which is the load from point source discharge, Load Allocation (LA) which is the load attributed to natural background and/or non-point sources, and a

Margin of Safety (MOS) (Equation 1).

(Equation 1) TMDL=WLA+LA+MOS

The mainstem of the Snake River from the source to Dillon Reservoir, including Saints John Creek (COUCBL06) and the mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8 (COUCBL07) are included on the 1998 303(d) list for exceeding the Aquatic Life use standards for cadmium, copper, lead, and zinc (WQCC, 2006a). Both segments are also on the 2006 303(d) list for pH and Peru Creek is also listed for manganese, in addition to the above metals.

A segment or pollutant may be removed from the list if the applicable standard is attained, if implementation of clean up activities via an alternate means will result in attainment of standards, if the original listing decision is shown to be in error, or if the standards have been changed as the result of a Use Attainability Analysis (UAA) or other EPA approved method.

II. GEOGRAPHICAL EXTENT

The Snake River watershed is the eastern tributary to the Blue River, and is immediately west of the Continental Divide. The headwaters of the mainstem Snake River begin immediately west of the Continental Divide near Teller Mountain and flow northwest until they terminate at the inflow to Dillon Reservoir. The Snake River and its tributaries are contained within the boundaries of the Arapahoe National Forest. Two major ski areas, Keystone Resort and Arapahoe Basin, lie within the Snake River watershed. There is currently one major permitted discharger to the river in segment 6 and no permitted dischargers in Segment 7.

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. By excavating veins of ore, miners exposed sulfidic minerals such as pyrite to oxygen, increasing their reactivity through microbially mediated reactions (Todd, 2005). This headwater reach also runs through a naturally occurring bog iron ore deposit (Theobald et. al. 1963). The first major tributary, Deer Creek, sustains a natural source of metals, and the inflow, which is approximately equal to the Snake River flow, raises the pH and causes precipitation of aluminum and iron hydroxides in the mainstem Snake River. Other major tributaries to the Snake River that may contribute a significant amount of metals are Saints John Creek (Cd, Pb, and Zn) and Keystone Gulch (Cu).

The next major tributary to the Snake River is Peru Creek, which also appears on the 1998 303(d) list. The headwaters of Peru Creek begin just south of Gray's and Torrey's peaks in the Arapahoe National Forest. In contrast to the upper Snake River, several abandoned mines are the principal sources of trace metals to the stream, primarily the Pennsylvania Mine. The Pennsylvania Mine, which discharges into Peru Creek, is located in the Colorado Rocky Mountains at an elevation of over 11,000 feet. Contaminants from the Pennsylvania Mine and other mines in the watershed have left Peru Creek with minimal aquatic life. The Pennsylvania Mine is estimated to be one of the largest sources of aqueous metals and acidity to the region (McKnight and Bencala 1990).

Other tributaries to Peru Creek that may contribute to the elevated metals levels are Warden Gulch (Cd, Cu, Pb, Mn, and Zn) and Cinnamon Gulch (Cd, Cu, Pb, and Zn).

The North Fork of the Snake River (North Fork), the third major tributary to the Snake River, originates near the summit of Loveland Pass and flows along U.S. Highway 6 until it drains into the Snake River in Keystone, Colorado. The North Fork of the Snake River is not impacted either by natural conditions or legacy mining features and exhibits water quality in attainment of the assigned Table Value Standards (or "statewide" WQS).

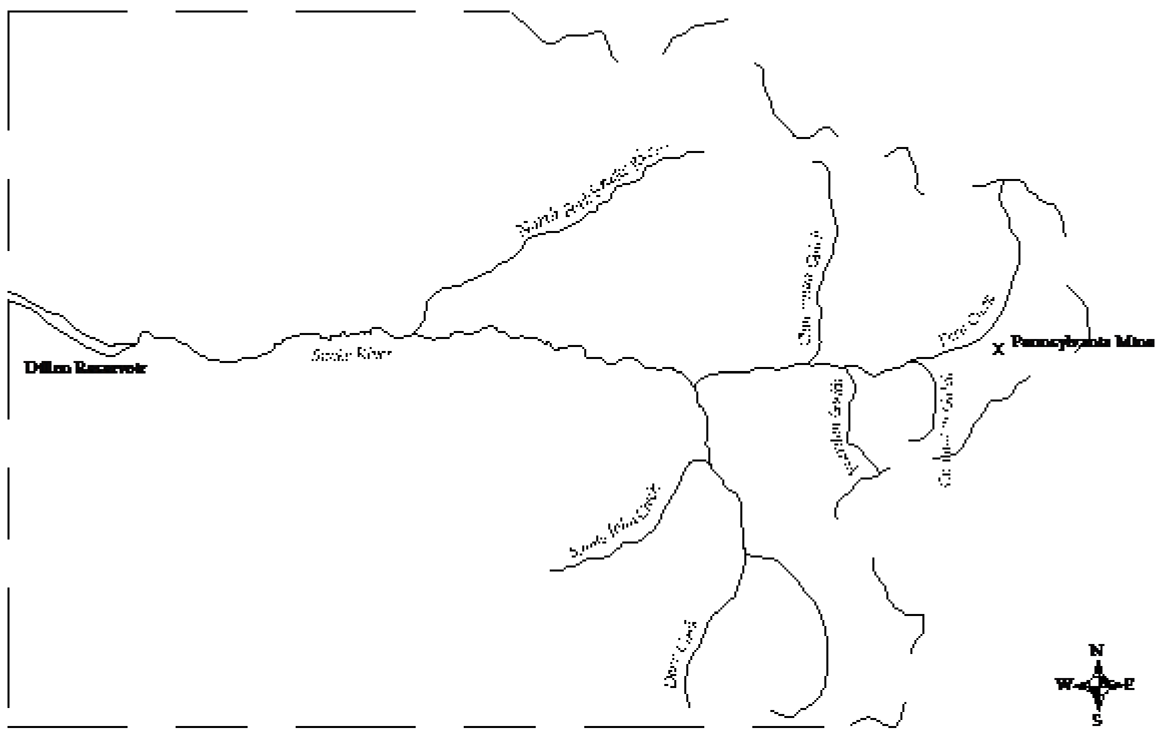


Figure 1. Snake River Watershed (For more detailed map of sampling sites, See Appendix A)

III. WATER QUALITY STANDARDS

Standards Framework

Waterbodies in Colorado are divided into discrete units or "segments". The Colorado *Basic Standards and Methodologies for Surface Water*, Regulation 31(WQCC 2006b), discusses segmentation of waterbodies in terms of several broad considerations:

> *31.6(4)(b)…Segments may constitute a specified stretch of a river mainstem, a specific tributary, a specific lake or reservoir, or a generally defined grouping of waters within the basin (e.g., a specific mainstem segment and all tributaries flowing into that mainstem segment.*

(c) Segments shall generally be delineated according to the points at which the use, physical characteristics or water quality characteristics of a watercourse are determined to change significantly enough to require a change in use classifications and/or water quality standards

As noted in paragraph 31.6(4)(c), the use or uses of surface waters are an important consideration with respect to segmentation. In Colorado there are four categories of beneficial use which are recognized. These include Aquatic Life Use, Recreational Use, Agricultural Use and Water Supply Use. A segment may be designated for any or all of these "Use Classifications":

31.6 Waters shall be classified for the present beneficial uses of the water or the beneficial uses that may be reasonably expected in the future for which the water is suitable in its present condition or the beneficial uses for which it is to become suitable as a goal.

Each assigned use is associated with a series of pollutant specific numeric standards. These pollutants may vary and are relevant to a given Classified Use. Numeric pollutant criteria are identified in sections 31.11 and 31.16 of the *Basic Standards and Methodologies for Surface Water.*

Uses and Standards Addressed in this TMDL

The Colorado Basic Standards and Methodologies for Surface Water, Regulation 31 identifies standards applicable to all surface waters statewide (WQCC 2006b). The pollutants of concern for this assessment are pH, dissolved cadmium, dissolved copper, dissolved lead, and dissolved zinc and also dissolved manganese for Peru Creek, Segment COUCBL07. The specific numeric standards assigned to the listed stream segments are contained in Regulation 33, the Classifications and Numeric Standards for the Upper Colorado River Basin and North Platte River (WQCC, 2006c) (Table 3). In the case of the Snake River, pH, cadmium, copper, lead and zinc concentrations exceed Aquatic Life Use-based standards intended to protect against short-term, acutely toxic conditions (acute) and longer-term, sub-lethal (chronic) effects. In the case of Peru Creek, pH, cadmium, copper, manganese, lead and zinc concentrations exceed Aquatic Life Use-based standards. Aquatic Life Use-based standards for other parameters are attained as are all assigned numeric standards associated with Recreational, Water Supply and Agricultural Use Classifications.

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COUCBL06	Mainstem of the Snake River, including all tributaries and wetlands from the source to Dillon Reservoir and Saints John Creek.	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Water Supply: Not Impaired Agriculture: Not Impaired

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COUCBL07	Mainstem of Peru Creek, including all tributaries and wetlands from the source to the confluence with the Snake River, except for specific listing in Segment 8.	Aquatic Life Cold 1: Impaired Recreation P: Not Impaired

Table 2. Designated uses and impairment status for Segments 6 and 7, mainstem of the Snake River, Saints John Creek, and Peru Creek mainstem.

Most of the relevant standards for the stream segments addressed in this document are Table Value Standards, which vary based on hardness. Because hardness fluctuates seasonally, standards are listed on a monthly basis using the average hardness for each month to calculate the standard. In addition to the variation in stream hardness, flows also vary seasonally, and the dilution factor of the metals is seasonally affected. This seasonal flow variation is also accounted for by monthly standard values.

Additionally, a new, more stringent cadmium and zinc standard has gone into effect following the scheduled 2008 Upper Colorado Basin hearings in June. Loading allocations in this TMDL will reflect the current revised cadmium and zinc standards.

The stream segments addressed here, COUCBL06 and COUCBL07 are use classified as Aquatic Life Cold 1 and Recreation 1a, and Recreation 2, respectively. Segment COUCBL06 is also use classified as water supply and agriculture. In all cases, the elevated levels of listed heavy metals exceed the Aquatic Life use-based standards, while other uses or "use-based standards" are attained (Table 2)

.

Water Quality Criteria for Impaired Designated Uses		
WBID	**Impaired Designated Use**	**Applicable Water Quality Criteria and Status**
COUCBL06	Aquatic Life Cold 1	pH (1) / Not Attained Dissolved Phase Cd (1) / Not Attained Dissolved Phase Cu (1) / Not Attained Dissolved Phase Pb (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
COUCBL07	Aquatic Life Cold 1	pH (1) / Not Attained Dissolved Phase Cd (1) / Not Attained Dissolved Phase Cu (1) / Not Attained Dissolved Phase Mn (1) / Not Attained Dissolved Phase Pb (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
Applicable State or Federal Regulations: (1) Classifications and Numeric Standards for the Upper Colorado River Basin and North Platte River (Reg 33)		

Table 3. Ambient water quality criteria and status for Segments 6 and 7, mainstem of the Snake River, Saints John Creek, and Peru Creek mainstem.

IV. PROBLEM IDENTIFICATION

There is one permitted discharger to the Snake River (Table 4), and there are no permitted dischargers on Peru Creek. Consequently, the majority of the loading to the Snake River and Peru Creek comes from natural geology and non-permitted point sources rather than point source dischargers.

	Dischargers	NPDES ID	SIC DESC	Design Capacity, mgd
Segment 6	Keystone Base 1 (River Run)	COG070488	heavy construction	0.050

Table 4. Permitted dischargers in 303(d) listed segment of the Snake River.

Much of the heavy metal loading throughout the Snake River watershed is the result of natural geologic conditions and historic mining activities. In the 1860's, prospectors were drawn to the Rocky Mountain region by the discovery of silver, and the mining boom continued until the turn of the century, with a brief resurgence during the 1940's (Todd, 2005). Excavation of veins of precious minerals exposed sulfidic minerals (predominantly pyrite) to oxygen. This makes possible chemical reactions mediated by the iron-oxidizing bacterium *Thiobacillus ferrooxidans* and other acidophiles, ultimately lowering pH. Due to resultant acidic conditions, this weathering increases the mobilization of metals (e.g. Zn, Cd, and Pb) within sulfide-containing minerals, as well as trace metals (e.g., Al, Mn) from other minerals in neighboring rock (McKnight and Bencala 1990). Due to copious quantities of mine waste rock and the slow biogeochemical process of acid rock discharge, this pollution can continue to flow long after the mining ends (Todd, 2005). The Pennsylvania Mine and other abandoned mines in this drainage have been identified as major anthropogenic sources of trace metals and acidity to Peru Creek (McKnight and Bencala 1990).

In the late 1980's, the Colorado Division of Minerals and Geology built a passive treatment system at the Pennsylvania Mine adit designed to remove metals with minimum operation and maintenance costs. This treatment system was designed to treat the acid mine drainage flowing from a mine tunnel on the site. When completed, the system proved ineffective because the water was too acidic and laden with heavy metals. A redesign project was initiated, but soon abandoned when a court case made it clear that the state agency could be held liable for all future discharge from the site (http://www.tu.org). Temporary modifications of current stream standards have been developed for both stream segments and are currently effective until February 28, 2009 (Table 5).

The impacts of extractive industrial activity (e.g. mining) conflict with the other major economic driver in the Colorado Rockies: tourism (Todd et al, 2003). Ski tourism accounted for 25% of Summit County's total income in 2001, and 31.5% of all Colorado skier visits in 2001 were to Summit County (Goldsmith, 2001). While the county has thrived on this new economic base, the potential negative impacts from a recreation-led economy in Summit County have been observed as early as three decades ago (Ulman, 1974). To meet the demand for recreation, ski areas are using river water for artificial snow-making to increase the duration of the ski season, thus increasing revenue. One impact of this practice is the application of heavy metal-contaminated Snake River water to ski runs through snow-making. This suggested practice has been evaluated as a mechanism for spreading metal contamination into un-impacted drainages (Hydrosphere 2001). Within the same watershed, Arapahoe Basin Ski Area has addressed the challenge of responsibly developing snow-making capabilities by utilizing uncontaminated water from the Snake River's North Fork, a sizable tributary which dilutes the waters of the mainstem as it enters the Keystone resort community (Todd et al, 2003).

	Cd-D, $\mu g\ l^{-1}$	Cu-D, $\mu g\ l^{-1}$	Pb-D, $\mu g\ l^{-1}$	Zn-D, $\mu g\ l^{-1}$
Segment 6	2.3	17	-	654
Segment 7	5.2	79	6.7	1380

Table 5. Temporary modifications on segments COUCBL06 and COUCBL07 which expire February 28, 2009.

One other potential impact to the Snake River watershed is the impact of drought. Analysis of historical dry and wet periods in the state show that more than 90% of the time, a minimum of 5% of Colorado is suffering drought conditions (Todd et al., 2003). Low flows in the Snake River decrease the amount of dilution flow and subsequently increase the in-stream heavy metals concentrations. Additionally, winds, bank storage, spring seepage, tributary streams, and the warming effect of the sun have greater impacts on stream water temperatures during low-flow periods. The exaggerated effects of these factors could be additional stressors to aquatic life (www.epa.gov/waterscience/models/dflow/flow101.htm).

Despite the magnitude of water-quality data gathered for both the Snake River and Peru Creek, there have been few recent aquatic life surveys. Chadwick and Associates performed a characterization of benthic invertebrates in 1985. The mean density and diversity of benthic invertebrate populations increased in a downstream direction along the Snake River in conjunction with increasing distance from the Peru Creek confluence (Chadwick & Associates, 1985a). In a follow-up study on trout populations, no fish were found at sites upstream of Deer Creek or just downstream of Peru Creek on the Snake River (Chadwick & Associates, 1985b). No fish were found at the Peru Creek site above the Pennsylvania Mine, despite the presence of relatively good habitat (Chadwick & Associates, 1985b). Brook trout were the most abundant fish species collected in the lower Snake River, and sizeable populations of brook trout existed in the lower North Fork Snake River and Deer Creek.

Chadwick and Associates performed another biological investigation on the Snake River watershed in 1995. They concluded that resident fish do not occur upstream of the North Fork Snake River (between Peru Creek and North Fork); moreover, stocking provides the majority of fish biomass downstream of the North Fork Snake River (Chadwick & Associates, 1996). Similar to previously conducted studies, the density of benthic macro-invertebrates and number of taxa were both significantly lower in the Snake River upstream of the North Fork. The USEPA performed a macroinvertebrate survey of the Snake River and Peru Creek in 2001. Preliminary results demonstrate a pronounced lack of metals tolerant taxa in both the Snake River and Peru Creek. A written report is still pending.

In-situ caged rainbow trout studies demonstrated significant mortality in the

Snake River below Peru Creek and above the North Fork (Todd et al., 2006). Trout mortality was positively correlated with concentrations of metals approaching or exceeding conservative toxicity thresholds (Cd, Cu, Mn, and Zn) (Todd et al., 2006). A portion of the North Fork Snake River drainage, however, is known to support a self-sustaining, healthy brook trout fishery.

In September 2006, a visual habitat characterization was performed by Walsh Aquatic Associates, Inc. to determine if the high level of metals in the Snake River and Peru Creek were the limiting factors for healthy trout populations. They concluded that abundant habitat exists to support healthy trout populations in the Snake River (Walsh, 2007 memo). Consequently, if water quality were to be improved, the physical habitat could potentially support a healthy and sustainable trout population.

Some electro-fishing was also done by the CDOW and volunteers in July and August 2007 to determine whether fish were present or absent in Segments 6 and 7. Stocked rainbow and brook trout were found in the Snake River below North Fork Snake River. Brook trout were also found in the Snake River directly above Peru Creek and in Saints John Creek. Fish were absent in the Snake River below Peru Creek and directly above the North Fork as well as in Peru Creek, both above and below the Pennsylvania Mine.

Macroinvertebrate sampling was also undertaken in July and September of 2007 on the mainstems of the Snake River and Peru Creek along with the corresponding tributaries. Diversity and number of taxa of macroinvertebrate populations were greatest on the mainstem of the Snake River below the North Fork Snake River and upstream of Peru Creek. Total number of taxa and diversity upstream and downstream of Peru Creek exhibited a sharp decline in the September sampling event due to a pulse of metals from a large rainfall event. Tributaries to the Snake River (North Fork Snake River, Saints John Creek, and Deer Creek) demonstrated high diversity numbers and an overall healthy number of taxa during the July sampling event. Peru Creek upstream of the Pennsylvania Mine demonstrated the highest number of taxa and diversity in macroinvertebrate assemblage of all of the mainstem sites during the July sampling event. The numbers dropped significantly during the September sampling event. Chihuahua Gulch reflected the most diverse macroinvertebrate assemblage as compared to Cinnamon Gulch.

V. Water Quality Goals

The water quality goal for 303(d) listed segments of the Snake River and Peru Creek is support of the Aquatic Life Cold 1 use classification and attainment of the corresponding standards. Reduction of metals loads would facilitate the establishment of a viable trout fishery.

Weathering of waste rock associated with inactive mines is one of the major sources of metals to the watershed. The natural mineralization of the area also contributes to the quantity of heavy metals in the listed stream reaches through precipitation events, snow-melt, and colluvial activity. Both natural and anthropogenic processes must be carefully evaluated when setting watershed-scale restoration goals (USGS, 1999). Currently, the U.S. Environmental Protection Agency (USEPA) has designated COUCBL07, Peru Creek, to be placed on the National Priorities List (NPL). A technology selection process is presently underway to determine the best treatment alternative for the Pennsylvania Mine and the surrounding area. Specific actions to reduce metals pollution, restore fisheries, and protect water supplies in the Snake River watershed are critical to its future (Snake River Task Force, 2006).

VI. Instream Conditions

6.1 Hydrology

The hydrograph of the Snake River and its tributaries is typical of high mountain streams, with low flows occurring in the late fall to early spring followed by a large increase in flow, usually in May or June, due to snowmelt that tails off through the summer (Figure 2). Average and median monthly flows for reaches on the Snake River were calculated from the nearest USGS gage, #9047500 and flow percentiles are demonstrated in Table 6. A linear regression was used to estimate flows for sites above the USGS gage site at Montezuma. Flows for the Snake River above Peru Creek were calculated by equation 2 (Table 7). Flows for the Snake River below Peru Creek were calculated by equation 3 (Table 7). Equation 4 was used to calculate flows for the Snake River above North Fork (Table 7). Peru Creek flows were estimated using equation 5 ($R^2 = 0.83$).

((USGS Gage #09047500 Flow * 0.3386) + 0.8995) Eq. 2

((USGS Gage #09047500 Flow * 0.7100) + 4.9867) Eq. 3

(USGS Gage #09047500 Flow * 0.6300) Eq. 4

((USGS Gage #09047500 Flow * 0.2698) - 0.3235) Eq. 5

The annual 1E3 and 30E3 (one day in three years and three day in thirty years respectively) low flows were calculated for the USGS station #09047500 using United States Environmental Protection Agency (USEPA) DFLOW software and daily flow data from the Snake River at Montezuma. The annual 1E3 and 30E3 (one day in three years and three day in thirty years respectively) low flows were also calculated for Peru Creek with Equation 5 (Table 8). Median flows were used to calculate stream loads. Median loads were compared to TMDL low flow conditions to provide an overly conservative estimate of stream load reductions.

Acute and chronic low flows were calculated using USEPA DFLOW software. Acute (1E3) and chronic (30E3) flows are biologically based low flows. Biologically-based design flows are intended to measure the actual occurrence of low flow events with respect to both the duration and frequency (i.e., the number of days aquatic life is subjected to flows below a certain level within a period of several years). Although the extreme value analytical techniques used to calculate hydrologically-based design flows have been used extensively in the field of hydrology and in state water quality standards, these methods do not capture the cumulative nature of effects of low flow events because they only consider the most extreme low flow in any given year. By considering all low flow events with a year, the biologically-based design flow method accounts for the cumulative nature of the biological effects related to low flow events. Acute low flows (1E3) refer to single low flow events that occur once in a three year period. Chronic low flows (30E3) refer to 30-day low flow periods which occur once in three years. The use of median loads and TMDL low flows to calculate load reductions tends to overestimate loading reductions.

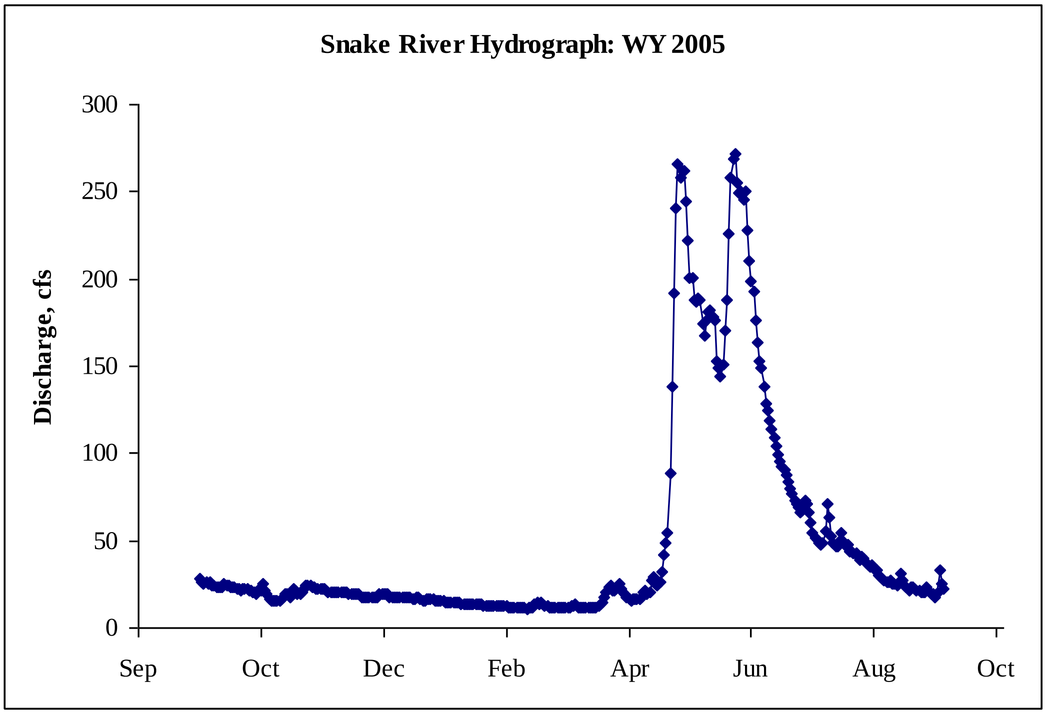


Figure 2. Hydrograph of the Snake River near Montezuma, USGS gage 9047500.

Snake River flows for USGS Gage #9047500 (1990-2006)								
	25th% Flows, cfs	5th% Flows, cfs	95th% Flows, cfs	75th% Flows, cfs	Average Flows, cfs	Median Flows, cfs	Acute Low Flow (1E3), cfs	Chronic Low Flow (30E3), cfs
Jan	12.0	11.0	18.0	16.0	14.2	15.0	9.4	9.3
Feb	10.0	9.1	16.0	14.0	12.1	12.0	9.0	9.3
Mar	10.0	8.7	17.0	13.0	11.9	12.0	8.4	9.3
Apr	13.0	11.0	30.6	22.0	18.5	16.0	9.4	9.3
May	38.0	16.0	316.8	190.0	121.2	88.0	12.0	12.0
Jun	168.3	77.0	579.1	368.8	276.2	244.5	25.0	22.0
Jul	74.0	36.3	333.0	160.0	134.8	108.0	17.0	20.0
Aug	40.0	24.3	131.0	72.0	60.2	52.0	16.0	18.0
Sep	30.0	20.0	61.6	43.0	37.8	37.0	14.0	18.0
Oct	24.0	20.0	38.0	33.0	28.3	27.0	16.0	15.0
Nov	17.0	15.0	28.0	23.0	20.6	20.0	15.0	13.0
Dec	15.0	12.0	22.0	20.0	17.3	17.0	13.0	12.0

Table 6. Flows (cfs), for 303(d) listed stream segment in the Snake River watershed. Acute and chronic low flows were calculated using USEPA DFLOW software.

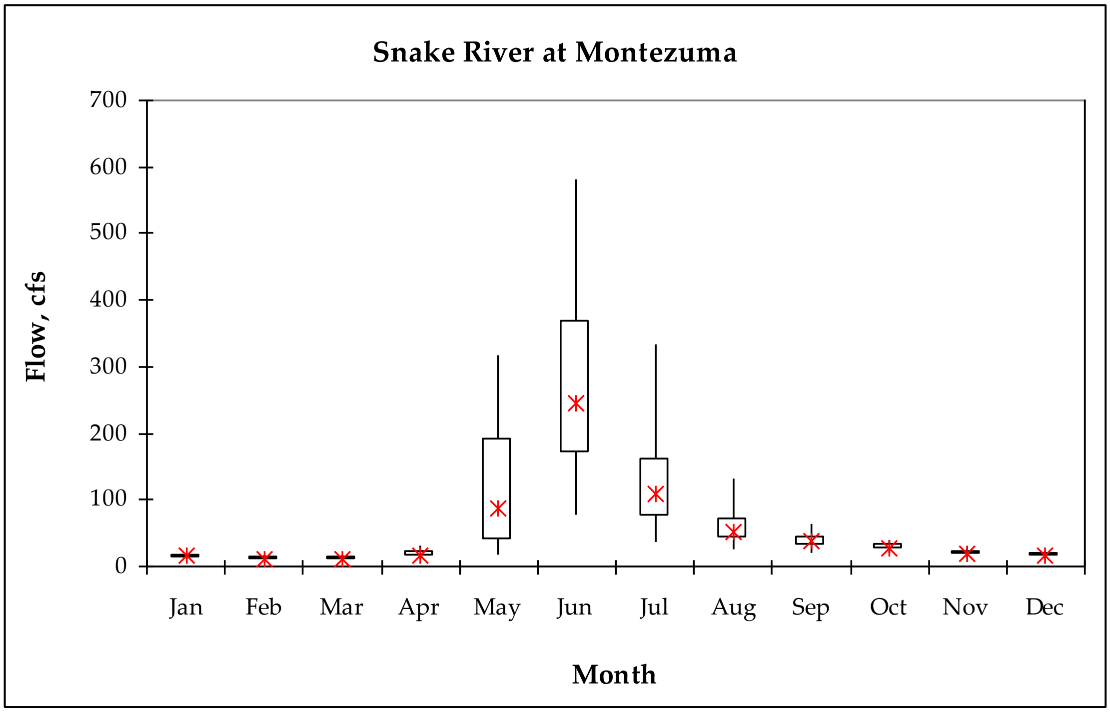


Figure 3. Box and whisker plot representing variability in monthly stream flows in the Snake River. Boxes represent quartiles (25^{th} and 75^{th} percentiles) while whiskers represent 5^{th} and 95^{th} percentile flow values. Stars indicate monthly median flows.

Flows for the Snake River at Montezuma, USGS Gage 09047500												
Estimated Flows for the Snake River above Peru Creek												
Flow (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	5.8	5.1	5.1	7.3	41.6	95.1	47.8	21.8	13.7	10.6	8.0	6.8
Estimated Flows for the Snake River below Peru Creek												
Flow (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	15.1	13.9	13.8	18.4	90.3	202.6	103.3	48.9	31.9	25.4	19.9	17.1
Estimated Flows for the Snake River above North Fork												
Flow (cfs)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	9.2	7.9	7.8	11.9	75.7	175.3	87.3	37.9	23.9	18.1	13.2	11.0

Table 7. Average flows (cfs), for 303(d) listed stream segment in the Snake River watershed

Predicted Peru Creek flows from #9047500 (POR 1990-2006)							
	25th% Flow, cfs	5th% Flow, cfs	95th% Flow, cfs	75th% Flow, cfs	Median Flow, cfs	Acute Low Flow (1E3), cfs	Chronic Low Flow (30E3), cfs
Jan	2.9	2.6	4.5	4.0	3.7	2.3	2.2
Feb	2.4	2.1	4.0	3.5	2.9	2.2	2.2
Mar	2.4	2.0	4.3	3.2	2.9	1.9	2.2
Apr	3.2	2.6	7.9	5.6	4.0	2.3	2.2
May	9.9	4.0	85.1	50.9	23.4	2.7	2.7
Jun	45.1	20.5	155.9	99.2	65.6	6.3	5.3
Jul	19.6	9.5	89.5	42.8	28.8	4.1	5.0
Aug	10.5	6.2	35.0	19.1	13.7	3.8	4.3
Sep	7.8	5.1	16.3	11.3	9.7	3.3	4.3
Oct	6.2	5.1	9.9	8.6	7.0	3.8	3.7
Nov	4.3	3.7	7.2	5.9	5.1	3.6	3.0
Dec	3.7	2.9	5.6	5.1	4.3	3.0	2.7

Table 8. Estimated flows (cfs), for 303(d) listed stream segment in Peru Creek. Peru Creek flows were estimated from the equation: ((USGS Gage #09047500 Flow * 0.2698) - 0.3235), $R^2 = 0.83$.

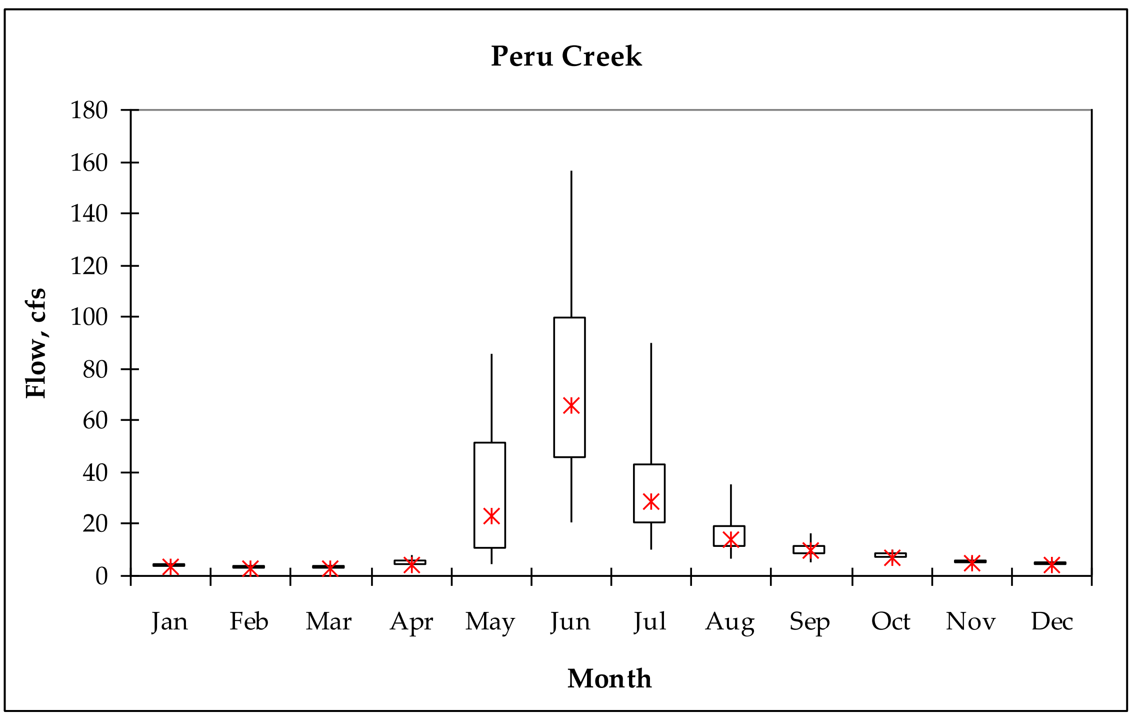


Figure 4. Box and whisker plot representing variability in monthly stream flows in Peru Creek. Boxes represent quartiles (25^{th} and 75^{th} percentiles) while whiskers represent 5^{th} and 95^{th} percentile flow values. Stars indicate monthly median flows.

6.2 Ambient Water Quality Data

To identify exceedances of the chronic water quality standard, the eighty-fifth percentile concentration of metals was calculated using the most current available data from the Snake River Watershed Task Force as compiled from a multitude of sources (Table 9).

Sources of water quality data for Snake River watershed
American Geological Services
Arapahoe Basin Ski Resort
Colorado Department of Public Health
Colorado Division of Wildlife River Watch
Colorado School of Mines
Colorado State University - Department of Fish, Wildlife & Conservation Biology
Denver Water Board
Hydrosphere Resource Consultants
Northwest Colorado Council of Governments
Summit Water Quality Committee
University of Colorado Institute for Arctic and Alpine Research
U.S. Environmental Protection Agency
U.S. Geological Survey

Table 9. Sources of water quality data for 303(d) listed stream segments in the Snake River watershed.

The principal database (SnakeRWatersFinal.xls) was developed by the USGS-SWQC (http://co.water.usgs.gov/cf/bluecf/) and supplemented with additional data by Tim Steele for his Snake River Watershed WQ Assessment (Steele, 2004). Over thirty years of combined data were collected in the Snake River and Peru Creek drainages. The period of record used for the calculation of ambient concentrations was 1990-2006 due to a change in standards from total recoverable to the dissolved metals species. Eighty-fifth percentile values were used to calculate ambient water quality concentrations in the Snake River and Peru Creek for this TMDL. Segment 6 was broken down into different reaches in order to characterize the difference in upstream and downstream metals concentrations in the Snake River watershed. The reaches were selected above and below the three major tributaries to the Snake River (Deer Creek, Peru Creek, and North Fork Snake River) (Table 10). Peru Creek reaches were selected above and below the Pennsylvania Mine influence (Table 11). As ongoing monitoring continues, the database continues to be supplemented.

Number of Samples						
Sampling Sites	Hardness	pH	Cd-D	Cu-D	Pb-D	Zn-D
Snake River above Deer Creek	230	182	220	258	54	261
Snake River below North Fork	276	347	225	225	176	223
Snake River above North Fork	110	179	106	110	57	110
Snake River below Peru Creek	38	33	34	36	17	36
Snake River above Peru Creek	439	331	414	401	52	437

Table 10. Snake River watershed data summary.

Number of Samples							
Sampling Sites	Hardness	pH	Cd-D	Cu-D	Mn-D	Pb-D	Zn-D
Peru Creek above Penn Mine	5	7	3	3	5	3	5
Peru Creek below Penn Mine	49	46	43	47	47	42	48

Table 11. Peru Creek watershed data summary.

As observed in Figure 5, ambient stream concentrations in the Snake River generally decrease as you travel downstream towards the inlet to Dillon Reservoir. The highest concentrations of all the listed metals are most often observed above the confluence with Deer Creek. The dissolved metal concentrations may be exacerbated by the significant decrease in pH above the Deer Creek confluence. Box and whisker plots demonstrating the variability among sample concentrations for sites on the Snake River above Peru Creek, below Peru Creek, and below the North Fork Snake River are provided in Appendix C.

The Snake River above Deer Creek is characterized by very low pH values and high metals concentrations (Table 12). Cadmium, copper, and zinc exceeded the TVS for all months of the year. Cadmium concentrations at the site above Deer Creek are the highest observed in the Snake River for all months of the year except May. Ambient cadmium concentrations were lowest in May and June above Deer Creek due to the increase in dilution flow and snowmelt. The temporary modification of 2.3 $\mu g\ l^{-1}$ was met in those months. Similar to cadmium, copper concentrations at the site above Deer Creek are the highest observed in the Snake River for all months of the year except September and October. The temporary modification of 17 $\mu g\ l^{-1}$ for copper was met only in June at this site. Copper concentrations remained above 20 $\mu g\ l^{-1}$ for the months of August through April. Zinc concentrations in January, November, and December (> 800 $\mu g\ l^{-1}$) at the site above Deer Creek were the highest observed in the Snake River. Similar to cadmium and copper, the lowest concentrations were observed in May and June due to the increase in stream flow and resulting dilution effect.

Ambient lead concentrations above Deer Creek exceeded the TVS for eight months of the year. The months of January, August, October and December were in attainment for lead. Ambient pH values above Deer Creek were also the lowest in the Snake River. TVS standards were not met, since pH values did not exceed 4.0 s.u. in any month of the year.

Acute cadmium trout standards were exceeded in one hundred forty-three of the one hundred seventy-five paired samples (82%). Acute copper standards were exceeded more frequently with two hundred two of the two hundred twenty-eight paired samples exceeding the acute standard (89%). All of the samples were in attainment of the acute lead standard; however, approximately 100% of the samples exceeded the acute zinc standard (229 out of 229 samples).

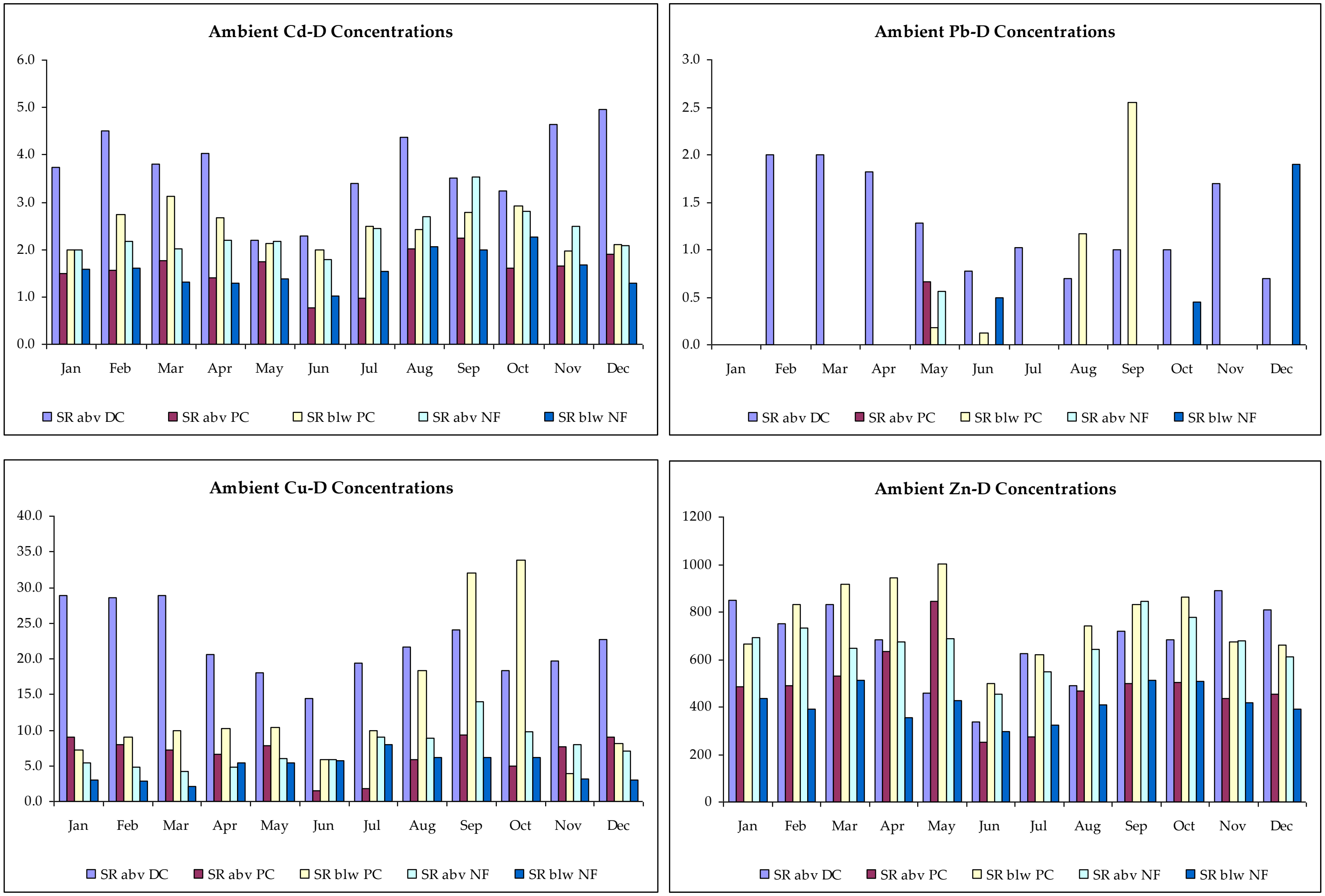


Figure 5. Ambient concentrations (85^{th} %) in 303(d) listed stream segment of the Snake River, COUCBL06.

Current TVS Standards and Ambient Water Quality for Snake River above Deer Creek											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, μg l^{-1}	Cu-D, TVS	Cu-D, μg l^{-1}	Pb-D, TVS	Pb-D, μg l^{-1}	Zn-D, TVS	Zn-D, μg l^{-1}
Jan	52	6.5-9.0	3.9	0.26	3.7	5.1	28.8	1.2	0.0	71.2	848.1
Feb	54	6.5-9.0	3.9	0.27	4.5	5.3	28.6	1.3	2.0	73.5	751.2
Mar	55	6.5-9.0	4.0	0.27	3.8	5.4	28.9	1.3	2.0	74.7	831.0
Apr	52	6.5-9.0	3.7	0.26	4.0	5.1	20.6	1.2	1.8	71.2	681.3
May	36	6.5-9.0	3.7	0.20	2.2	3.7	18.0	0.8	1.3	52.0	458.3
Jun	26	6.5-9.0	3.8	0.15	2.3	2.8	14.5	0.6	0.8	39.4	338.9
Jul	32	6.5-9.0	3.8	0.18	3.4	3.4	19.4	0.7	1.0	47.1	626.2
Aug	32	6.5-9.0	3.8	0.18	4.4	3.4	21.7	0.7	0.7	47.1	488.4
Sep	39	6.5-9.0	3.9	0.21	3.5	4.0	24.0	0.9	1.0	55.7	721.2
Oct	47	6.5-9.0	3.7	0.24	3.2	4.7	18.4	1.1	1.0	65.3	683.8
Nov	48	6.5-9.0	3.8	0.24	4.6	4.8	19.7	1.1	1.7	66.5	888.4
Dec	50	6.5-9.0	3.8	0.25	4.9	5.0	22.8	1.2	0.7	68.8	809.6

Table 12. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above Deer Creek. Concentrations are given as 85^{th}% values.

The Snake River above Peru Creek and below Deer Creek is characterized by increasing pH values and decreasing metals concentrations (Table 13). Cadmium, copper, and zinc still exceeded TVS for the majority of the year. Dissolved cadmium concentrations were not in attainment of TVS standards for the entire year. Ambient cadmium concentrations above Peru Creek were lowest in June, and July due to the increase in dilution flow. The temporary modification of 2.3 μg l^{-1} was met in all months of the year. Copper concentrations were lowest in the summer months (June and July), and the temporary modification of 17 μg l^{-1} for copper was met for all months of the year. The site above Peru Creek was in attainment of dissolved copper TVS in June, July, and October. Zinc concentrations above Peru Creek peaked in the months leading up to runoff (April and May) with concentrations above 600 μg l^{-1}. The temporary modification for zinc of 654 μg l^{-1} was met in all months but May, but no months were in attainment of table value standards. Ambient lead concentrations above Peru Creek were in attainment of TVS year round. Ambient pH values above Peru Creek increased in range to 5.2-6.3 s.u. in this downstream reach. TVS standards were still not met, however, since pH values did not reach 6.5 s.u. in any month of the year.

Acute cadmium trout standards were exceeded in two hundred forty-eight of the four hundred fourteen samples (60%). Acute copper standards were exceeded less frequently with one hundred ninety-eight of the four hundred one samples exceeding the acute standard (49%). All of the samples were in attainment of the acute lead standard; however, approximately 98% of the samples exceeded the acute zinc standard (427 out of 437 samples).

Current TVS Standards and Ambient Water Quality for Snake River above Peru Creek

	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	62	6.5-9.0	6.3	0.27	1.5	6.0	9.0	1.5	0.0	74.7	483.9
Feb	59	6.5-9.0	5.7	0.26	1.6	5.7	7.9	1.4	0.0	72.4	490.9
Mar	65	6.5-9.0	5.4	0.29	1.8	6.2	7.2	1.6	0.0	80.4	531.3
Apr	57	6.5-9.0	5.2	0.26	1.4	5.5	6.6	1.4	0.0	71.2	634.9
May	43	6.5-9.0	5.3	0.22	1.8	4.4	7.9	1.0	0.7	59.3	844.5
Jun	33	6.5-9.0	5.9	0.16	0.8	3.5	1.5	0.7	0.0	42.0	250.0
Jul	42	6.5-9.0	5.7	0.18	1.0	4.3	1.8	1.0	0.0	47.1	275.4
Aug	53	6.5-9.0	5.7	0.19	2.0	5.2	5.8	1.3	0.0	50.8	469.1
Sep	54	6.5-9.0	5.5	0.22	2.2	5.3	9.3	1.3	0.0	60.5	498.8
Oct	60	6.5-9.0	5.4	0.25	1.6	5.8	5.0	1.4	0.0	67.7	505.6
Nov	56	6.5-9.0	5.2	0.26	1.7	5.5	7.6	1.3	0.0	71.2	436.2
Dec	57	6.5-9.0	5.8	0.25	1.9	5.5	9.0	1.4	0.0	70.0	456.0

Table 13. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above Peru Creek. Concentrations are given as 85^{th}% values.

The Snake River below Peru Creek demonstrates higher hardness values, which in turn, results in higher TVS standards (Table 14). Despite the higher TVS, cadmium, copper and zinc still exceeded the TVS in all months except November for copper. Zinc was not in attainment of TVS for any month of the year. Cadmium concentrations in the Snake River below Peru Creek remained lower than the concentrations at the Snake River above Deer Creek. The highest concentrations were observed in March, September and October where concentrations were approximately 3.0 µg l^{-1}. The attainment of the temporary modification of 2.3 µg l^{-1} was met in both low flow months (November, December and January) and high flow months (May and June). Copper concentrations in the Snake River below Peru Creek were the highest observed in the Snake River in September and October, reaching concentrations of 32.1 and 33.8 µg l^{-1}, respectively. Copper concentrations were lowest (less than 10 µg l^{-1}) in periods of both high (June) and low flow (November through February). The temporary modification of 17 µg l^{-1} for copper was met for all months except August, September and October. Zinc concentrations below Peru Creek peaked in March through May with concentrations exceeding 900 µg l^{-1}. The lowest zinc concentrations were observed in June and July corresponding with periods of high dilution flow. The eighty-fifth percentile zinc concentrations averaged between six and twelve times the corresponding table value standards. The temporary modification for zinc of 654 µg l^{-1} was met in June and July. The Snake River below Peru Creek had the highest lead concentration in the Snake River in September with a concentration of 2.6 µg l^{-1}. All other months were in attainment of TVS. Ambient pH values below Peru Creek continued to increase and were in attainment of TVS for eight out of twelve months.

Acute exceedances followed a similar pattern in the Snake River below the confluence with Peru Creek. Acute cadmium trout standards were exceeded in thirty-three of the thirty-four samples (97%). Acute copper standards were exceeded less frequently with thirty-three of the one hundred ten samples exceeding the acute standard (30%). All of the samples were in attainment of the acute lead standard; however, 96%

of the samples exceeded the acute zinc standard (106 out of 110 samples).

Current TVS Standards and Ambient Water Quality for Snake River below Peru Creek											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	77	6.5-9.0	7.3	0.35	2.0	7.2	7.3	1.9	0.0	99.5	666.5
Feb	74	6.5-9.0	7.0	0.34	2.7	6.9	9.0	1.8	0.0	96.2	829.8
Mar	71	6.5-9.0	6.8	0.33	3.1	6.7	10.0	1.7	0.0	92.8	916.9
Apr	57	6.5-9.0	6.9	0.28	2.7	5.5	10.2	1.4	0.0	77.0	942.0
May	43	6.5-9.0	6.5	0.22	2.1	4.4	10.4	1.0	0.2	60.5	1000.6
Jun	39	6.5-9.0	6.6	0.21	2.0	4.0	5.9	0.9	0.1	55.7	499.4
Jul	49	6.5-9.0	6.4	0.25	2.5	4.9	10.0	1.2	0.0	67.7	621.9
Aug	51	6.5-9.0	6.5	0.25	2.4	5.0	18.4	1.2	1.2	70.0	742.4
Sep	63	6.5-9.0	5.4	0.30	2.8	6.0	32.1	1.5	2.6	83.8	829.6
Oct	63	6.5-9.0	5.9	0.30	2.9	6.0	33.8	1.5	0.0	83.8	860.8
Nov	70	6.5-9.0	6.2	0.32	2.0	6.6	4.0	1.7	0.0	91.7	675.6
Dec	72	6.5-9.0	7.0	0.33	2.1	6.8	8.1	1.8	0.0	93.9	658.5

Table 14. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites below Peru Creek. Concentrations are given as 85^{th}% values.

The Snake River above North Fork Snake River displays a decrease in hardness values, resulting in lower table value standards (Table 15). Cadmium and zinc concentrations remain high and exceed TVS for all months of the year. Cadmium concentrations are consistent around 2.0 µg l^{-1}, peaking in September with a concentration of 3.5 µg l^{-1}. The cadmium temporary modification of 2.3 µg l^{-1} was met for eight months of the year (excluding August through November). Copper concentrations continued to decrease downstream of Peru Creek. Copper TVS were attained in the months of January through April. Concentrations peaked in September with a concentration of 14.0 µg l^{-1} which is slightly over half of that observed immediately below Peru Creek. Attainment of the copper temporary modification of 17 µg l^{-1} was met year round. Zinc concentrations remained consistently higher than sites above Peru Creek for the majority of the year, but were less than directly below Peru Creek. Concentrations were between seven and ten times higher than table value standards. Zinc concentrations were lowest in June and July and highest in September. The temporary modification for zinc of 654 µg l^{-1} was met in March, June through August, and December. The only detectable levels of lead in the Snake River above the North Fork were observed in May with a concentration of 0.6 µg l^{-1}, which still attained TVS. Contrary to sites upstream, ambient pH values above the North Fork Snake River were in attainment of TVS year round.

Acute exceedances followed the same pattern in the Snake River above the confluence with the North Fork Snake River. Acute cadmium trout standards were exceeded in ninety-seven of the one hundred six samples (92%). Acute copper standards were exceeded less frequently with one hundred fifteen of the thirty-six samples exceeding the acute standard (42%). All of the samples were in attainment of the acute lead standard; however, 100% of the samples exceeded the acute zinc standard (36 out of 36 samples).

Water quality in the Snake River below the North Fork Snake River shows significant improvement due to increased dilution flow from the pristine waters of the North Fork, however, lower hardness values appeared to minimize this effect (Table 16). Cadmium concentrations were still not in attainment of TVS for the entire year with concentrations averaging between five and eight times the table value standard.

Current TVS Standards and Ambient Water Quality for Snake River above North Fork											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	66	6.5-9.0	6.8	0.31	2.0	6.3	5.4	1.6	0.0	87.2	694.2
Feb	62	6.5-9.0	6.4	0.29	2.2	6.0	4.9	1.5	0.0	82.7	733.6
Mar	60	6.5-9.0	7.1	0.29	2.0	5.8	4.3	1.4	0.0	80.4	648.6
Apr	58	6.5-9.0	7.0	0.28	2.2	5.6	4.8	1.4	0.0	78.1	672.1
May	45	6.5-9.0	6.7	0.23	2.2	4.5	6.0	1.0	0.6	62.9	687.0
Jun	37	6.5-9.0	6.8	0.20	1.8	3.8	5.9	0.8	0.0	53.3	454.8
Jul	43	6.5-9.0	6.7	0.22	2.4	4.4	9.0	1.0	0.0	60.5	548.6
Aug	49	6.5-9.0	6.6	0.25	2.7	4.9	8.9	1.2	0.0	67.7	643.9
Sep	59	6.5-9.0	6.6	0.28	3.5	5.7	14.0	1.4	0.0	79.3	845.8
Oct	50	6.5-9.0	6.5	0.25	2.8	5.0	9.8	1.2	0.0	68.8	776.8
Nov	56	6.5-9.0	6.6	0.27	2.5	5.5	8.0	1.3	0.0	75.8	678.4
Dec	64	6.5-9.0	6.8	0.30	2.1	6.1	7.0	1.5	0.0	85.0	609.0

Table 15. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites above North Fork Snake River. Concentrations are given as 85^{th}% values.

Current TVS Standards and Ambient Water Quality for Snake River below North Fork											
	Avg. Hardness, mg l^{-1}	pH Std.	Observed pH	Cd-D, TVS	Cd-D, µg l^{-1}	Cu-D, TVS	Cu-D, µg l^{-1}	Pb-D, TVS	Pb-D, µg l^{-1}	Zn-D, TVS	Zn-D, µg l^{-1}
Jan	56	6.5-9.0	6.8	0.27	1.6	5.5	2.9	1.3	0.0	75.8	434.5
Feb	52	6.5-9.0	6.7	0.27	1.6	5.1	2.8	1.2	0.0	74.7	388.9
Mar	55	6.5-9.0	6.7	0.27	1.3	5.4	2.1	1.3	0.0	74.7	512.0
Apr	56	6.5-9.0	6.9	0.27	1.3	5.5	5.5	1.3	0.0	75.8	355.7
May	43	6.5-9.0	6.9	0.22	1.4	4.4	5.4	1.0	0.0	59.3	427.8
Jun	32	6.5-9.0	7.0	0.18	1.0	3.4	5.7	0.7	0.5	48.3	296.9
Jul	40	6.5-9.0	7.0	0.20	1.6	4.1	8.0	0.9	0.0	54.5	325.1
Aug	49	6.5-9.0	7.1	0.24	2.1	4.9	6.2	1.2	0.0	64.1	408.5
Sep	47	6.5-9.0	7.0	0.25	2.0	4.7	6.1	1.1	0.0	70.0	510.3
Oct	51	6.5-9.0	6.9	0.26	2.3	5.0	6.1	1.2	0.5	72.4	508.5
Nov	52	6.5-9.0	7.0	0.26	1.7	5.1	3.2	1.2	0.0	72.4	417.7
Dec	58	6.5-9.0	6.5	0.26	1.3	5.6	3.0	1.4	1.9	72.4	392.0

Table 16. Current TVS and ambient water quality for 303(d) listed segment of the Snake River at sites below North Fork Snake River. Concentrations are given as 85^{th}% values.

Copper concentrations are well below their temporary modification of 17 µg l^{-1}, and they are in attainment of TVS for six months of the year. Concentrations hover between 5.0 and 8.0 µg l^{-1} from May through October. Zinc concentrations meet their temporary modification of 654 µg l^{-1} for the entire year. Concentrations are lowest in

June and July and highest in March, September and October. Similar to cadmium, zinc concentrations are approximately five to seven times the chronic table value standard. The ambient lead concentration is in attainment of TVS for all months of the year except December. Ambient pH values attain TVS, and a pH value at or around 7.0 s.u., is met in April through November.

Acute exceedances in the Snake River below the confluence with the North Fork Snake River were similar in detail, although fewer exceedances occurred for all metals but zinc. Acute cadmium trout standards were exceeded in ninety-nine of the two hundred twenty-five samples (44%). Acute copper standards exceedances were about half of those observed above the North Fork with sixteen of the two hundred twenty-five samples exceeding the acute standard (16%). All of the samples were in attainment of the acute lead standard; however, 97% of the samples exceeded the acute zinc standard (216 out of 223 samples).

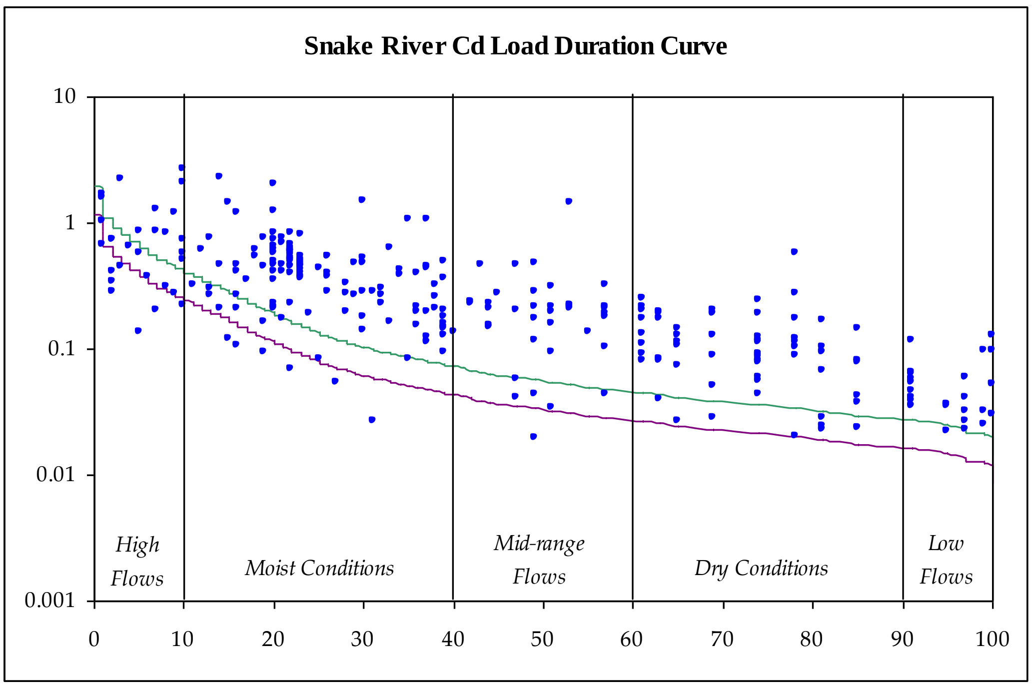


Figure 6. Load duration curve for dissolved cadmium for entire Snake River reach. Purple line represents TVS loads at a hardness of 50 mg/L while green line represents chronic TVS loads at an average hardness of 100 mg/L.

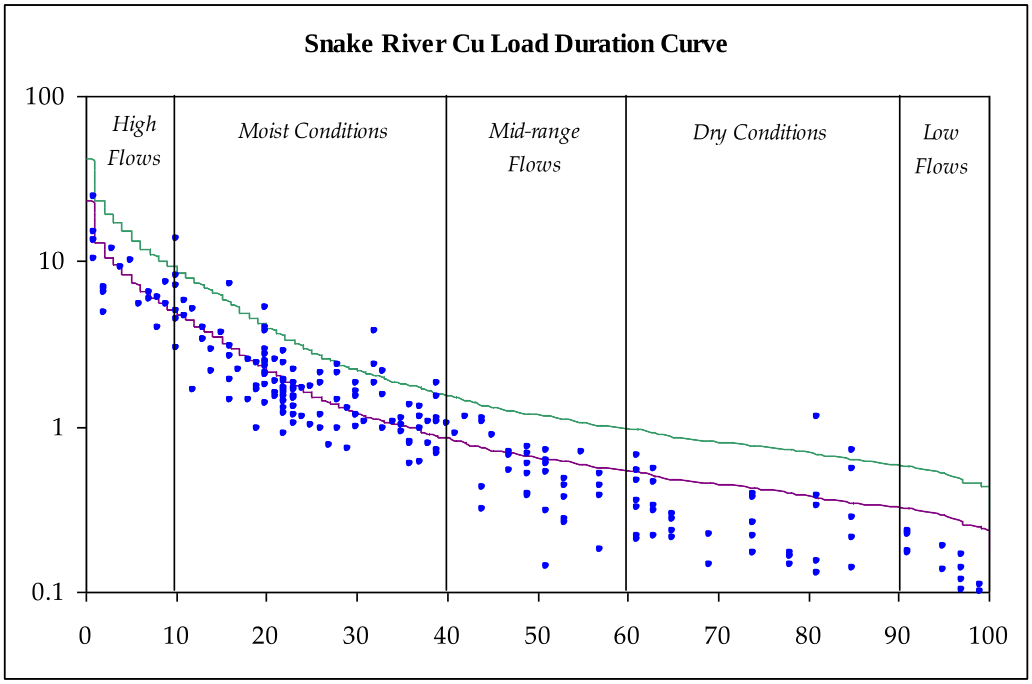


Figure 7. Load duration curve for dissolved copper for entire Snake River reach. Purple line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

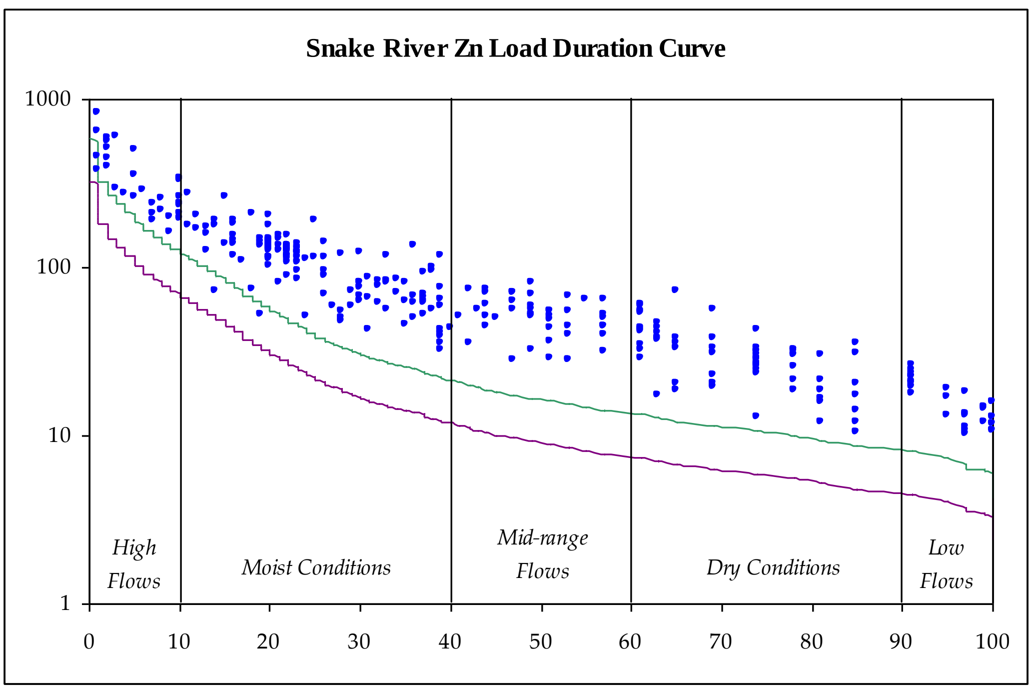


Figure 8. Load duration curve for dissolved zinc for entire Snake River reach. Purple line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

Figures 6 through 8, illustrate load duration curves for the mainstem of the Snake River for dissolved cadmium, dissolved copper, and dissolved zinc. Exceedances of the cadmium standard occurred primarily during low flows through moist conditions (Figure 6). Loads demonstrated attainment primarily during the highest decile of observed flows. As demonstrated by the green line, at higher hardness values (100 mg/L), more samples were in attainment of the dissolved cadmium standard. The variability in pollutant loading rates induced by hydrologic events may in fact have a beneficial effect on attainment of dissolved cadmium water quality standards. Rainfall events, similar to snow melt, may lead to significant short term increases in pollutant concentrations; however, the dilution effect may counteract the increases in concentration (Figure 6).

Exceedances of the copper standard, on the other hand, were observed during moist conditions and high flows (Figure 7). Some exceedances did however occur during mid-range flows and dry conditions. At a hardness value of 100 mg/L, less than 10 samples were not in compliance with the table value standard. Therefore, in this case, hydrologic events may have a detrimental effect on copper concentrations in the Snake River.

Exceedances of the zinc standard occurred during all flow conditions (Figure 8). At a hardness of 50 mg/L, no dates sampled are in attainment of the table value standard. At a hardness value of 100 mg/L, two samples were in attainment with the table value standard during moist flow conditions. Hydrologic events, consequently, do not have a predicted effect on zinc concentrations in the Snake River.

Current TVS Standards and Ambient Water Quality for Peru Creek

	Avg. Hardness, mg/L	pH Std.	Observed pH	Cd-D, TVS	Cd-D, ug/L	Cu-D, TVS	Cu-D, ug/L	Pb-D, TVS	Pb-D, ug/L	Mn-D, TVS	Mn-D, ug/L	Zn-D, TVS	Zn-D, ug/L
Jan	58	6.5-9.0	-	0.28	-	5.6	-	1.4	-	1375.9	-	78.1	-
Feb	61	6.5-9.0	4.9	0.29	5.2	5.9	60.3	1.4	7.2	1399.2	844.9	81.6	1398.2
Mar	60	6.5-9.0	5.6	0.29	5.3	5.8	69.7	1.4	4.3	1391.5	928.0	80.4	1640.0
Apr	61	6.5-9.0	5.9	0.29	5.5	5.9	64.3	1.4	5.9	1399.2	1138.5	81.6	1397.5
May	48	6.5-9.0	5.0	0.24	5.2	4.8	69.4	1.5	6.1	1291.8	1104.0	66.5	1264.0
Jun	36	6.5-9.0	5.1	0.20	6.3	3.7	102.0	1.5	7.1	1173.8	1298.5	52.0	1487.5
Jul	44	6.5-9.0	4.7	0.23	5.7	4.4	167.0	1.5	6.0	1254.9	1009.0	61.7	1508.5
Aug	41	6.5-9.0	5.1	0.22	3.4	4.2	56.6	1.5	4.8	1225.7	680.0	58.1	955.0
Sep	57	6.5-9.0	4.7	0.28	4.6	5.5	108.6	1.4	6.0	1367.9	976.0	77.0	1290.0
Oct	54	6.5-9.0	4.3	0.27	7.3	5.3	230.3	1.4	7.5	1343.5	1418.0	73.5	1700.0
Nov	59	6.5-9.0	5.4	0.28	5.7	5.7	75.5	1.4	5.8	1383.7	980.0	79.3	1369.7
Dec	56	6.5-9.0	5.0	0.27	4.4	5.5	60.0	1.4	4.0	1359.9	810.0	75.8	1300.0

Table 17. Current TVS and ambient water quality for 303(d) listed segment on Peru Creek. Concentrations are given as 85^{th}% values.

In Segment 7, the TVS standards were exceeded in all months of the year for all of the listed metals except manganese. Values observed for pH never reached 6.0 s.u, and remained significantly below the TVS standard of 6.5-9.0 s.u. in all months of the year. The highest ambient stream concentrations (85^{th} %) for the dissolved metals occurred during months of both low and high flow. The highest cadmium and copper concentrations were observed in October. Lead, and zinc concentrations were also highest in October, coinciding with a low stream flow period. Manganese was highest in October and June, which represented the only months Peru Creek did not attain its chronic manganese standard. Cadmium, copper, lead, and zinc were not in attainment of table value standards for any month of the year. Manganese was in attainment of TVS for nine months of the year. Zinc concentrations in Peru Creek continued to have average concentrations greater than 1000 $\mu g\ l^{-1}$ for ten months of the year except August (Table 17).

Acute exceedances in Peru Creek occurred for all metals but dissolved manganese and lead. Acute cadmium trout standards were exceeded in thirty-six of the forty-three samples (84%). Acute copper standard exceedances were approximately equal with forty of the forty-seven samples exceeding the acute standard (85%). All of the samples were in attainment of the acute lead and manganese standards; however, 96% of the samples exceeded the acute zinc standard (46 out of 48 samples).

Figures 9 through 13 illustrate load duration curves for the mainstem of Peru Creek for dissolved cadmium, dissolved copper, dissolved lead, dissolved manganese, and dissolved zinc. Exceedances of the cadmium standard occurred primarily during low flows through moist conditions (Figure 9). Cadmium loads rarely demonstrated attainment during any flow regime. As demonstrated by the green line, at higher hardness values (100 mg/L), only two additional samples were in attainment of the dissolved cadmium standard. The variability in pollutant loading rates induced by hydrologic events may in fact have a beneficial effect on attainment of dissolved cadmium water quality standards. Rainfall events, similar to snow melt, may lead to significant short term increases in pollutant concentrations; however, the dilution effect may counteract the increases in concentration (Figure 9).

Exceedances of the copper standard also occurred during all flow patterns (Figure 10). At a hardness value of 100 mg/L, approximately ten samples were in compliance with the table value standard as opposed to seven at a hardness of 50 mg/L. However, those values in attainment were primarily during moist conditions and the upper decile of flow values.

Exceedances of the lead standard also occurred during all flow patterns but were more evident during dry conditions and periods of low flow (Figure 11). At a hardness value of 100 mg/L, more samples were in compliance with the table value standard. However, those values in attainment were primarily during moist conditions and the upper decile of flow values. The variability in pollutant loading rates induced by hydrologic events may in fact have a beneficial effect on attainment of dissolved lead water quality standards. Rainfall events, similar to snow melt, may lead to significant short term increases in pollutant concentrations; however, the dilution effect may counteract the increases in concentration (Figure 11).

Contrary to the other listed metals, exceedances of the manganese standard primarily occurred during mid-range flow and moist conditions (Figure 12). When exceedances are observed, it is primarily at hardness values of less than 100 mg/L. At a hardness value of 100 mg/L, only two samples were not in attainment with the table value standard. Hydrologic events, consequently, do not have a significant effect on manganese concentrations in Peru Creek.

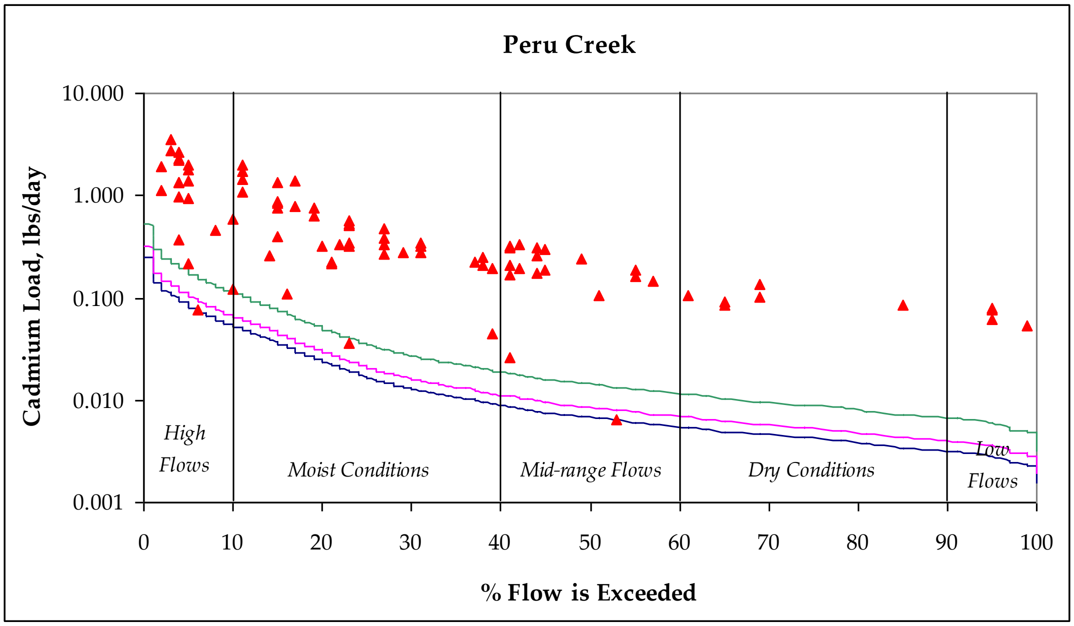


Figure 9. Load duration curve for dissolved cadmium for Peru Creek. Blue line represents TVS loads at a hardness of 36 mg/L, pink line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

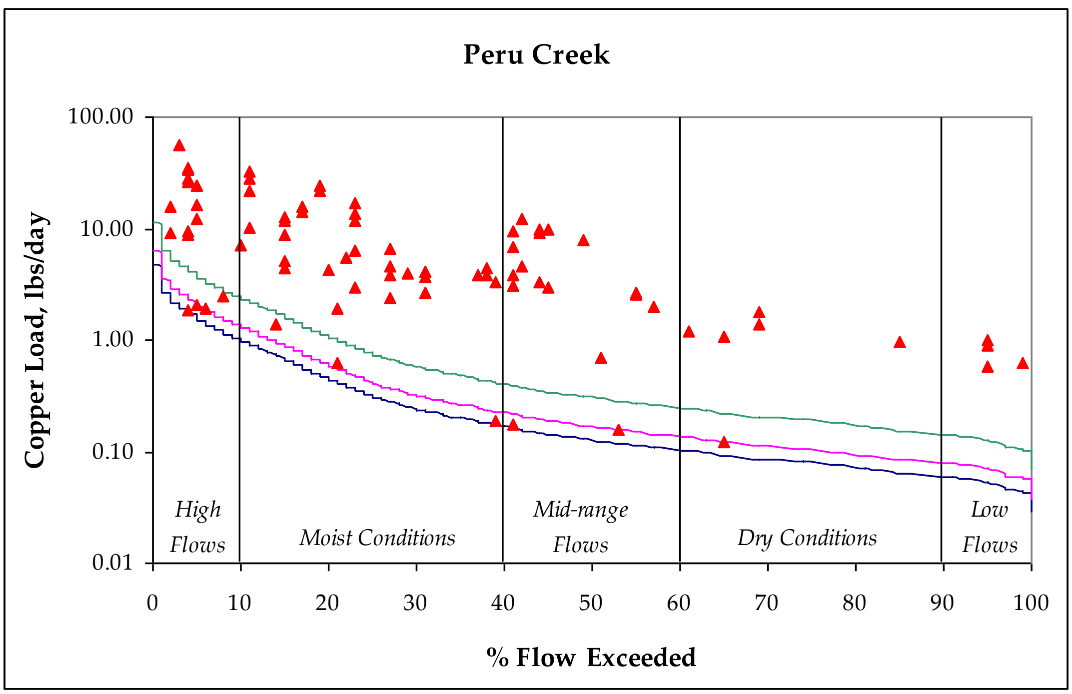


Figure 10. Load duration curve for dissolved copper for Peru Creek. Blue line represents TVS loads at a hardness of 36 mg/L, pink line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

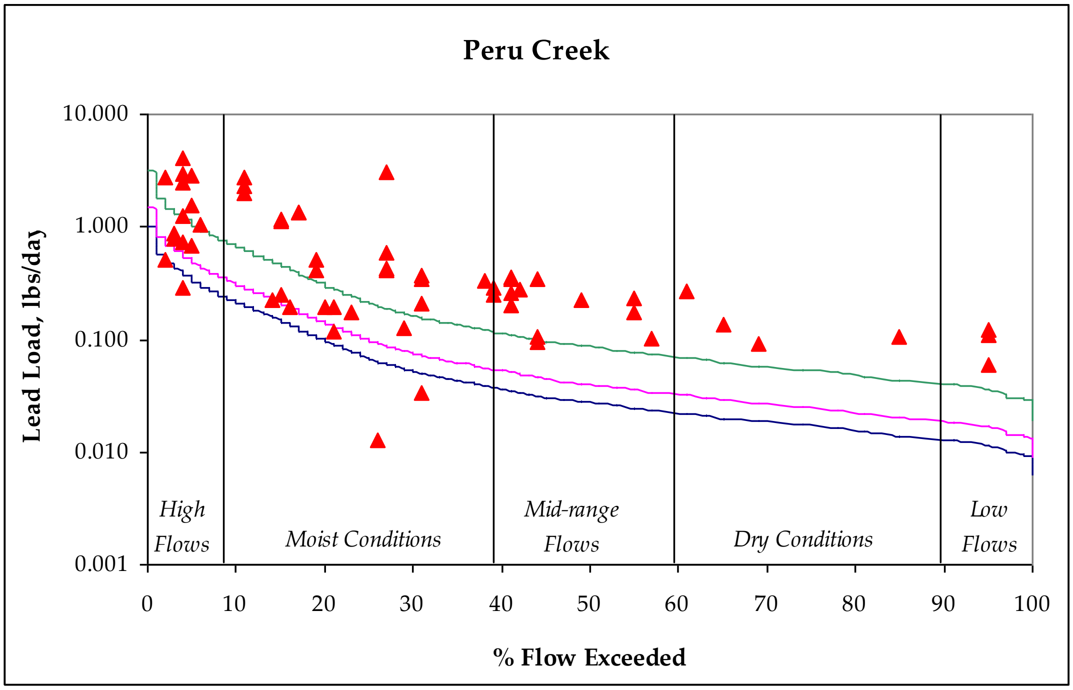


Figure 11. Load duration curve for dissolved lead for Peru Creek. Blue line represents TVS loads at a hardness of 36 mg/L, pink line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

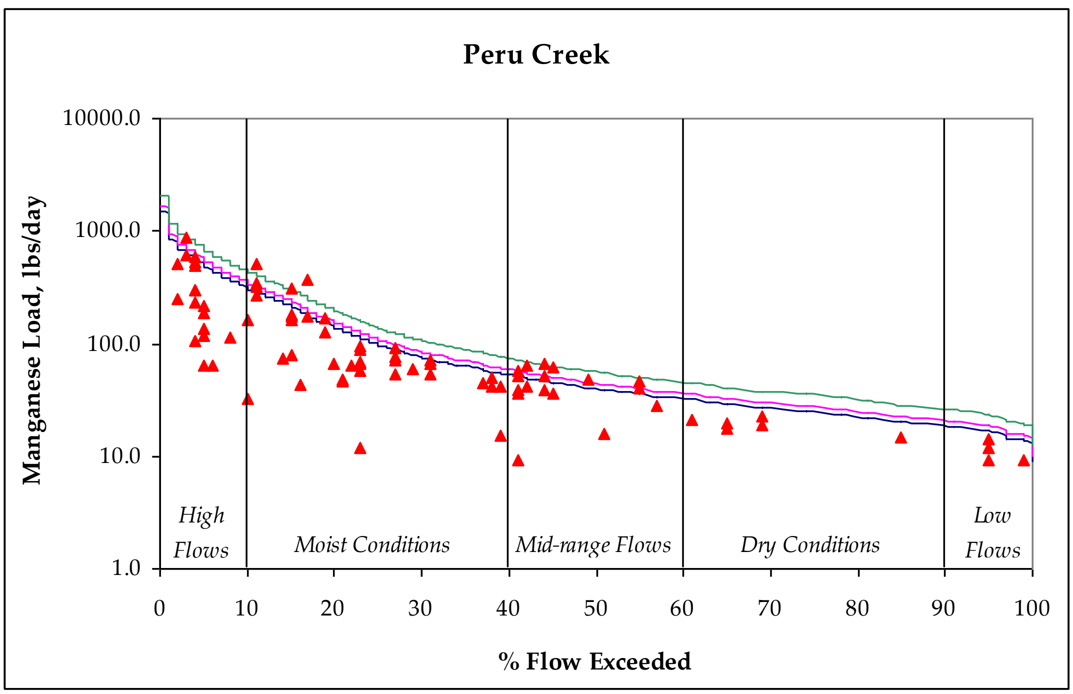


Figure 12. Load duration curve for dissolved manganese for Peru Creek. Blue line represents TVS loads at a hardness of 36 mg/L, pink line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

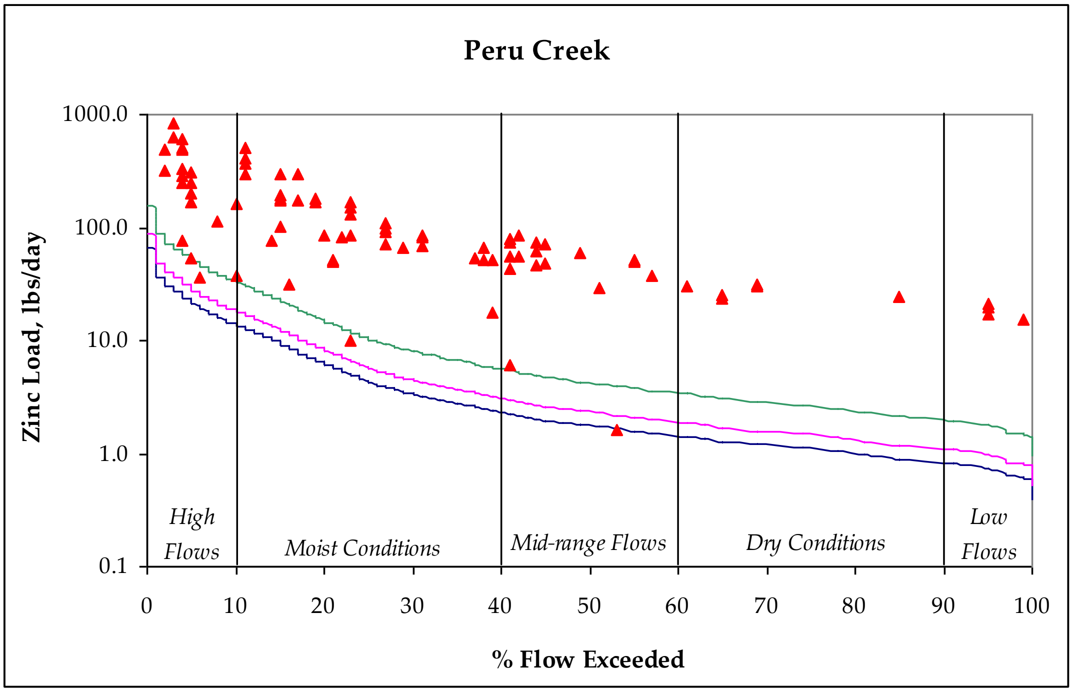


Figure 13. Load duration curve for dissolved zinc for Peru Creek. Blue line represents TVS loads at a hardness of 36 mg/L, pink line represents TVS loads at a hardness of 50 mg/L while green line represents TVS loads at an average hardness of 100 mg/L.

Exceedances of the zinc standard occurred during all flow conditions (Figure 13). Attainment of the standard occurred during high to mid-range flows (N=4). At a hardness of 50 mg/L, only one date sampled is in attainment of the table value standard. At a hardness value of 100 mg/L, four samples were in attainment with the table value standard through mid-range flow conditions. Hydrologic events, consequently, are not a reliable predictor for attainment of the chronic zinc standard in Peru Creek.

As demonstrated in Table 18, concentrations of heavy metals in supporting tributaries were varied. Deer Creek met the TVS for all metals. Due to a significant increase in observed water quality after 1988, ambient concentrations for Deer Creek were calculated from 1989-2006. Saints John Creek exceeded the TVS for cadmium, lead and zinc while attaining the standards for copper. The North Fork Snake River attained all of the TVS for its segment. Keystone Gulch, a smaller tributary to the Snake River, is also considered a healthy tributary, meeting the TVS for every metal but cadmium and copper. Because of low hardness values, cadmium table value standards are very stringent, and difficult to attain. All of the Snake River tributaries do, however, meet the temporary modifications for the segment.

Of the Peru Creek tributaries, Chihuahua Gulch is the only segment that meets current TVS standards for metals (cadmium, copper, lead, manganese, and zinc) (Table 18). Both Cinnamon and Warden Gulches are significant sources of heavy metals to Peru Creek, and ambient pH concentrations do not exceed 4.0 s.u.. Copper concentrations in Cinnamon Gulch are above 200 $\mu g\ l^{-1}$, while zinc concentrations in Warden Gulch exceed 11,000 $\mu g\ l^{-1}$. These are 46 and 224 times the current TVS, respectively. Manganese TVS are also exceeded on both Cinnamon and Warden Gulches, with ambient concentrations of 3170 $\mu g\ l^{-1}$ and 7750 $\mu g\ l^{-1}$, respectively.

Figure 14 demonstrates the impacts of Cinnamon and Warden Gulch on ambient metals concentrations in Peru Creek. Concentrations of copper and lead are highest after Cinnamon Gulch, while cadmium and zinc are highest after Warden Gulch. Currently, TVS are met for cadmium and copper at a sampling point above the Pennsylvania Mine on Peru Creek.

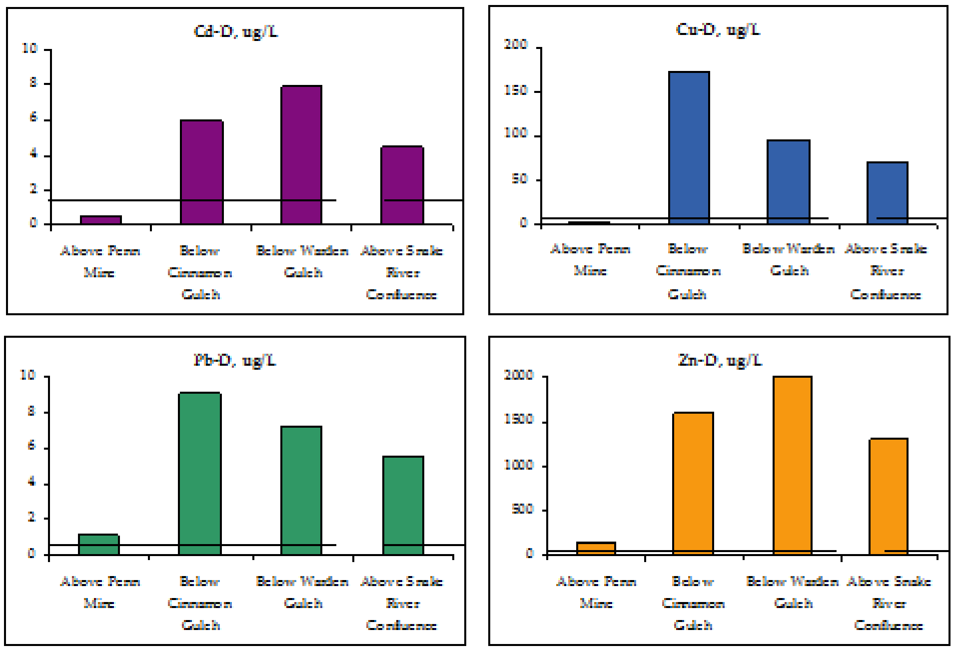


Figure 14. Ambient metals concentrations along 303(d) listed segment of Peru Creek. Distance downstream increases from left to right.

	Snake River Tributaries								Peru Creek Tributaries					
	Deer Creek		Saints John Creek		North Fork Snake		Keystone Gulch		Cinnamon Gulch		Warden Gulch		Chihuahua Gulch	
Pollutant	TVS Standard	Ambient Conc**., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}	TVS Standard	Ambient Conc., μg l^{-1}
Hardness	-	36	-	69	-	38	-	34	-	48	-	61	-	36
pH	6.5-9.0	6.6	6.5-9.0	6.7	6.5-9.0	7.4	6.5-9.0	6.5	6.5-9.0	3.7	6.5-9.0	3.8	6.5-9.0	6.9
Cd-D	0.2	0.02	0.3	0.8	0.2	0.0	0.2	0.3	0.2	9.0	0.3	37.6	0.2	0.0
Cu-D	3.7	1.7	6.5	0.0	3.9	1.5	3.3	15.6	4.8	223.1	5.9	61.6	3.7	0.0
Mn-D	-	-	-	-	-	-	-	-	1291.8	3170.0	1399.2	7749.5	1173.8	5.2
Pb-D	0.6	0.1	1.7	3.0	0.9	0.0	0.8	0.0	1.1	47.8	1.5	1.2	0.6	0.0
Zn-D	52.0	41	90.6	392.0	54.5	7.8	49.6	15.7	66.5	1770.0	81.6	11481.5	52.0	0.8

** Ambient concentration calculated from 1989-2006.

Table 18. Current TVS and ambient water quality for tributaries to the Snake River and Peru Creek. Concentrations are given as 85^{th}% values.

VII. SOURCES, TECHNICAL, ANALYSIS, AND TMDL ALLOCATIONS

7.0 Total Maximum Daily Loads (TMDL)

A TMDL is comprised of the load allocation (LA), which is that portion of the pollutant load attributed to natural background or the non-point sources, the Waste Load Allocation (WLA), which is that portion of the pollutant load associated with point source discharges and abandoned mine influence, and a Margin of Safety (MOS). The TMDL may also include an allocation reserved to accommodate future growth. The TMDL may be expressed as the sum of the LA, WLA, and MOS.

TMDL = WLA + LA + MOS

TMDL = Sum of Waste Load Allocations + Sum of Load Allocations + Margin of Safety

Waste Load Allocations (WLA)

There is one identified point source to this segment, Keystone ski area. The metal load calculated from the discharger was calculated using the design capacity for flow multiplied by the effluent concentration (assuming the concentration in the effluent is equal to the standard). An average stream hardness of 53 mg/L was used to calculate TVS. Historic effects from abandoned mines however, are also treated as non-permitted point sources in Segment 7 of this TMDL.

Load Allocation (LA)

All other sources that were examined are considered non-point sources and are therefore accountable to load allocations. Load calculations were done by subtracting the WLA from the TMDL. Where the ambient stream load was higher than the TMDL a load reduction was calculated.

Margin of Safety (MOS)

According to the Federal Clean Water Act, TMDLs require a margin of safety (MOS) component that accounts for the uncertainty about the relationship between the pollutant loads and the receiving waterbody. The margin of safety may be explicit (a separate value in the TMDL) or implicit (included in factors determining the TMDL). In the case of the Snake River/Peru Creek TMDL, the margin of safety lies in the calculation of the allowable TMDL based on 30-day chronic low flows, which illustrates the stream's "critical condition". Ambient stream loads were calculated using median stream flows. As a result, proposed reductions also address exceedances of the acute cadmium (trout) standard as well as all other acute standards assigned to these listed segments. The proposed reductions are conservative over-estimates of the reductions needed in order to attain chronic standards; however, they also take into account the stringent acute standards for cadmium.

The TMDL was calculated using a monthly chronic flow estimated from USGS gage #09047500 with Equations 1 through 4, multiplied by the existing stream standard and a conversion factor (0.0054) to approximate a load in pounds/day. Metals concentrations were interpolated to obtain daily concentrations. Eighty-fifth percentile concentrations were calculated from daily values on a monthly basis and multiplied by monthly median flows and a conversion factor (0.0054) to estimate a daily load in pounds/day.

Acute and chronic low flows were calculated using USEPA DFLOW software. Acute (1E3) and chronic (30E3) flows are biologically based low flows. Biologically-based design flows are intended to measure the actual occurrence of low flow events with respect to both the duration and frequency (i.e., the number of days aquatic life is subjected to flows below a certain level within a period of several years). Although the extreme value analytical techniques used to calculate hydrologically-based design flows have been used extensively in the field of hydrology and in state water quality standards, these methods do not capture the cumulative nature of effects of low flow events because they only consider the most extreme low flow in any given year. By considering all low flow events with a year, the biologically-based design flow method accounts for the cumulative nature of the biological effects related to low flow events. Acute low flows (1E3) refer to single low flow events that occur once in a three year period. Chronic low flows (30E3) refer to 30-day low flow periods which occur once in three years. A conservative element is included with the use of chronic low flows and median monthly stream flows which more closely approximates the critical condition in the Snake River and Peru Creek. By incorporating the critical condition into the calculation of the TMDL, load reductions tend to be overestimated.

Cadmium						
Snake River above Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.006	0.0	0.006	0.064	0.058	91%
Feb	0.006	0.0	0.006	0.056	0.050	90%
Mar	0.006	0.0	0.006	0.056	0.050	89%
Apr	0.006	0.0	0.006	0.072	0.066	92%
May	0.006	0.0	0.006	0.314	0.309	98%
Jun	0.007	0.0	0.007	0.514	0.506	99%
Jul	0.007	0.0	0.007	0.581	0.573	99%
Aug	0.007	0.0	0.007	0.118	0.111	94%
Sep	0.008	0.0	0.008	0.234	0.226	96%
Oct	0.008	0.0	0.008	0.102	0.094	92%
Nov	0.007	0.0	0.007	0.217	0.209	97%
Dec	0.006	0.0	0.006	0.074	0.067	92%
Annual Load:	0.081	0.0	0.081	2.401	2.320	97%

Table 19. Cadmium total maximum daily load allocations for the upper portion of Segment 6, from the headwaters of the Snake River to immediately above the Peru Creek confluence. Stream loads are given for dissolved cadmium. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows

Copper						
Snake River above Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.117	0.0	0.117	0.534	0.416	78%
Feb	0.114	0.0	0.114	0.307	0.193	63%
Mar	0.127	0.0	0.127	0.417	0.291	70%
Apr	0.112	0.0	0.112	0.439	0.327	74%
May	0.114	0.0	0.114	2.246	2.132	95%
Jun	0.136	0.0	0.136	3.596	3.460	96%
Jul	0.140	0.0	0.140	2.323	2.183	94%
Aug	0.138	0.0	0.138	1.534	1.396	91%
Sep	0.164	0.0	0.164	1.489	1.325	89%
Oct	0.157	0.0	0.157	0.829	0.672	81%
Nov	0.147	0.0	0.147	0.620	0.474	76%
Dec	0.126	0.0	0.126	0.442	0.317	72%
Annual Load:	1.592	0.0	1.592	14.777	13.185	89%

Table 20. Copper total maximum daily load allocations for the portion of Segment 6, the upper portion of Segment 6, from the headwaters of the Snake River to immediately above the Peru Creek confluence. Stream loads are given for dissolved copper. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Lead						
Snake River above Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.029	0.0	0.029	0.013	-0.016	0%
Feb	0.027	0.0	0.027	0.000	-0.027	0%
Mar	0.031	0.0	0.031	0.000	-0.031	0%
Apr	0.027	0.0	0.027	0.000	-0.027	0%
May	0.026	0.0	0.026	0.135	0.109	81%
Jun	0.028	0.0	0.028	1.027	1.000	97%
Jul	0.029	0.0	0.029	0.529	0.500	94%
Aug	0.030	0.0	0.030	0.000	-0.030	0%
Sep	0.037	0.0	0.037	0.174	0.137	79%
Oct	0.037	0.0	0.037	0.000	-0.037	0%
Nov	0.035	0.0	0.035	0.052	0.017	32%
Dec	0.030	0.0	0.030	0.035	0.005	14%
Annual Load:	0.367	0.0	0.367	1.965	1.598	81%

Table 21. Lead total maximum daily load allocations for the portion of Segment 6, the upper portion of Segment 6, from the headwaters of the Snake River to immediately above the Peru Creek confluence. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Zinc						
Snake River above Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	1.63	0.0	1.63	15.41	13.78	89%
Feb	1.58	0.0	1.58	10.93	9.35	86%
Mar	1.76	0.0	1.76	14.85	13.10	88%
Apr	1.56	0.0	1.56	16.67	15.11	91%
May	1.59	0.0	1.59	75.54	73.95	98%
Jun	1.89	0.0	1.89	116.12	114.23	98%
Jul	1.95	0.0	1.95	70.40	68.45	97%
Aug	1.92	0.0	1.92	38.50	36.58	95%
Sep	2.29	0.0	2.29	29.42	27.13	92%
Oct	2.18	0.0	2.18	24.74	22.56	91%
Nov	2.04	0.0	2.04	18.37	16.33	89%
Dec	1.75	0.0	1.75	16.48	14.73	89%
Annual Load:	22.14	0.0	22.14	447.43	425.29	95%

Table 22. Zinc total maximum daily load allocations for the portion of Segment 6, the upper portion of Segment 6, from the headwaters of the Snake River to immediately above the Peru Creek confluence. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Cadmium						
Snake River below Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.052	0.0	0.052	0.099	0.047	48%
Feb	0.050	0.0	0.050	0.093	0.044	47%
Mar	0.048	0.0	0.048	0.085	0.036	43%
Apr	0.047	0.0	0.047	0.141	0.093	66%
May	0.051	0.0	0.051	0.889	0.839	94%
Jun	0.080	0.0	0.080	1.700	1.620	95%
Jul	0.082	0.0	0.082	1.148	1.067	93%
Aug	0.081	0.0	0.081	0.550	0.469	85%
Sep	0.092	0.0	0.092	0.454	0.362	80%
Oct	0.068	0.0	0.068	0.274	0.205	75%
Nov	0.065	0.0	0.065	0.178	0.114	64%
Dec	0.060	0.0	0.060	0.124	0.064	51%
Annual Load:	0.777	0.0	0.7766	5.736	4.960	86%

Table 23. Cadmium total maximum daily load allocations for the portion of Segment 6, the Snake River just below the Peru Creek confluence. Stream loads are given for dissolved cadmium. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Copper						
Snake River below Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.4481	0.0	0.4481	0.556	0.108	19%
Feb	0.4331	0.0	0.4331	0.635	0.202	32%
Mar	0.4181	0.0	0.4181	0.752	0.334	44%
Apr	0.3467	0.0	0.3467	1.052	0.705	67%
May	0.3173	0.0	0.3173	2.602	2.285	88%
Jun	0.4462	0.0	0.4462	7.096	6.650	94%
Jul	0.5046	0.0	0.5046	7.099	6.594	93%
Aug	0.4835	0.0	0.4835	4.572	4.089	89%
Sep	0.5785	0.0	0.5785	6.962	6.384	92%
Oct	0.5092	0.0	0.5092	5.050	4.540	90%
Nov	0.5067	0.0	0.5067	0.440	-0.067	0%
Dec	0.4671	0.0	0.4671	0.747	0.279	37%
Annual Load:	5.459	0.0	5.459	37.562	32.103	85%

Table 24. Copper total maximum daily load allocations for the portion of Segment 6, the Snake River just below the Peru Creek confluence. Stream loads are given for dissolved copper. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Lead						
Snake River below Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.1183	0.0	0.118	0.000	-0.118	0%
Feb	0.1133	0.0	0.113	0.000	-0.113	0%
Mar	0.1083	0.0	0.108	0.000	-0.108	0%
Apr	0.0851	0.0	0.085	0.000	-0.085	0%
May	0.0722	0.0	0.072	0.074	0.002	2%
Jun	0.0990	0.0	0.099	0.140	0.041	29%
Jul	0.1191	0.0	0.119	0.000	-0.119	0%
Aug	0.1151	0.0	0.115	0.000	-0.115	0%
Sep	0.1458	0.0	0.146	0.410	0.264	64%
Oct	0.1283	0.0	0.128	0.000	-0.128	0%
Nov	0.1305	0.0	0.131	0.000	-0.131	0%
Dec	0.1216	0.0	0.122	0.000	-0.122	0%
Annual Load:	1.357	0.0	1.357	0.624	-0.733	0%

Table 25. Lead total maximum daily load allocations for the portion of Segment 6, the Snake River below the Peru Creek confluence. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Zinc						
Snake River below Peru Creek Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	6.23	0.0	6.23	50.74	44.51	88%
Feb	6.02	0.0	6.02	58.40	52.38	90%
Mar	5.81	0.0	5.81	69.52	63.71	92%
Apr	4.82	0.0	4.82	96.77	91.95	95%
May	4.42	0.0	4.42	294.59	290.18	99%
Jun	6.20	0.0	6.20	593.83	587.63	99%
Jul	7.01	0.0	7.01	339.38	332.37	98%
Aug	6.72	0.0	6.72	195.32	188.61	97%
Sep	8.04	0.0	8.04	146.83	138.79	95%
Oct	7.08	0.0	7.08	120.44	113.36	94%
Nov	7.04	0.0	7.04	72.60	65.56	90%
Dec	6.49	0.0	6.49	60.66	54.16	89%
Annual Load:	75.87	0.0	75.87	2099.07	2023.20	96%

Table 26. Zinc total maximum daily load allocations for the portion of Segment 6, the Snake River below the Peru Creek confluence. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Cadmium						
Snake River above North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.010	0.0	0.010	0.099	0.090	90%
Feb	0.009	0.0	0.009	0.093	0.084	90%
Mar	0.009	0.0	0.009	0.085	0.076	89%
Apr	0.009	0.0	0.009	0.141	0.132	94%
May	0.009	0.0	0.009	0.889	0.880	99%
Jun	0.015	0.0	0.015	1.700	1.685	99%
Jul	0.015	0.0	0.015	1.148	1.133	99%
Aug	0.015	0.0	0.015	0.550	0.535	97%
Sep	0.017	0.0	0.017	0.454	0.437	96%
Oct	0.013	0.0	0.013	0.274	0.261	95%
Nov	0.012	0.0	0.012	0.178	0.166	93%
Dec	0.011	0.0	0.011	0.124	0.113	91%
Annual Load:	0.145	0.0	0.1447	5.736	5.591	97%

Table 27. Cadmium total maximum daily load allocations for the portion of Segment 6, the Snake River below Peru Creek and above the North Fork Snake River. Stream loads are given for dissolved cadmium. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Copper						
Snake River above North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.199	0.0	0.199	0.269	0.070	26%
Feb	0.188	0.0	0.188	0.209	0.021	10%
Mar	0.183	0.0	0.183	0.181	-0.003	0%
Apr	0.178	0.0	0.178	0.306	0.128	42%
May	0.185	0.0	0.185	2.453	2.268	92%
Jun	0.287	0.0	0.287	5.575	5.289	95%
Jul	0.296	0.0	0.296	4.260	3.964	93%
Aug	0.298	0.0	0.298	1.815	1.517	84%
Sep	0.350	0.0	0.350	1.804	1.454	81%
Oct	0.253	0.0	0.253	0.956	0.704	74%
Nov	0.241	0.0	0.241	0.571	0.329	58%
Dec	0.229	0.0	0.229	0.417	0.188	45%
Annual Load:	2.886	0.0	2.886	18.816	15.929	85%

Table 28. Copper total maximum daily load allocations for the portion of Segment 6, the Snake River below Peru Creek and above North Fork Snake River. Stream loads are given for dissolved copper. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Lead						
Snake River above North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.051	0.0	0.051	0.000	-0.0506	0%
Feb	0.047	0.0	0.047	0.000	-0.0471	0%
Mar	0.046	0.0	0.046	0.000	-0.0456	0%
Apr	0.044	0.0	0.044	0.000	-0.0437	0%
May	0.042	0.0	0.042	0.229	0.1865	81%
Jun	0.063	0.0	0.063	0.000	-0.0629	0%
Jul	0.067	0.0	0.067	0.000	-0.0674	0%
Aug	0.070	0.0	0.070	0.000	-0.0704	0%
Sep	0.086	0.0	0.086	0.000	-0.0863	0%
Oct	0.060	0.0	0.060	0.000	-0.0597	0%
Nov	0.059	0.0	0.059	0.000	-0.0588	0%
Dec	0.058	0.0	0.058	0.000	-0.0576	0%
Annual Load:	0.693	0.0	0.693	0.229	-0.4636	0%

Table 29. Lead total maximum daily load allocations for the portion of Segment 6, the Snake River below Peru Creek and above North Fork Snake River. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Zinc						
Snake River above North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	2.76	0.0	2.76	34.51	31.75	92%
Feb	2.62	0.0	2.62	31.42	28.80	92%
Mar	2.54	0.0	2.54	27.36	24.82	91%
Apr	2.47	0.0	2.47	43.18	40.71	94%
May	2.57	0.0	2.57	280.91	278.34	99%
Jun	3.99	0.0	3.99	430.59	426.60	99%
Jul	4.12	0.0	4.12	258.50	254.38	98%
Aug	4.14	0.0	4.14	131.61	127.46	97%
Sep	4.85	0.0	4.85	108.96	104.11	96%
Oct	3.51	0.0	3.51	75.89	72.38	95%
Nov	3.35	0.0	3.35	48.40	45.04	93%
Dec	3.18	0.0	3.18	36.27	33.09	91%
Annual Load:	40.11	0.0	40.11	1507.59	1467.48	97%

Table 30. Zinc total maximum daily load allocations for the portion of Segment 6, the Snake River below Peru Creek and above North Fork Snake River. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Cadmium						
Snake River below North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.014	0.0001	0.013	0.123	0.110	89%
Feb	0.014	0.0001	0.013	0.108	0.095	87%
Mar	0.014	0.0001	0.013	0.092	0.078	85%
Apr	0.014	0.0001	0.013	0.131	0.118	90%
May	0.014	0.0001	0.014	0.844	0.829	98%
Jun	0.021	0.0001	0.021	1.503	1.481	99%
Jul	0.022	0.0001	0.021	1.086	1.064	98%
Aug	0.023	0.0001	0.023	0.549	0.526	96%
Sep	0.024	0.0001	0.024	0.405	0.381	94%
Oct	0.021	0.0001	0.021	0.329	0.308	94%
Nov	0.018	0.0001	0.018	0.191	0.173	90%
Dec	0.015	0.0001	0.015	0.132	0.117	88%
Annual Load:	0.214	0.0001	0.018	5.493	5.279	96%

Table 31. Cadmium total maximum daily load, waste load allocation, and load allocations for the portion of Segment 6, the Snake River below the North Fork Snake River to the confluence with Dillon Reservoir. Stream loads are given for dissolved cadmium, waste loads are given for potentially dissolved cadmium. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Copper						
Snake River below North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.274	0.002	0.2722	0.249	-0.0256	0%
Feb	0.270	0.002	0.2677	0.214	-0.0553	0%
Mar	0.270	0.002	0.2677	0.173	-0.0962	0%
Apr	0.274	0.002	0.2722	0.306	0.0318	10%
May	0.277	0.002	0.2747	3.868	3.5915	93%
Jun	0.412	0.002	0.4102	9.528	9.1155	96%
Jul	0.423	0.002	0.4214	4.726	4.3024	91%
Aug	0.448	0.002	0.4461	2.111	1.6633	79%
Sep	0.490	0.002	0.4879	1.268	0.7780	61%
Oct	0.422	0.002	0.4200	1.036	0.6139	59%
Nov	0.366	0.002	0.3637	0.566	0.2004	35%
Dec	0.309	0.002	0.3075	0.321	0.0120	4%
Annual Load:	4.235	0.024	4.2113	24.367	20.1317	83%

Table 32. Copper total maximum daily load, waste load allocation, and load allocations for the portion of Segment 6, the Snake River below the North Fork Snake River to the confluence with Dillon Reservoir. Stream loads are given for dissolved copper, waste loads are given for potentially dissolved copper. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Lead						
Snake River below North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.067	0.0002	0.067	0.000	-0.0668	0%
Feb	0.066	0.0002	0.066	0.000	-0.0658	0%
Mar	0.066	0.0002	0.066	0.000	-0.0658	0%
Apr	0.067	0.0002	0.067	0.000	-0.0668	0%
May	0.063	0.0002	0.063	0.000	-0.0629	0%
Jun	0.088	0.0002	0.088	0.000	-0.0879	0%
Jul	0.082	0.0002	0.082	0.000	-0.0821	0%
Aug	0.104	0.0002	0.104	0.000	-0.1040	0%
Sep	0.117	0.0002	0.116	0.000	-0.1166	0%
Oct	0.101	0.0002	0.101	0.000	-0.1013	0%
Nov	0.088	0.0002	0.088	0.000	-0.0878	0%
Dec	0.074	0.0002	0.074	0.000	-0.0743	0%
Annual Load:	0.982	0.003	0.979	0.0000	-0.9819	0%

Table 33. Lead total maximum daily load, waste load allocation, and load allocations for the portion of Segment 6, the Snake River below the North Fork Snake River to the confluence with Dillon Reservoir. Stream loads are given for dissolved lead, waste loads are given for potentially dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Zinc						
Snake River below North Fork Load Allocation, lbs/day						
	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	3.81	0.030	3.78	34.37	30.57	89%
Feb	3.75	0.030	3.72	26.76	23.01	86%
Mar	3.75	0.030	3.72	29.61	25.86	87%
Apr	3.81	0.030	3.78	36.65	32.84	90%
May	3.84	0.030	3.81	229.08	225.23	98%
Jun	5.74	0.030	5.71	409.96	404.22	99%
Jul	5.88	0.030	5.85	241.24	235.36	98%
Aug	6.23	0.030	6.20	125.80	119.57	95%
Sep	6.80	0.030	6.77	108.82	102.02	94%
Oct	5.86	0.030	5.83	78.79	72.93	93%
Nov	5.08	0.030	5.05	47.56	42.48	89%
Dec	4.30	0.030	4.27	36.66	32.36	88%
Annual Load:	58.86	0.37	58.49	1405.29	1346.43	96%

Table 34. Zinc total maximum daily load, waste load allocation, and load allocations for the portion of Segment 6, the Snake River below the North Fork Snake River to the confluence with Dillon Reservoir. Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Cadmium						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.008	0.007	0.001	-	-	-
Feb	0.008	0.007	0.001	0.170	0.161	95%
Mar	0.008	0.007	0.001	0.171	0.163	95%
Apr	0.008	0.007	0.001	0.211	0.203	96%
May	0.008	0.007	0.001	0.584	0.576	99%
Jun	0.009	0.008	0.001	2.215	2.206	100%
Jul	0.010	0.008	0.001	0.892	0.883	99%
Aug	0.009	0.008	0.001	0.295	0.286	97%
Sep	0.011	0.010	0.002	0.297	0.286	96%
Oct	0.010	0.008	0.001	0.388	0.378	97%
Nov	0.009	0.008	0.001	0.240	0.230	96%
Dec	0.008	0.007	0.001	0.170	0.161	95%
Annual Load	0.108	0.093	0.015	5.632	5.533	98%

Table 35. Cadmium total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved cadmium. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Copper						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.165	0.156	0.008	-	-	-
Feb	0.172	0.163	0.009	1.963	1.791	91%
Mar	0.170	0.161	0.008	2.267	2.097	93%
Apr	0.172	0.163	0.009	2.479	2.307	93%
May	0.155	0.148	0.008	7.852	7.696	98%
Jun	0.167	0.158	0.008	35.857	35.690	100%
Jul	0.187	0.178	0.009	26.333	26.145	99%
Aug	0.166	0.158	0.008	4.892	4.726	97%
Sep	0.220	0.209	0.011	7.034	6.814	97%
Oct	0.191	0.182	0.010	12.268	12.077	98%
Nov	0.193	0.183	0.010	3.181	2.988	94%
Dec	0.171	0.162	0.009	2.313	2.142	93%
Annual Load	2.128	2.022	0.106	106.438	104.474	98%

Table 36. Copper total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved copper. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Manganese						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Avg. Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	40.3	30.6	9.7	-	-	-
Feb	41.0	31.1	9.8	27.5	-13.5	0%
Mar	40.7	31.0	9.8	30.2	-10.6	0%
Apr	41.0	31.1	9.8	43.9	2.9	7%
May	42.0	31.9	10.1	124.9	82.9	66%
Jun	52.3	39.8	12.6	456.5	404.2	89%
Jul	52.9	40.2	12.7	159.1	106.2	67%
Aug	48.7	37.0	11.7	58.8	10.0	17%
Sep	54.4	41.3	13.0	63.2	8.9	14%
Oct	48.5	36.9	11.7	75.5	27.0	36%
Nov	46.7	35.5	11.2	41.3	-5.4	0%
Dec	42.6	32.4	10.2	31.2	-11.4	0%
Annual Load	551.1	418.8	132.3	1112.1	601.3	54%

Table 37. Manganese total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved manganese. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Lead						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Avg. Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	0.041	0.031	0.010	-	-	-
Feb	0.041	0.031	0.010	0.235	0.194	83%
Mar	0.041	0.031	0.010	0.138	0.097	70%
Apr	0.041	0.031	0.010	0.228	0.187	82%
May	0.047	0.036	0.012	0.693	0.645	93%
Jun	0.068	0.051	0.017	2.496	2.428	97%
Jul	0.062	0.047	0.016	0.943	0.881	93%
Aug	0.060	0.045	0.015	0.410	0.351	85%
Sep	0.056	0.042	0.014	0.388	0.332	85%
Oct	0.052	0.039	0.013	0.398	0.347	87%
Nov	0.048	0.036	0.012	0.243	0.196	80%
Dec	0.044	0.033	0.011	0.154	0.110	71%
Annual Load	0.602	0.452	0.151	6.327	5.766	91%

Table 38. Lead total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved lead. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

Zinc						
Peru Creek TMDL, lbs/day						
	TMDL, lbs/day	WLA for non-permitted dischargers, lbs/day	LA, lbs/day	Avg. Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL
Jan	2.29	2.04	0.25	-	-	-
Feb	2.39	2.13	0.26	45.48	43.09	95%
Mar	2.35	2.10	0.26	53.34	50.99	96%
Apr	2.39	2.13	0.26	53.86	51.48	96%
May	2.16	1.92	0.24	143.05	140.88	98%
Jun	2.32	2.06	0.26	522.92	520.60	100%
Jul	2.60	2.32	0.29	237.86	235.26	99%
Aug	2.31	2.06	0.25	82.51	80.20	97%
Sep	3.06	2.72	0.34	83.59	80.53	96%
Oct	2.66	2.36	0.29	90.56	87.90	97%
Nov	2.67	2.38	0.29	57.74	55.06	95%
Dec	2.37	2.11	0.26	50.11	47.73	95%
Annual Load	29.58	26.32	3.25	1421.01	1393.72	98%

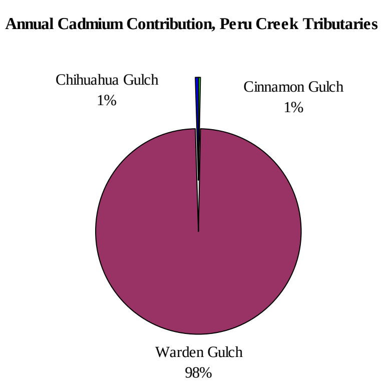
Table 39. Zinc total maximum daily load, waste load, and load allocations for Segment 7, Peru Creek at the mouth. Stream loads are given for dissolved zinc. TMDL loads were calculated with chronic low flows (30E3) by USEPA DFLOW software while stream loads were calculated from median monthly flows.

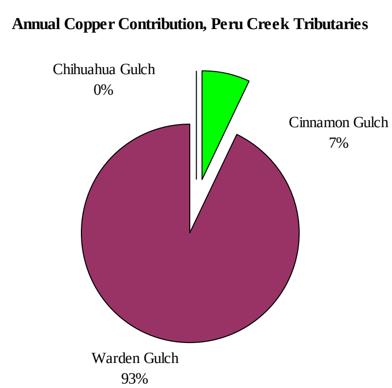
	Snake River				Peru Creek		
	Deer Creek	Saints John Creek	North Fork Snake	Keystone Gulch	Cinnamon Gulch	Warden Gulch	Chihuahua Gulch
Pollutant	Load Contribution, lbs/day	Load Contribution, lbs/day	Load Contribution, lbs/day	Load Contribution, lbs/day	Load Contribution, lbs/day	Load Contribution, lbs/day	Load Contribution, lbs/day
Cd-D	0.003	0.010	0.000	0.003	0.002	0.468	0.003
Cu-D	0.267	0.000	0.215	0.136	0.060	0.765	0.000
Pb-D	0.016	0.037	0.000	0.000	0.013	0.015	0.000
Zn-D	6.443	4.869	1.123	0.136	0.478	142.60	0.000

Table 40. Cadmium, copper, lead and zinc total maximum daily load contributions for the Snake River and Peru Creek tributaries. Stream loads are given for dissolved cadmium, copper, lead and zinc.

	Snake River				Peru Creek		
	Deer Creek	Saints John Creek	North Fork Snake	Keystone Gulch	Cinnamon Gulch	Warden Gulch	Chihuahua Gulch
Pollutant	Load Contribution, lbs/year	Load Contribution, lbs/year	Load Contribution, lbs/year	Load Contribution, lbs/year	Load Contribution, lbs/year	Load Contribution, lbs/year	Load Contribution, lbs/year
Cd-D	1.1	3.7	0.0	1.0	0.9	170.7	1.1
Cu-D	97.5	0.0	78.3	49.6	22.0	279.3	0.0
Pb-D	5.7	13.6	0.0	0.0	4.7	5.4	0.0
Zn-D	2351.6	1777.1	409.8	49.8	174.4	52049.1	0.1

Table 41. Annual cadmium, copper, lead and zinc total maximum daily load contributions for the Snake River and Peru Creek tributaries. Stream loads are given for dissolved cadmium, copper, lead and zinc.





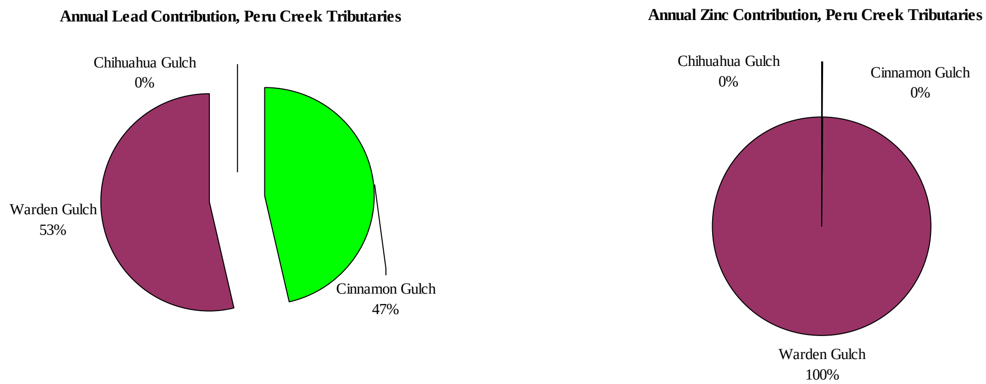


Figure 13. Annual percent contributions for the three major tributaries to Peru Creek; Cinnamon, Warden, and Chihuahua Gulch.

Additional Acute Standard Reductions											
January	February	March	April	May	June	July	August	September	October	November	December
17%	9%	31%	18%	0%	2%	0%	0%	6%	28%	3%	29%

Table 42. Additional monthly cadmium reductions required for the upper portion of the Snake River from its headwaters to the confluence with Peru Creek in order for the segment to attain acute cadmium trout standards.

In order to attain the TMDL, the Snake River must reduce its annual metals loads (Tables 19-34). The amount of load reduction necessary to meet the TMDL differs through differing stream reaches as demonstrated in Tables 19 through 34. A new, more stringent cadmium standard was adopted in the Basic Standards and Methodology for Surface Waters (5 CCR 1002-31) and became effective following the Upper Colorado Basin hearings in June 2008, thus increasing the TMDL load reduction for the Snake River.

The headwaters of the Snake River drain a region of disseminated pyrite before running through a naturally occurring iron bog. Natural weathering of pyrite produces waters in the upper Snake River that are acidic (pH 4.0) and have high concentrations of heavy metals (Bencala et al., 1987). The presence of this natural source of metals and acidity complicates remediation efforts, as background conditions may be sufficient to severely stress aquatic ecosystems along large sections of stream reach (Belanger, 2002). The load reductions in the Snake River are therefore treated as load allocations.

The annual cadmium load reduction begins at 97% above Peru Creek, becoming 86% directly below the confluence with Peru Creek after some flow dilution with Peru Creek, returns to a 97% reduction just above the North Fork Snake River, and concludes in a 96% reduction below the North Fork Snake River. Of the Snake River tributaries, Saints John Creek contributes the largest portion of the annual cadmium load to the Snake River (Tables 40-41). Cadmium loads are further broken down into monthly loads at each site. The highest load reductions are observed in the months of highest flow; May, June, and July. These months represent the largest disparity between median loads and loads based on chronic 30-day low flows, thus it exemplifies the critical condition of the Snake River. Additionally, a new, more stringent cadmium standard (by almost an order of magnitude) has also been adopted in the Basic Standards and Methodology for Surface Waters (5 CCR 1002-31) and has gone into place following the Upper Colorado Basin hearings in June 2008, thus increasing the TMDL load reduction for the Snake

River.

Annual copper load reductions are highest in the Snake River above Peru Creek with an annual reduction of 89% (Table 20). The amount of load reduction necessary to attain the TMDL decreases as it travels downstream with reductions of 85% below Peru Creek and above the North Fork Snake River, and 83% below the North Fork, respectively. Contrary to cadmium, of the major tributaries, Deer Creek contributes the largest portion of the copper load to the Snake River (Tables 40-41). Annual copper load reductions follow the same pattern as cadmium, with the months of highest flow generating the largest copper reductions.

Lead loading for the Snake River is in attainment of the TMDL for most of the year (Tables 21, 25, 29 and 33). Lead would only require an annual reduction to meet the TMDL in the Snake River above Peru Creek, with a load reduction of 81% required. The portion of the Snake River from the headwaters to Peru Creek is in attainment of the lead TMDL for six months of the year (Table 14). The months of May-July, September, and November-December all require reductions in the lead load. The sites on the Snake River directly below the confluence with Peru Creek meet the annual TMDL allocation; however, the months of May-June and September are not in attainment of their monthly allocations. Like cadmium, Saints John Creek contributes the largest lead load of the major Snake River tributaries (Tables 40-41). The Snake River directly above the North Fork does not require an annual load reduction for lead to meet the TMDL even though the month of May is not attaining its TMDL allocation (Table 29). No load reduction would be required for the Snake River below the North Fork to meet the TMDL loading allocations (Table 33).

In order to attain the TMDL for zinc, the Snake River must reduce its annual zinc load by 95 - 97% (Table 22, 26, 30, and 34). In addition, a new, more stringent zinc standard has also been adopted in the Basic Standards and Methodology for Surface Waters (5 CCR 1002-31) and will become effective following the Upper Colorado Basin hearings in June 2008, thus increasing the TMDL load reduction for the Snake River. There is little to no seasonality in the zinc load, as demonstrated by the monthly load reductions of over 90% year round at all of the locations along the Snake River. Deer Creek and Saints John Creek contribute more zinc to the Snake River annually than the other tributaries (Tables 40-41). The highest metal loadings to the Snake River annually come from Deer Creek (Tables 40-41). The low pH in the upper portion of the Snake River, however, may more likely be the result of the iron fen.

Exceedances of the acute standards were addressed by multiplying the sample data by monthly chronic load reductions. In the case of the Snake River from its headwaters to the inlet to Dillon Reservoir chronic monthly load reductions address acute exceedances of all of the acute dissolved cadmium (trout), copper, lead, and zinc standards.

Peru Creek requires significant reductions in metals loads in order to attain its chronic standards (Tables 35-39). The TMDL is divided into both Waste Load and Load Allocations. A separate waste load allocation is not required since there are no permitted dischargers to Peru Creek. The waste load allocation for the non-permitted discharges was determined first by calculating a background, or upstream concentration from sampling sites on Peru Creek above the Pennsylvania Mine. A concentration for downstream of the mine influence, Peru Creek at the mouth, was also calculated. The difference in upstream and downstream concentrations was attributed to mine influence. This percentage was then multiplied by the calculated TMDL to generate a WLA for abandoned mine sources. The percent reduction was calculated as the difference between the existing stream load (lbs/day) and the calculated TMDL (lbs/day) divided by the existing stream load. Eighty-six percent of the cadmium load was attributed to abandoned mine sources, while ninety-five percent of the copper load was considered to be from non-permitted discharges. Seventy-six percent of the manganese load and seventy-five percent of the lead load was considered to be from abandoned mine sources. Eight-nine percent of the zinc load was attributed to non-permitted point discharges and was therefore given a waste load allocation.

There is a slight seasonality to metals loads, with the greatest load reductions occurring in the months of May through August. An annual cadmium load reduction of 98% is required in order to attain chronic standards. An annual 98% reduction is needed in order to meet chronic copper standards. Similar to cadmium, reductions are required in every month. Manganese is in attainment of its TMDL for four months of the year. The months of April through October are the only months requiring load reductions resulting in an annual load reduction of 54%. Similar to cadmium and copper, all months of the year require reductions in both lead and zinc loads. An annual 91% reduction is required in order for lead to attain its TMDL while an annual 98% reduction is required in zinc loading.

Warden Gulch contributes the largest annual load of cadmium and copper to Peru Creek (Tables 40-41, Figure 13). Of the tributaries, Cinnamon and Warden Gulch are the largest contributors to lead load in Peru Creek (Tables 40-41, Figure 13). Warden Gulch contributes approximately one hundred percent of the annual zinc load to Peru Creek (Tables 40-41, Figure 13). Comparable to the Snake River, a heavy metal loading reduction would result in an increase in stream pH.

Exceedances of the acute standards in Peru Creek were addressed by multiplying the sample data by monthly chronic load reductions. If the monthly chronic reductions are accomplished, Peru Creek will be in attainment of its acute dissolved cadmium (trout), copper, lead, manganese, and zinc standards.

The metal ions in mine drainage can undergo hydrolysis reactions that release hydrogen ions if the solution is neutralized or oxidized. These metals ions represent a significant source of “latent” or “stored” acidity that has the potential to release additional H+ ions, re-lowering the pH. Values for pH in the Snake River and Peru Creek, Segments 6 and 7, are not in attainment of their acute and chronic standards. By addressing the sources of acid mine drainage (Cd, Cu, Pb, Mn and Zn contamination), contributions to the low pH values will also be ameliorated. This assumption can be verified upon implementation of abandoned mine remediation plans

Pennsylvania Mine Load Contribution lbs/day (@ 0.33 cfs)							
	Hardness	pH	Cd-D	Cu-D	Mn-D	Pb-D	Zn-D
Daily	555	2.8	0.51	12.32	59.0	0.059	106.6
Annual lbs/yr	--	--	186	4496	21529	21	38896

Table 43. Annual load contribution of Pennsylvania Mine to Peru Creek.

The Pennsylvania Mine contributes a significant load to Peru Creek. Annually, mine adit discharge contributes 186 pounds of cadmium, 4,496 pounds of copper, 21,529 ponds of manganese, 21 pounds of lead, and 39, 896 pounds of zinc (Table 43). Remediation of this site could potentially reduce the load to Peru Creek by an estimated 20 to 40% dependent upon parameters.

7.1 Previous Water Quality Improvements in the Watershed

There has been extensive water quality studies and data collection efforts focused on metals in the Snake River watershed. To address the problems associated with acid mine drainage and development pressures in the Snake River watershed, the Snake River Watershed

Task Force was formed in April 1999. For the past few years, the Snake River Task Force has been compiling available data and identifying gaps with the goal of developing projects that prevent, reduce, or eliminate pollution from the various sources in the basin (McKnight, 2001). The Task Force includes state and federal government agencies, public, industry, and other parties that are participating in the development of the TMDL for this watershed.

The Keystone Center, the University of Colorado, and a Task Force member (Diane McKnight) wrote an EPA grant (X-98840101-0, Mining Legacies in the Snake River Basin) in 2001 to further characterize the physical, chemical, and biological parameters within the upper Snake, upper Peru Creek, and reaches below the confluence (Hamlin, 2002). These surveys were coordinated with an EPA Brownfields Assessment Project.

Under a Clean Water Act Section 319 grant (ending September 2004) from USEPA Region VIII, the (SWQC) NWCCOG (in partnership with the Keystone Center and the Snake River Task Force) gathered all available water quality information (historic and current data) for this watershed, with the emphasis on the TMDL listed segments and parameters of concern. Under the 319 grant, a water quality database for the watershed was developed, which is now available to the public.

In 2001, EPA contracted a Snake River Technical Support Project, Site Assessment (Phase I/Phase II). This assessment evaluated, characterized, and documented water quality conditions in Peru Creek, and the impact of this creek on the water quality of the Snake River. Phase I of the assessment was undertaken during a low flow event in September 2001. Phase II was undertaken during a high flow event in May 2002 (peak runoff was decreased however due to severe drought).

Currently, the Pennsylvania Mine on Segment 7, and the associated mill tailings and waste piles, is being studied for potential NPL listing. Remediation of the Pennsylvania Mine and the surrounding area has the potential to greatly impact and improve water quality in the Snake River below its confluence with Peru Creek.

7.2 Rehabilitation of the Snake River Watershed

The primary objectives for the Snake River watershed are to institute a water quality treatment program for the Pennsylvania Mine discharge to reduce metals pollution, to redevelop the area into open space, and to establish a healthy trout fishery in the Snake River. A recent development in the ongoing rehabilitation is the inclusion of the EPA. The USEPA has designated the site for a removal action under CERCLA. EPA is currently preparing an Engineering Evaluation Cost Assessment (EECA) and a re-evaluation of the technical issues on the site for the preferred technology and cost associated with a passive treatment system. This removal action provides some liability protection since the action would be under the direction of an EPA On-Scene Coordinator. EPA is prepared to sign an Administrative Order on consent (AOC) that will provide CERCLA protection to the operator of the system. Options are currently being explored as to who would be responsible for continued operation of the system.

7.3 Monitoring

In order to insure that the TMDL is adequately protective of segments COUCBL06 and COUCBL07, and to evaluate the progress of heavy metal treatment from the Pennsylvania Mine, monitoring is required. A more thorough site investigation continues to be performed by USEPA, HMWMD, and the local watershed group in order to better quantify the current water quality of the Peru Creek drainage.

XIII. CONCLUSION

The goal of this TMDL is attainment of the TVS for cadmium, copper, lead, zinc, and pH within Segments COUCBL06, and additionally manganese in COUCBL07. Annual loading reductions in both the Snake River and Peru Creek are necessary to reach the TMDL.

IX. PUBLIC INVOLVEMENT

There has been a strong public participation in protecting and enhancing the water quality of the Snake River Watershed for several decades. Many organizations have been extensively involved including the Snake River Watershed Task Force, Northwest Colorado Council of Governments (NWCCOG), Colorado Department of Public Health and Environment, Environmental Protection Agency, US Geological Survey, US Forest Service, Colorado Division of Wildlife, Colorado Division of Minerals and Geology, University of Colorado (INSTAAR), Trout Unlimited, and a multitude of other entities from Summit County and around the state.

The public has had an opportunity to be involved in the Water Quality Control Commission (WQCC) hearings, and throughout the years, the WQCC has adopted new, temporary modifications for this segment where the public has had the opportunity to get involved. Opportunities have also been available through the 303(d) listing process which also has a public notice period for public involvement.

Public involvement was also achieved through collaboration with Lane Wyatt (NWCCOG) and the Snake River Watershed Task Force. Public participation will continue to promote future restoration of the Snake River Watershed, as new remediation possibilities are explored.

A draft of the TMDL was presented to the Snake River Watershed Task Force in May of 2007. A review and comment period was also made available to the public for the month of October, 2007. No public comments were received.

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APPENDIX G

Supplemental Information, Zinc Concentration/Loads Reduction Assessment

<u>*Appendix G figures and tables*</u>:

Figure G-4 – Interstation Regressions and Plots for Estimating Streamflows (PCDZ)

a. Snake River above Peru Creek (SW-047) vs. USGS Stream-Gage 09047500
b. Peru Creek at Mouth (SW-049) vs. USGS Stream-Gage 09047500
c. Snake River below Peru Creek (SW-047) vs. USGS Stream-Gage 09047500

Additional data concerning zinc concentrations and loadings and flow at selected sites are also on these spread sheets for the discerning reviewer. The data are organized as follows:

PCDZ:	SRabPC(Zn)	SW-47
	PeruCk(Zn)	SW-49
	SRblPC(Zn)	SW-50
LSRZ:	SRabNF(Zn)	SW-117
	NFSR(Zn)	SW-83
	SRblNF(Zn)	SW-82