Soda Butte Creek monitoring and sampling schemes
Final report for the Greater Yellowstone Network Vital Signs Monitoring Program
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SODA BUTTE CREEK and REESE CREEK: VITAL SIGNS MONITORING PROGRAM:

FINAL REPORT

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EXECUTIVE SUMMARY

We have put together a final report on the recommendations for the Soda Butte Creek and Reese Creek Vital Signs Monitoring Program. The purpose of the grant was to develop detailed protocols necessary to monitor the ecological health of Soda Butte Creek and Reese Creek in and near Yellowstone National Park. The main objectives was to compile existing information on these creeks into one database, document the current conditions of Soda Butte and Reese Creeks by a one-time synoptic sampling event, and present recommendations for vital signs monitoring programs tailored to each creek's needs.

The database is composed of information from government projects by the United States Geological Survey and the United States Environmental Protection Agency, graduate student master's theses, academic research, and private contractor reports. The information dates back to 1972 and includes surface water quality, groundwater quality, sediment contamination, vegetation diversity, and macroinvertebrate populations. All data have been entered into STORET by the EPA.

1.0 Reese Creek

1.1 Vital signs considered and selected.

Minimum in-stream flow. The simplest, most cost-effective, and least controversial vital sign is to measure in-stream flow. Currently, minimum instream flows are 1.3 cfs from April 15 through October 15, but only if the streamflow above the diversion is above 2.8 cfs. Moreover, the Fish and Wildlife has recommended minimum stream flows of 4.3 cfs from May 15-July 30 (FWS 1987). We recommend:

- Measuring in-stream flow **CONTINUOUSLY** at a minimum of two sites: (a) above the up-stream diversion, and (b) below the lowest diversion. Further, we recommend that discharge measurements be transmitted in real-time to the NPS. Real-time transmission is possible at Reese Creek through either radio frequency or wireless broadband to the town of Gardiner. Real-time transmission provides the ability to check on discharge for illegal diversions without having to go to the field site.
- Negotiate with the current water rights holders to increase in-stream flows from 1.3 cfs to 4.3 cfs from May 15-July 30.

Set minimum number of spawning fry in the impacted stream reach between the lower diversion and Yellowstone River. The ideal situation would be to conduct research as discussed in section 4.2.4 to determine the population goal for cutthroat trout in the impacted lower 0.8 stretch of Reese Creek. One potential drawback to such research is that it can be very difficult to establish what the trout population should be, given natural and large changes in climate, few other similar streams for comparison, and perturbations to the Yellowstone River itself. Interpretation of well-conducted research results may still be controversial. Therefore we recommend this vital sign as a future goal.

1.2 Objectives for vital signs selected

The objective of the vital signs is to maintain a viable cutthroat trout population that migrates to the Yellowstone River. There is no existing information on the baseline population of spawning fry prior to the water diversions. There appears to be no information on which to base an estimate of what a viable population of spawning trout fry would be. However, the US

Fish and Wildlife has produced an in-stream flow metric of 4.3 cfs from May 15-July 30 that most likely will lead to a stable trout population.

2.0 Soda Butte Creek

2.1 Vital signs considered and selected

Macro-invertebrates. Macroinvertebrate communities are very sensitive to stress and demonstrate responses to metals contamination (EPA 1990). Moreover, macroinvertebrate communities integrate over time potential impairment caused by metals content, where that metals content can vary substantially by more than a factor of two both diurnally and seasonally. There are numerous metrics that provide measures of the macro-invertebrate community diversity, including species richness, EPT index, Shannon diversity, and Shannon evenness. We recommend using the Montana Impairment Score because: (a) it integrates several indices into a score that is relatively easy to understand and hence can be communicated to the public; and (b) it is used by the State of Montana and hence has credibility with that land manager. *The vital sign is that the Montana Impairment Score be 0.75 or higher at the sampling site at the park boundary.*

Metals content in water and sediments. Distinguishing natural versus anthropogenic contributions of metals to Soda Butte Creek and resulting biological effects is made difficult by the unique hydrothermal characteristics of Yellowstone National Park and surrounding environments. For example, our measurements show that the highest arsenic concentrations occur in the Warm Creek control. There is no known mining activity associated with Warm Creek and hence the arsenic is most likely natural in origin. We thus take a conservative strategy with respect to metals content. *The vital sign is that a metals content in stream water exceeds Montana's DEQ numeric water quality standards (Circular WQB-7) at the park boundary.*

Status of the McLaren tailings pile. The tailings pile is currently stable and does not appear to be eroding. The worst-case scenario is a catastrophic failure of the tailings pile. Monitoring of the status of the tailings pile is essential to prevent resource damage within YNP. *We recommend that the NPS develop a neighborhood watch program to report any failures of the tailings pile.*

2.2 Objectives for vital signs selected

The primary objective for selecting vital signs is to detect impairment of biological, physical, and/or hydrologic resources within Yellowstone National Park by metals contamination transported in Soda Butte Creek. The second objective is to indicate the possibility of future resource damage to Yellowstone National Park, even if there is no resource damage occurring at the present time.

Catastrophic failure of the tailings pile is the worst possible situation. Because the tailings pile is located in the valley bottom adjacent to Soda Butte Creek, any disturbance to the tailings pile may result in rapid transmission of toxic metals to the creek. In turn, once metals are in the creek, they can be transmitted efficiently and quickly within the borders of Yellowstone National Park. Thus the chances of stopping the movement of trace metals into the park from a failure of the tailings pile is unrealistic. *Therefore we recommend that the YNP take the lead in partnering with other land managers to develop a remediation plan and budget to move the tailings pile out of the valley bottom and into a storage system with no hydrologic contact with Soda Butte Creek.*

Thus, the tailings pile should only be moved out of the watershed or well above the floodplain of Soda Butte Creek.

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1.0 INTRODUCTION

We report on our efforts to develop the detailed protocols necessary to monitor the ecological health of Soda Butte Creek and Reese Creek in and near Yellowstone National Park. Both these water bodies are on the State of Montana 303(d) list. Critical parameters or 'vital signs' that we are evaluating in and near the streams include (1) water quality, (2) toxic metals in bed sediments, (3) biological data, and (4) habitat quality.

2.0 OBJECTIVES

(1) Document existing ecological problems through (a) compilation of existing information into a database, and (b) one-time synoptic sampling

(2) Develop a monitoring strategy based on sampling critical parameters guided by the information from (1) to develop 'vital signs' that (a) assess the basic health and integrity to guide the decisions of land managers, and (b) do so in a rigorous fashion that can withstand legal challenge.

3.0 TASK A: COLLATE EXISTING INFORMATION INTO A DATABASE

We have compiled historical data concerning physical and ecological parameters in and near Soda Butte and Reese Creeks. The database contains two parts:

(1) Bibliography of references relating to the sites, and

(2) Data from a subset of the bibliographic materials

3.1 Soda Butte Creek

The amount of previous monitoring and research activities on Soda Butte Creek was larger than initially thought. The database is collated from a variety of sources, including graduate student work, government contracts, the Environmental Protection Agency (EPA), the United States Geological Survey (USGS) and academic research. The annual timeframe for individual projects ranged from the initiation of spring run-off in May through September to yearlong sampling events. Initial research was conducted in 1972 and continued sporadically through the mid-1990's. The data includes results from surface water, sediment, groundwater, soil, benthic invertebrates, and flora and fauna. The database also contains flow measurements, well data, and slug permeability tests. A list of references and a short description of the sources in the database follows.

3.1.1 Sources (in database)

Barret, Peter. August 24, 1987. Sampling Activities Report: McLaren Tailings, CookeCity, Montana. TDD# T08-8705-016. Ecology and Environment, Inc. Technical Assistance Team.

The goal of this study was to fully characterize the quality of surface and groundwater of the Soda Butte Creek watershed near the McLaren tailings pile in order to evaluate the potential threat to human health and the environment. Surface water, soil, sediment, and groundwater samples were collected to determine if a risk existed. Chemical analyses including metals were conducted on all samples.

Bureau of Reclamation. April 8, 1994. Response Action Report for the McLaren Tailings Site: Cooke City, Montana. Billings: Great Plains Region.

The report summarizes response actions that were conducted by Region VIII of the Environmental Protection Agency. The report includes a follow up on the reclamation activities to the McLaren tailings pile. The data collected for this report includes depth to water, ground to water, and water surface elevation.

Chadwick, James Woodrow. 1974. The effects of iron on the macroinvertebrates of Soda Butte Creek. Master's thesis. Montana State University, Bozeman, Montana

Water samples were taken monthly at five stations from May 1972 to June 1973. Water was analyzed for alkalinity, hardness, sulfate, orthophosphate, nitrate, iron, copper, zinc, manganese, magnesium, sodium, potassium and calcium.

Charters, David W., Gary A. Buchanan, and Richard G. Henry. 1988. McLaren Mine Tailing Pile: Cooke City, Montana. US EPA, Environmental Response Team. New Jersey.

The U.S. EPA environmental response team conducted a synoptic sampling event to examine the impact of the McLaren Mine tailings pile on Soda Butte Creek. A total of 29 stations were examined for the following water quality parameters: dissolved oxygen, pH, temperature, conductivity, and oxidation-reduction potential. Water, sediment and benthic invertebrate samples were gathered from 11 of the 29 sites. Water samples were analyzed for alkalinity, sulfate, sulfide, total suspended solids, total hardness, and the priority pollutant metals plus aluminum and iron. Sediments were analyzed for priority pollutant metals and total organic carbon. Benthic invertebrates were analyzed for density, species number, diversity, and evenness, and maximum diversity.

Environmental Protection Agency. 1995. EPA Assists NBS in Soda Butte Creek Monitoring Project.

Sampling was collected by the EPA in 1995 in order to characterize the level and extent of existing contamination and "baseline" conditions in the drainage during spring flow. The EPA collected chemical analyses on 26 water samples and 11 sediment samples. Flow measurements were collected when possible. Field measurements such as pH, conductivity, temperature, and flow were also collected.

Stoughton, J.A. 1995. The impacts of trace metals on grass communities along the floodplains of Soda Butte Creek, Montana and Wyoming. Master's thesis. Montana State University, Bozeman, Montana.

Research was conducted to determine the spatial extent of ecosystem disturbance due to deposition of metals along the floodplain of Soda Butte Creek. Four meadow sites downstream from the McLaren tailings pile were selected for this study. Vegetation density, biomass, and diversity information was collected from the meadow grass growing at each site.

United States Geological Survey. 2001. Yellowstone NAWQUA Water Quality Site #06187915.

As part of the NAWQUA program, USGS had a station located on Soda Butte Creek at the Yellowstone National Park boundary at Silver Gate from January 1999 to September 2001. Overall, 39 water quality samples were measured and reported.

3.1.2 Additional Sources

These sources were not included in the database because the site descriptions in the publication did not have sufficient information to relocate the sites.

Ladd, S.C.; W.A. Marcus, and S. Cherry. 1998. Differences in trace metal Concentrations among fluvial morphologic units and implications for sampling. Environmental Geology. ***36****(3-4): 259-270.*

The study examined the within and between differences of metals concentrations in fluvial morphologic units in sand-sized and finer bed sediments in Soda Butte Creek. The results showed that Eddy drop zones and attached bars had consistently higher metal concentrations.

Marcus, W. Andrew; Scott C. Ladd and Michael Crotteau. 1996. Channel Morphology and copper concentrations in streambed sediments. In Tailings and Mine Waste '96. Balkena: Rotterdam: 421-430.

Spatial variation of copper concentrations in fluvial morphologic units on Soda Butte Creek prove important for aquatic species and future sampling plans. It was found that hydraulic processes play the greatest role in spatial variations of copper concentrations at reach scales. However, geochemical processes can also play a significant role for within-unit temporal variations.

Marcus, W. Andrew; Grant A. Meyer; and DelWayne R. Nimmo. 2001. Geomorphic control of persistent mine impacts in a Yellowstone Park Stream and implications for the recovery of fluvial systems. Geology. ***29****(4): 355-358.*

Research conducted at Soda Butte Creek indicated that geomorphic processes controlling movement of contaminated sediments failed to lower copper concentrations in the floodplain during a 50-year and 100-year flood. This has major implications for the persistence of contaminated sediments to stay in the soil and cause impacts to the ecosystem on longer time scales.

Nimmo, DelWayne R.; Mary J. Wilcox, Toben D. LaFrancois; Phillip L. Chapman; Stephen F. Brinkman; and Joseph C. Greene. 1998. Effects of metal mining and milling on boundary waters of Yellowstone National Park, USA. Environmental Management. ***22****(6): 913-926.*

The purpose of the study was to determine baseline concentrations of metals in water, sediment and biota, the contribution of metals from the McLaren tailings, the toxicity of metals to aquatic species, and the influence of seasonal differences in discharge on metals in water and sediment of the aquatic ecosystem. The information collected and included in the database are: metal analysis of McLaren tailings pile water and sediment for spring and fall, LC_{50} values for interstitial and overlying water from Soda Butte Creek and Yellowstone National Park's northeast boundary, and metal concentrations from the tissue of macroinvertebrates from 10 sites on Soda Butte Creek.

Sergent, Hauskins and Beckwith. July 24, 1990. Geotechnical investigation report: Kennecott Corporation, McLaren Tailings Site, Cooke City, Montana. SHB Job #: E90-2129.

A geotechnical investigation was launched to evaluate groundwater and seepage conditions for the dam on the McLaren tailings pile. Based upon geologic data and static and dynamic slope stability analyses, the dam was found to be safe. No new remedial actions were recommended.

3.2 Reese Creek

The types of information in the following publications were not appropriate for the STORET database. However, the sources provide a rich history of the health of Reese Creek and the efforts to improve instream water rights and flow. They also detail some of the fish surveys that have been conducted to determine fish and fry populations in Reese Creek.

3.2.1 Sources (not included in database)

Kaeding, Lynn R.; Carty, Daniel G.; and Daniel L. Mahony. 1994. Annual project technical report for 1993. Fishery and Aquatic Management Program. Yellowstone National Park.
The streamflow in Reese Creek was found to be higher than the negotiated baseflow of 0.037 m/s^2 through the end of July. The emergence of cutthrout trout was also documented in areas that had be historically dewatered. Historical information on fish populations is limited but the emergence of fry does coincide with the dewatering of Reese Creek. The report also recommended that streamflow be closely monitored and that spawner surveys should be conducted to evaluate long-term effects of the new minimum flow agreements.

Mahoney, Daniel. 1987. Aquatic Resource Inventory and Fisheries Habitat Assessment in Reese Creek, Yellowstone National Park.
In 1986, an aquatic resource inventory and habitat assessment were conducted on Reese Creek through the summer season. Fish inventories were collected in conjunction with monitoring of natural and diverted streamflows. The fisheries habitat was rated as moderately high, with the exception of the areas subjected to dewatering. It was found that almost 91% of the streamflow was diverted during the spawning run. Reese Creek was also completely dewatered two weeks after the peak migration. It was found that the diversions may negatively impact the trout fisheries population.

National Park Service. 2000. Yellowstone Center for Resources: 1999 Annual Report. Yellowstone Center for Resources; National Park Service. Yellowstone National Park, Wyoming. YCR –AR-99.
Reese Creek is the only stream within Yellowstone National Park where water is withdrawn by private landowners. In 1991, a minimum flow agreement was reached in order to prevent seasonal dewatering. New self-cleaning fish screens were installed at the diversions to prevent fish from swimming into irrigation ditches. A study was performed on fish in Reece Creek in 1999 to determine if the fish screens worked. It was found that the screens were functioning as intended.

4.0 TASK B: SYNOPTIC SAMPLING

Field sampling was conducted during the week of October 7th, 2003. The sampling team was composed of Mark W. Williams and Meredith Knauf of the University of Colorado, and from Region VIII of the Environmental Protection Agency, Mike Wireman, Bill Schroeder, and Richard Evans, macroinvertebrate specialist. Jeff Arnold, water quality specialist from Yellowstone National Park also participated in the synoptic survey. A sampling and analysis plan was created and reviewed by Meredith Knauf and Bill Schroeder (see Appendix A). The plan was modified in the field based on conditions that were observed upon arrival.

4.1 Reese Creek

Reese Creek is the northernmost tributary of the Yellowstone River in Yellowstone National Park FWS 1987). Reese Creek's headwaters originate from Cache Lake and flows approximately 7.2 miles to the Yellowstone River. The Reese Creek Drainage basin encompasses 8327 acres and is bounded by Electric Peak on the west and Sepulcher Mountain on the east (FWS 1987). Its' fisheries has been listed as moderately high, with exception of the 2 km reach before the confluence with the Yellowstone River. Three diversions owned by private landowners are located at 0.8, 1.6, and 2.0 km upstream from the confluence of Reese Creek with the Yellowstone River (FWS 1994).

In 1926, Congress included the downstream portion of Reese Creek to Yellowstone National Park. However, the entire Reese Creek watershed did not officially become a part of the park until 1937. Even today, private land owners still retain the water rights to Reese Creek (FWS 1987). It is one of 12 tributaries that is used by Salmonids for spawning in Yellowstone National Park (FWS 1994).

The National Park Service has reported that the lowermost reach of Reese Creek goes dry during the spawning season (FWS 1987). In 1991, the park service was able to reach an agreement with private landowners for a required minimum flow. The adjudicated water rights stipulated that Reese Creek was to have minimum flows of 0.037 m^3/s between April 15 and October 15, and 50 percent of the available discharge the remainder of the year. However, if the discharge is less than 0.079 m^3/s, then the amount of water for minimum stream flow for Reese Creek decreases (FWS 1994).

Despite these efforts, Reese Creek has continued to go dry or nearly dry during drought years (FWS 1994). Other improvements have been added to the diversion structures on Reese Creek. Adjustable V-notched fish ladders, rotating fish screens to prevent fish from going into diversion ditches, and irrigation ditch headgates were laid in concrete foundations (FWS 1994). A study conducted by the US Fish and Wildlife Service noted improvement in the habitat for Reese Creek and the emergence of cutthroat trout fry (1994). They also determined that inadequate streamflow has limited the magnitude of trout populations in the lower 2 km of Reese Creek (FWS 1994).

Mark Williams and Meredith Knauf visited Reese Creek on the first day of the sampling event. During the sampling event, about ¼ of the streamflow above the first diversion was being diverted through the three diversion structures. A visual inspection of the stream and riparian habitat suggested little if any impacts. Based upon previous knowledge of Reese Creek and current site observations, the SAP was modified. The sampling team did not feel a full water quality analysis would be necessary.

A total of five water samples were collected in order to best represent the creek and the possible impacts to the creek. The first sampling site was located at the park boundary and about 100 m below the most downstream diversion. The next three sampling sites were located above and/or below a water diversion structure. The final site was selected as a control and is located upstream of all diversion structures. The samples were filtered *in situ* and delivered to the Kiowa and the DOC labs at the University of Colorado. Photographs were also taken at each site. Water samples were analyzed for pH, conductance, alkalinity, base cations, strong mineral acids, and ammonium. No biological or habitat quality information was collected.

4.2 Results for Reese Creek

4.2.1 Current Status of Ecosystem Health

Previous studies have noted that chemical concentrations and macroinvertebrate assemblages were considered good (Mahoney, 1987). There was no significant difference in the water quality parameters we measured in Reese Creek between the control before diversion of water and below the last diversion. These results are similar to the finding of good habitat quality by the US Fish and Wildlife Service (1987 and 1991). There has been a re-emergence of cutthroat trout fry in Reese Creek over the last decade. However, during the last decade there have been occasional unauthorized withdrawals of water that have resulted in dewatering of Reese Creek such that the cutthroat trout fry were not able to reach the main fork of the Yellowstone River (D. Mahoney, NPS, personal communication). The final 0.8 km before the confluence with the Yellowstone River is the most adversely impacted reach on Reese Creek. Despite adjudicated in-stream flows, NPS personnel have observed on several occasions that this reach continues to go dry in low water years (D. Mahoney, NPS, personal communication).

4.2.2 Normal limits of variation for vitals signs

There are three potential vital signs:

- In-stream flows;
- Target levels for cutthroat fry population; and
- Successful migration of fry from Reese Creek to the main stem of the Yellowstone river.

Reese Creek is a snowmelt-dominated system. We can expect more than a ten-fold range in discharge between peak flow in May/June and baseflow during the winter. The National Park Service has recommended minimum streamflows of 4.3 cfs from May 15-July 30 (FWS 1987). Their belief is that 4.3 cfs is the minimal streamflow at this time under natural conditions and normal climatic conditions.

The normal limits of variation for fish populations on Reese Creek are not known at this time. However, the section of Reese Creek above the first diversion is considered a moderately high quality fishery and should have fish communities similar to Cedar Creek and Mol Heron Creek (FWS, 1994). Population levels of cutthroat fry population in the affected stream areas can be set by the population levels above the diversion.

The normal limits of variation for spawning cutthroat fry in the 0.8 section of Reese Creek between the diversions and the main stem of the Yellowstone are not known. Moreover, year-to-year variation under natural conditions is expected to be high.

4.2.3 Past or Present Resource Damage

Prior to the establishment of minimum flows in Reese Creek in 1991, 91 percent of the streamflow from Reese Creek was diverted during the spawning run. This dewatering of the stream lead to the reduction of the number of fry in the lower reaches of Reese Creek because the lower section often went dry during trout spawning in July and August. In 1993 minimum instream flows were negotiated at 1.3 cfs from April 15 through October 15, but only if the streamflow above the diversion is above 2.8 cfs. If the stream is lower than 2.8 cfs, then the minimum stream flow also drops accordingly. Anecdotal observations include that water is “pirated” at times and diverted below the negotiated instream flow value.

4.2.4 Additional Research

An outstanding need is to determine what the natural population of cutthroat trout would be under natural conditions. One method would be to conduct fish population surveys to Cedar Creek and Mol Heron Creek and use these values as a baseline for Reese Creek. A second solution would be establish the baseline fry population in the impacted 0.8 mile stretch below the diversions either during high water years when there is adequate stream flow. A third possibility is to stop diversions for a year so that "natural" discharge conditions exist and census trout fry from June 15 to August 15.

Discharge measurements with high accuracy and high precision are a must. Colorado State University is working with the NPS to improve the rating curves necessary to estimate discharge from staff gages. We recommend this activity be continued.

4.2.5 Remedial Treatments

It is important that the National Park Service continue to work with private landowners and the forest service to acquire and purchase more water rights for Reese Creek. Dan Mahoney of the National Park Service has been working diligently on acquiring additional water rights for Reese Creek.

4.2.6 Compliance with existing laws and regulations

The state of Montana has designated Reese Creek a 303(d) listing because of impairment due to low flow. It is not know what flows were before diversion. However, the National Park Service has recommended minimum streamflows of 4.3 cfs from May 15-July 30 (FWS 1987). Currently, minimum instream flows were negotiated at 1.3 cfs from April 15 through October 15, but only if the streamflow above the diversion is above 2.8 cfs. If the stream is lower than 2.8 cfs, then the minimum stream flow also drops accordingly.

4.2.7 Endpoints of success/partial success for physical, biological, and chemical

Parameters

- Minimum in-stream flow
- Minimum census numbers of spawning fry in the impacted stream reach between the lower diversion and Yellowstone River.

4.3 Soda Butte Creek

Soda Butte Creek is a third order cobble and gravel bed stream with a laterally unstable wandering channel (Ladd et al 1998). Soda Butte Creek's headwaters originate near Henderson Mountain, 2 km east of Cooke City, Montana (Park County) and flows approximately 6 km into the northeast corner of Yellowstone National Park. Soda Butte Creek then flows 28 km and joins the Lamar River, which is a tributary of the Yellowstone River (Nimmo et al 1998). Along its course into Yellowstone National Park, Soda Butte Creek flows directly north of the McLaren tailings site, which is a large tailings pile consisting of 191,000 cubic meters of tailings (Sergent, Hauskins, and Beckwith 1990). The tailings pile consists of phyllosilicates, tectosilicates, sulfides, iron oxides, and calcium salts (Sergent, Hauskins, and Beckwith 1990). Although the actual path of Soda Butte Creek has been diverted around the tailings pile from its previous course directly through the tailings pile, evidence of perturbed water and habitat quality is still apparent downstream (Charters et al 1988, Nimmo et al 1998, Marcus et al 2001).

Soda Butte Creek is located in the Beartooth Mountains. The region has been subjected to extensive uplifting and thrust faulting that has exposed Precambrian crystalline rocks. Elevation ranges of the Soda Butte drainage is between 2300 and 2400 meters. The valley is steep sided and has morphological and lithological characteristics that are typical in glaciated landscapes. Elevations of mountain peaks in the area commonly exceed 3000 meters. The McLaren tailings site is characterized by three general geologic units which include Precambrian and tertiary age intrusive rocks, Pleistocene age sediments, and Holocene age sediments resulting from mining activity (Sergent, Hauskins, and Beckwith 1990).

Placer gold was discovered in the Cooke City area in 1869. Hard rock mining for gold and silver from the McLaren Mine near Daisy Pass was processed intermittingly at the McLaren mill site directly above the tailings pile from the 1870's until 1967. The mine has not been active since this time. There is a small pile of unprocessed ore still remaining at the mill site.

Even though Soda Butte Creek has been diverted around the tailings pile, water pathways through the tailings pile can contribute to decreased water quality in the stream. Possible pathways include overland and subsurface flow, seepage from rain and snowmelt, and inflow from Soda Butte Creek and subsurface flow in the Holocene alluvium below the tailings pile and dam (Sergent, Hauskins, and Beckwith 1990). Avalanches and other catastrophic events could alter the course of the stream or flush tailings into Soda Butte Creek despite remediation efforts. The role of groundwater transport is unknown.

The National Park Service reported an impoundment failure in June 1950 that spilled tailings into creek (Nimmo et al 1998). In 1969, the creek was rerouted and the tailings pile was leveled, graded and seeded with grass (Nimmo et al 1990). From 1989-1991, the EPA, through the Superfund program, conducted remediation activities at the McLaren tailing sites. The remediation project included construction of a small emergency dike, a stability dam, an embarkment drain, earth berm, and an open interceptor drain. Tailings were removed from the toe and were replaced with clean fill. The disturbed area was then reseeded (Bureau of Reclamation 1994).

A total of 20 stations were sampled on Soda Butte Creek and its tributaries (Figure 1, Table 1). The majority of sampling sites were sampled in previous studies (e.g. Nemmo et al., 1998). All samples were collected in accordance with the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Periphyton, Benthic Macroinvertebrates and Fish (EPA 842-B-99-002). Field procedures followed protocols for standard operating procedures and requirements listed in US EPA Region VIII – *Minimum Requirements for Field Sampling Activities*, United States Environmental Protection Agency Region VIII, September 1996. A complete list of sample parameters are in Table 2. All 20 stations were examined for non-analytical water quality parameters using a Hydrolab or YSI 650 multimeter. The non-analytical parameters measured include pH, temperature, dissolved oxygen and redox potential. Photographs, GPS coordinates, and detailed site descriptions were collected at each location. Finally, flow measurements were made at each sampling site using a Marsh McBirney flow meter.

4.3.1 Surface Water

Water samples were collected on eight sites on Soda Butte Creek, one site from the tailings pile, and eleven sites from the following tributaries: Republic Creek, Warm Creek, Miller Creek and Woody Creek (Figure 1). Surface water samples were collected from downstream to upstream to eliminate sediment disturbance in other sampling locations. Surface water was collected into a large bucket that was then used to pour off individual samples. Water samples were analyzed for hardness, mercury, dissolved metals and total metals, sulfate and alkalinity, and nitrate + nitrite. The bucket was rinsed three times with native water before sample collection began. Each sample container was rinsed three times before samples were collected. Water for the dissolved metals was filtered *in situ* using a 45-micron filter. Filtered water was used to rinse the dissolved metals container. Total metals, dissolved metals, and mercury samples were preserved using nitric acid to a pH <2. The nitrate and nitrite samples were preserved using sulfuric acid to a pH <2. Sulfate and alkalinity samples were stored on ice. Field duplicates were conducted at two locations. The Region VIII EPA laboratory performed the analyses. Discharge was measured at each site using the volume-area technique.

4.3.2 Sediment

Sixteen sediment samples were collected at fifteen sites. The sediment samples were collected using Teflon scoops and were placed in 60 ml plastic containers. All sediment samples were stored on ice. The sediment samples were analyzed for mercury, percent solids, and metals in solids by ICP. The Region VIII EPA laboratory performed the analyses.

4.3.3 Benthic Invertebrates

Benthic invertebrate samples were collected at a subset of 10 sites (Figure 1, Table 2). The sites were selected based upon availability and opportunity. From each location, three surber samples from riffles were collected at random. A qualitative composite over approximately 100 meters was also taken using a Qualitative D-ring net. All samples were elutriated (to lessen amounts of detritus) *in situ* and preserved in 95% ethanol. Physical habitat at each site was evaluated following the EPA Rapid Bioassessment Protocols.

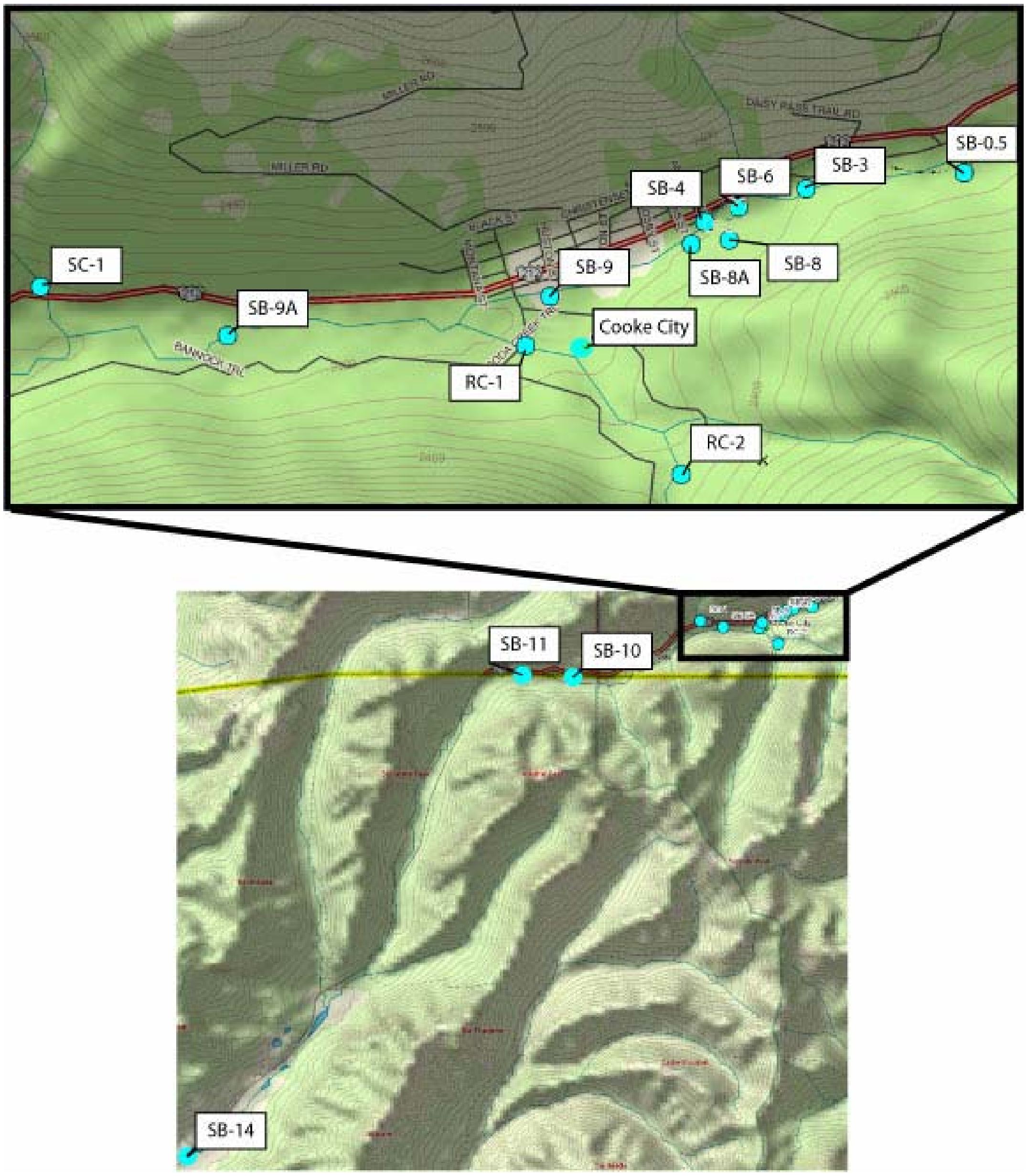
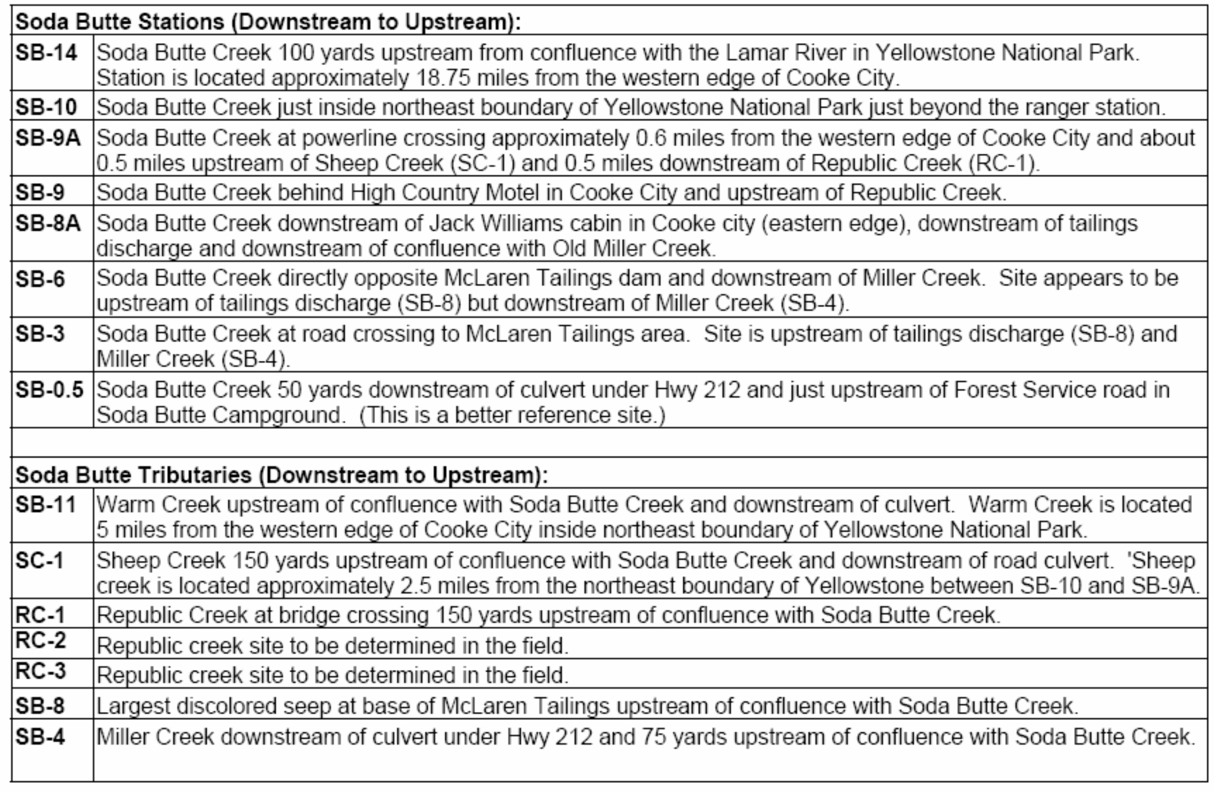


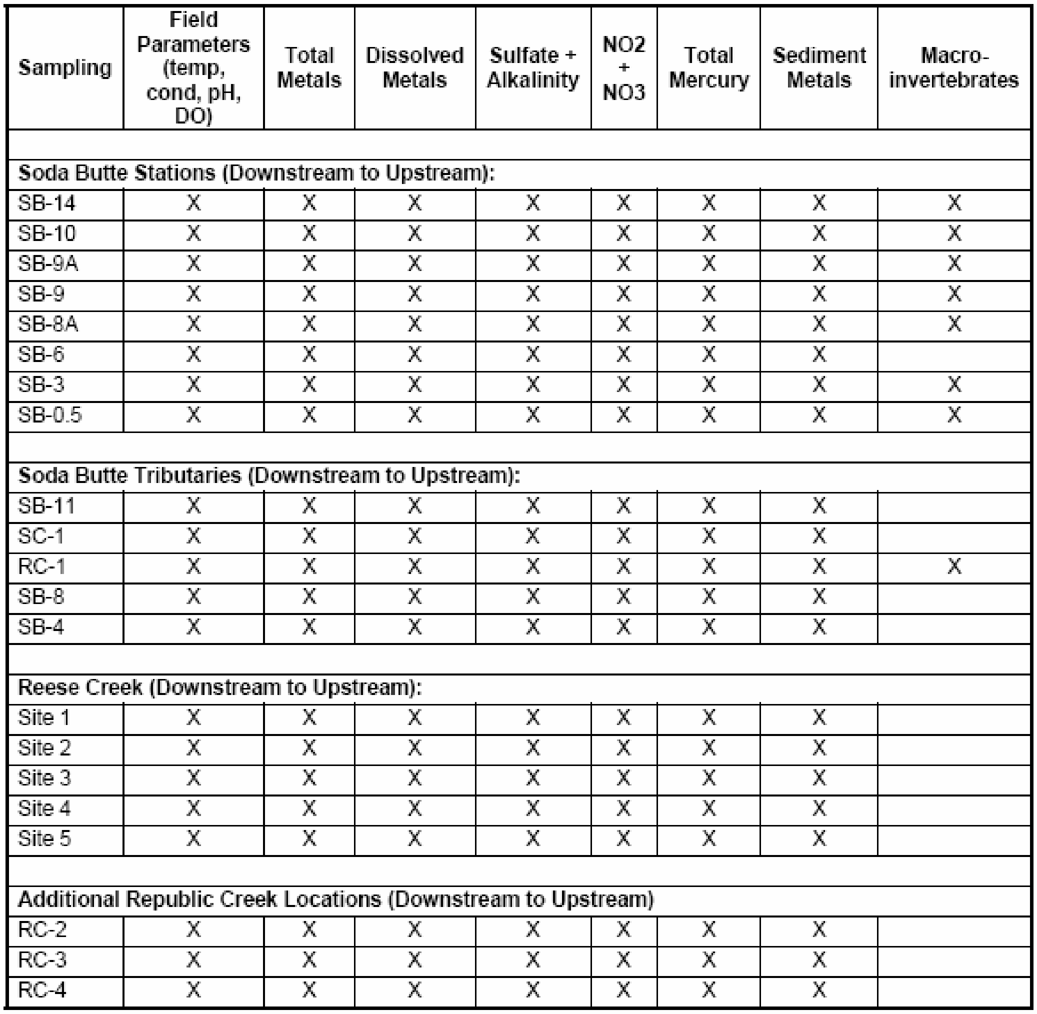
Figure 1. Map of sampling locations studied during the synoptic survey, Oct. 7-9, 2003. SB-0.5 is the most upstream sampling location (upstream of Cooke City, MT) and SB-14 is the most downstream sampling location (downstream of YNP boundary).

Table 1. Sampling stations for Soda Butte Creek and tributaries.



Soda Butte Stations (Downstream to Upstream):	
SB-14	Soda Butte Creek 100 yards upstream from confluence with the Lamar River in Yellowstone National Park. Station is located approximately 18.75 miles from the western edge of Cooke City.
SB-10	Soda Butte Creek just inside northeast boundary of Yellowstone National Park just beyond the ranger station.
SB-9A	Soda Butte Creek at powerline crossing approximately 0.6 miles from the western edge of Cooke City and about 0.5 miles upstream of Sheep Creek (SC-1) and 0.5 miles downstream of Republic Creek (RC-1).
SB-9	Soda Butte Creek behind High Country Motel in Cooke City and upstream of Republic Creek.
SB-8A	Soda Butte Creek downstream of Jack Williams cabin in Cooke city (eastern edge), downstream of tailings discharge and downstream of confluence with Old Miller Creek.
SB-6	Soda Butte Creek directly opposite McLaren Tailings dam and downstream of Miller Creek. Site appears to be upstream of tailings discharge (SB-8) but downstream of Miller Creek (SB-4).
SB-3	Soda Butte Creek at road crossing to McLaren Tailings area. Site is upstream of tailings discharge (SB-8) and Miller Creek (SB-4).
SB-0.5	Soda Butte Creek 50 yards downstream of culvert under Hwy 212 and just upstream of Forest Service road in Soda Butte Campground. (This is a better reference site.)
Soda Butte Tributaries (Downstream to Upstream):	
SB-11	Warm Creek upstream of confluence with Soda Butte Creek and downstream of culvert. Warm Creek is located 5 miles from the western edge of Cooke City inside northeast boundary of Yellowstone National Park.
SC-1	Sheep Creek 150 yards upstream of confluence with Soda Butte Creek and downstream of road culvert. 'Sheep creek is located approximately 2.5 miles from the northeast boundary of Yellowstone between SB-10 and SB-9A.
RC-1	Republic Creek at bridge crossing 150 yards upstream of confluence with Soda Butte Creek.
RC-2	Republic creek site to be determined in the field.
RC-3	Republic creek site to be determined in the field.
SB-8	Largest discolored seep at base of McLaren Tailings upstream of confluence with Soda Butte Creek.
SB-4	Miller Creek downstream of culvert under Hwy 212 and 75 yards upstream of confluence with Soda Butte Creek.

Table 2. Parameters collected at each sampling station.



Sampling	Field Parameters (temp, cond, pH, DO)	Total Metals	Dissolved Metals	Sulfate + Alkalinity	NO2 + NO3	Total Mercury	Sediment Metals	Macro-invertebrates
Soda Butte Stations (Downstream to Upstream):								
SB-14	X	X	X	X	X	X	X	X
SB-10	X	X	X	X	X	X	X	X
SB-9A	X	X	X	X	X	X	X	X
SB-9	X	X	X	X	X	X	X	X
SB-8A	X	X	X	X	X	X	X	X
SB-6	X	X	X	X	X	X	X	
SB-3	X	X	X	X	X	X	X	X
SB-0.5	X	X	X	X	X	X	X	X
Soda Butte Tributaries (Downstream to Upstream):								
SB-11	X	X	X	X	X	X	X	
SC-1	X	X	X	X	X	X	X	
RC-1	X	X	X	X	X	X	X	X
SB-8	X	X	X	X	X	X	X	
SB-4	X	X	X	X	X	X	X	
Reese Creek (Downstream to Upstream):								
Site 1	X	X	X	X	X	X	X	
Site 2	X	X	X	X	X	X	X	
Site 3	X	X	X	X	X	X	X	
Site 4	X	X	X	X	X	X	X	
Site 5	X	X	X	X	X	X	X	
Additional Republic Creek Locations (Downstream to Upstream)								
RC-2	X	X	X	X	X	X	X	
RC-3	X	X	X	X	X	X	X	
RC-4	X	X	X	X	X	X	X	

4.4 Results for Soda Butte Creek

4.4.1 Current Status of Ecosystem Health

The current status of Soda Butte Creek can be defined as a stream moderately impacted by mining activities. Soda Butte Creek water quality is similar to and perhaps somewhat improved compared to measurements taken in 1995.

Alkalinity values for Soda Butte Creek were robust, ranging between 100 and 120 mg/L (Figure 2). Alkalinity values for Soda Butte Creek were always at least twice as high as the Woody Creek control and similar to the Warm Creek control.

Conductivity in Soda Butte Creek increased below the tailings pile, from about 240 uS/cm to 320 uS/cm, suggesting an input of high-conductance water from the tailings pile. The conductance decreased back to 240 uS/cm at the park boundary, a conductance value similar to the Warm Creek control.

The pH values of Soda Butte Creek ranged from about 7.9 to 8.3, considerably higher than the pH 3-5 values consistent with acid mine drainage. Moreover, pH values for Soda Butte Creek were similar to the two control streams.

Dissolved metal contents in Soda Butte Creek were generally near detection limits. For example, copper and lead concentrations at all sites were near detection limits (Figure 3). Mercury concentrations at all sites were also near detection limits (data not shown). Iron concentrations increased below the tailings pile from detection limits to about 200 ug/L (Figure 3). However, this value was considerably below the chronic threshold of 62,500 ug/L set by the Montana DEQ. Only selenium values exceeded Montana DEQ standards of 5 ug/L. Selenium concentrations ranged widely from detection limits to 18 ug/L both above and below the tailings pile. However, selenium concentrations decreased to detection limits above the park boundary.

Sediment concentrations for copper, iron, and arsenic were above Montana's chronic threshold for aquatic life for water and the EPA's probable effect concentrations (PEC) for sediment (Figure 4). Mercury storage in sediments was near detection limits at all sites. The highest sediment concentrations for copper were in Miller creek; this was also the only site that exceeded standards. Copper amounts in sediments then decreased downgradient in Soda Butte Creek. Miller Creek thus appears to be a potential large source of copper to Soda Butte Creek.

Arsenic values in sediment were highest in the Warm Creek Control (Figure 4). This is the only location that exceeded arsenic standards for sediments. Moreover, arsenic values increased in Soda Butte Creek downstream of the tailings pile. The results suggest a natural source of arsenic.

Macroinvertebrate values generally decreased below the tailings pile and then rapidly recovered downstream (Figure 5). For example, the percentage of scrapes decreased from 75% above the tailings pile to 10% below the tailings pile, then increased rapidly back to 80%. The EPT score decreased from 85% above the tailings pile to 65% below the tailings pile and then recovered to values greater than 85%. There was a dramatic decline in both total taxa and number of EPT above and below the tailings pile (Figure 6). The total number of taxa decreased from 23 above the tailings pile to 7 below the tailings pile; similarly the number of EPT decreased from 18 to 6. Both the total number of taxa and the number of EPT rapidly recovered further downstream.

Using Montana's Rapid Bioassessment Macroinvertebrate Protocols (1998), impairment scores were calculated for each site to determine the health of each section of the stream sampled (Figure 7). The Montana impairment score ranges from 0 –1.0, with 0.75 indicating full support; standards are not violated. See Figure 7 for an explanation on how this score is derived. Based upon the Montana impairment score, it was found that Soda Butte Creek is moderately impaired through the town of Cooke City. The impairment score of about 0.6 at site SB-0.5 indicates some impairment about the tailings pile; perhaps from the old mill site. There was a dramatic drop in the impairment score from 0.73 above the tailings pile to 0.35 below the tailings pile. However, within and near the park boundary, the scores improve and Soda Butte Creek fully supports macroinvertebrate communities at the park boundary.

Note that the impairment scores indicate some impairment in Soda Butte Creek above the tailings piles. These results suggest other sources of impairment for upper Soda Butte Creek in addition to the tailings pile.

Republic Creek also was moderately impaired. The impairment score of 0.50 indicates moderate impairment. The primary focus of concern on Soda Butte Creek is the McLaren Tailings pile, however, Republic Creek could be a potential source of metals as well. Republic Creek is a tributary of Soda Butte Creek and there were previous mining activities in the basin. The impairment score on Republic Creek of 0.5 is as low as one of the sites directly below the McLaren Tailings Pile.

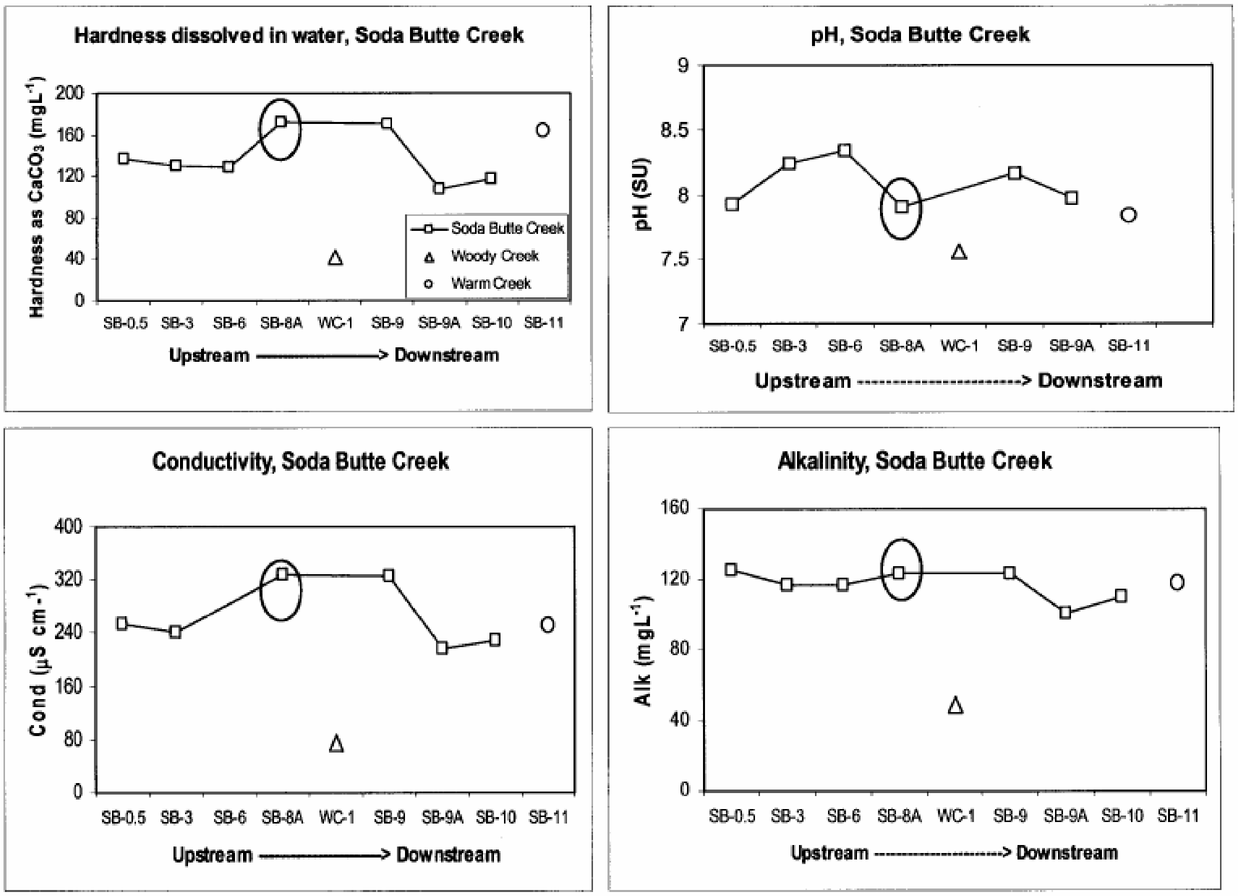


Figure 2. Basic water quality parameters for Soda Butte Creek and the two reference streams Warm Creek and Woody Creek. The influence of the tailings pile occurs at the fourth sampling location for ANC, pH and Hardness and the third sampling site for Conductivity (Depicted by the oval on the graphs). The graphs are not spatially scaled.

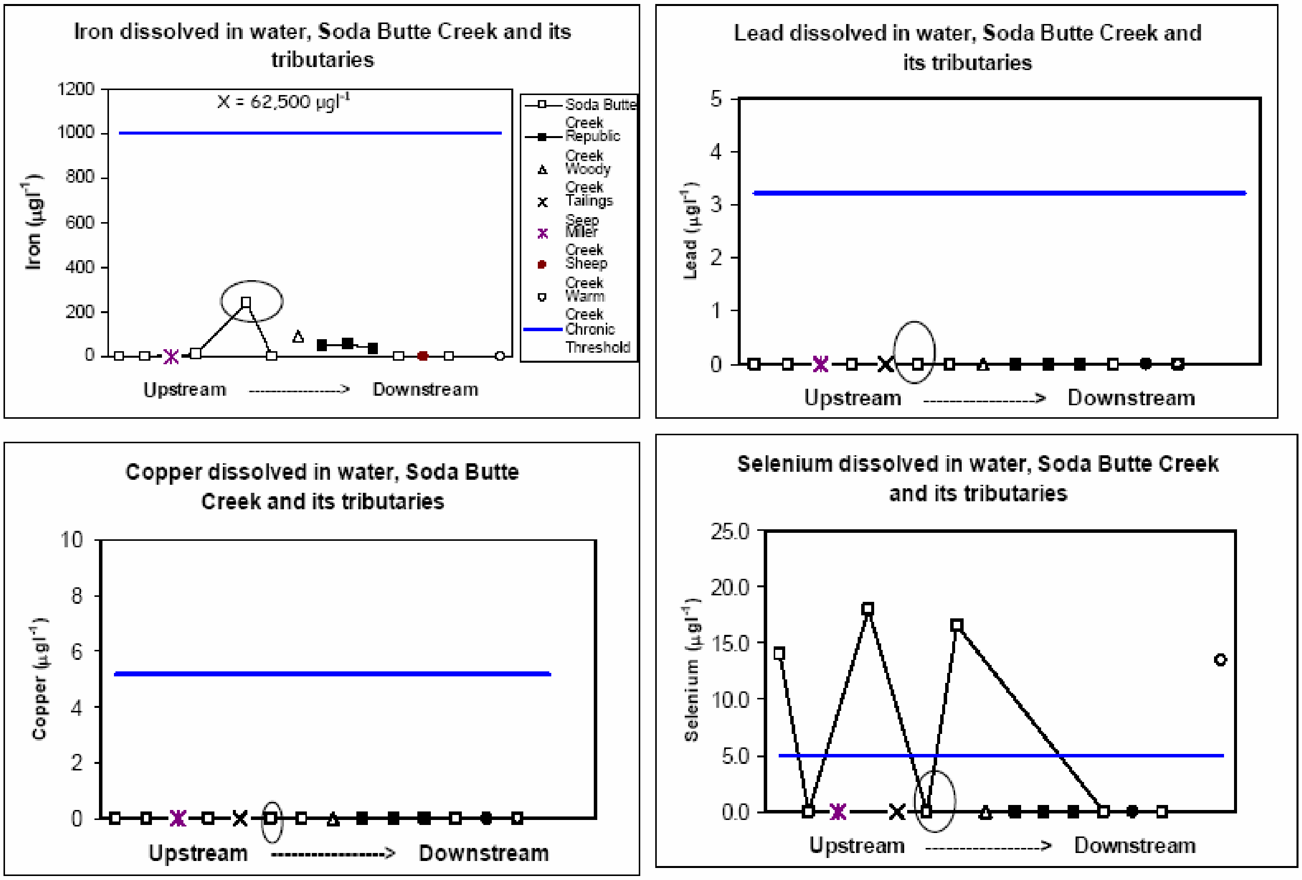


Figure 3. Graphs of copper, lead, selenium and iron dissolved in water for Soda Butte Creek and its tributaries from the Oct 2003 study. The Chronic thresholds for aquatic life are from Circular WQB-7: Montana Numeric Water Quality Standards from the Montana Department of Environmental Quality. The chronic thresholds for aquatic life established for copper are 5.2 µgl^{-1}, lead 3.2 µgl^{-1}, selenium 5 µgl^{-1}, and iron 1000 µgl^{-1}. The highest concentrations of the metals occur in the tailings seepage or in Soda Butte Creek downstream from where the tailings seep enters the creek with the exception of selenium (Sampling location downstream of tailings seep is depicted by an oval). All other metals not shown did not exceed water quality standards or were below detection limits. Copper is listed here although it did not exceed chronic thresholds, because it has been listed as a metal of concern in previous studies that sampled in the spring and it is elevated in sediment.

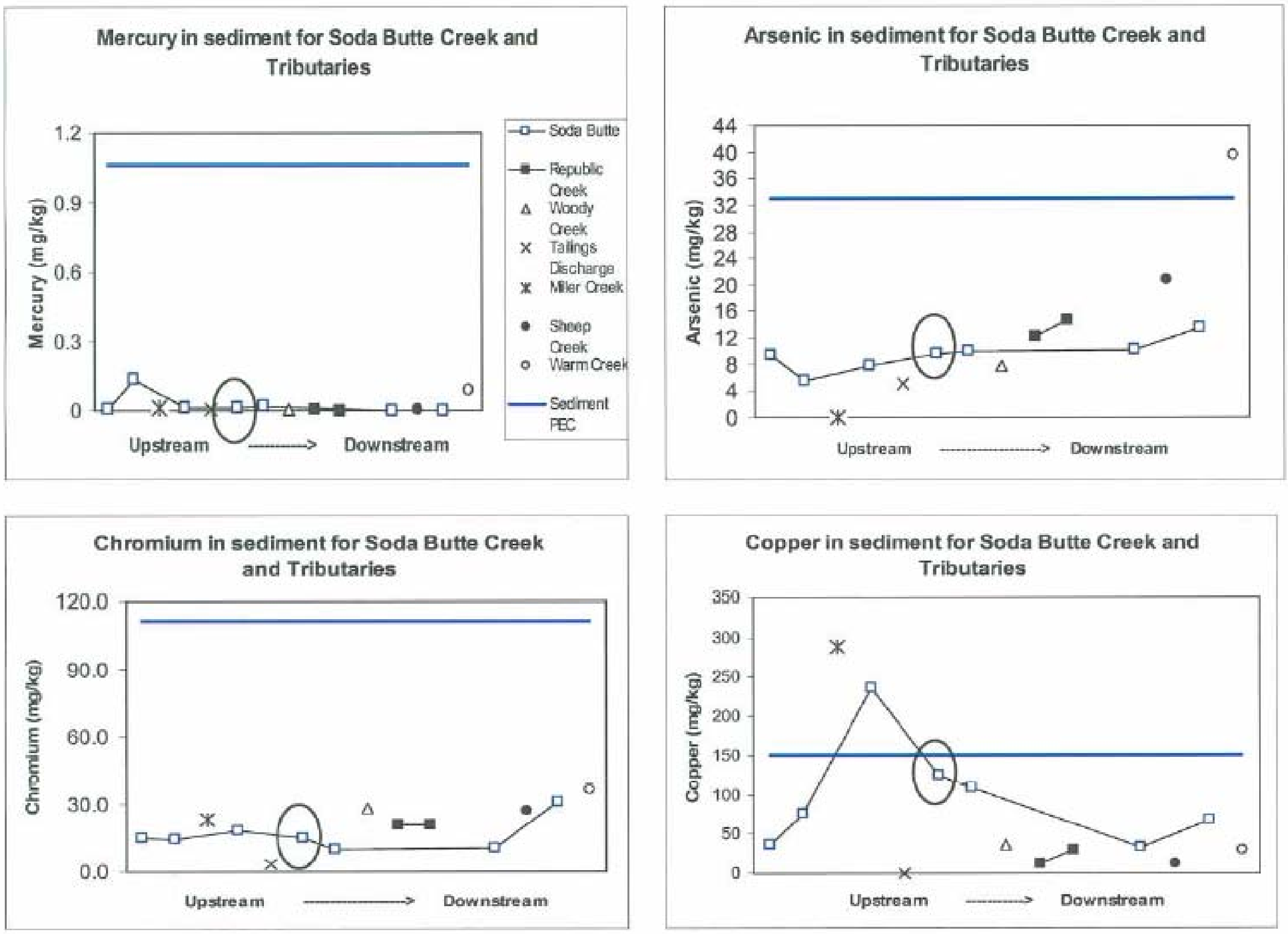


Figure 4. Graphs of mercury, arsenic, chromium and copper concentrations in the sediment concentrations in Soda Butte Creek and its tributaries from the October 2003 study. The sediment PEC was taken from McDonald et al 2000, since current guidelines are not in place for sediment at this time. Probable effect concentration (PEC) is the level above which harmful effects are likely to be observed. The PEC for Mercury is 1.06 mg/kg, Arsenic 33.0 mg/kg, chromium 111 mg/kg and copper 149 mg/kg (from EPA 2002). The sampling location downstream from the tailings pile is highlighted by an oval.

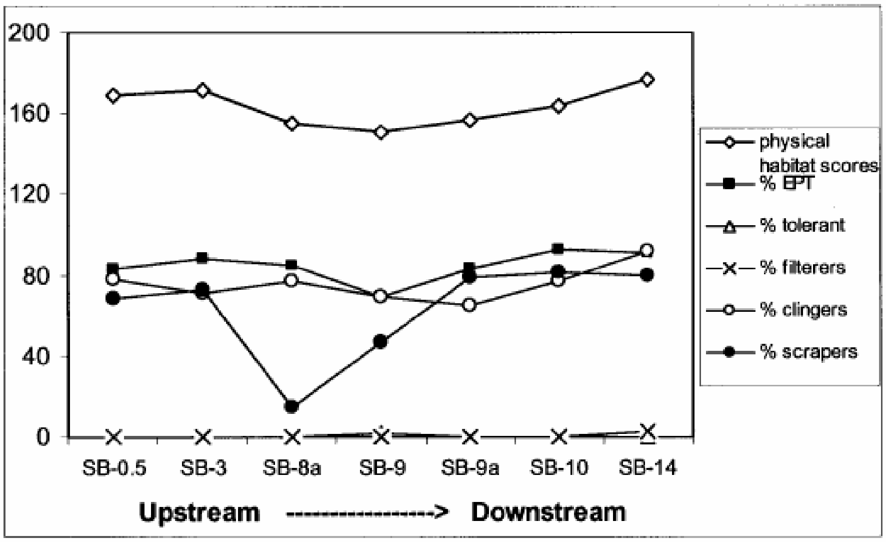


Figure 5. Graph depicting downstream trends of macroinvertebrate assemblages for sample sites on Soda Butte Creek. Sampling location SB-8A is directly downstream from the tailing seep.

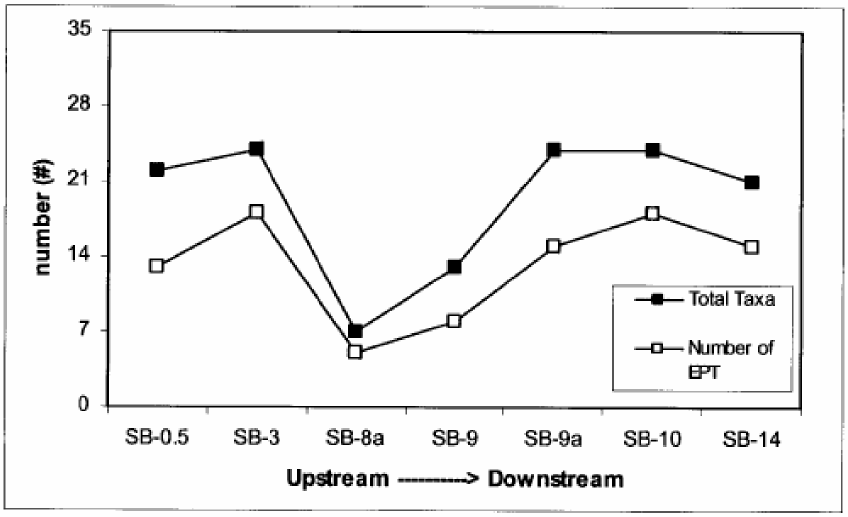


Figure 6. Graph depicting the total number of taxa and the number of EPT individuals for sampling sites on Soda Butte Creek. The influence of the tailings seep occurs upstream of sampling site SB-8a.

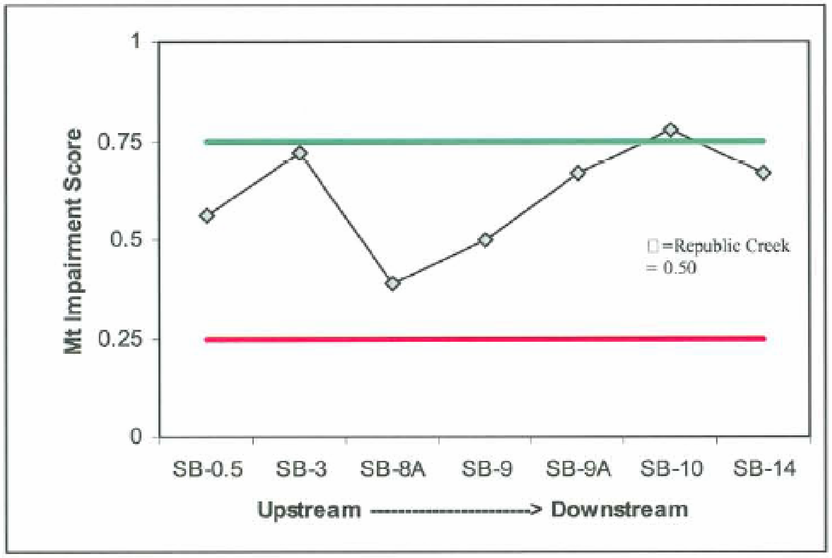


Figure 7. Montana Impairment score was calculated for macro-invertebrate samples collected on Soda Butte Creek. For the purposes of this report, Soda Butte Creek was considered a mountain stream. This Mt. impairment values were calculated using Taxa richness, EPT richness, % dominant, % collectors, % scrapers and shredders, and % EPT (McGuire 2004). A Mt. Impairment value less than 0.25 (the red line) indicates nonsupport---severe impairment—standards violated. A Mt. impairment value between 0.25-0.75 indicates partial support---moderate impairment—standards violated. Finally, a Mt. Impairment score of greater than 0.75 indicates full support --- standards are not violated. The influence of the tailings seep is first seen in sampling location SB-8A.

4.4.2 Normal limits of variation for vitals signs in Soda Butte Creek

Concurrent sampling in the two control streams provides information on the normal limits of variation for vital signs in Soda Butte Creek. All measurements sampled in Soda Butte Creek at the park boundary (macro-invertebrates, metals in water and sediments) were comparable to the control streams. Thus, vital signs for Soda Butte Creek at the park boundary appear to be within the normal limits of variation for these parameters during baseflow conditions. However, note that stream waters in many parts of Yellowstone National Park have unique solute concentrations as a result of hydrothermal contributions. Distinguishing natural versus anthropogenic contributions of metals and biological effects may be difficult. The high arsenic values in the Warm Creek control stream illustrate this problem.

Movement of metals through Soda Butte Creek are subject to potentially large diurnal and seasonal variations. In-stream processes can change metal concentrations by a factor of two between day and night. Even greater changes in metal concentrations may occur during snowmelt when large volumes of water may move metal-rich sediment directly into streams from the tailings piles and/or a rising water table may move dissolved metals from the tailings pile into the stream system. Both Nemmo et al. (1998) and Marcus et al. (1996) argue that a single series of samplings in one season in such a dynamic system is inadequate for assessing the physical-chemical changes that may be occurring.

4.4.3 Past or Present Resource Damage

The bibliographic references and data base document extensive resource damage to Soda Butte Creek in the past. In the late 1800's, Soda Butte Creek had a reputation for "fast fishing and large trout", but by 1931 the fishery was reported as only "fair to poor" (US Fish and Wildlife and Service, 1979). Stabilization of the tailings pile on Soda Butte Creek along with the secession of mining activities appears to have reduced the input of metals into Soda Butte Creek since the 1979 report.

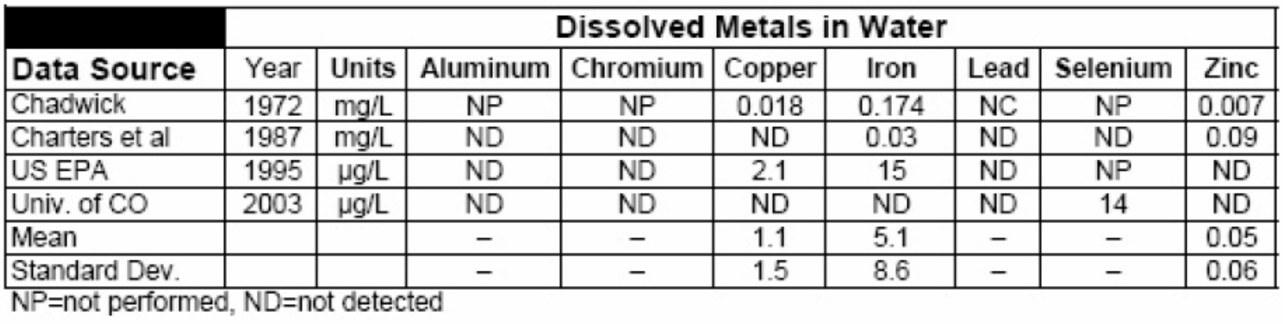
Our results in general show lower metal concentrations in water and sediments than the US EPA study conducted in 1995 (Tables 3-10) (Figure 8 and 9). For example, they report chromium amounts in sediments about twice that of our results at all sites. Our zinc values are lower than those of the 1995 study by a factor of three for most sites. Zinc and lead were labeled as metals of concern by Nimmo et al (1998). However, they did not exceed sediment standards in our study. Like our results, metal content in sediments measured by the 1995 study decreased sharply before the park boundary. The one exception is chromium, which increases at the park boundary (Figure 8). As with arsenic, these results suggest a potential natural mineral source for chromium.

We found much lower dissolved metal amounts in Soda Butte Creek than did the 1995 study (Figure 9). For example, they report zinc values of about 6 ug/L while zinc was undetectable in our samples. However, note that the 1995 study was sampled at high flow in June while we sampled at low flow in October.

These results indicate that there are still large amounts of metals stored in the sediments of Soda Butte Creek. In general the storage load of these metal-laden sediments increases upstream from the park boundary to the tailings pile.

The tailings pile appears stable at this time. However, the two sampling sites directly downstream from the tailings pile generally had the highest concentration of metals in sediment and water, and the lowest Montana impairment scores and % EPT (Figures 10 and 11). We observed a sustained seep out of the toe of the tailings pile, but no connection of that surface flow to Soda Butte Creek. Groundwater may be a potential source of metals from the tailings pile to Soda Butte Creek. A contaminated groundwater plume under the tailings pile is a possibility.

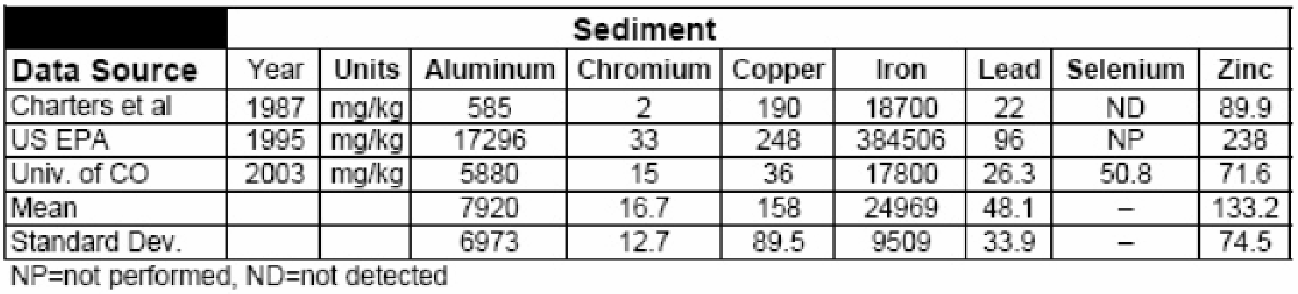
Table 3. Synopsis of dissolved metals at site above tailings pile, Soda Butte Creek, MT.



	Dissolved Metals in Water								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Chadwick	1972	mg/L	NP	NP	0.018	0.174	NC	NP	0.007
Charters et al	1987	mg/L	ND	ND	ND	0.03	ND	ND	0.09
US EPA	1995	µg/L	ND	ND	2.1	15	ND	NP	ND
Univ. of CO	2003	µg/L	ND	ND	ND	ND	ND	14	ND
Mean			–	–	1.1	5.1	–	–	0.05
Standard Dev.			–	–	1.5	8.6	–	–	0.06

NP=not performed, ND=not detected

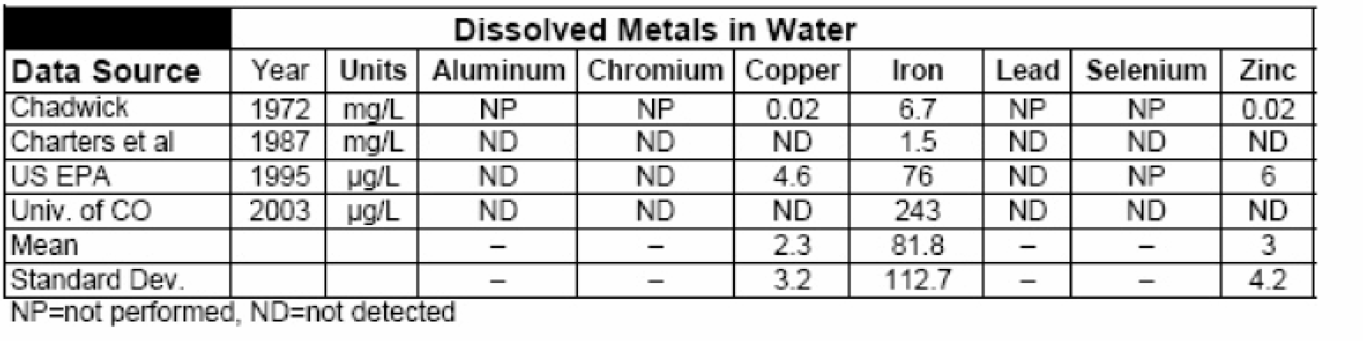
Table 4. Synopsis of metals in sediment at site above tailings pile, Soda Butte Creek, MT.



	Sediment								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Charters et al	1987	mg/kg	585	2	190	18700	22	ND	89.9
US EPA	1995	mg/kg	17296	33	248	384506	96	NP	238
Univ. of CO	2003	mg/kg	5880	15	36	17800	26.3	50.8	71.6
Mean			7920	16.7	158	24969	48.1	–	133.2
Standard Dev.			6973	12.7	89.5	9509	33.9	–	74.5

NP=not performed, ND=not detected

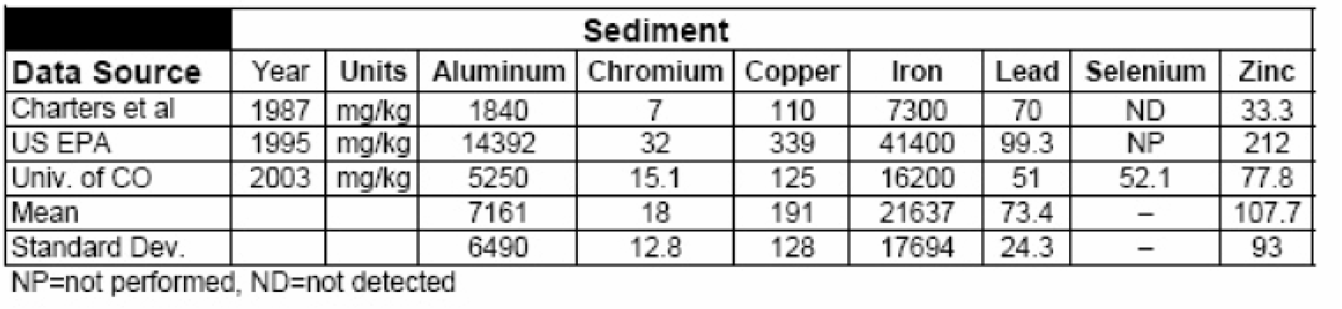
Table 5. Synopsis of dissolved metals at site below tailings pile, Soda Butte Creek, MT.



	Dissolved Metals in Water							
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Chadwick	1972	mg/L	NP	NP	0.02	6.7	NP	NP	0.02
Charters et al	1987	mg/L	ND	ND	ND	1.5	ND	ND	ND
US EPA	1995	µg/L	ND	ND	4.6	76	ND	NP	6
Univ. of CO	2003	µg/L	ND	ND	ND	243	ND	ND	ND
Mean			–	–	2.3	81.8	–	–	3
Standard Dev.			–	–	3.2	112.7	–	–	4.2

NP=not performed, ND=not detected

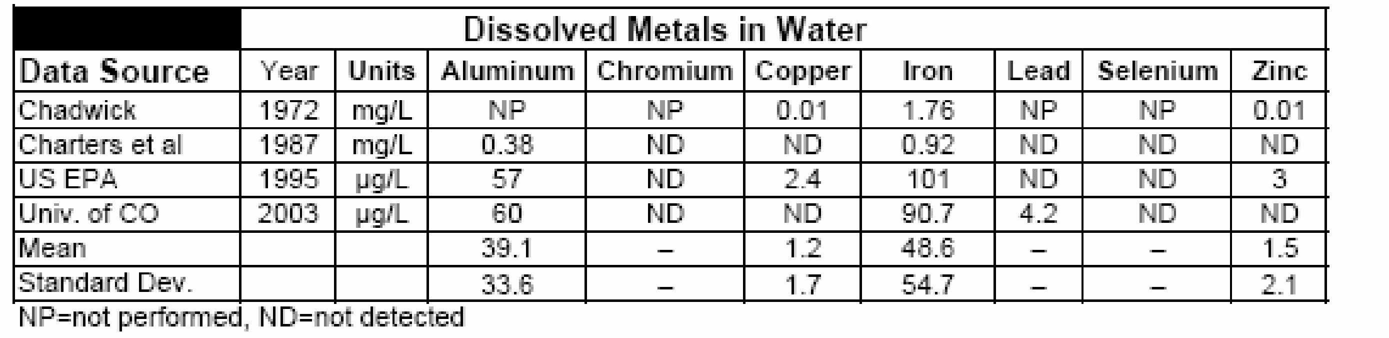
Table 6. Synopsis of metals in sediment at site below tailings pile, Soda Butte Creek, MT.



	Sediment								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Charters et al	1987	mg/kg	1840	7	110	7300	70	ND	33.3
US EPA	1995	mg/kg	14392	32	339	41400	99.3	NP	212
Univ. of CO	2003	mg/kg	5250	15.1	125	16200	51	52.1	77.8
Mean			7161	18	191	21637	73.4	–	107.7
Standard Dev.			6490	12.8	128	17694	24.3	–	93

NP=not performed, ND=not detected

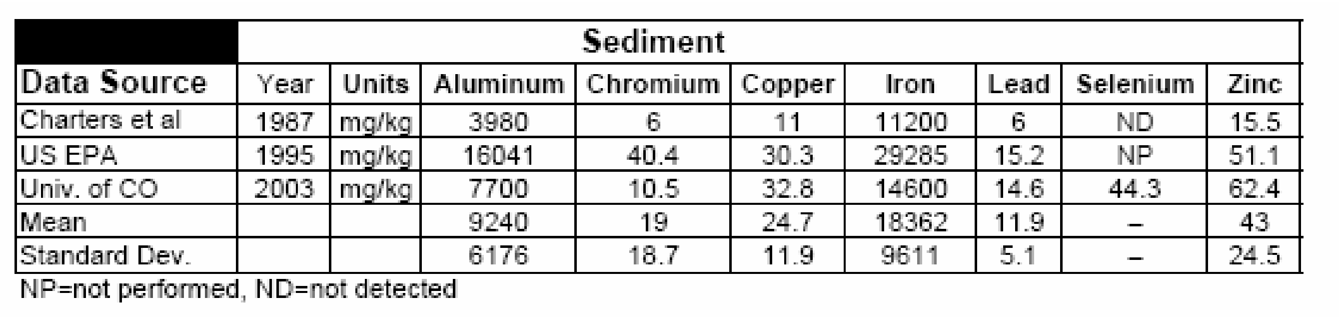
Table 7. Synopsis of dissolved metals at site west of Cooke City, Soda Butte Creek, MT.



	Dissolved Metals in Water								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Chadwick	1972	mg/L	NP	NP	0.01	1.76	NP	NP	0.01
Charters et al	1987	mg/L	0.38	ND	ND	0.92	ND	ND	ND
US EPA	1995	µg/L	57	ND	2.4	101	ND	ND	3
Univ. of CO	2003	µg/L	60	ND	ND	90.7	4.2	ND	ND
Mean			39.1	–	1.2	48.6	–	–	1.5
Standard Dev.			33.6	–	1.7	54.7	–	–	2.1

NP=not performed, ND=not detected

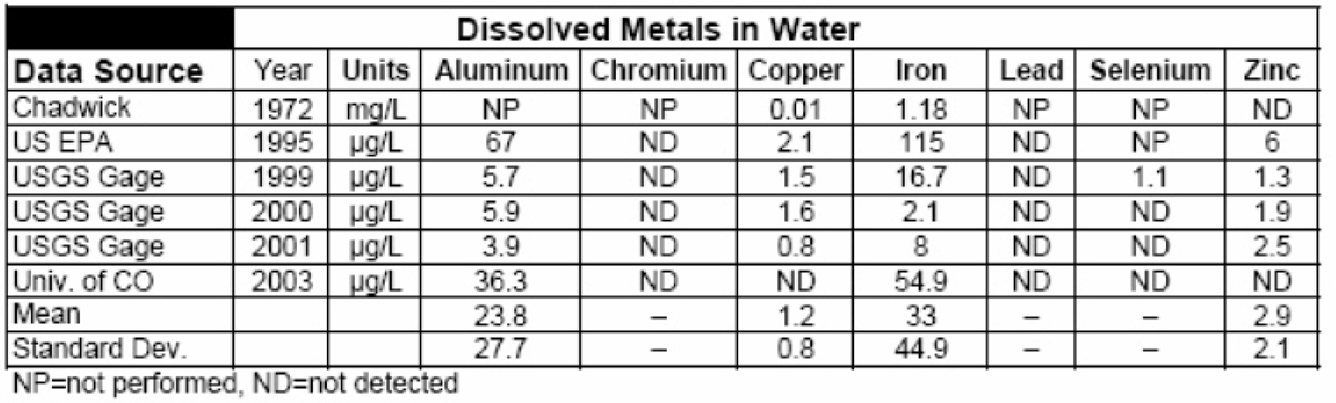
Table 8. Synopsis of metals in sediment at site west of Cooke City, Soda Butte Creek, MT.



	Sediment								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Charters et al	1987	mg/kg	3980	6	11	11200	6	ND	15.5
US EPA	1995	mg/kg	16041	40.4	30.3	29285	15.2	NP	51.1
Univ. of CO	2003	mg/kg	7700	10.5	32.8	14600	14.6	44.3	62.4
Mean			9240	19	24.7	18362	11.9	–	43
Standard Dev.			6176	18.7	11.9	9611	5.1	–	24.5

NP=not performed, ND=not detected

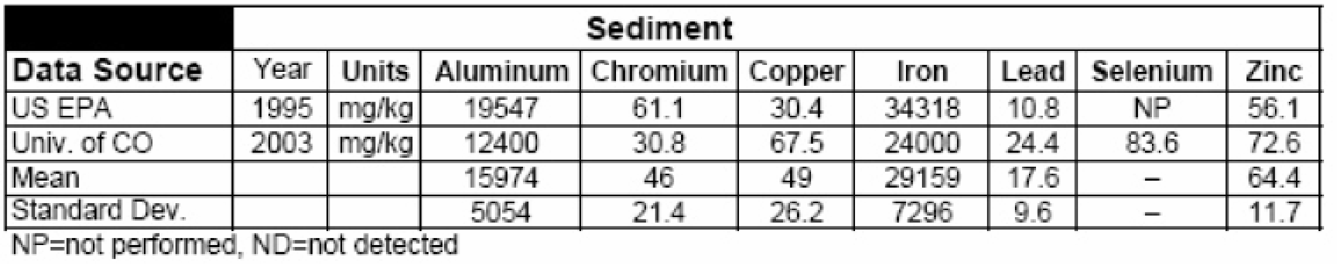
Table 9. Synopsis of dissolved metals at YNP boundary, Soda Butte Creek, MT.



	Dissolved Metals in Water								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
Chadwick	1972	mg/L	NP	NP	0.01	1.18	NP	NP	ND
US EPA	1995	µg/L	67	ND	2.1	115	ND	NP	6
USGS Gage	1999	µg/L	5.7	ND	1.5	16.7	ND	1.1	1.3
USGS Gage	2000	µg/L	5.9	ND	1.6	2.1	ND	ND	1.9
USGS Gage	2001	µg/L	3.9	ND	0.8	8	ND	ND	2.5
Univ. of CO	2003	µg/L	36.3	ND	ND	54.9	ND	ND	ND
Mean			23.8	–	1.2	33	–	–	2.9
Standard Dev.			27.7	–	0.8	44.9	–	–	2.1

NP=not performed, ND=not detected

Table 10. Synopsis of metals in sediment at YNP boundary, Soda Butte Creek, MT.



	Sediment								
Data Source	Year	Units	Aluminum	Chromium	Copper	Iron	Lead	Selenium	Zinc
US EPA	1995	mg/kg	19547	61.1	30.4	34318	10.8	NP	56.1
Univ. of CO	2003	mg/kg	12400	30.8	67.5	24000	24.4	83.6	72.6
Mean			15974	46	49	29159	17.6	–	64.4
Standard Dev.			5054	21.4	26.2	7296	9.6	–	11.7

NP=not performed, ND=not detected

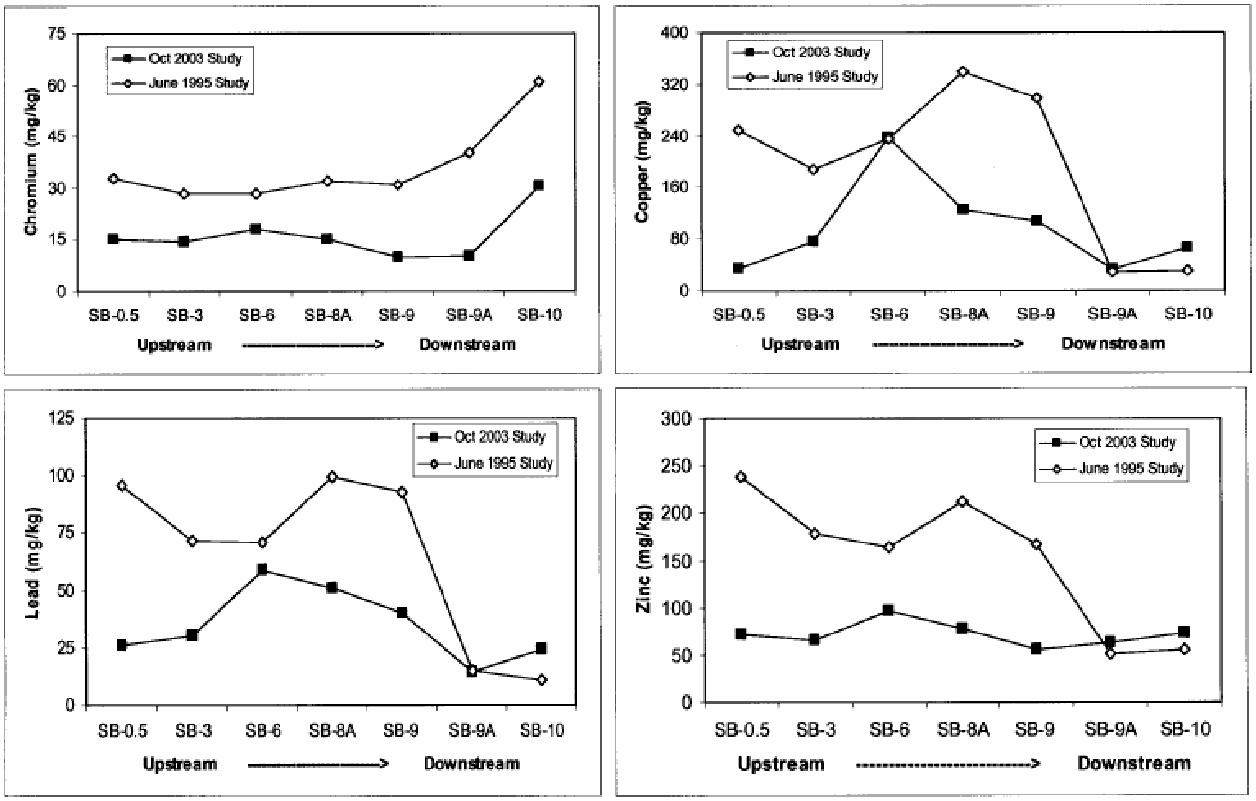


Figure 8. Comparison of selected metals concentrations between the EPA's 1995 study and the current study. It does appear that the metals concentrations in the sediment have decreased since 1995. However, it is important to note that the studies were in June and October. The EPA recommends sampling in the fall so the full impacts of run-off can be evaluated in the sediment (EPA 2002). Sample locations were similar for both studies.

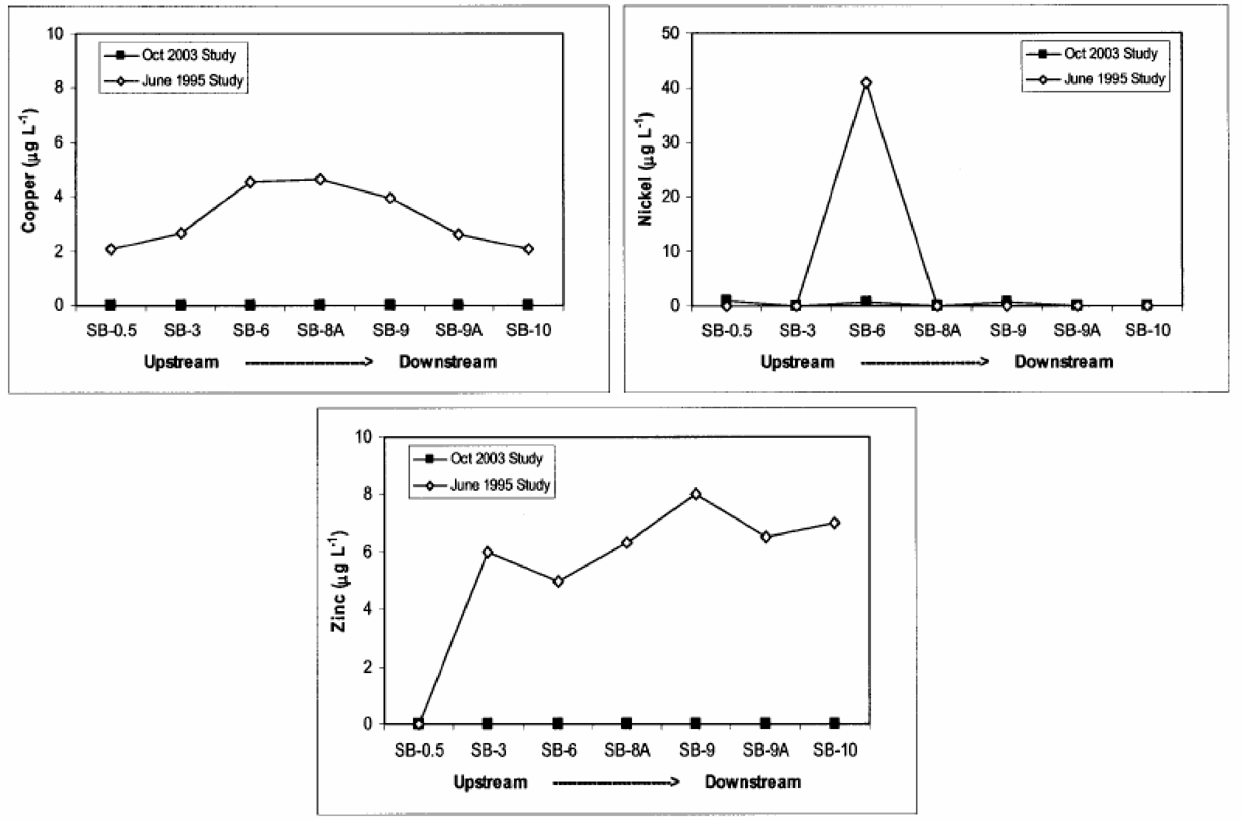


Figure 9. Comparison of metals dissolved in water for the EPA's 1995 study and the current study. Sampling locations were similar for both studies.

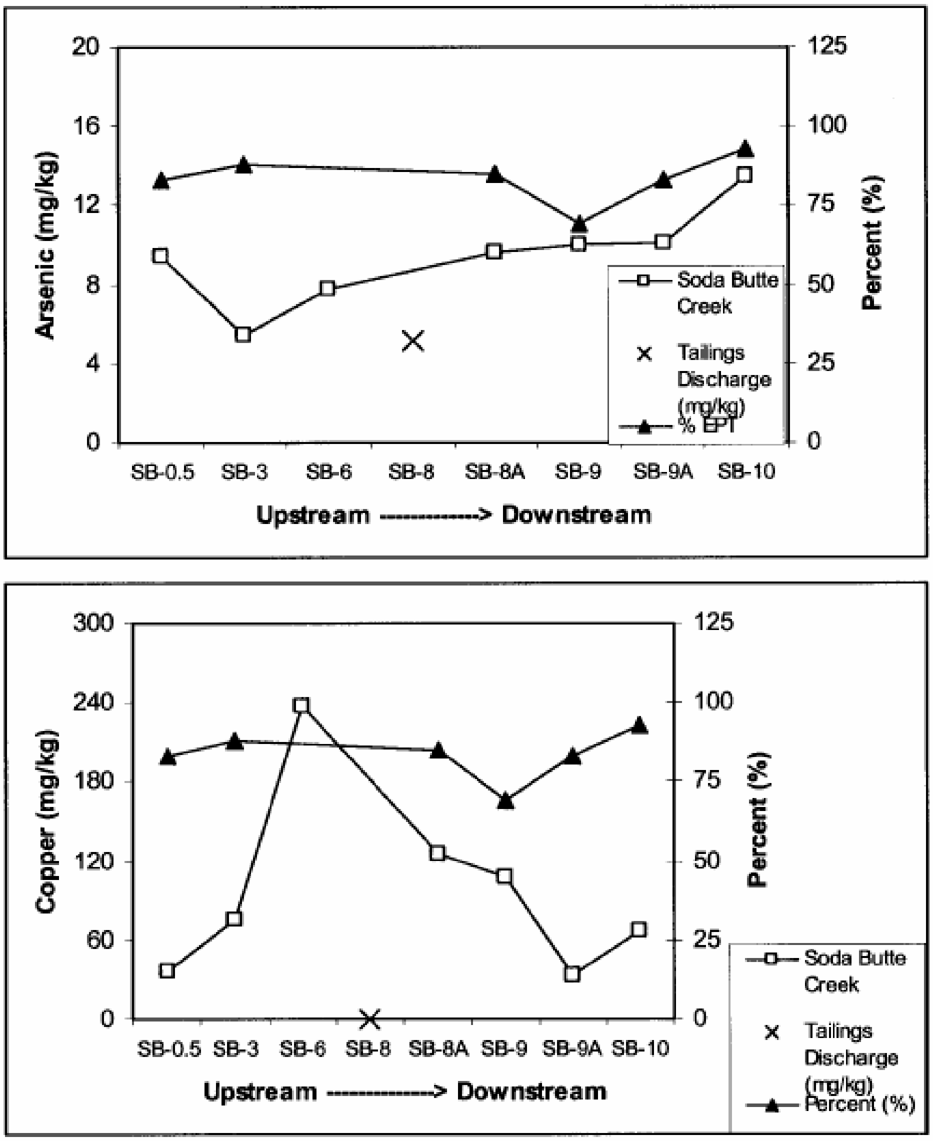


Figure 10. Comparison of arsenic and copper concentrations in Soda Butte Creek with % EPT macroinvertebrates. Arsenic and Copper were selected because they exceeded the Probable Effect Concentrations for sediment.

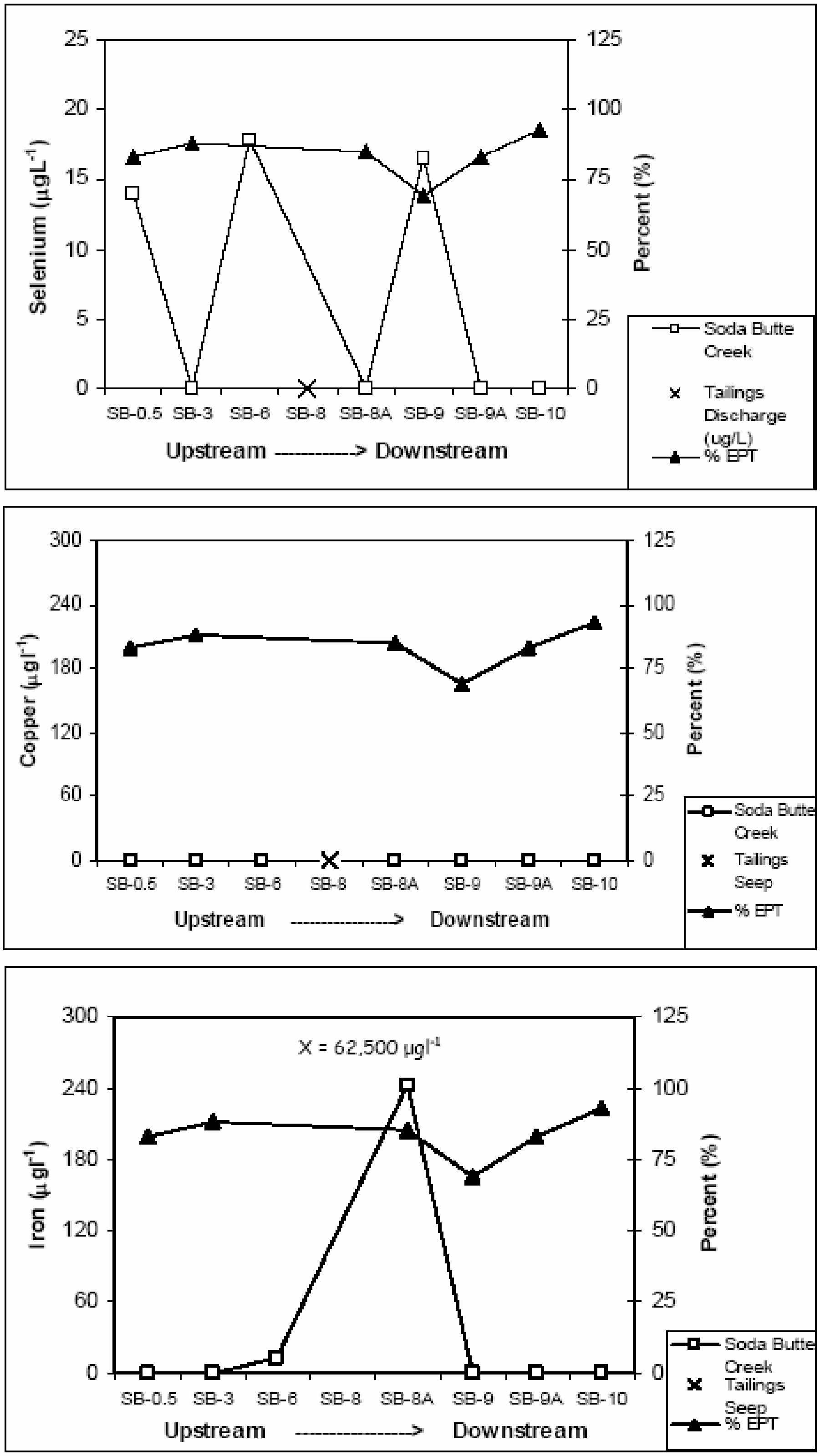


Figure 11. Comparison of metals dissolved in water and % EPT macroinvertebrates for Soda Butte Creek. Iron and Selenium were chosen because they exceeded water quality standards. Copper was selected because it was a metal of concern in previous studies that sampled in the spring.

4.4.4 Additional Research

Soda Butte Creek does have elevated amounts of some metals in surface waters and sediments below the tailings pile. There is dramatic improvement in these parameters prior to the park boundary. However, fish are mobile and may move back and forth from the park to the tailings pile. Additional research that would be helpful in determining the potential harm to NPS resources would be to collect fish tissue and analyze that tissue for metals content. The potential presence of a contaminated groundwater plume should be investigated. The tailings pile is about 20 years old. The formation and then movement of a contaminated plume of metal-rich water under the tailings pile is likely.

4.4.5 Compliance with existing laws and regulations

The metals dissolved in water were compared with Montana's DEQ numeric water quality standards (Circular WQB-7). Iron, copper, arsenic and selenium were the only metals to exceed the chronic thresholds for aquatic life (Figures 3, 4). At the park boundary, only arsenic exceeded these water quality standards. The Montana impairment score for macro-invertebrates is a guideline or a tool that can be used to assess the health of Soda Butte Creek, but is not a law or regulation.

4.4.6 Endpoints of Success/Partial Success for physical, biological, and chemical parameters

The endpoints for success are as follows:

(1) Metal concentrations in stream waters are below the chronic thresholds for aquatic life for the state of Montana at the park boundary.
(2) The Montana impairment score is > 0.75 at the park boundary.
(3) The tailings pile remains stable.
(4) There is no significant disturbance to the stream channel in Soda Butte Creek.
(5) There is no significant disturbance to tailings piles, ore repositories, and other mining structures in the catchments that drain into Soda Butte Creek.

5.0 VITAL SIGNS MONITORING STRATEGIES

5.1 Reese Creek

5.1.1 Vital signs considered and selected

Our approach to developing vital signs for Reese Creek is illustrated in Figure 12.

Minimum in-stream flow. The simplest, most cost-effective, and least controversial vital sign is to measure in-stream flow. Currently, minimum instream flows are 1.3 cfs from April 15 through October 15, but only if the streamflow above the diversion is above 2.8 cfs. Moreover, the Fish and Wildlife has recommended minimum stream flows of 4.3 cfs from May 15-July 30 (FWS 1987). We recommend:

- Measuring in-stream flow **CONTINUOUSLY** at a minimum of two sites: (a) above the up-stream diversion, and (b) below the lowest diversion. Further, we recommend that discharge measurements be transmitted in real-time to the NPS. Real-time transmission is possible at Reese Creek through either radio frequency or wireless broadband to the town of Gardiner. Real-time transmission provides the ability to check on discharge for illegal diversions without having to go to the field site.

- Negotiate with the current water rights holders to increase in-stream flows from 1.3 cfs to 4.3 cfs from May 15-July 30.

Set minimum number of spawning fry in the impacted stream reach between the lower diversion and Yellowstone River. The ideal situation would be to conduct research as discussed in section 4.2.4 to determine the population goal for cutthroat trout in the impacted lower 0.8 stretch of Reese Creek. One potential drawback to such research is that it can be very difficult to establish what the trout population should be, given natural and large changes in climate, few other similar streams for comparison, and perturbations to the Yellowstone River itself. Interpretation of well-conducted research results may still be controversial. Therefore we recommend this vital sign as a future goal.

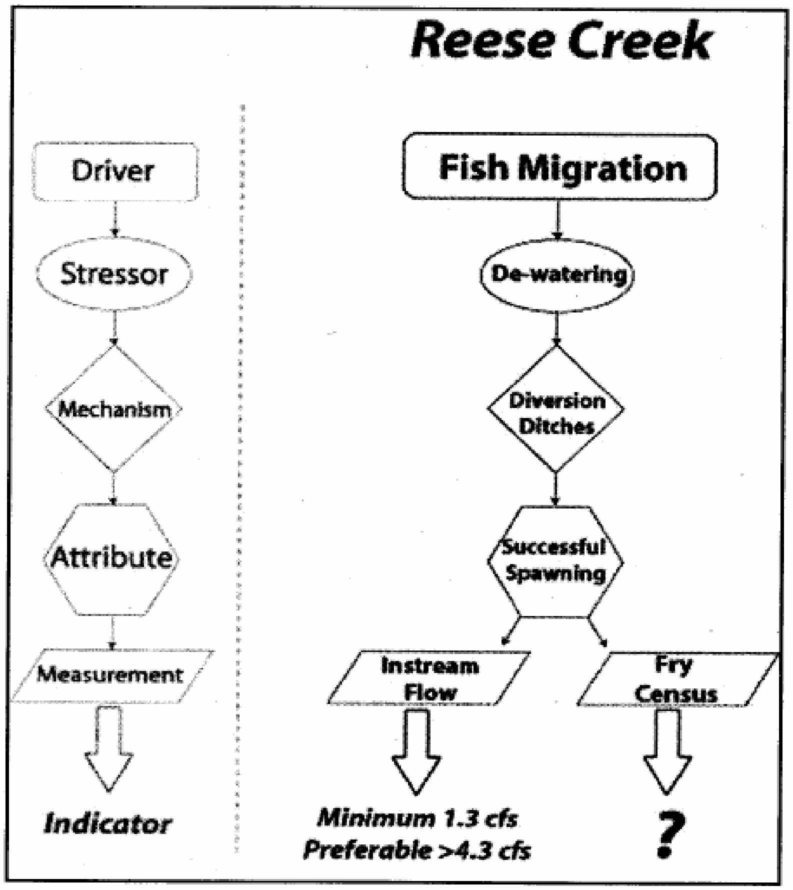


Figure 12. Flow diagram of approach to developing vital signs for Reese Creek.

5.1.2 Objectives for vital signs selected

The objective of the vital signs is to maintain a viable cutthroat trout population that migrates to the Yellowstone River. There is no existing information on the baseline population of spawning fry prior to the water diversions. There appears to be no information on which to base an estimate of what a viable population of spawning trout fry would be. However, the US Fish and Wildlife has produced an in-stream flow metric of 4.3 cfs from May 15-July 30 that most likely will lead to a stable trout population

5.1.3 Sampling and Analysis Plan

See Appendix B.

5.1.4 Budget

- Campbell CR 510 datalogger - $750 plus $75 for extended temperature testing.
- Keller pressure transducer - either the cs400($450) or cs405($510) plus resistor assembly($25) plus cable($1.57/ft.).
- Power supply system:
    - 21 watt photovoltaic panel, non-breakable glass, $180.00
    - 34 amp-hour storage battery, $75.00
    - regulator, Morning Start sun saver 6, $52.00
- Radio: Free Wave DGR-115R, 902-928 MHz, spread spectrum, frequency hopping, one watt, type N female RF connector, $1300
- Radio: Free Wave DGR-115W, 902-928 MHz, waterproof , $170

5.2 Soda Butte Creek

5.2.1 Vital signs considered and selected

Our approach to developing vital signs for Soda Butte Creek is illustrated by the flow diagram in Figure 13.

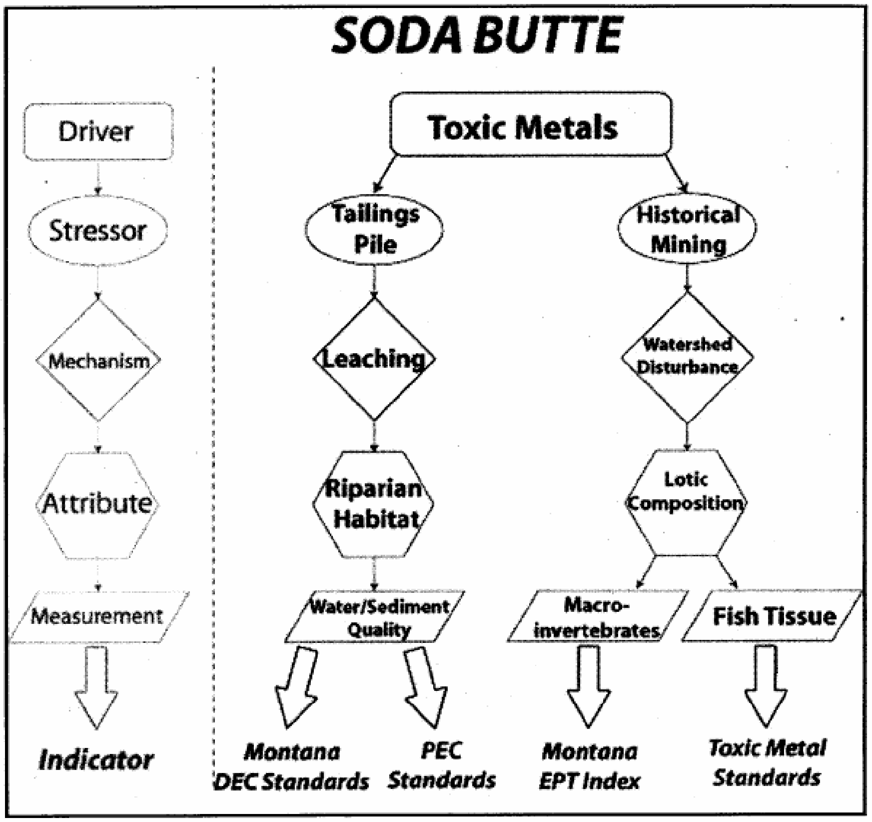


Figure 13. Flow diagram of our approach for developing vital signs for Soda Butte Creek.

<u>Macro-invertebrates.</u> Macroinvertebrate communities are very sensitve to stress and demonstrate responses to metals contamination (EPA 1990). Moreover, macroinvertebrate communities integrate over time potential impairment caused by metals content, where that metals content can vary substantially by more than a factor of two both diurnally and seasonally. There are numerous metrics that provide measures of the macro-invertebrate community diversity, including species richness, EPT index, Shannon diversity, and Shannon evenness. We recommend using the Montana Impairment Score because: (a) it integrates several indices into a score that is relatively easy to understand and hence can be communicated to the public; and (b) it is used by the State of Montana and hence has credibility with that land manager. *The vital sign is that the Montana Impairment Score be 0.75 or higher at the sampling site at the park boundary.*

Metals content in water and sediments. Distinguishing natural versus anthropogenic contributions of metals to Soda Butte Creek and resulting biological effects is made difficult by the unique hydrothermal characteristics of Yellowstone National Park and surrounding environments. For example, our measurements show that the highest arsenic concentrations occur in the Warm Creek control. There is no known mining activity associated with Warm Creek and hence the arsenic is most likely natural in origin. We thus take a conservative strategy with respect to metals content. *The vital sign is that a metals content in stream water exceeds Montana's DEQ numeric water quality standards (Circular WQB-7) at both the park boundary sampling site and the uppermost sampling site on Soda Creek.*

Status of the McLaren tailings pile. The tailings pile is a time-bomb waiting to go off. The worst-case scenario is a catastrophic failure of the tailings pile. Monitoring of the status of the tailings pile is essential to prevent resource damage within YNP. *We recommend that the NPS develop a neighborhood watch program to report any failures of the tailings pile.*

5.2.2 Objectives for vital signs selected

The primary objective for selecting vital signs is to detect impairment of biological, physical, and/or hydrologic resources within Yellowstone National Park by metals contamination transported in Soda Butte Creek. The second objective is to indicate the possibility of future resource damage to Yellowstone National Park, even if there is no resource damage occurring at the present time.

Catastrophic failure of the tailings pile is the worst possible situation. Because the tailings pile is located in the valley bottom adjacent to Soda Butte Creek, any disturbance to the tailings pile may result in rapid transmission of toxic metals to the creek. In turn, once metals are in the creek, they can be transmitted efficiently and quickly within the borders of Yellowstone National Park. Thus the chances of stopping the movement of trace metals into the park from a failure of the tailings pile is unrealistic. *Therefore we recommend that the YNP take the lead in partnering with other land managers to develop a remediation plan and budget to move the tailings pile out of the valley bottom and into a storage system with no hydrologic contact with Soda*

Sampling design. We recommend the following sampling design. We provide three different sampling frequencies, with all other sampling components remaining the same. Sites: 4. The first location is on the tributary of Woody Creek and will serve as a control. The second site selected is down stream of the McLaren tailings seep and is labeled SB-8A. The third sampling site is located downstream from the confluence of Soda Butte Creek with Republic Creek and is labeled SB-9A. The final site is located at the Boundary of Yellowstone National Park. This site is labeled SB-10. These sites were selected for the following reasons:

1) The sampling sites provide: (a) a control; (b) evaluate potential impairment of Soda Butte Creek at the park boundary; and (c) provide information on potential

contributions directly from the tailings seep and Republic Creek, which also has a history of mining.

2) These sites have been sampled previously and there is historical information for each of these sites.

All sites were sampled for macro-invertebrates and dissolved metals content in stream waters as detailed in the SAP (Appendix C).

Scenario One: Sample collection twice a year once every five years. Our synoptic survey suggests that water quality on Soda Butte Creek has been stable and improving in the last 10 years. Samples will be collected: (a) during snowmelt on the ascending limb of the hydrograph; and (b) baseflow conditions. Snowmelt may cause episodic movement of toxic metals into Soda Butte Creek or mobilize metals stored in stream sediments. Sampling during baseflow provides an opportunity to evaluate chronic conditions.

Scenario Two: Sample collection annually. Same as scenario one, but conducted annually.

Scenario Three: diurnal sampling. Same as scenario two, but sample twice daily to account for potential diurnal effects.

Scenario Four: All 20 sites in Figure 1, Table 2, twice a year.

Scenario Five: All 20 sites, twice a year and diurnally at each date.

Scenario Six: All 20 sites, diurnally and 10 times a year distributed through the hydrograph.

5.2.3 Sampling and Analysis Plans

See appendix C.

5.2.4 Budget

Following are approximate costs to conduct these analyses by contracting companies.

- Invertebrates, $270 per sample.
- Dissolved metals, $195 per sample.

Scenario One: $4,000 every five years.
Scenario Two: $4,000 annually.
Scenario Three: $8,000 annually.
Scenario Four: $20,000
Scenario Five: $40,000
Scenario Six: $200,000

These costs do not take into consideration sample collection or delivery to the firm that will conduct the sample analyses. These costs do not take into account field equipment or sample bottles and filters. Nor do these costs consider data analysis.

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APPENDIX A:

Sampling and Analysis Plan
for
Oct. 7-9, 2003
Synoptic Survey

Sampling and Analysis Plan for the Chemical and Biological Assessment Of

Soda Butte Creek and Associated Tributaries
Greater Yellowstone Area
October 2003

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1.0 INTRODUCTION

The University of Colorado-Boulder and Region 8 of the U.S. Environmental Protection Agency are working in collaboration with a grant administered by the National Park Service to develop detailed protocol necessary to monitor the ecological health of Soda Butte and Reese Creeks in Montana and Wyoming. Soda Butte Creek and Reese Creek are on Montana's 303(d) list as streams impaired by mining activities. Soda Butte Creek is the only creek that enters Yellowstone National Park that has been adversely impacted. By creating a detailed protocol, park and forest service officials can create a database of information that is consistent, cost efficient, and applicable to the greater Yellowstone area. Critical parameters or "vital signs" that will be evaluated in this study include water quality, toxic metals in bedload, biological data, and habitat quality. For the purposes of this study, only Soda Butte Creek will be rigorously sampled but the resulting protocol will be made applicable for Reese Creek as well.

This SAP was prepared to outline the analytical objectives and to guide field sampling for a large synoptic sampling event scheduled for October 9 and 10, 2003. This SAP calls for the collection of surface water and sediment samples at 21 locations as well as quantitative macroinvertebrate sampling at 8 locations. In addition, the sampling team will provide quality assurance/quality control samples consisting of field blanks, duplicate samples, and triple volume water samples for laboratory calibration purposes.

2.0 OBJECTIVES

This SAP is intended to fulfill the following objectives:

1) Document existing ecological problems through a one-time synoptic sampling event.
2) Develop a monitoring strategy based on sampling critical parameters guided by the information from the synoptic sampling event to develop "vital signs" unique to the greater Yellowstone area that assesses the basic health and integrity to guide the decisions of land managers, and do so in a rigorous fashion that can withstand legal challenge.
3) Above work will be done in order to better characterize and monitor water quality of Soda Butte and Reese Creeks as a tool for continued monitoring and future remediation goals.
4) Use this project as a means of facilitating RM-CESU and EPA cooperation.

3.0 BACKGROUND INFORMATION

3.1 Location and site description

Soda Butte Creek is a third order cobble and gravel bed stream with a laterally unstable wandering channel (Ladd et al 1998). Soda Butte Creek's headwaters originate near Henderson Mountain, 2 km east of Cooke City, Montana (Park County) and flows approximately 6 km into the northeast corner of Yellowstone National Park. Soda Butte Creek then flows 28 km and joins the Lamar River, which is a tributary of the Yellowstone River (Nimmo et al 1998). Along its course into Yellowstone National Park, Soda Butte Creek flows directly north of the McLaren Mine site. There is a large tailings pile consisting of 191,000 cubic meters of tailings (Sergent, Hauskins, and Beckwith 1990). The tailings pile consists of phyllosilicates, tectosilicates, sulfides, iron oxides, and calcium salts (Sergent, Hauskins, and Beckwith 1990). Although the actual path of Soda Butte Creek has been diverted around the tailings pile from its previous course directly through the tailings pile, evidence of deteriorating water and habitat quality is still apparent downstream (Charters et al 1988, Nimmo et al 1998, Marcus et al 2001).

3.2 Geology and hydrogeology

Soda Butte Creek is located in the Beartooth Mountains. The region has been subjected to extensive uplifting and thrust faulting that has exposed Precambrian crystalline rocks. Elevation ranges of the Soda Butte drainage is between 2300 and 2400 meters. The valley is steep sided and has morphological and lithological characteristics that are typical in glaciated landscapes. Elevations of mountain peaks in the area commonly exceed 3000 meters. The McLaren tailings site is characterized by three general geologic units which include Precambrian and tertiary age intrusive rocks, Pleistocene age sediments, and Holocene age sediments resulting from mining activity (Sergent, Hauskins, and Beckwith 1990).

Even though Soda Butte Creek has been diverted around the tailings pile, water pathways through the tailings pile can contribute to decreased water quality in the stream. Possible pathways include overland and subsurface flow, seepage from precipitation, and inflow from Soda Butte Creek and subsurface flow in the Holocene alluvium below the tailings pile and dam (Sergent, Hauskins, and Beckwith 1990). Avalanches and other catastrophic events could alter the course of the stream or flush tailings into Soda Butte Creek despite remediation efforts.

3.3 Site History and previous work

Placer gold was discovered in the Cooke City area in 1869. Hard rock mining for gold and silver from the McLaren Mine near Daisy Pass was processed intermittingly at the McLaren Tailings site from the 1870's until 1967. The mine has not been active since this time.

The National Park Service reported an impoundment failure in June 1950 that spilled tailings into creek (Nimmo et al 1998). In 1969, the creek was rerouted and the tailings pile was leveled, graded and seeded with grass (Nimmo et al 1990). From 1989-1991, the EPA, through the Superfund program, underwent remediation activities at the McLaren tailing sites. The remediation project included construction of a small emergency dike, a stability dam, an embarkment drain, earth berm, and an open interceptor drain. Tailings were removed from the toe and were replaced with clean fill. The disturbed area was then reseeded (Bureau of Reclamation 1994).

Despite these efforts, research has shown decreased water quality and compromised habitat downstream from the McLaren tailings pile. The Bureau of Reclamation released a report indicating that Soda Butte Creek violated Montana state water quality standards, and compromised the water quality within the national park (1994). Nimmo et al (1998) found that sediment collected in Soda Butte Creek was toxic to amphipods and that an emphasis should be place upon copper concentrations in future studies. Macro-invertebrate diversity also decreased downstream from the tailings pile. Shuler also noted elevated metal contamination in fish tissue (1994). Increased concentrations of metals and pH were also noted at four meadow sites downstream of the tailings that adversely affected density, diversity and biomass of the vegetation (Stoughton 1995). Seasonal variations in heavy metal concentrations and local variations in stream flow and turbulence has complicated exact measurements of water quality and should be taken into consideration during any sampling event (Nimmo et al 1998, Marcus et al 2001).

4.0 FIELD PROCEDURES

4.1 Schedule

Field sampling will take place on October 8th, 9th,10th. Representatives from the Environmental Protection Agency Region 8 and the University of Colorado-Boulder will assist in any operations. National Park Service employees may assist in the sampling event.

4.2 Safety and Emergency Contacts

Several teams will conduct the sampling project. Personal protective clothing and powderless gloves will be worn during all sample collections. The Site Safety Officer for the sampling event is Mike Wireman. In case of an emergency, field personnel can seek help from the following entities:

Fire/Police/Sheriff/Ambulance:
911

Park County Sheriff:
414 E. Callender Street #2
Livingston, Montana
(406) 222-4172

West Yellowstone Police
Department:
124 Yellowstone Avenue
West Yellowstone, Montana
(406) 646-7600

Yellowstone National Park:
(307) 344-2386

Livingston Memorial Hospital
504 S 13th Street
Livingston, Montana
(406) 222-3541

Gardiner Ambulance Service:
213 Main Street
Gardiner, Montana
(406) 848-7226

4.3 Site access and logistics

The project manager will coordinate access to all sample locations. The National Park Service has already granted entry in Yellowstone National Park. Proper paperwork will be given to each team who will sample within park boundaries. Some of the sampling locations are located on private land. Landowners will be contacted previous to sampling.

4.4 Sample locations

This SAP calls for the collection of samples from 21 different locations. Eight locations on Soda Butte Creek, 5 samples from Tributaries, 5 samples on Reese Creek, and 3 on Republic Creek. Macroinvertebrate samples will be collected at 8 specific sites that have already been determined. (see Table A-1 for the full list of sample locations).

4.5 Sampling methods

All samples will be collected in accordance with the protocols identified in the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Periphyton, Benthic Macroinvertebrates, and Fish (EPA 842-B-99-002). Field procedures will follow protocols for standard operating procedures and requirements listed in *US EPA Region VIII - Minimum Requirements for Field Sampling Activities*, United States Environmental Protection Agency Region VIII, September 1996. All containers and preservation techniques for sampling will follow protocols listed in Table II of 40 CFR § 136.3.

Measures have been taken to minimize the amount of in-field equipment decontamination required for the sampling events. Field measurements will be taken in-situ and decontamination procedures will not be necessary. Equipment such as filters and syringes, bottles, etc. will not be reused, and decontamination will not be required in the field.

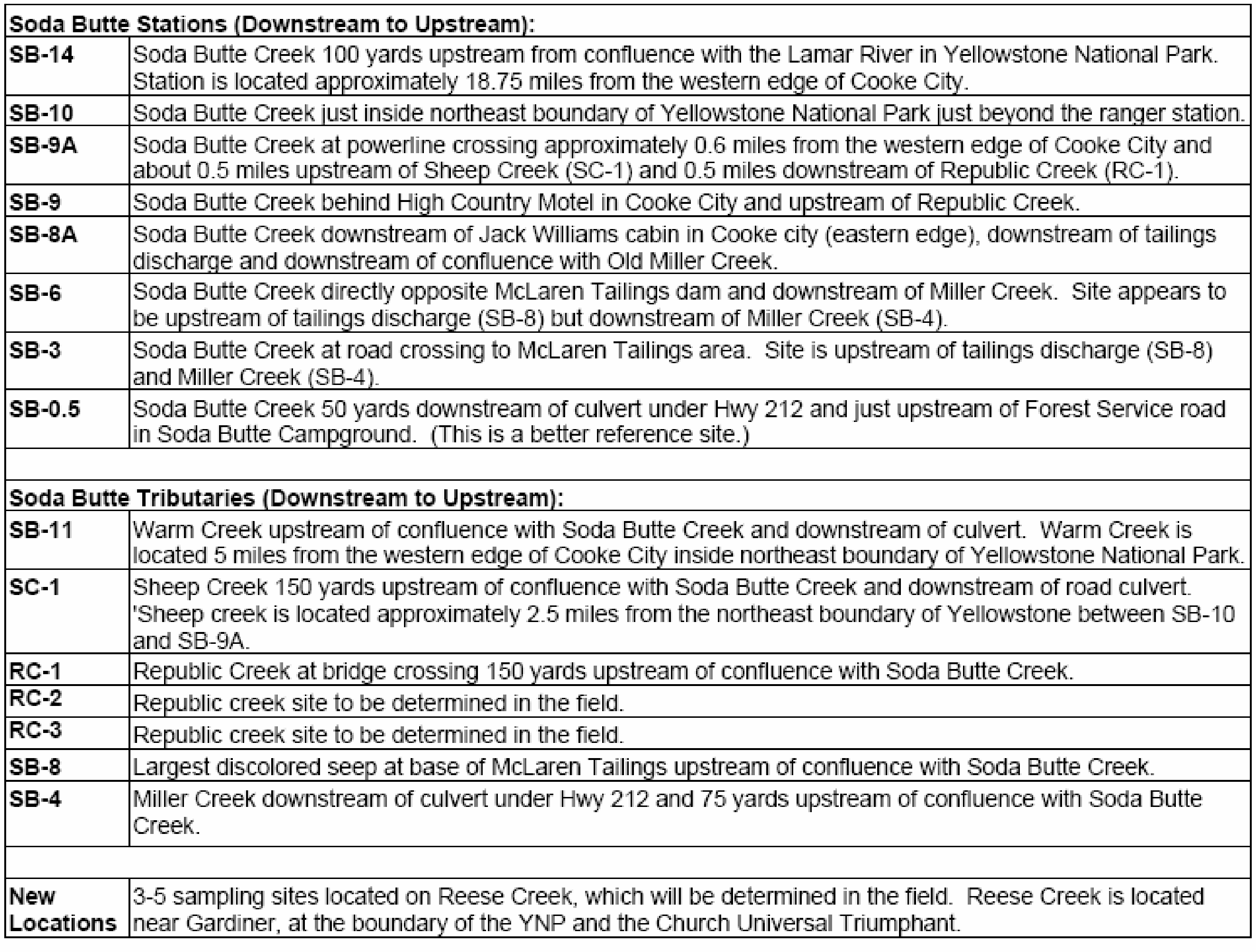
Water: Where possible, surface water will be consolidated into a bucket which will be used to pour off individual samples for total metals, dissolved metals, SO4 + alkalinity, NO2+NO3, and total mercury. The bucket will be rinsed at least three times with native water before sample collection. In the event that water is too shallow to obtain enough water in the bucket, sample containers will be dipped directly from the stream. Each sample container will be rinsed three times before sample collection. Water for the dissolved metals sample will be filtered in the field using a 45 micron filter. Filtered water will be used to rinse the dissolved metals container three times before the sample is sequestered. Total metals, dissolved metals, and mercury samples will be preserved to a pH <2 using nitric acid. The NO2+NO3 sample will be preserved to a pH <2 using sulfuric acid. The SO4 + alkalinity will be iced to 4 °C for preservation.

Surface sampling will progress from downstream to upstream to eliminate sediment disturbance in subsequent sampling locations.

Quantitative Macroinvertebrates: Two to three quantitative macroinvertebrate samples will be collected from the locations listed in Table A-2. The samples will be collected following EPA Rapid Bioassessment Protocols (RBP) using Surber samplers (1' x 1'). Only riffle habitats will be sampled quantitatively. The number of Surber samples to be collected at each location (2 or 3) will depend upon workload of the EPA Region VIII Laboratory, weather conditions, and personnel available at the time of sampling. Personnel will also perform a quick D-frame qualitative sampling of all stream habitats (riffles, pools, debris snags, etc.) at each macroinvertebrate location. All macroinvertebrates will be stored in 1 to 2 liter plastic containers and preserved with 95% ethanol in the field. All procedures for the sorting and identification of macroinvertebrates in the laboratory will follow EPA Region VIII standard operating procedures.

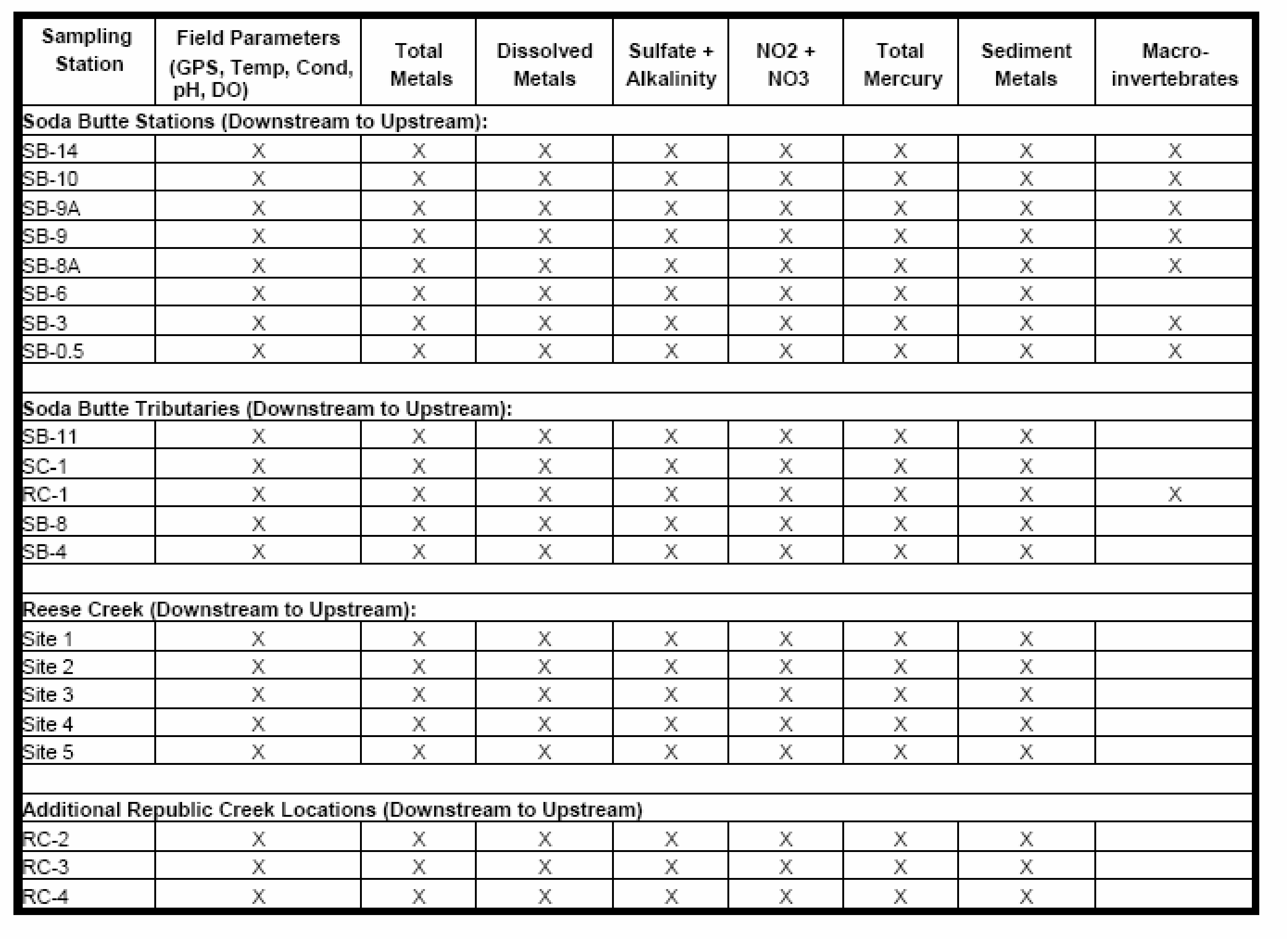
Sediment: Sediment samples for metals analyses will be collected using teflon scoops and will be consolidated into 60 ml plastic containers. Samplers will collect the organic fraction of sediment from the stream bottom where particles are 62 microns in size or less. Sediment shall be consolidated into the sample container from depositional areas on both sides of the stream, if possible. All sediment samples will be preserved to a temperature < 4 °C using ice.

Table A - 1. Sampling stations for Soda Butte Creek and tributaries.



Soda Butte Stations (Downstream to Upstream):	
SB-14	Soda Butte Creek 100 yards upstream from confluence with the Lamar River in Yellowstone National Park. Station is located approximately 18.75 miles from the western edge of Cooke City.
SB-10	Soda Butte Creek just inside northeast boundary of Yellowstone National Park just beyond the ranger station.
SB-9A	Soda Butte Creek at powerline crossing approximately 0.6 miles from the western edge of Cooke City and about 0.5 miles upstream of Sheep Creek (SC-1) and 0.5 miles downstream of Republic Creek (RC-1).
SB-9	Soda Butte Creek behind High Country Motel in Cooke City and upstream of Republic Creek.
SB-8A	Soda Butte Creek downstream of Jack Williams cabin in Cooke city (eastern edge), downstream of tailings discharge and downstream of confluence with Old Miller Creek.
SB-6	Soda Butte Creek directly opposite McLaren Tailings dam and downstream of Miller Creek. Site appears to be upstream of tailings discharge (SB-8) but downstream of Miller Creek (SB-4).
SB-3	Soda Butte Creek at road crossing to McLaren Tailings area. Site is upstream of tailings discharge (SB-8) and Miller Creek (SB-4).
SB-0.5	Soda Butte Creek 50 yards downstream of culvert under Hwy 212 and just upstream of Forest Service road in Soda Butte Campground. (This is a better reference site.)
Soda Butte Tributaries (Downstream to Upstream):	
SB-11	Warm Creek upstream of confluence with Soda Butte Creek and downstream of culvert. Warm Creek is located 5 miles from the western edge of Cooke City inside northeast boundary of Yellowstone National Park.
SC-1	Sheep Creek 150 yards upstream of confluence with Soda Butte Creek and downstream of road culvert. 'Sheep creek is located approximately 2.5 miles from the northeast boundary of Yellowstone between SB-10 and SB-9A.
RC-1	Republic Creek at bridge crossing 150 yards upstream of confluence with Soda Butte Creek.
RC-2	Republic creek site to be determined in the field.
RC-3	Republic creek site to be determined in the field.
SB-8	Largest discolored seep at base of McLaren Tailings upstream of confluence with Soda Butte Creek.
SB-4	Miller Creek downstream of culvert under Hwy 212 and 75 yards upstream of confluence with Soda Butte Creek.
New Locations	3-5 sampling sites located on Reese Creek, which will be determined in the field. Reese Creek is located near Gardiner, at the boundary of the YNP and the Church Universal Triumphant.

Table A - 2. Parameters collected at each sampling station.



Sampling Station	Field Parameters (GPS, Temp, Cond, pH, DO)	Total Metals	Dissolved Metals	Sulfate + Alkalinity	NO2 + NO3	Total Mercury	Sediment Metals	Macro-invertebrates
Soda Butte Stations (Downstream to Upstream):								
SB-14	X	X	X	X	X	X	X	X
SB-10	X	X	X	X	X	X	X	X
SB-9A	X	X	X	X	X	X	X	X
SB-9	X	X	X	X	X	X	X	X
SB-8A	X	X	X	X	X	X	X	X
SB-6	X	X	X	X	X	X	X	
SB-3	X	X	X	X	X	X	X	X
SB-0.5	X	X	X	X	X	X	X	X
Soda Butte Tributaries (Downstream to Upstream):								
SB-11	X	X	X	X	X	X	X	
SC-1	X	X	X	X	X	X	X	
RC-1	X	X	X	X	X	X	X	X
SB-8	X	X	X	X	X	X	X	
SB-4	X	X	X	X	X	X	X	
Reese Creek (Downstream to Upstream):								
Site 1	X	X	X	X	X	X	X	
Site 2	X	X	X	X	X	X	X	
Site 3	X	X	X	X	X	X	X	
Site 4	X	X	X	X	X	X	X	
Site 5	X	X	X	X	X	X	X	
Additional Republic Creek Locations (Downstream to Upstream)								
RC-2	X	X	X	X	X	X	X	
RC-3	X	X	X	X	X	X	X	
RC-4	X	X	X	X	X	X	X	

4.6 Control of contaminated materials

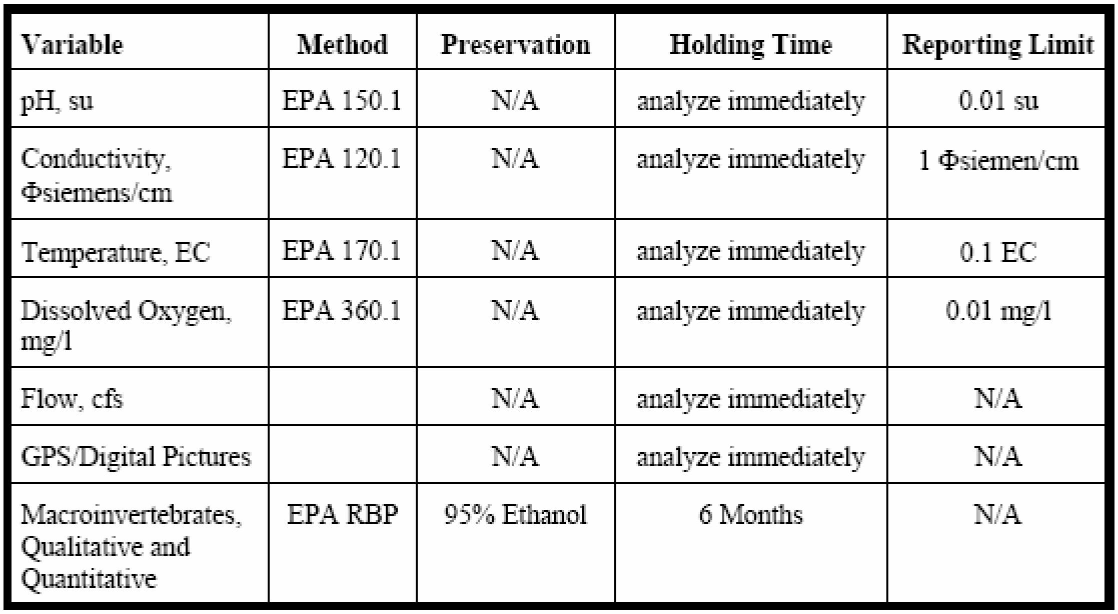
The sampling team will dispose of all wastes produced during this field event in accordance with EPA document 540-G-91-009 entitled *Management of Investigation-Derived Wastes During Site Inspections*. Disposable sampling equipment, including latex gloves, used preservative ampules, and filters, will be disposed of as a non-hazardous solid waste.

4.7 Analytical parameters

Table A-2 describes sample identification, type, and specific analyses to be performed on each sample. Twenty-one water samples will be measured for sulfate and alkalinity, NO_2 and NO_3, total and dissolved metals, and mercury. Eight of the sites will also be sampled qualitatively and quantitatively for macroinvertebrates. Sediment from the same 21 locations will also be analyzed for total recoverable metals. A visual stream assessment of the physical habitat will also be conducted where the macroinvertebrates will be collected. Field parameters will be taken at each location. (See Table A-2).

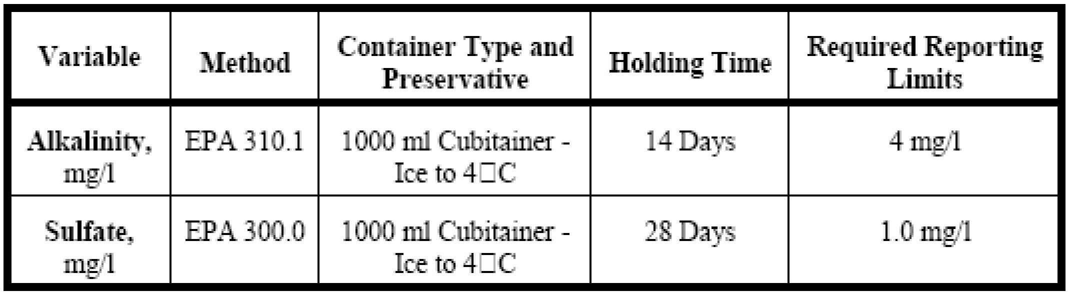
The EPA Region 8 laboratory will only perform the fieldwork, sulfate + alkalinity, NO2+NO3, and macroinvertebrate analyses (please see Tables A-3 through A-7). Water and sediment samples for mercury and total metals analyses will be analyzed at a laboratory yet to be determined.

Table A - 3. Field measurements.



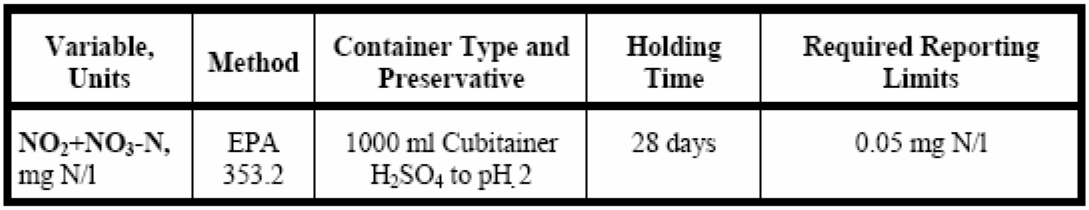
Variable	Method	Preservation	Holding Time	Reporting Limit
pH, su	EPA 150.1	N/A	analyze immediately	0.01 su
Conductivity, Φsiemens/cm	EPA 120.1	N/A	analyze immediately	1 Φsiemen/cm
Temperature, EC	EPA 170.1	N/A	analyze immediately	0.1 EC
Dissolved Oxygen, mg/l	EPA 360.1	N/A	analyze immediately	0.01 mg/l
Flow, cfs		N/A	analyze immediately	N/A
GPS/Digital Pictures		N/A	analyze immediately	N/A
Macroinvertebrates, Qualitative and Quantitative	EPA RBP	95% Ethanol	6 Months	N/A

Table A - 4. Alkalinity and sulfate.



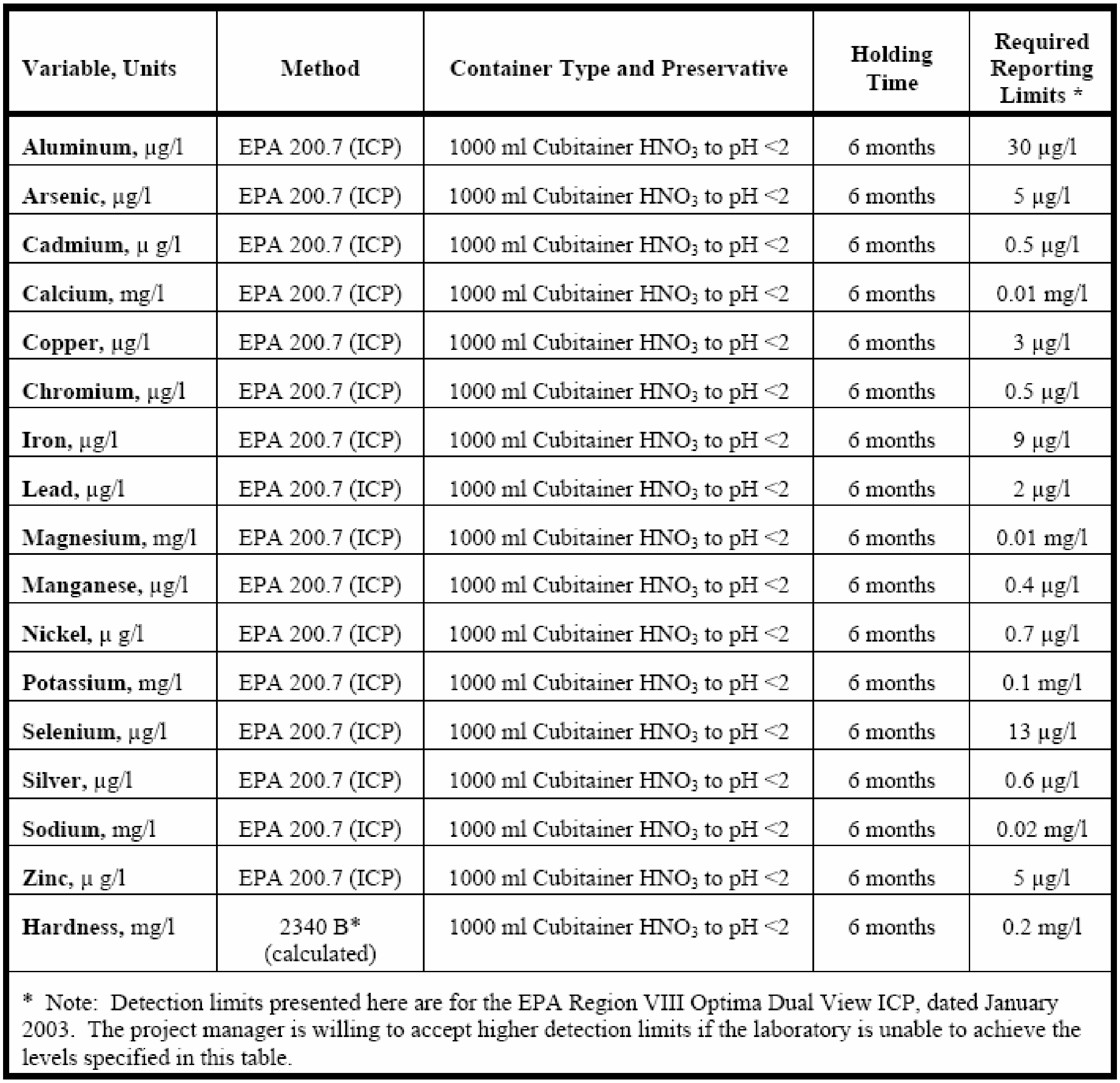
Variable	Method	Container Type and Preservative	Holding Time	Required Reporting Limits
Alkalinity, mg/l	EPA 310.1	1000 ml Cubitainer - Ice to 4□C	14 Days	4 mg/l
Sulfate, mg/l	EPA 300.0	1000 ml Cubitainer - Ice to 4□C	28 Days	1.0 mg/l

Table A - 5. NO2 + NO3.



Variable, Units	Method	Container Type and Preservative	Holding Time	Required Reporting Limits
NO_2+NO_3-N, mg N/l	EPA 353.2	1000 ml Cubitainer H_2SO_4 to pH 2	28 days	0.05 mg N/l

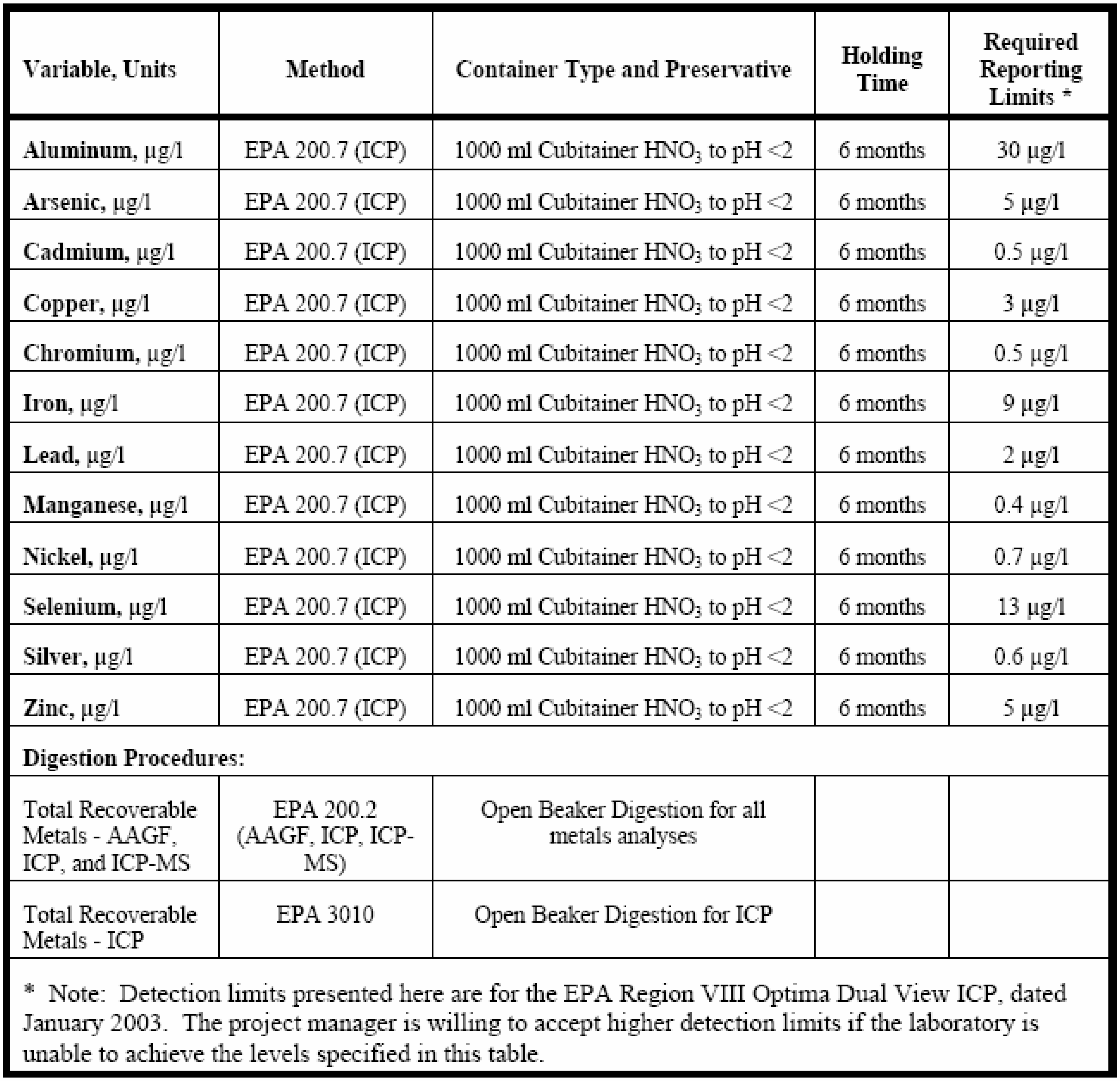
Table A - 6. Dissolved metals.



Variable, Units	Method	Container Type and Preservative	Holding Time	Required Reporting Limits *
Aluminum, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	30 µg/l
Arsenic, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	5 µg/l
Cadmium, µ g/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.5 µg/l
Calcium, mg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.01 mg/l
Copper, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	3 µg/l
Chromium, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.5 µg/l
Iron, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	9 µg/l
Lead, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	2 µg/l
Magnesium, mg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.01 mg/l
Manganese, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.4 µg/l
Nickel, µ g/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.7 µg/l
Potassium, mg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.1 mg/l
Selenium, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	13 µg/l
Silver, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.6 µg/l
Sodium, mg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.02 mg/l
Zinc, µ g/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	5 µg/l
Hardness, mg/l	2340 B* (calculated)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.2 mg/l

* Note: Detection limits presented here are for the EPA Region VIII Optima Dual View ICP, dated January 2003. The project manager is willing to accept higher detection limits if the laboratory is unable to achieve the levels specified in this table.

Table A - 7. Total recoverable metals for water.



Variable, Units	Method	Container Type and Preservative	Holding Time	Required Reporting Limits *
Aluminum, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	30 µg/l
Arsenic, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	5 µg/l
Cadmium, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.5 µg/l
Copper, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	3 µg/l
Chromium, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.5 µg/l
Iron, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	9 µg/l
Lead, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	2 µg/l
Manganese, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.4 µg/l
Nickel, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.7 µg/l
Selenium, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	13 µg/l
Silver, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	0.6 µg/l
Zinc, µg/l	EPA 200.7 (ICP)	1000 ml Cubitainer HNO_3 to pH <2	6 months	5 µg/l
Digestion Procedures:				
Total Recoverable Metals - AAGF, ICP, and ICP-MS	EPA 200.2 (AAGF, ICP, ICP-MS)	Open Beaker Digestion for all metals analyses		
Total Recoverable Metals - ICP	EPA 3010	Open Beaker Digestion for ICP		

* Note: Detection limits presented here are for the EPA Region VIII Optima Dual View ICP, dated January 2003. The project manager is willing to accept higher detection limits if the laboratory is unable to achieve the levels specified in this table.

4.8 Non-analytical parameters

The following non-analytical data will be collected:

- GPS coordinates and digital pictures for each sampling location
- Detail site description of all locations sampled.
- Flow measurements using a Marsh McBirney flow meter.
- Field water chemistry measurements (including pH, temperature, specific conductance, and dissolved oxygen) using a Hydrolab or YSI 650 multimeter.
- Physical Habitat assessment?

5.0 FIELD QA/QC

Duplicate sample(s) will be collected from surface water and sent to the laboratories for metals, NO2/NO3, sulfate, and alkalinity analyses. Set(s) of field blanks (container, preservation and filter) from a surface water sampling location will also be collected to check on the sample container, filtration apparatus and acids used in preservation. Blanks will be prepared from ultra-pure deionized water that has been brought into the field from the laboratory. Blanks will be prepared in the same manner as typical samples under the same environmental conditions. One round of QC samples (blanks, duplicates, etc.) will be collected for every 10 locations sampled in the field.

6.0 LAB QA/QC

Laboratory QC will follow standard operating procedures drafted by the Region 8 laboratory. Please see Table A-8 for a full description of the Lab QA/QC procedures.

7.0 SAMPLE CUSTODY

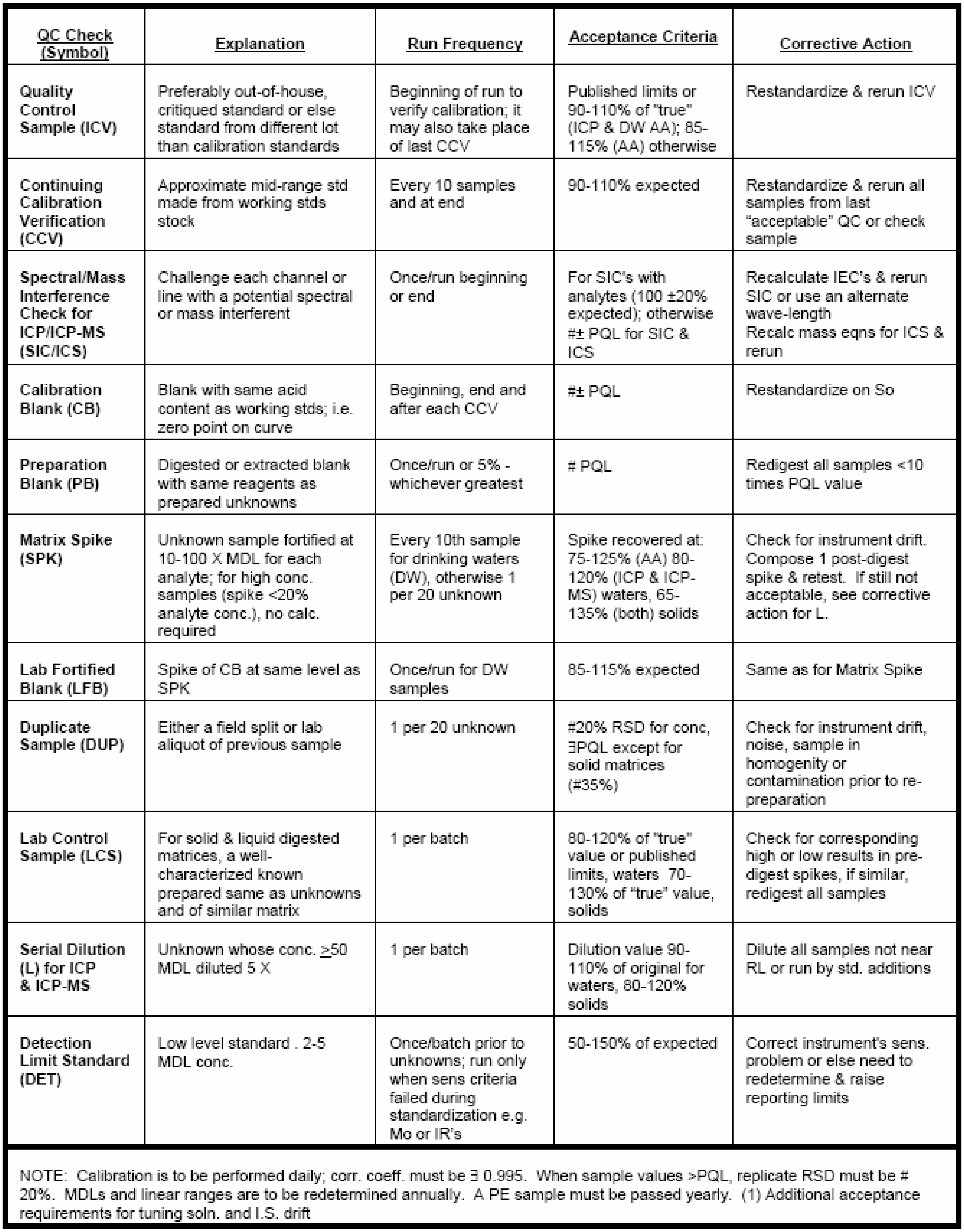
Chain-of-custody procedures will follow EPA Region VIII SOP for Field Samplers, 1996. Mike Wireman and Mark Williams will be the sample custodians and will keep records of all samples collected for analysis at the EPA Region VIII laboratory. A chain-of-custody record will accompany all samples and will be checked by the appropriate sample custodian. All samples will be tagged with pre-numbered and recorded sample tags.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

The results of the analyses conducted by Region VIII's laboratory, including a narrative, QA/QC report, and a summary of the data, will be forwarded to the project manager, Mike Wireman. If any laboratory QA/QC does not meet the EPA Region VIII laboratory acceptance criteria, the project manager will be immediately notified for further instructions.

Records will be kept of actual sample locations and sample points will be accurately located on topographic maps using the measured Latitude/longitude. Procedures will provide documentation of changes in sample locations as they occur in the field due to unanticipated site conditions. Sample locations and sample collection procedures will be documented through the keeping of a field notebook and photographs. Upon receipt of analytical data, results will be compiled into a report and used to create a "vital signs" monitoring plan for the park service at Yellowstone National Park.

Table A - 8. Metals QC check protocol for ICP, ICP-MS (1), AA (each run).



QC Check (Symbol)	Explanation	Run Frequency	Acceptance Criteria	Corrective Action
Quality Control Sample (ICV)	Preferably out-of-house, critiqued standard or else standard from different lot than calibration standards	Beginning of run to verify calibration; it may also take place of last CCV	Published limits or 90-110% of "true" (ICP & DW AA); 85-115% (AA) otherwise	Restandardize & rerun ICV
Continuing Calibration Verification (CCV)	Approximate mid-range std made from working stds stock	Every 10 samples and at end	90-110% expected	Restandardize & rerun all samples from last "acceptable" QC or check sample
Spectral/Mass Interference Check for ICP/ICP-MS (SIC/ICS)	Challenge each channel or line with a potential spectral or mass interferent	Once/run beginning or end	For SIC's with analytes (100 ±20% expected); otherwise #± PQL for SIC & ICS	Recalculate IEC's & rerun SIC or use an alternate wave-length Recalc mass eqns for ICS & rerun
Calibration Blank (CB)	Blank with same acid content as working stds; i.e. zero point on curve	Beginning, end and after each CCV	#± PQL	Restandardize on So
Preparation Blank (PB)	Digested or extracted blank with same reagents as prepared unknowns	Once/run or 5% - whichever greatest	# PQL	Redigest all samples <10 times PQL value
Matrix Spike (SPK)	Unknown sample fortified at 10-100 X MDL for each analyte; for high conc. samples (spike <20% analyte conc.), no calc. required	Every 10th sample for drinking waters (DW), otherwise 1 per 20 unknown	Spike recovered at: 75-125% (AA) 80-120% (ICP & ICP-MS) waters, 65-135% (both) solids	Check for instrument drift. Compose 1 post-digest spike & retest. If still not acceptable, see corrective action for L.
Lab Fortified Blank (LFB)	Spike of CB at same level as SPK	Once/run for DW samples	85-115% expected	Same as for Matrix Spike
Duplicate Sample (DUP)	Either a field split or lab aliquot of previous sample	1 per 20 unknown	#20% RSD for conc, ∃PQL except for solid matrices (#35%)	Check for instrument drift, noise, sample in homogenity or contamination prior to re-preparation
Lab Control Sample (LCS)	For solid & liquid digested matrices, a well-characterized known prepared same as unknowns and of similar matrix	1 per batch	80-120% of "true" value or published limits, waters 70-130% of "true" value, solids	Check for corresponding high or low results in pre-digest spikes, if similar, redigest all samples
Serial Dilution (L) for ICP & ICP-MS	Unknown whose conc. $\geq$50 MDL diluted 5 X	1 per batch	Dilution value 90-110% of original for waters, 80-120% solids	Dilute all samples not near RL or run by std. additions
Detection Limit Standard (DET)	Low level standard . 2-5 MDL conc.	Once/batch prior to unknowns; run only when sens criteria failed during standardization e.g. Mo or IR's	50-150% of expected	Correct instrument's sens. problem or else need to redetermine & raise reporting limits

NOTE: Calibration is to be performed daily; corr. coeff. must be ∃ 0.995. When sample values >PQL, replicate RSD must be # 20%. MDLs and linear ranges are to be redetermined annually. A PE sample must be passed yearly. (1) Additional acceptance requirements for tuning soln. and I.S. drift

9.0 REFERENCES

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APPENDIX B:

Sampling and Analysis Plan for Reese Creek

Sampling and Analysis Plan for the Long Term Vital Signs Monitoring for

Reese Creek
Greater Yellowstone Area
December 2004

University of Colorado, Boulder
Department of Geography
260 UCB
Boulder, Colorado 80309

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1.0 INTRODUCTION

The University of Colorado-Boulder worked with a grant administered by the National Park Service to develop detailed protocol necessary to monitor the ecological health of Reese Creek in Montana and Wyoming. Reese Creek is on Montana's 303(d) list as a stream impaired by dewatering from irrigation by private landowners. We created a detailed, long term monitoring plan so that park and forest service officials can create and continue to build a database of information that is consistent cost efficient, and applicable to the greater Yellowstone area. Critical parameters or "vital signs" that will be used in this plan include water quality and biological data.

2.0 OBJECTIVES

This SAP is intended to fulfill the following objectives:

5) Implement a monitoring strategy based on sampling critical parameters guided by the information provided by the synoptic sampling.
6) This monitoring strategy will result in the production of data of known quality that is accessible to managers and other researchers, and that has an explicit link to decision making by managers.

3.0 BACKGROUND INFORMATION

3.1 Location and site description

Reese Creek is the northernmost tributary of the Yellowstone River in Yellowstone National Park FWS 1987). Reese Creek's headwaters originate from Cache Lake and flows approximately 7.2 miles to the Yellowstone River. The Reese Creek Drainage basin encompasses 8327 acres and is bounded by Electric Peak on the west and Sepulcher Mountain on the east (FWS 1987). Its' fisheries has been listed as moderately high, with exception of the 2 km before the confluence with the Yellowstone River. Three diversions owned by private landowners are located at 0.8, 1.6, and 2.0 km upstream from the confluence of Reese Creek with the Yellowstone River (FWS 1994). It has been noted that during spawning season 91% of the water flowing in Reese Creek has been diverted during the spawning season.

3.2 Physical characteristics

The physical description is provided by (FWS 1987): The Reese Creek watershed is located in the Gallatin Range Mountains of the Western Absorka Belt, a region characterized by intensive Eocene volcanic activity. Precambrian sedimentary materials from the South Snowy Block of the Beartooth uplift underlie the lava flows that formed the Reese Creek Valley. The major influence on present topography was the Pinedale glaciation and subsequent floods. Lower portions of the basin are covered with large amounts of glacial till and carbonaceous alluvium. Evidence of major floods and landslides from the Sepulcher Formation is most notable in the middle portions of Reese Creek (FWS 1987).

3.3 Site History and previous work

In 1926, Congress included the downstream portion of Reese Creek to Yellowstone National Park. However, the entire Reese Creek watershed did not officially become a part of the park until 1937. Even today, private land owners still retained the water rights to Reese Creek (FWS 1987). It is one of 12 tributaries that is used by Salmonids for spawning (FWS 1994)

The National Park Service has reported that the lowermost reach of Reese Creek goes dry during the spawning season (FWS 1987). In 1991, the park service was able to reach an agreement with private landowners for a required minimum flow. The adjudicated water rights stipulated that Reese Creek was to have minimum flows of 0.037 m^3/s between April 15 and October 15, and 50 percent of the available discharge the remainder of the year. However, if the discharge is less than 0.079 m^3/s, then the amount of water for minimum stream flow for Reese Creek decreases (FWS 1994).

Despite these efforts, Reese Creek has continued to go dry or nearly dry during drought years (FWS 1994). Other improvements have been added to the diversion structures on Reese Creek. Adjustable V-notched fish ladders, rotating fish screens to prevent fish from going into diversion ditches, and irrigation ditch headgates were laid in concrete foundations (FWS 1994). A study conducted by the US Fish and Wildlife Service noted improvement in the habitat for Reese Creek and the emergence of cutthroat trout fry (1994). They also determined that inadequate streamflow has limited the magnitude of trout populations in the lower 2 km of Reese Creek (FWS 1994).

4.0 FIELD PROCEDURES

4.1 Sampling Protocols

4.1.2 Continuous Discharge

We recommend measuring in-stream flow **CONTINUOUSLY** at a minimum of two sites: (a) above the up-stream diversion, and (b) below the lowest diversion. Additional measurements above and below diversions between (a) and (b) would also be helpful to determine the exact location of any diversion that causes discharge to fall below the negotiated in-stream flow value, but are not as important as the first two sites.

Our recommendation is that discharge be measured continuously using a pressure transducer and electronic data logger. Most important is that the measurements be transmitted in real time from each field site to an NPS facility. It is essential that discharge values be monitored continuously so that field personnel can be alerted and respond if discharge values fall below the negotiated minimum in-stream flow of 1.3 cfs.

We recommend a Keller pressure transducer and Campbell Scientific data logger. However, there are numerous other pressure transducers and data loggers that would also be adequate. Follow the operating instructions provided by the manufacture.

Velocity-Area Method of Measuring Discharge: Continuous gaging stations only measure stage height of the stream. You need to establish a rating curve by measuring discharge using the velocity-area method. The rating curve converts stage height to discharge. Discharge measurements using the velocity-area method should be made over a range of stage heights. You need:

- tape measure
- stop-watch
- wading rod
- headphones

- current meter
- at least two people; one to count clicks, one to record data.

For the velocity-area method you will establish a cross section through each sampling site on Reese Creek and measure velocity at points along this cross section at known intervals (see Figure B-1). Functionally, you will do this by dividing your stream into discrete sections where you can calculate the cross-sectional area and measure an average velocity (area x velocity = discharge). Then you will sum the discharges, Q, of each section to determine the total Q of the stream at that cross-section. Obviously, the more sections you include, the more accurate your determination of discharge is, but there must be a balance between accuracy and efficiency.

You will be using current meters like the Price AA or its little brother, the Pygmy to measure velocity. The measurements you make of velocity will be used to estimate the average velocity for the area, or vertical where the velocity measurement was made. String a measuring tape across the channel perpendicular to the flow and secure both ends. You should have at least 10 verticals (mark 10 spots on the line with red tape). It is most convenient if the spacing between the verticals is even, but it is OK if they are not. Measure the velocity at each vertical. You will be counting the number of clicks that occur in at least 40 seconds. For the Pygmy meter and one of the settings on the Price AA, one click indicates one revolution of the cups. For depths of 0.75 meters (2.5 feet) or less, we assume that the average velocity can be estimated by measuring the velocity at 0.4 of the depth off the bottom (i.e. for a depth of 1 meter you would measure the velocity at a depth of 0.4 meters, see Figure B-2). The velocity meters are mounted on wading rods that have increments of measurement on them. Keep good notes and record the distance from the bank (location of each vertical), number of clicks, time, and depth for each vertical on your data sheet.

4.1.2 Fish Populations

At present there is no agreed-upon vital sign for fish populations. Therefore we do not present any sampling and analysis protocol for fish populations. We do emphasize that additional research to determine appropriate vital signs for fish populations is warranted.

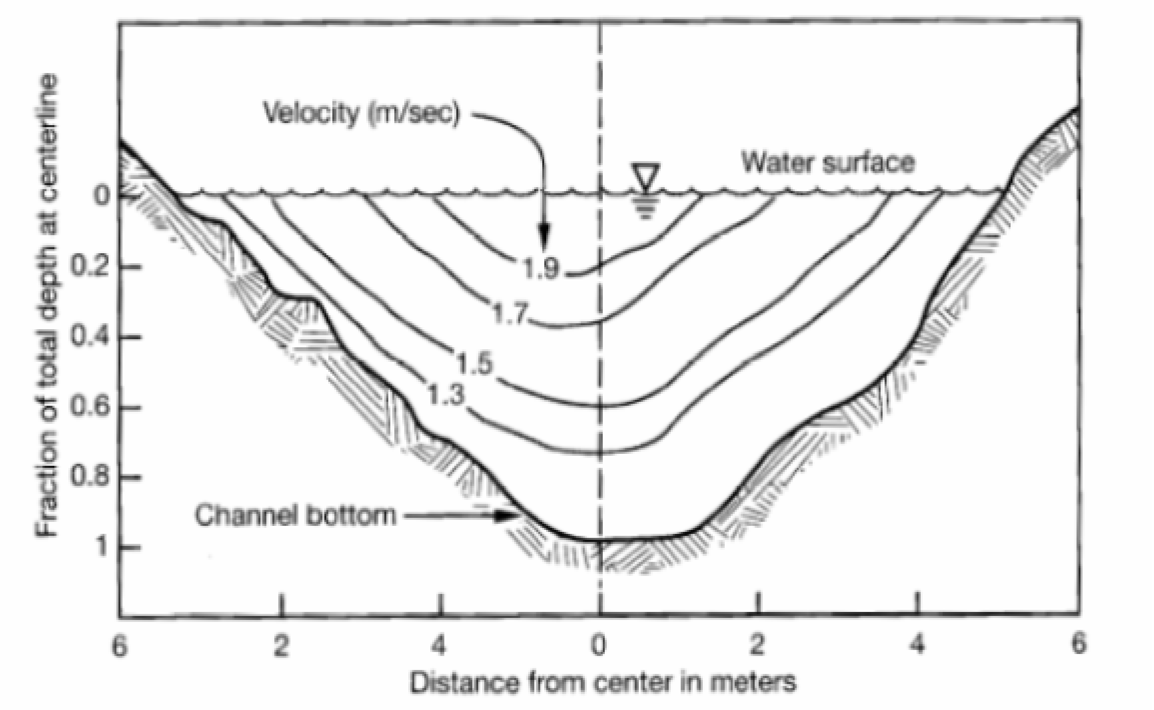

Figure B - 1. Stream velocity distribution: A cross-sectional view with contours indicating how velocity varies from top to bottom and across the stream channel.

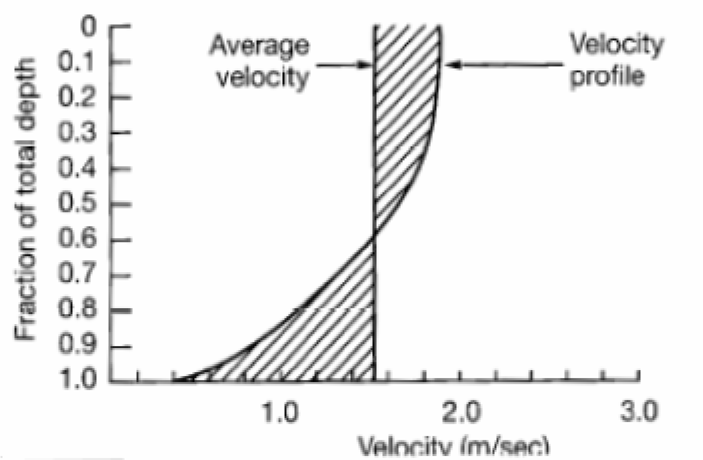

Figure B - 2. Stream velocity distribution: An example of a velocity profile. Notice how velocity changes with increasing depth, reaching the average velocity at approximately 0.6 of the total depth (or 0.4 of the depth from the bottom).

4.2 Safety and Emergency Contacts

Several teams will conduct the sampling project. Personal protective clothing and powderless gloves will be worn during all sample collections. In case of an emergency, field personnel can seek help from the following entities:

Fire/Police/Sheriff/Ambulance:	Park County Sheriff:
911	414 E. Callender Street #2

Livingston, Montana
(406) 222-4172

West Yellowstone Police Department:
124 Yellowstone Avenue
West Yellowstone, Montana
(406) 646-7600

Yellowstone National Park:
(307) 344-2386

Livingston Memorial Hospital
504 S 13th Street
Livingston, Montana
(406) 222-3541

Gardiner Ambulance Service:
213 Main Street
Gardiner, Montana
(406) 848-7226

5.0 REFERENCES

US Environmental Protection Agency. July 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. Second Edition.

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APPENDIX C:

Sampling and Analysis Plan: Soda Butte Creek

Sampling and Analysis Plan for the Long Term Vital Signs Monitoring for

Soda Butte Creek:
Stable Tailings Pile
Greater Yellowstone Area

December 2004

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1.0 INTRODUCTION

The University of Colorado-Boulder worked in collaboration with a grant administered by the National Park Service to develop detailed protocol necessary to monitor the ecological health of Soda Butte in Montana and Wyoming. Soda Butte Creek is on Montana's 303(d) list as a stream impaired by mining activities and is the only creek that enters Yellowstone National Park that has been adversely impacted. We created a detailed, long term monitoring plan so that park and forest service officials can create and continue to build a database of information that is consistent, cost efficient, and applicable to the greater Yellowstone area. Critical parameters or "vital signs" that will be used in this plan include water quality and biological data.

This SAP was prepared to outline the analytical objectives and to guide field sampling for a vital signs monitoring for Soda Butte Creek if the McLaren Tailings pile is not moved or is modified so that discharge of metals into the creek does not increase. Currently, the tailings pile is stable, and the impact to the stream is moderate throughout Cooke City to good within the park boundary. This SAP calls for the collection of surface water and macroinvertebrate sampling on Soda Butte Creek. Quality assurance/quality control samples consisting of field blanks, duplicate samples, and triple volume water samples should be also collected in the field for laboratory calibration purposes.

2.0 OBJECTIVES

This SAP is intended to fulfill the following objectives:

7) Implement a monitoring strategy based on sampling critical parameters guided by the information from the synoptic sampling.
8) Continue to better characterize and monitor water quality of Soda Butte Creek as a tool for continued monitoring and future remediation goals.
9) Result in the production of data of known quality that is accessible to managers and other researchers, and that has an explicit link to future decision making by managers.

3.0 BACKGROUND INFORMATION

3.1 Location and site description

Soda Butte Creek is a third order cobble and gravel bed stream with a laterally unstable wandering channel (Ladd et al 1998). Soda Butte Creek's headwaters originate near Henderson Mountain, 2 km east of Cooke City, Montana (Park County) and flows approximately 6 km into the northeast corner of Yellowstone National Park. Soda Butte Creek then flows 28 km and joins the Lamar River, which is a tributary of the Yellowstone River (Nimmo et al 1998). Along its course into Yellowstone National Park, Soda Butte Creek flows directly north of the McLaren Mine site. There is a large tailings pile consisting of 191,000 cubic meters of tailings (Sergent, Hauskins, and Beckwith 1990). The tailings pile consists of phyllosilicates, tectosilicates, sulfides, iron oxides, and calcium salts (Sergent, Hauskins, and Beckwith 1990). Although the actual path of Soda Butte Creek has been diverted around the tailings pile from its previous course directly through the tailings pile, evidence of deteriorating water and habitat quality is still apparent downstream (Charters et al 1988, Nimmo et al 1998, Marcus et al 2001).

3.2 Geology and hydrogeology

Soda Butte Creek is located in the Beartooth Mountains. The region has been subjected to extensive uplifting and thrust faulting that has exposed Precambrian crystalline rocks. Elevation ranges of the Soda Butte drainage is between 2300 and 2400 meters. The valley is steep sided and has morphological and lithological characteristics that are typical in glaciated landscapes. Elevations of mountain peaks in the area commonly exceed 3000 meters. The McLaren tailings site is characterized by three general geologic units which include Precambrian and tertiary age intrusive rocks, Pleistocene age sediments, and Holocene age sediments resulting from mining activity (Sergent, Hauskins, and Beckwith 1990).

Even though Soda Butte Creek has been diverted around the tailings pile, water pathways through the tailings pile can contribute to decreased water quality in the stream. Possible pathways include overland and subsurface flow, seepage from precipitation, and inflow from Soda Butte Creek and subsurface flow in the Holocene alluvium below the tailings pile and dam (Sergent, Hauskins, and Beckwith 1990). Avalanches and other catastrophic events could alter the course of the stream or flush tailings into Soda Butte Creek despite remediation efforts.

3.3 Site history and previous work

Placer gold was discovered in the Cooke City area in 1869. Hard rock mining for gold and silver from the McLaren Mine near Daisy Pass was processed intermittingly at the McLaren Tailings site from the 1870's until 1967. The mine has not been active since this time.

The National Park Service reported an impoundment failure in June 1950 that spilled tailings into creek (Nimmo et al 1998). In 1969, the creek was rerouted and the tailings pile was leveled, graded and seeded with grass (Nimmo et al 1990). From 1989-1991, the EPA, through the Superfund program, underwent remediation activities at the McLaren tailing sites. The remediation project included construction of a small emergency dike, a stability dam, an embarkment drain, earth berm, and an open interceptor drain. Tailings were removed from the toe and were replaced with clean fill. The disturbed area was then reseeded (Bureau of Reclamation 1994).

Despite these efforts, research has shown decreased water quality and compromised habitat downstream from the McLaren tailings pile. The Bureau of Reclamation released a report indicating that Soda Butte Creek violated Montana state water quality standards, and compromised the water quality within the national park (1994). Nimmo et al (1998) found that sediment collected in Soda Butte Creek was toxic to amphipods and that an emphasis should be place upon copper concentrations in future studies. Macro-invertebrate diversity also decreased downstream from the tailings pile. Shuler also noted elevated metal contamination in fish tissue (1994). Increased concentrations of metals and pH were also noted at four meadow sites downstream of the tailings that adversely affected density, diversity and biomass of the vegetation (Stoughton 1995). Seasonal variations in heavy metal concentrations and local variations in stream flow and turbulence has complicated exact measurements of water quality and should be taken into consideration during any sampling event (Nimmo et al 1998, Marcus et al 2001).

4.0 FIELD PROCEDURES

We recommend the following sampling design. We provide different sampling frequencies, with all other sampling components remaining the same. Four sampling sites are recommended (Table C-1). The first location is on the tributary of Woody Creek and will serve as a control. The second site selected is down stream of the McLaren tailings seep and is labeled SB-8A. The third sampling site is located downstream from the confluence of Soda Butte Creek with Republic Creek and is labeled SB-9A. The final site is located at the Boundary of Yellowstone National Park. This site is labeled SB-10. These sites were selected for two reasons.

3) The sampling sites provide: (a) a control; (b) evaluate potential impairment of Soda Butte Creek at the park boundary; and (c) provide information on potential contributions directly from the tailings seep and Republic Creek, which also has a history of mining.
4) These sites have been sampled previously and there is historical information for each of these sites.

All sites will be sampled for macro-invertebrates and dissolved metals content in stream waters as well as normal field parameters (Table C-2).

Scenario One: Sample collection twice a year every five years. Data has shown that water quality on Soda Butte Creek has been stable and improving in the last 10 years. Samples will be collected: (a) during snowmelt on the ascending limb of the hydrograph; and (b) baseflow conditions. Snowmelt may cause episodic movement of toxic metals into Soda Butte Creek or mobilize metals stored in stream sediments. Sampling during baseflow provides an opportunity to evaluate chronic conditions.

Scenario Two: Sample collection annually. Same as scenario one, but conducted annually.

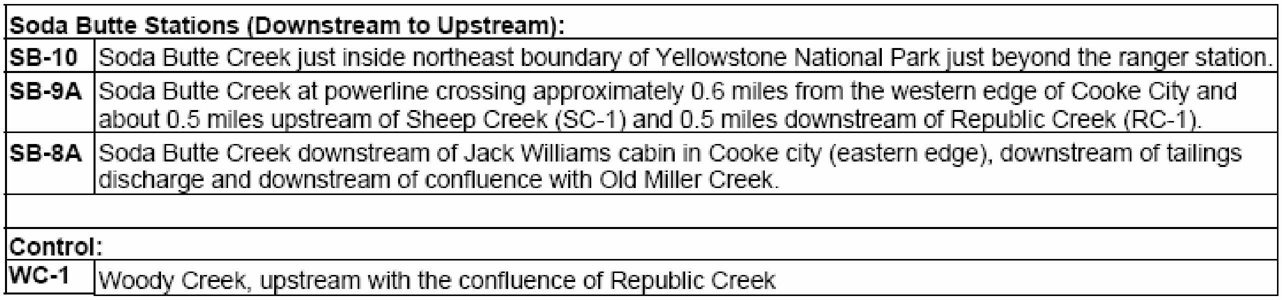
Scenario Three: diurnal sampling. Same as scenario two, but sample twice daily to account for potential diurnal effects.

Scenario Four: All 15 sites, twice a year (Table C-3).

Scenario Five: All 15 sites, twice a year and diurnally at each date (Table C-3).

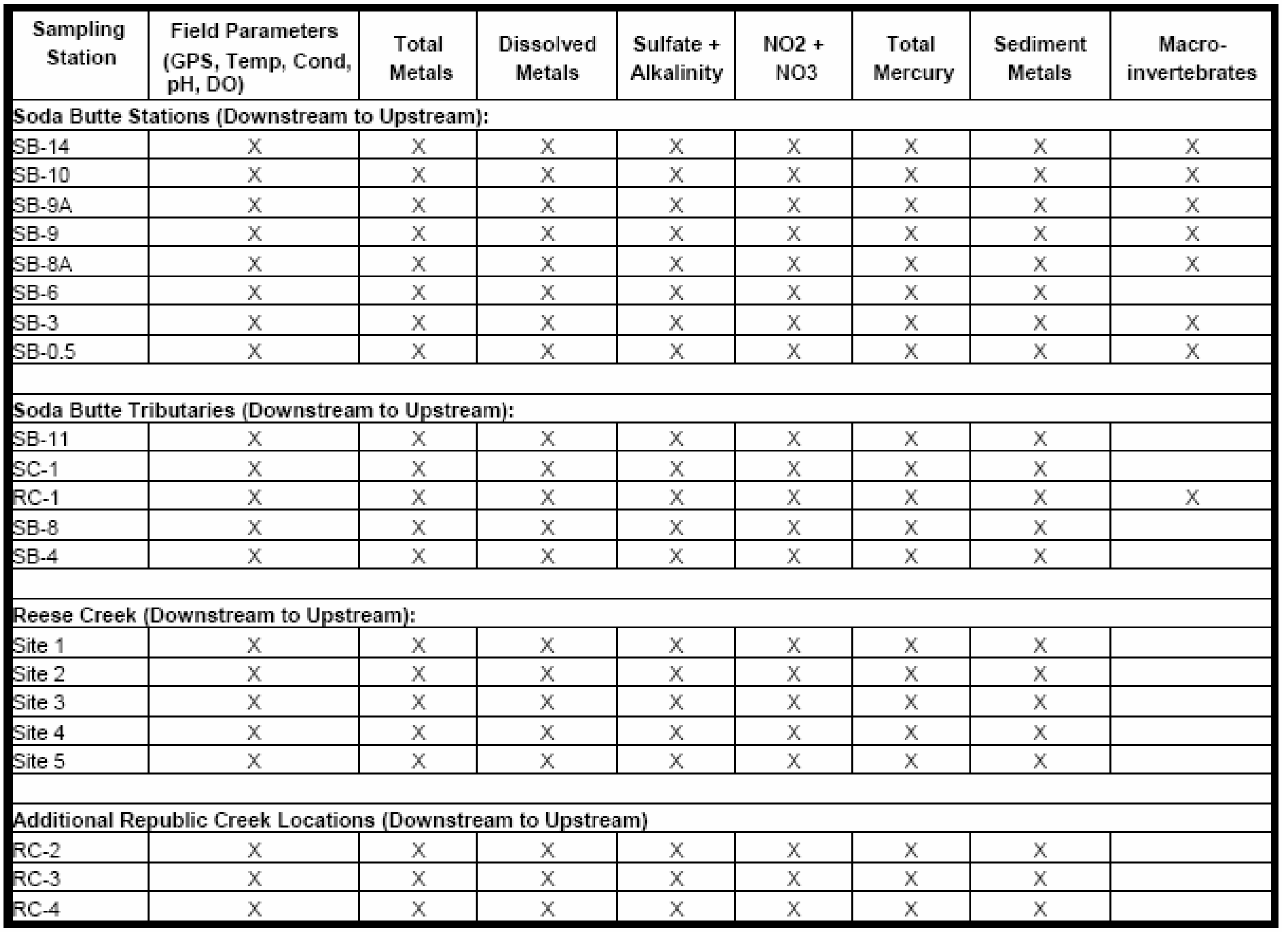
Scenario Six: All 15 sites, diurnally and 10 times a year distributed through the hydrograph (Table C-3).

Table C - 1. Sampling stations for Soda Butte Creek (scenarios 1-3).



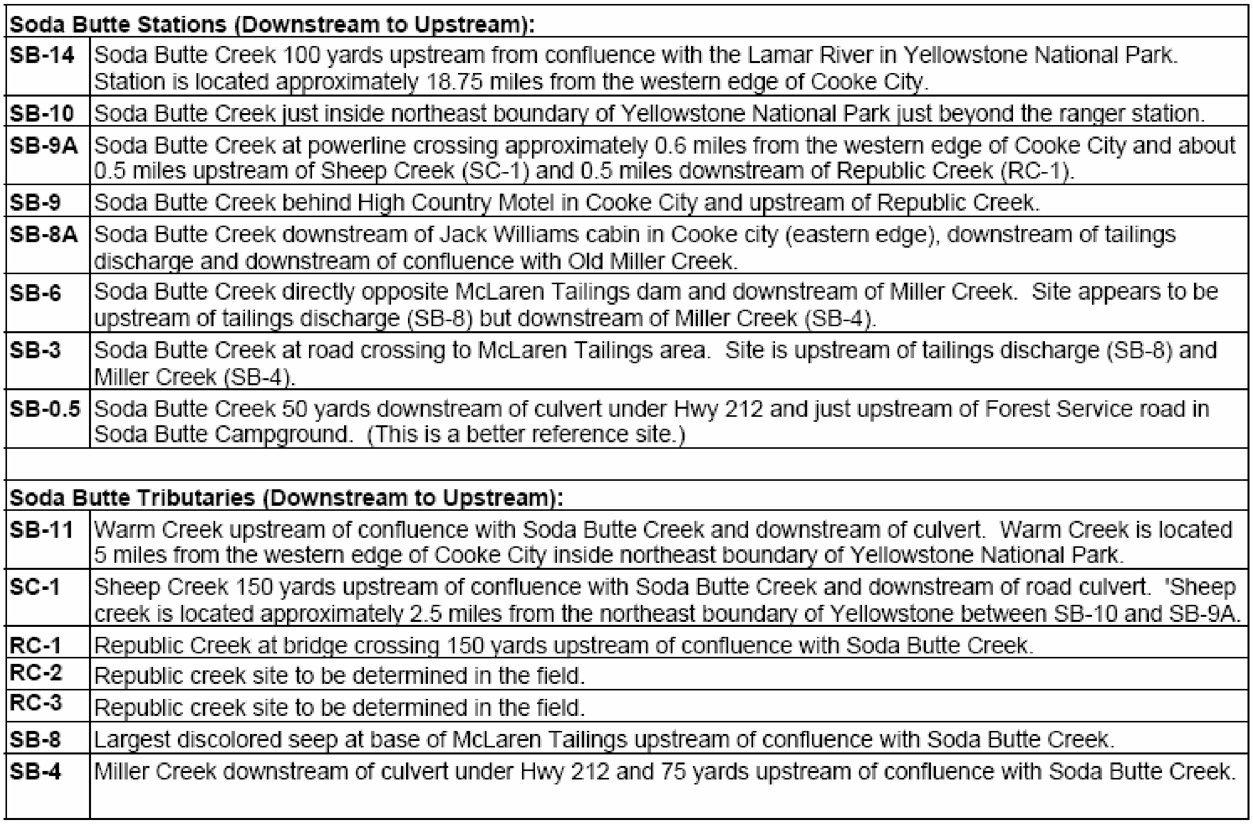
Soda Butte Stations (Downstream to Upstream):	
SB-10	Soda Butte Creek just inside northeast boundary of Yellowstone National Park just beyond the ranger station.
SB-9A	Soda Butte Creek at powerline crossing approximately 0.6 miles from the western edge of Cooke City and about 0.5 miles upstream of Sheep Creek (SC-1) and 0.5 miles downstream of Republic Creek (RC-1).
SB-8A	Soda Butte Creek downstream of Jack Williams cabin in Cooke city (eastern edge), downstream of tailings discharge and downstream of confluence with Old Miller Creek.
Control:	
WC-1	Woody Creek, upstream with the confluence of Republic Creek

Table C - 2. Parameters collected at each sampling station.



Sampling Station	Field Parameters (GPS, Temp, Cond, pH, DO)	Total Metals	Dissolved Metals	Sulfate + Alkalinity	NO2 + NO3	Total Mercury	Sediment Metals	Macro-invertebrates
Soda Butte Stations (Downstream to Upstream):								
SB-14	X	X	X	X	X	X	X	X
SB-10	X	X	X	X	X	X	X	X
SB-9A	X	X	X	X	X	X	X	X
SB-9	X	X	X	X	X	X	X	X
SB-8A	X	X	X	X	X	X	X	X
SB-6	X	X	X	X	X	X	X	
SB-3	X	X	X	X	X	X	X	X
SB-0.5	X	X	X	X	X	X	X	X
Soda Butte Tributaries (Downstream to Upstream):								
SB-11	X	X	X	X	X	X	X	
SC-1	X	X	X	X	X	X	X	
RC-1	X	X	X	X	X	X	X	X
SB-8	X	X	X	X	X	X	X	
SB-4	X	X	X	X	X	X	X	
Reese Creek (Downstream to Upstream):								
Site 1	X	X	X	X	X	X	X	
Site 2	X	X	X	X	X	X	X	
Site 3	X	X	X	X	X	X	X	
Site 4	X	X	X	X	X	X	X	
Site 5	X	X	X	X	X	X	X	
Additional Republic Creek Locations (Downstream to Upstream)								
RC-2	X	X	X	X	X	X	X	
RC-3	X	X	X	X	X	X	X	
RC-4	X	X	X	X	X	X	X	

Table C - 3. Sampling stations for Soda Butte Creek and tributaries (scenarios 4-6).



Soda Butte Stations (Downstream to Upstream):	
SB-14	Soda Butte Creek 100 yards upstream from confluence with the Lamar River in Yellowstone National Park. Station is located approximately 18.75 miles from the western edge of Cooke City.
SB-10	Soda Butte Creek just inside northeast boundary of Yellowstone National Park just beyond the ranger station.
SB-9A	Soda Butte Creek at powerline crossing approximately 0.6 miles from the western edge of Cooke City and about 0.5 miles upstream of Sheep Creek (SC-1) and 0.5 miles downstream of Republic Creek (RC-1).
SB-9	Soda Butte Creek behind High Country Motel in Cooke City and upstream of Republic Creek.
SB-8A	Soda Butte Creek downstream of Jack Williams cabin in Cooke city (eastern edge), downstream of tailings discharge and downstream of confluence with Old Miller Creek.
SB-6	Soda Butte Creek directly opposite McLaren Tailings dam and downstream of Miller Creek. Site appears to be upstream of tailings discharge (SB-8) but downstream of Miller Creek (SB-4).
SB-3	Soda Butte Creek at road crossing to McLaren Tailings area. Site is upstream of tailings discharge (SB-8) and Miller Creek (SB-4).
SB-0.5	Soda Butte Creek 50 yards downstream of culvert under Hwy 212 and just upstream of Forest Service road in Soda Butte Campground. (This is a better reference site.)
Soda Butte Tributaries (Downstream to Upstream):	
SB-11	Warm Creek upstream of confluence with Soda Butte Creek and downstream of culvert. Warm Creek is located 5 miles from the western edge of Cooke City inside northeast boundary of Yellowstone National Park.
SC-1	Sheep Creek 150 yards upstream of confluence with Soda Butte Creek and downstream of road culvert. 'Sheep creek is located approximately 2.5 miles from the northeast boundary of Yellowstone between SB-10 and SB-9A.
RC-1	Republic Creek at bridge crossing 150 yards upstream of confluence with Soda Butte Creek.
RC-2	Republic creek site to be determined in the field.
RC-3	Republic creek site to be determined in the field.
SB-8	Largest discolored seep at base of McLaren Tailings upstream of confluence with Soda Butte Creek.
SB-4	Miller Creek downstream of culvert under Hwy 212 and 75 yards upstream of confluence with Soda Butte Creek.

5.0 SAFETY AND EMERGENCY CONTACTS

Several teams will conduct the sampling project. Personal protective clothing and powderless gloves will be worn during all sample collections. In case of a emergency, field personnel can seek help from the following entities:

Fire/Police/Sheriff/Ambulance:
911

Park County Sheriff:
414 E. Callender Street #2
Livingston, Montana
(406) 222-4172

West Yellowstone Police
Department:
124 Yellowstone Avenue
West Yellowstone, Montana
(406) 646-7600

Yellowstone National Park:
(307) 344-2386

Livingston Memorial Hospital
504 S 13th Street
Livingston, Montana
(406) 222-3541

Gardiner Ambulance Service:
213 Main Street
Gardiner, Montana
(406) 848-7226

6.0 SAMPLING PROTOCOLS

All samples will be collected in accordance with the protocols identified in the Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, Periphyton, Benthic Macroinvertebrates, and Fish (EPA 842-B-99-002)(http://www.epa.gov/owow/monitoring/rbp/). Field procedures will follow protocols for standard operating procedures and requirements listed in *US EPA Region VIII - Minimum Requirements for Field Sampling Activities*, United States Environmental Protection Agency Region VIII, September 1996. All containers and preservation techniques for sampling will follow protocols listed in Table II of 40 CFR § 136.3 (http://www.access.gpo.gov/nara/cfr/waisidx_03/40cfr136_03.html).

Measures have been taken to minimize the amount of in-field equipment decontamination required for the sampling events. Field measurements will be taken in-situ and decontamination procedures will not be necessary. Equipment such as filters and syringes, bottles, etc. will not be reused, and decontamination will not be required in the field.

Water: Where possible, surface water will be consolidated into a bucket that will be used to pour off individual samples. The bucket will be rinsed at least three times with native water before sample collection. In the event that water is too shallow to obtain enough water in the bucket, sample containers will be dipped directly from the stream. Each sample container will be rinsed three times before sample collection. Water for the dissolved metals sample will be filtered in the field using a 4.5 micron filter. Filtered water will be used to rinse the dissolved metals container three times before the sample is sequestered. Dissolved metals will be preserved to a pH <2 using nitric acid.

Surface sampling will progress from downstream to upstream to eliminate sediment disturbance in subsequent sampling locations.

Quantitative Macroinvertebrates: Two to three quantitative macroinvertebrate samples will be collected from the four sampling locations. The samples will be collected following EPA Rapid Bioassessment Protocols (RBP) using Surber samplers (1’ x 1’). Surber samplers provide a unit area or unit volume and are used on shallow, flowing streams, with rubble substrate, mud, sand, or gravel. Only riffle habitats will be sampled quantitatively. The surber should be positioned with its net mouth open, facing upstream. The bottom of the surber sampler should be touching the substrate. The substrate in front of the surber sampler should be overturned in order to collect benthic invertebrates residing in the substrate. The number of surber samples to be collected at each location (3-5) will depend upon, weather conditions, and personnel available at the time of sampling. Replicate samples must be taken to ensure precision. Personnel will also perform a quick qualitative sampling using a D-frame kick net of all stream habitats (riffles, pools, debris snags, etc.) at each macroinvertebrate location. This is done as a check to make sure the surber sampling was done correctly. It also serves to make sure keystone species are not missed. Personnel will take quick samples for about 100 meters of the reach.

Samples will be removed from the net into the sample container. All macroinvertebrates will be stored in 1 to 2 liter plastic containers and preserved with 95% ethanol in the field. All procedures for the sorting and identification of macroinvertebrates in the laboratory will follow EPA Region VIII standard operating procedures. It is important to rinse the net between each sample so that samples will not be contaminated.

6.1 Control of contaminated materials

The sampling team will dispose of all wastes produced during this field event in accordance with EPA document 540-G-91-009 entitled *Management of Investigation-Derived Wastes During Site Inspectionshttp*:(//www.epa.gov/superfund/resources/remedy/pdf/93-45303fs-s.pdf). Disposable sampling equipment, including latex gloves, used preservative ampules, and filters, will be disposed of as a non-hazardous solid waste.

6.2 Analytical parameters

Table C-2 describes sample identification, type, and specific analyses to be performed on each sample. Samples will be measured for dissolved metals. Each of the sites will also be sampled qualitatively and quantitatively for macroinvertebrates. Field parameters will be taken at each location.

6.3 Non-analytical parameters

The following non-analytical data will be collected:

- GPS coordinates and digital pictures for each sampling location
- Flow measurements using a Marsh McBirney flow meter.
- Field water chemistry measurements (including pH, temperature, specific conductance, and dissolved oxygen) using a Hydrolab or YSI 650 multimeter.

6.4 Field QA/QC

Duplicate sample(s) will be collected from surface water and sent to the laboratories for metals. Set(s) of field blanks (container, preservation and filter) from a surface water sampling location will also be collected to check on the sample container, filtration apparatus and acids used in preservation. Blanks will be prepared from ultra-pure deionized water that has been brought into the field from the laboratory. Blanks will be prepared in the same manner as typical samples under the same environmental conditions. One round of QC samples (blanks, duplicates, etc.) will be collected for every 10 locations sampled in the field.

6.5 Lab QA/QC

Laboratory QC will follow standard operating procedures drafted by the Region 8 laboratory. Please see Table C-4 for a full description of the Lab QA/QC procedures. The laboratory selected must be EPA certified.

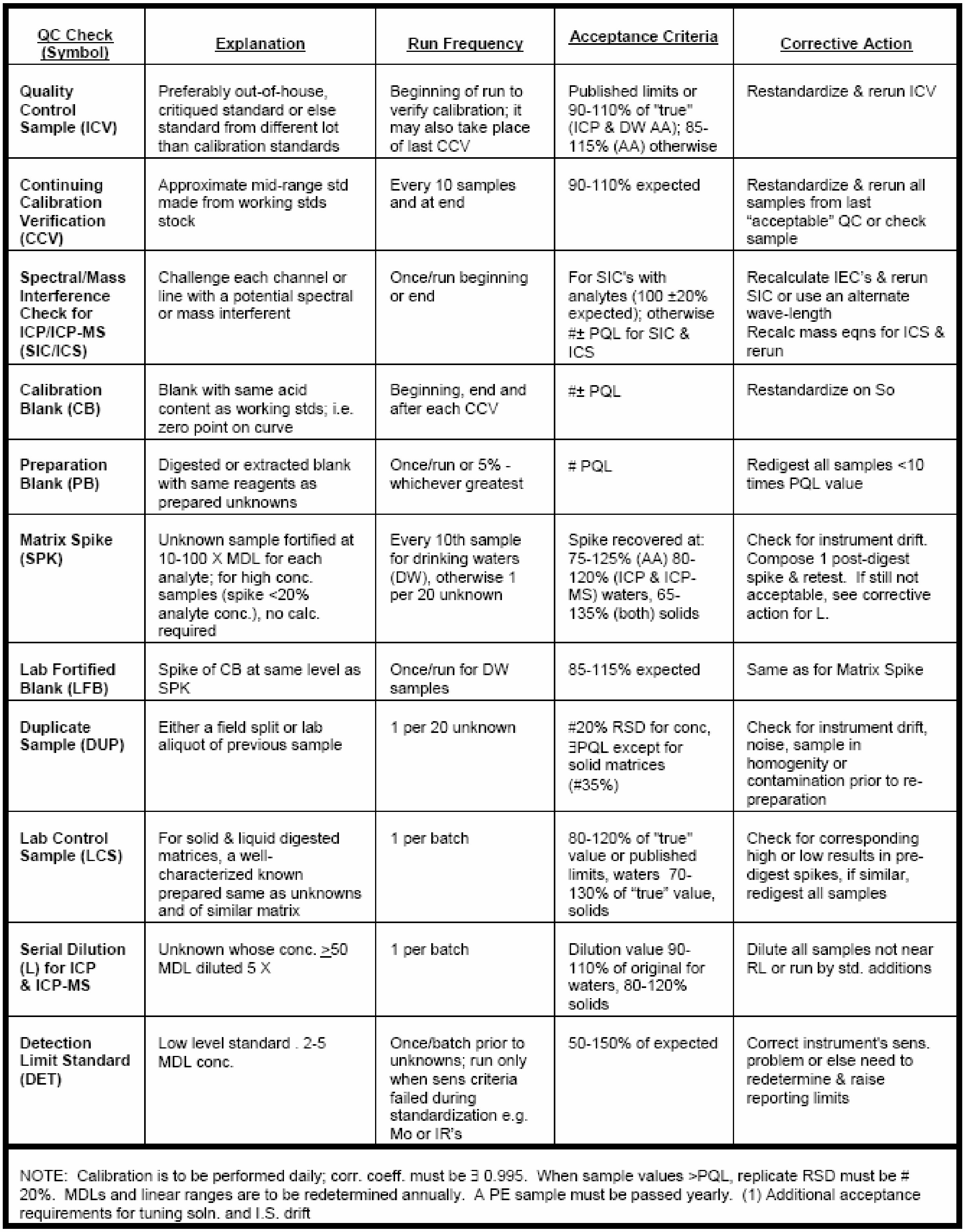
7.0 SAMPLE CUSTODY

Chain-of-custody procedures will follow EPA Region VIII SOP for Field Samplers, 1996. The sample custodians and will keep records of all samples collected for analysis. A chain-of-custody record will accompany all samples and will be checked by the appropriate sample custodian. All samples will be tagged with pre-numbered and recorded sample tags.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

Upon receipt of analytical data, results will be entered into the database for use for current and future resource management decisions.

Table C - 4. Metals QC check protocol for ICP, ICP-MS (1), AA (each run).



QC Check (Symbol)	Explanation	Run Frequency	Acceptance Criteria	Corrective Action
Quality Control Sample (ICV)	Preferably out-of-house, critiqued standard or else standard from different lot than calibration standards	Beginning of run to verify calibration; it may also take place of last CCV	Published limits or 90-110% of "true" (ICP & DW AA); 85-115% (AA) otherwise	Restandardize & rerun ICV
Continuing Calibration Verification (CCV)	Approximate mid-range std made from working stds stock	Every 10 samples and at end	90-110% expected	Restandardize & rerun all samples from last "acceptable" QC or check sample
Spectral/Mass Interference Check for ICP/ICP-MS (SIC/ICS)	Challenge each channel or line with a potential spectral or mass interferent	Once/run beginning or end	For SIC's with analytes (100 ±20% expected); otherwise #± PQL for SIC & ICS	Recalculate IEC's & rerun SIC or use an alternate wave-length Recalc mass eqns for ICS & rerun
Calibration Blank (CB)	Blank with same acid content as working stds; i.e. zero point on curve	Beginning, end and after each CCV	#± PQL	Restandardize on So
Preparation Blank (PB)	Digested or extracted blank with same reagents as prepared unknowns	Once/run or 5% - whichever greatest	# PQL	Redigest all samples <10 times PQL value
Matrix Spike (SPK)	Unknown sample fortified at 10-100 X MDL for each analyte; for high conc. samples (spike <20% analyte conc.), no calc. required	Every 10th sample for drinking waters (DW), otherwise 1 per 20 unknown	Spike recovered at: 75-125% (AA) 80-120% (ICP & ICP-MS) waters, 65-135% (both) solids	Check for instrument drift. Compose 1 post-digest spike & retest. If still not acceptable, see corrective action for L.
Lab Fortified Blank (LFB)	Spike of CB at same level as SPK	Once/run for DW samples	85-115% expected	Same as for Matrix Spike
Duplicate Sample (DUP)	Either a field split or lab aliquot of previous sample	1 per 20 unknown	#20% RSD for conc, ∃PQL except for solid matrices (#35%)	Check for instrument drift, noise, sample in homogenity or contamination prior to re-preparation
Lab Control Sample (LCS)	For solid & liquid digested matrices, a well-characterized known prepared same as unknowns and of similar matrix	1 per batch	80-120% of "true" value or published limits, waters 70-130% of "true" value, solids	Check for corresponding high or low results in pre-digest spikes, if similar, redigest all samples
Serial Dilution (L) for ICP & ICP-MS	Unknown whose conc. ≥50 MDL diluted 5 X	1 per batch	Dilution value 90-110% of original for waters, 80-120% solids	Dilute all samples not near RL or run by std. additions
Detection Limit Standard (DET)	Low level standard . 2-5 MDL conc.	Once/batch prior to unknowns; run only when sens criteria failed during standardization e.g. Mo or IR's	50-150% of expected	Correct instrument's sens. problem or else need to redetermine & raise reporting limits

NOTE: Calibration is to be performed daily; corr. coeff. must be ∃ 0.995. When sample values >PQL, replicate RSD must be # 20%. MDLs and linear ranges are to be redetermined annually. A PE sample must be passed yearly. (1) Additional acceptance requirements for tuning soln. and I.S. drift

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