

LIVINGSTON MILL SITE INSPECTION REPORT

Sawtooth National Forest, Idaho

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Submitted to:



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INTRODUCTION

Millennium Science and Engineering, Inc. was contracted by the USDA Forest Service to conduct a Site Inspection (SI) for the Livingston Mill site in central Idaho. The purpose of this investigation is to support a decision whether or not to pursue a removal action under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). This report presents the results of that SI.

Site Description

The project site is located in the Sawtooth National Forest, in Custer County, Idaho (T.9N, R.16E, S.1), approximately 14 miles southeast of Clayton, Idaho (Map 1). The site contains two historic mills and five tailings areas. It is wholly within the Sawtooth National Recreation Area, and a Forest Service campground and trailhead for the Castle Peak Trail are located in the immediate vicinity. Cabins in the former mining camp appear to be intermittently occupied.

The mine adits associated with the project site are located on private land at the head of Jim Creek, and are not within the scope of this investigation. The Little Livingston Mine, located on private land in the nearby Livingston Creek drainage, is also not a subject of this investigation.

The project site is located at an elevation of 7,200 feet in the Upper Salmon watershed (Hydrologic Unit Code 17060201; Figure 1), near the confluence of Jim Creek and Big Boulder Creek. Big Boulder Creek is a main tributary to the East Fork of the Salmon River, which is habitat for anadromous steelhead, trout and Chinook salmon. No stream segments of Big Boulder Creek, Jim Creek or the East Fork of the Salmon River have been identified as having impaired water quality. These streams do not appear on the 1998 "303(d) list," so named in reference to section 303(d) of the federal Clean Water Act.



Figure 1. The Upper Salmon watershed (HUC 17060201) and its location (EPA 2002).

Site History and Previous Investigations

The following background information was obtained by reviewing information provided by the Forest Service, readily available published reports from the Idaho Geological Survey, geologic maps and aerial photographs (dated 7/26/92). Key site features are visible on Maps 2A and 2B.

The Livingston Mine is located on private land approximately four miles west of the mill site, near the headwaters of Jim Creek, and is not included in this SI. The mine operated intermittently from the late 1800s to the 1950s, and produced approximately 86,700 tons of lead-zinc-silver ore. According to published reports, the first mill facility was constructed in 1924. This mill is located approximately 3,000 feet west of the confluence of Jim Creek with Big Boulder Creek, and is identified by the Forest Service as Mill 2. The high metals concentrations reported in the mill tailings suggest that this mill was somewhat ineffective in the recovery of lead, zinc and silver. Based on available information, tailings from the initial mill facility appear to have been placed in Tailings Areas 4 and 5. The site temporarily closed in 1930, and only operated intermittently during the 1930s and 1940s. Following expansion and construction of a new mill facility in approximately 1950 (Mill 1), mine operators began reprocessing mill tailings from the existing tailing ponds (recovering significant amounts of lead and zinc). Tailings from the reprocessing appear to have been placed in Tailings Areas 1, 2 and 3 (reportedly approximately 60,000 tons were reprocessed) (Mitchell 1997). On-site visual observations suggest that as each tailings pond filled up, the earthen dike was breached to allow excess tailings to flow into the next area. This practice also appears to have resulted in tailings being discharged into Big Boulder Creek.

Published reports on the Livingston Mine area indicate that in the 1970s, high levels of lead and zinc were present in samples from Tailings Areas 3 and 4, as well as in a stockpile of material then present directly south of tailing area 4. The current status of this stockpile is not known and is not included in the scope of this SI. In these samples, lead concentrations ranged from approximately 0.5% to over 3% (Mitchell 1997). Additional data in the literature also confirms the presence of metals (lead) in stream sediment samples from both Jim Creek and Big Boulder Creek. Concentrations of lead in Jim Creek directly downstream from Livingston Mine ranged from 1,000 to 33,000 milligrams per kilogram (mg/kg). Stream sediment concentrations in Big Boulder Creek downstream of Livingston Mill ranged from 70 to 149 mg/kg (Van Noy, *et al.*, 1986).

The Forest Service conducted a Preliminary Assessment (PA; the first phase of site investigation under CERCLA) in 1993. The Forest Service attempted to evaluate the volume of tailings material at the site, characterize contaminants of concern within the tailings, and evaluate the integrity of the containment and the potential for the material to be leached into the groundwater system.

Results of these limited investigations indicated the following:

- For Tailings Areas 2–3 the thickness of tailings along a roughly east-west transect ranged from approximately 5 to 10 feet at five locations (more detailed information or data on other tailings areas was not collected);
- Groundwater was not encountered in borings extended to a depth of up to 45 feet below ground surface (directly southeast of Tailings Areas 2–3);
- Analytical results indicate that lead is present in mill tailings at concentrations up to 38,600 milligrams per kilogram;
- Analytical results from a toxicity characteristic leaching procedure (TCLP) analysis of mill tailings samples indicates that the tailings would be considered a hazardous waste under the Resource Conservation and Recovery Act (RCRA), due to lead and cadmium concentrations in the laboratory leachate;
- Low TCLP concentrations for lead and cadmium in a surface sample from the tailings area (while elevated levels were found in samples collected from 2 to 5 feet below ground surface) suggest that some leaching of metals has occurred in the mill tailings area; and
- During the PA, it was determined that a CERCLA Site Inspection should be performed.

Scope of Present Study

A Site Inspection under CERCLA is intended to support a decision whether or not to pursue a Removal Action. The decision will be based on the extent to which a site presents a threat to human health or the environment. This is determined by collecting and analyzing waste and environmental media samples to determine whether hazardous substances are present at the site and migrating to the surrounding environment. An SI is not expected to provide a detailed assessment of the extent of contamination or a full risk assessment. It may include a scoring according to the Hazard Ranking System (HRS) for possible placement on the EPA's National Priorities List (NPL; EPA 1992).

This SI was performed in accordance with our September 5, 2001 and May 17, 2002 proposals to the Forest Service. In an attempt to streamline the CERCLA process, data were collected to support possible removal action options, as well as to assess the need for removal action. This is intended to reduce the need for future data gathering. No HRS scoring was performed. The presumed remedy could involve one or more of the following:

- no action;
- cap tailings in place;
- excavate tailings and place in an on-site constructed containment cell; or
- redirect surface water to avoid tailings deposits.

VISUAL SITE INSPECTION AND CONCEPTUAL MODEL

The conceptual model of the site presented here is derived from visual inspections conducted during 2001–2002, and also incorporates the field data described below. It is presented here as an aid to understanding both the rationale for collecting field data and the interpretation of those data. For ease of understanding, the model is presented here in order from higher elevation to lower. This is the reverse order of feature numbering previously used by the Forest Service (*i.e.*, Mill 2 is above Mill 1). Key site features are visible in the aerial photograph (Maps 2A and 2B).

Site access by humans and wildlife has not been restricted. The area is subject to recreational use for camping, hiking and hunting, and includes a trailhead campground for the Sawtooth National Recreation Area. Moose and deer were observed during field activities. Tailings have been placed in complex topological and hydrological settings, with both surface water and subsurface water flowing through the tailings. Tailings transport by both water and air is evident. The Forest Service reported that a significant redistribution of tailings occurred during a large storm event in the 1980s. The “site operator” attempted to contain the tailings, as evidenced by significant ground disturbance and anecdotal knowledge of local members of the community.

Jim Creek flows eastward down from the mine adits, and passes below Tailings Area 5 and the older mill (Mill 2) in a narrow canyon (Figure 2). These tailings are relatively coarse grained, and date from the earlier, less efficient stage of production. The tailings appear to have been formerly contained within a dike that is now breached. Some erosion due to surface flow through the dam breach is visible (Figure 3), and the eroded tailings form a wide shelf below the dam. Water was observed flowing out from beneath the tailings shelf below the dam, and flowing into Jim Creek. Unnamed tributaries enter Jim Creek about 250 feet upstream and downstream of Tailings Area 5. These tributaries may be dry during the summer months.



Figure 2. Mill 2, Tailings Area 5 and Jim Creek.



Figure 3. Tailings Area 5.

As the canyon widens near the confluence with Big Boulder Creek, Jim Creek passes about 200 feet below Tailings Area 4 (Figure 4). A set of cabins lies about 100 feet south of Jim Creek, in the relatively flat area between Jim Creek and Big Boulder Creek. Tailings Area 4 forms a large bowl on the northern slope of the valley, with a containment dike along the east and southeast. Most of the tailings have been removed, probably for processing at Mill 1. The central depression has variable topography and shows signs of trail riding by off-road vehicles and erosion by both wind and water. The tailings are relatively isolated from streams, but some runoff can flow in from the slope directly above. There is a “saddle” in the dike along the south, but its elevation is too high to pass water, except in extreme events. The tailings appeared dry on each visit, suggesting that water that collects in the bowl evaporates or exits via subsurface flow. An intermittent drainage flows about 50 feet west of the west end of these tailings, and a drainage ditch runs along the east edge, just west of Railroad Ridge Road. The outflow from this ditch crosses the road south of Tailings Area 4, and then works its way toward Jim Creek via a complex set of man-made channels and beaver ponds. Several features of Tailings Area 4 make it a likely candidate for a tailings repository: its location on a bench, its relative isolation from surface water, its ability to accommodate a large volume of material and its location adjacent to an existing road.

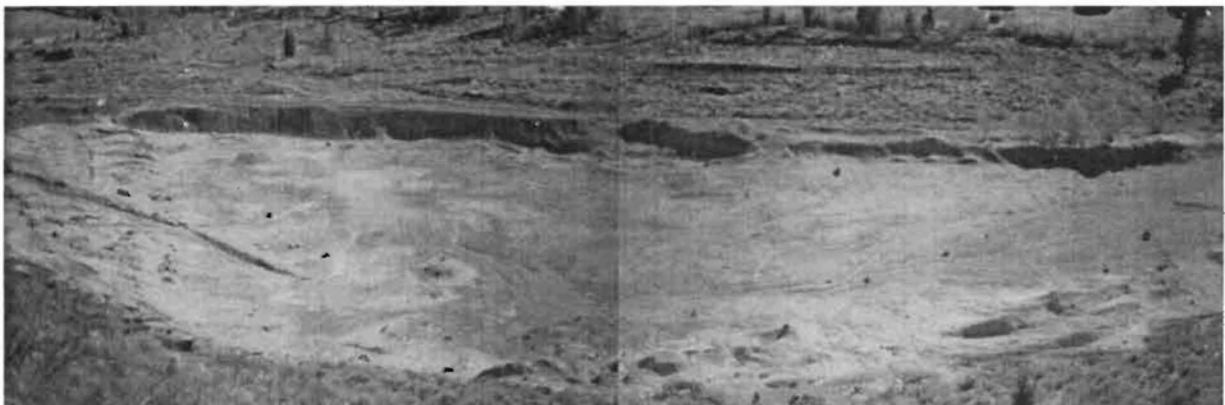


Figure 4. Tailings Area 4.

Mill 1 is located east of Tailings Area 4, across Railroad Ridge Road. Surface water routing is complex in this area, due to a combination of man-made diversions, beaver ponds and possibly natural stream braiding. An unnamed intermittent tributary of Jim Creek flows out of a rocky canyon just north of the Mill. For purposes of this report, it is referred to as “M1 Creek.” The remains of a wooden flume are

visible in the canyon, suggesting that M1 Creek furnished process water for the mill at one time. The course of the creek has been diverted sharply eastward to bypass the Mill; its original course appears to have run through the current location of Mill 1.

Jim Creek has also been diverted in this area; south of the road and west of Tailings Area 3, after passing through beaver ponds it has been redirected in a southeasterly direction towards its present confluence with Big Boulder Creek. It appears that the main channel of Jim Creek passed just south of the present Tailings Area 3 in the past. Its historic confluence with Big Boulder Creek (or one of its braids) was apparently just south of the east edge of Tailings Area 3 (the current fence line). This channel continues eastward along the south edge of Tailings Areas 2 and 1, with many branches, until it eventually joins Big Boulder Creek. It does not have an outlet into Tailings Areas 2 or 1.

Tailings Area 3 (Figure 5) is located south of Mill 1. It is bounded on the east by a low tailings dam and fence line, on the north by an unpaved road, and on the south by a berm that separates it from the former channel of Jim Creek. A channel running inside the berm along much of the south side of the tailings area can be seen in the photograph. This channel may have been intended to facilitate tailings transfer from Area 3 to Area 2. It is fed by a conveyance running through the berm from the former Jim Creek channel, but it did not contain standing or running water during 2001–2002 field observations. The low tailings dam has been breached, and shows definite evidence of erosion. There is also evidence of ponding and surface water erosion on the surface of the tailings area.



Figure 5. Tailings Areas 3 (foreground) and 2.

Tailings Area 2 covers a large area east of the fence line and breached dam. It is bounded on the north by the unpaved road and on the south and east by a berm. The former Jim Creek channel lies to the south. A low ridge runs roughly east–west across the area, topped by deciduous trees and large boulders (Figure 6). This suggests that the underlying topography is higher along this ridge than on either side of it. For purposes of discussion, we have designated the zone north of this ridge as Area 2A, and the zone to the south as Area 2B.

M1 Creek crosses the unpaved road and enters Tailings Area 2A (Figure 7). Eastward from this point, the northern tailings boundary is marked by a series of willow bushes and a few small pine trees. Since the tailings themselves are barren (except along the ridge) and the vegetated zone along the north edge is characterized by willows and grasses, this suggests the presence of water along the northern boundary of Area 2A. Careful examination of the tailings topography indicated that the topographic low is not along the boundary, but somewhat south of it. A temporary piezometer constructed of 2-inch polyvinyl chloride well screen was installed near one of the willow bushes (Figure 8). Although the piezometer was screened down to the soil contact, no groundwater was observed. This may be due to seasonal conditions.

Moist subsurface tailings had been observed during sample collection about ten feet into Area 2A from the “inlet” of M1 Creek.

The presence of a few bushes and small trees in Tailings Area 2B below the breached dam was also suggestive of subsurface water flows. Attempts to install a piezometer using a hand-auger were unsuccessful. The presence of a fair amount of gravel, with cobble diameters up to an inch, caused auger refusal. Significant amounts of gravel were not observed elsewhere in tailings areas, and were attributed to high water velocities at the time of the dam breach. Tailings topography suggests that any water on the surface will run parallel to the southern berm until it joins flows from Area 2A at the southeast corner.



Figure 6. Tailings Area 2.



Figure 7. “M1 Creek” crossing road towards Tailings Area 2A (at willow).



Figure 8. Line of willows and piezometer near north edge of Tailings Area 2A.

Tailings Area 1 is a widely dispersed area east of the berm containing Tailings Area 2. Significant disturbance and mixing is evident, with repeated attempts to contain tailings in the downstream portion of the tailings by means of soil berms. A drainage coming down from the northern valley slope was covered with tailings in places, but was dry where exposed at the confluence with Jim Creek. A potential source of soil cover is located on the far downstream side.

A campground and trailhead are located along Big Boulder Creek to the southeast of Tailings Area 1. The Shoshone–Bannock Tribes conducted a limited habitat improvement project in 1994 in this section of the creek. This involved sloping vertical banks, diverting the stream away from high cutbanks and

returning the stream to a more natural meander pattern (Columbia Basin Fish and Wildlife Authority, undated).

FIELD DATA COLLECTION

Field data collected in this study include:

- visual inspection of the site and assessment of site hydrology;
- water quality and flow monitoring along Jim Creek and Big Boulder creek to assess whether chemical impacts have occurred;
- macroinvertebrate sampling along Jim Creek and Big Boulder Creek to assess whether aquatic biological communities have been impacted;
- tailings analysis for metal constituents and acid–base accounting;
- process residuals analysis for metals constituents;
- estimates of tailings volume by augering;
- agronomic analysis of soil/tailings mixtures to assess suitability as plant growth medium; and
- geotechnical analysis of tailings and soils for assessment of suitability in a possible containment cell.

Field efforts commenced during the week of October 11, 2001. This included macroinvertebrate sampling and sampling the tailings and process residuals. Field efforts were interrupted by heavy snowfall. Water quality sampling, flow monitoring and field mapping were conducted the following week. Depth measurements of the Tailings Areas 2 and 3 and collection of the water quality sample from Tailings Area 5 were conducted on November 20. Based on data needs identified after the 2001 field efforts, additional water quality monitoring and soil and waste sampling were performed in June and July 2002.

Water Quality Monitoring

Surface water samples were collected from six locations on Big Boulder Creek and Jim Creek (W1–W6) on October 17–18, 2001 for laboratory analysis. The unfiltered samples were collected into polyethylene bottles, packed in an ice–filled cooler and shipped by overnight courier to SVL Laboratories of Kellogg, Idaho for analysis. SVL determined arsenic by EPA method 206.2, calcium, copper, magnesium and zinc by EPA method 200.7, lead by EPA method 239.2, selenium by EPA method 270.2. SVL calculated hardness for each sample, based on the measured calcium and magnesium concentrations. Samples were submitted without acid preservative in order to allow laboratory determination of pH by EPA method 150.2. A second aliquot of sample W1 from Jim Creek was submitted to the laboratory as blind duplicate (W7). An additional water quality sample (W8) was collected from the water emanating from Tailings Area 5 on November 20, 2001. This sample was also submitted to SVL for analysis in a like manner to samples W1–W7, except that pH determination was omitted in error. The laboratory’s quality assurance methodology included the analysis of laboratory control spikes (LCS) and matrix spikes (MS), as well as method blanks.

Flow was measured at each of the sample collection sites W1–W6, using a Marsh–McBirney, Inc. Flo–Mate Model 2000 electromagnetic velocity meter. Stream width was measured with a tape measure, and the cross section was divided into nominal one–foot wide sections. Stream velocity was measured at 60%

of the flow depth in each section. Flow was calculated by summing the products of the stream velocities and their associated depths and interval widths. Stream flow was too low to measure by this technique at sample site W8.

A second round of water quality monitoring was conducted the following spring, on June 19–20, 2002. Field and laboratory procedures were the same as during 2001, except that selenium was determined by the gaseous hydride atomic absorption method (EPA method 270.3), in order to avoid possible sulfate interferences to the conventional atomic absorption method (EPA method 270.2). To the extent possible, samples were collected from the same sites as in 2001 (W9–W16). Perfect identification of some of the sites in the upper Jim Creek area was not possible, because of poor GPS performance in this narrow portion of the canyon, and because many of the site flags could not be found. Flow measurement locations were also similar to the 2001 locations (see Table 2), with a few exceptions. The flow measurements associated with the upper Big Boulder Creek sample (W11) were actually made from a log bridging the creek about 80 feet upstream of the sample. This was necessary because the spring flow was too fast and deep to wade in this area (Figures 9 and 10). Autumn 2001 flow measurements at Big Boulder Creek #1 and #2 were essentially duplicative of the measurements at Big Boulder Creek #3, and gave an indication of measurement precision. They were replaced by measurements adjacent to and below Tailings Area 1, in order to allow assessment of subsurface flows through these tailings. The seep from Tailings Area 5 (W9) had too little flow to measure using the velocity meter. The flow was estimated by measuring the amount of time that it took to fill a 500mL sample bottle.



Figure 9. Upper Big Boulder Creek near W6 in October 2001.



Figure 10. Upper Big Boulder Creek near W6 in June 2002.

Macroinvertebrate Sampling

Macroinvertebrate samples were collected on October 11, 2001, following protocols outlined in the *1999 Beneficial Use Reconnaissance Project Workplan for Wadable Streams* (IDEQ 1999). Macroinvertebrates were collected using a Hess sampler from three different riffle/run habitats for each of four nominal sample locations. These locations were: Big Boulder Creek below Tailings Area 1; Jim Creek above Tailings Area 5; Jim Creek prior to its confluence with Big Boulder Creek, and Big Boulder Creek upstream of its confluence with Jim Creek. A field duplicate sample (consisting of three subsamples) was collected from Big Boulder Creek upstream of its confluence with Jim Creek. Samples were preserved with ethanol and labeled (both inside and outside the container) with information such as sample identification, stream name, date, site location, and collector's name.

Samples were shipped to EcoAnalysts, Inc. in Moscow, Idaho for processing. EcoAnalysts combined the three subsamples for each nominal location and performed a 500-count subsample. Macroinvertebrates were identified to the lowest taxonomic level possible. Appendix I illustrates the identified taxa and number of individuals present at each location.

EcoAnalysts performed quality control and quality assurance (QA/QC) procedures for each of the following tasks: sorting, identification, and data entry. The sorting QA/QC is a methodology aimed to ensure that at least 90% of the invertebrates have been removed from each sample. This is accomplished through a second technician resorting the subsample to estimate the efficacy of the original sort. If the estimate is 90% or greater, the sample passes the QC check. If the estimate is less than 90%, the sample is completely resorted, and the process is repeated. Two QA/QC methodologies are utilized for the taxonomic task. The first is to establish a voucher collection composed of one specimen of each taxon. A second taxonomist checks the collection, and any differences encountered are discussed and reconciled between the two taxonomists. The second methodology is quantitative and requires ten percent of the sample (randomly chosen prior to the first identification) to be re-identified by a second taxonomist. The two taxonomists discuss and reconcile any differences that arise. The taxonomists used a proprietary macroinvertebrate data entry program to record their results. The program has intrinsic safeguards to protect against many common data entry mistakes (duplicates, typographic errors, etc.). The project taxonomist and one other taxonomist then reviewed the list.

Waste Sampling

Tailings samples were collected from each of Tailings Areas 1 through 5 on October 11, 2001. Samples were generally collected from depths of one to two feet, using hand tools. Visual observations during sampling of Tailings Area 1 suggested that the tailings in this area form a relatively surface thin layer, typically only a few inches in depth. With increasing sample depth, the tailings appeared to be increasingly mixed with what appeared to be native soils. Materials from this area were anticipated to be available for use as potential containment cell cover. Because of heavy snowfall during sampling, an excess number of samples were collected, placed into plastic sample bags and transported to Boise for further sample selection. Two samples from each of Tailings Areas 2A, 2B, 3, 4 and 5 were ultimately submitted to SVL for analysis. Separate samples were submitted from the upper fines layer and the mixed upper six inches of Tailings Area 1. Sample locations were estimated using a handheld Global Positioning System (GPS) receiver (Garmin GPS12) or a wheel and compass when the site was revisited on October 16–18. Sample locations are displayed on Maps 2A and 2B.

Four process residuals samples (M001 through M004) were collected from around Mill 1 on October 11 (Figure 11). These samples were collected from near the ground surface, where visual evidence of discoloration was observed. Several drums were observed in the vicinity of Mill 1. One sample of a white granular solid (M005) was collected from one drum, and one sample of a yellowish granular solid (M006) from another drum was collected for analysis (Figure 12). No samples were collected from inside the building or at Mill 2 at this time because of access restrictions.

Samples were shipped to SVL Laboratories of Kellogg, Idaho for analysis. Two samples from each Tailings Area, the four process waste samples and the two drum samples were submitted for determination of arsenic (As), copper (Cu), lead (Pb), selenium (Se) and zinc (Zn) in each sample by EPA method 6010B. In addition, calcium (Ca) was determined by EPA method 6010B and cyanide (CN) by EPA method 9012A in sample M004. Composite samples for each Tailings Area (T1C–T5C) were prepared from six subsamples from that area and submitted to SVL for Acid–Base Accounting analysis.



Figure 11. Process residuals samples M001–M004 (flagged) and transformer sample M007 at Mill 1.



Figure 12. Drum samples M005–M006 at Mill 1.



Figure 13. Sample M008 of blue crystalline material at Mill 1.



Figure 14. Empty cyanide can south of Tailings Area 2.

A portable auger powered by an electric drill was used to measure the depth of the contact between tailings and native materials at 28 points in Tailings Areas 2 and 3. It was assumed that the contact was reached when a change in the auger resistance of the subsurface material was encountered. Split-spoon samples were collected at a number of points and visually inspected to confirm that the contact had been reached. Visual observations at Tailings Area 1 during sampling indicated that the tailings deposits were of varied thickness, not exceeding two feet, and augering was not deemed necessary. Augering was not performed at Tailings Area 4, since it was anticipated that this area would be a likely place to accept additional tailings, should a containment cell be required. Some dimensions were measured at Tailings Area 5 during the initial site visit. However, during the November 2001 site visit, MSE personnel encountered a local resident who claimed that this area was private property. For this reason, no augering was performed in this area.

MSE and Forest Service personnel inspected the interior of Mill#1 and collected samples on July 29, 2002. Based on the age of the mill building, the three transformers outside the building were thought to have been manufactured prior to July 2, 1979. In that case, federal regulations (40 CFR 761.2) require that they be assumed to contain PCBs, unless testing proves otherwise. One sample of transformer oil (M007) was collected from the easternmost of the three transformers for confirmation. This sample was submitted to Alchem Laboratories of Boise, Idaho for determination of polychlorinated biphenyls (PCBs) by EPA method 8081. Samples of a blue crystalline material (M008; Figure 13) and a grayish powder (M009) were collected from containers inside the mill building and submitted to SVL for analysis. Each

sample was analyzed for corrosivity by EPA method 9045, for total sulfur by LECO analyzer, for total cyanide by EPA method 335.4, for mercury by EPA method 7471, and for arsenic, copper, lead, selenium, zinc, sodium, potassium, calcium and magnesium by EPA method 6010B. Sample M008 was also analyzed for sulfate, nitrate and chloride by EPA method 300.0. An empty can labeled “sodium cyanide” (Figure 14) was observed south of Tailings Area 2 during June 2002, but there was no evidence of spilled materials, and no sample was collected.

Agronomic and Geotechnical Sampling

Initial agronomic and geotechnical sampling was conducted on October 11, 2001. Tailings Area 1 was observed to consist of a thin layer of tailings mixed with native soils. Three samples collected from this area (T1M1, T1M2 and T1M4) were submitted to Western Laboratories, Inc., of Parma, Idaho for agronomic analysis, in order to assess the suitability of this soil for seeding. Western Laboratories determined soil pH, soluble salts, lime, organic matter, nitrates, phosphorus, potassium, calcium, aluminum, magnesium, sodium, zinc, manganese, iron, copper, sulfate, boron and cation exchange capacity.

Four tailings samples (BT-2A, BT-2B, BT-3 and BT-4) were collected in brass tubes from Tailings Areas 2A, 2B, 3 and 4, respectively. These samples were analyzed for *in situ* dry density and *in situ* moisture content by Strata, a materials testing laboratory located in Boise, Idaho.

A grab sample of soil (SOIL) was collected from the shallow subsurface north of the road, across from Tailings Area 2 for geotechnical testing to assess its suitability as cover material for a possible containment cell. A composite tailings sample (TC) was also prepared for geotechnical analysis to assess the feasibility of disposing of the tailings in a containment cell. This composite sample was prepared by combining portions of two of the samples collected from each of six Tailings Areas (1, 2A, 2B, 3, 4 and 5) in approximately equal volumes to form composite sample TC. Strata performed a sieve analysis and developed a moisture–density relationship (“modified proctor curve”) for samples TC and SOIL.

The initial analytical results indicated that additional testing was necessary for characterization of possible cover material. Additional samples were collected for agronomic analysis on June 20, 2002. Sample SOIL-1 was collected from the same excavation as SOIL, but a few inches deeper (about 12 inches below ground surface). Other soils for agronomic testing were collected from depths of 6–10 inches. SOIL-2 was collected from the alluvial fan above Tailings Areas 2 and 1, SOIL-3 was collected about 15 feet above the north side of the road in the alluvial fan northeast of the campground, and SOIL-4 was collected about 25–30 feet above and to the northeast of Tailings Area 4.

RESULTS AND DISCUSSION

Field data collected in this study are presented and discussed in detail in the following sections. Key results that follow from these data are:

- Zinc and lead concentrations exceed the State freshwater criteria in some surface water samples;
- The primary source of metals loading to Big Boulder Creek is Jim Creek;
- Some of the metals load is coming from upstream of Tailings Area 5, possibly from adit discharges;

- The outflow from beneath Tailings Area 5 contains elevated lead, zinc, arsenic and copper levels, but these are diluted in Jim Creek and Big Boulder Creek;
- Inflows and metals loading to streams from Tailings Areas 1–4 are minimal;
- During both autumn low-flow and summer high-flow conditions, Big Boulder Creek and Jim Creek are losing streams, and these tailings appear to be substantially dry during both autumn and spring;
- Aquatic selenium data are not affected by sulfate interference;
- Limited historical Big Boulder Creek flow data suggest that bank overflows will be a common occurrence;
- Macroinvertebrate assemblages were not impaired at sample sites on Jim Creek and Big Boulder Creek;
- Concentrations of each of the metals exceeded BLM Risk Management Criteria in one or more samples of tailings and process waste;
- Acid-Base Accounting indicates that the potential for acid generation from tailings is high, but low-flow surface water quality samples do not show acid drainage impacts outside of Tailings Area 5;
- Two drums at Mill 1 contained cyanide salts, one at levels that should prudently be disposed of as hazardous waste;
- One transformer at Mill 1 contained no detectable PCBs;
- Soils from Tailings Area 1 contained more tailings than expected, and are probably unsuitable to support vegetation without substantial supplements;
- Agronomic and geotechnical properties of the alluvial soils north of Tailings Areas 1–4 make them suitable for cover; and
- Tailings Area 4 is a likely candidate as a tailings repository, but design needs to take into account recent landslide activity.

Surface Water Quality and Flows

Surface water quality analytical results are presented in Table 1. The data are listed generally from upstream to downstream in order to aid interpretation. These data show that the primary sources of metals loading to Big Boulder Creek are from Jim Creek, especially near and upstream of Tailings Area 5.

State Water Quality Criteria (IDAPA 58.01.02.210) for Human Health (water and organism ingestion) and Freshwater Aquatic Life (Continuous Maximum Concentration) are included in the table for reference. The most stringent Bureau of Land Management Risk Management Criteria (Ford 1996) are also included. These are for campers (except the criterion for arsenic, which is slightly lower for boaters).

The concentrations presented in Table 1 are color-coded according to the degree of relative risk they pose. The risk categories correspond to the BLM logarithmic classification system, with relative risk expressed in terms of the factor by which concentrations exceed a reference criterion (Ford 1996). Idaho's freshwater Criteria Continuous Concentrations (CCC) were adopted as the reference criteria for all metals except arsenic. The residential fish ingestion RMC was adopted for arsenic, since it is lower than the CCC. It can be readily seen from the table that the risk to aquatic organisms from surface water

is driven by concentrations of lead and zinc, with a moderate risk presented by arsenic and copper concentrations in the effluent from Tailings Area 5. The risk to human health is low, except for the Tailings Area 5 effluent. The human health risk presented by lead is high and by arsenic is moderate, according to the most stringent RMC.

All arsenic concentrations meet the Idaho toxic substance criterion of 50 µg/L for recreational and domestic uses (IDAPA 58.01.02.210.01). The much lower human health criterion of 0.018 µg/L applies only to trivalent arsenic (IDAPA 58.01.02.201.02d), and is based on cancer risk (40 CFR 136(b)). In oxygenated waters such as Jim Creek and Big Boulder Creek, arsenic is expected to be present primarily in the pentavalent form. Arsenic concentrations exceed the most stringent BLM human risk criteria only in the Tailings Area 5 effluent (W8 and W9). Zinc concentrations exceeded the Freshwater Criteria Continuous Concentration (CCC) at the Jim Creek sites (W4, W5, W10 and W12) and the Tailings Area 5 effluent (W8 and W9). The lead concentration exceeded the Freshwater CCC in the Tailings Area 5 effluent sample (W8, W9) and in the June 2002 samples from Jim Creek (W10 and W12) and upper Big Boulder Creek (W11).

Zinc concentrations were generally about three times as high in June 2002 as in autumn 2001. Lead concentrations were also somewhat higher, except in the Tailings Area 5 effluent. Arsenic, copper and selenium concentrations do not exhibit a clear seasonal difference, perhaps because the concentrations are generally low.

The Upper Big Boulder Creek samples (W6 and W11) were collected from upstream of both the mine tailings and Jim Creek confluence. It can be considered to be representative of “background” conditions in that stream. The metals of concern (copper, zinc, lead and arsenic) were notably absent during autumn 2001, but this water contained 5 µg/L lead (moderate risk) during June 2002. The other seasonal differences were that the pH value and hardness were lower in June 2002 than autumn 2001 by about 0.3 unit and 20 mg/L, respectively.

Samples W5 and W12 were collected from upper Jim Creek above Tailings Area 5, and can be considered to be representative of conditions in Jim Creek below the mine adits but before the tailings deposits. This water is slightly alkaline, with pH near 8.0 and June 2002 alkalinity of 47.8 mg/L. However, it contained zinc concentrations of 97 µg/L and 410 µg/L during October 2001 and June 2002, respectively. Lead, arsenic and selenium were also detected in one or both samples at concentrations ranging from the RL to 3 µg/L. The June 2002 lead concentration and both zinc concentrations upstream of Tailings Area 5 present a moderate relative risk to freshwater organisms.

The effluent from Tailings Area 5 contained the highest concentrations of the metals of concern in both autumn 2001 and June 2002 samples. However, this effluent contained the lowest sulfate concentration (1510 µg/L) during June 2002. Coupled with the 7.23 pH value and 38.5 mg/L alkalinity, this suggests that acid generation is of less concern at Tailings Area 5 than at other areas. Sulfate, pH and alkalinity data were not collected during autumn 2001.

Concentrations of most of the metals of concern at Jim Creek #1 (W4, W12 and W13) downstream of Tailings Area 5 were comparable to those upstream of the tailings (W5 and W10). The exceptions were lead and selenium. The lead concentration in Jim Creek increased from 2 µg/L upstream of the tailings to 11–13 µg/L downstream of the tailings in June 2002. Selenium concentrations were below the RL upstream, but just at the RL downstream in October 2001, and 3 µg/L both upstream and downstream of the tailings in June 2002. Metals loads emanating from beneath Tailings Area 5 were diluted by Jim Creek under both spring and late autumn flow conditions. This is consistent with the low flows estimated below for the tailings effluent. Further dilution occurs at the confluence with Big Boulder Creek.

Table 1. Surface Water Quality

Sample	Description	Collected	pH	alk. mg/L	hard. mg/L	Ca mg/L	Mg mg/L	Cu µg/L	Zn µg/L	As µg/L	Pb µg/L	Se µg/L	SO ₄ ²⁻ µg/L
W6	upper Big Boulder Creek	16-Oct-2001	7.83	—	41.1	14.7	1.05	<3	<5	<1	<1	<2	—
W5	upper Jim Creek #2	16-Oct-2001	8.06	—	81.9	28.0	2.90	<3	97	1	<1	<2	—
W8	Tailings #5 effluent	20-Nov-2001	—	—	66.6	22.1	2.76	7	490	36	705	<2	—
W4	Jim Creek #1	16-Oct-2001	8.09	—	83.2	28.3	3.03	<3	102	1	1	2	—
W1	Big Boulder Creek #3	16-Oct-2001	7.84	—	48.4	17.1	1.41	<3	17	<1	<1	<2	—
W7	duplicate of W1	16-Oct-2001	7.86	—	49.3	17.3	1.50	<3	17	<1	<1	<2	—
W2	Big Boulder Creek #2	16-Oct-2001	7.87	—	48.9	17.2	1.46	<3	16	<1	<1	<2	—
W3	Big Boulder Creek #1	16-Oct-2001	7.86	—	49.1	17.3	1.47	<3	16	<1	<1	8	—
W11 ⁴	upper Big Boulder Creek	19-Jun-2002	7.48	17.1	19.9	7.22	0.46	<3	<5	<1	5	<1	4100
W10 ⁴	upper Jim Creek #3	19-Jun-2002	7.90	47.2	64.1	21.7	2.44	<3	410	2	2	3	19600
W9 ⁴	Tailings #5 effluent	19-Jun-2002	7.23	38.5	41.3	13.4	1.88	9	1760	43	619	3	1510
W12 ⁴	Jim Creek #1	19-Jun-2002	7.97	47.8	64.8	21.8	2.54	<3	342	2	11	3	19600
W13 ⁴	duplicate of W12	19-Jun-2002	7.98	47.8	64.8	21.8	2.50	<3	337	2	13	3	19500
W14 ⁴	Big Boulder Cr (Tail#2)	19-Jun-2002	7.64	22.1	25.0	8.91	0.68	<3	40	<1	1	<1	5900
W15 ⁴	Big Boulder Cr (Tail#1)	19-Jun-2002	7.63	22.3	25.2	9.02	0.66	<3	39	<1	<1	<1	5900
W16 ⁴	Big Boulder Creek #1	19-Jun-2002	7.67	22.7	25.3	9.01	0.69	<3	39	<1	<2	<1	5900
Idaho Toxics Water Quality Criteria													
Human Health (water and organisms)			none					none	none	50 ²	note 3	note 3	—
Freshwater CCC			6.5–9					6	60	190	1.2	5	—
BLM Human Risk Management Criteria													
camper (boater)								11490	92909	81	50	1548	—
fish ingestion by resident								2907	23505	24	200	392	—
fish ingestion by camper								5984	48390	48	200	807	—

- NOTES: 1. Idaho Toxics Water Quality Criteria are from IDAPA 58.01.02.210 and 58.01.02.250 (2002). Criteria are calculated based on pH = 7.85 and Hardness = 50 mg/L.
2. The Idaho criterion for total As for recreation and domestic uses is 50 µg/L. A human health criterion of 0.018 applies only to As(III), and is based on a 10⁻⁶ cancer risk.
3. Narrative criteria only.
4. Selenium results are presented for the hydride method (EPA 270.3) only.

Relative Risk vs. Contaminant Concentration in Water

Concentration Range	Relative Risk
≤ reference criterion ^a	Low
1–10× reference criterion ^a	Moderate
10–100× reference criterion ^a	High
>100× reference criterion ^a	Extremely high

NOTE a. Residential fish ingestion RMC for arsenic, freshwater CCC for other metals.

The selenium results for October 2001 appeared to show that selenium concentrations were at or below the RL for all water samples except the one collected furthest downstream (W3). This would suggest that the source of selenium is different than the source for arsenic, copper, lead and zinc, and that this source lies downstream of known tailings deposits. This seems unlikely, although there could be localized geologic conditions that contribute a selenium load to lower Big Boulder Creek. The laboratory blanks and matrix spikes showed good method performance, and do not suggest laboratory error. However, sulfate and chlorides are known interferences for selenium (EPA 1983) when determined by EPA method 270.2, and there was concern that these non-target analytes may have been present in some of the samples at interfering levels. The limited historical data for Big Boulder Creek available in the National Water Information System (NWIS) database (USGS 2002) also suggested the possibility of sulfate interference. Selenium had been determined in five samples during 1972–74, with concentrations ranging from below the RL to 2 µg/L. Sulfate had been determined in 15 samples from 1971–77, and concentrations were three orders of magnitude higher, ranging from 2–18 mg/L. This is well above the 200 µg/L interference level cited by EPA. The exact sampling location is unknown, but was probably near the confluence with the East Fork of the Salmon River (the latitude and longitude in the database are on the East Fork, about two miles above this confluence).

Selenium concentrations in June 2002 water samples ranged from below the RL to 3 µg/L using EPA method 270.2. Determinations using EPA method 270.3 (not shown in the table) also ranged from below the RL to 3 µg/L. Although sulfate concentrations exceeded the reported interference level, it appears that sulfate interference was not significant. The 8 µg/L selenium concentration in October 2001 sample W3 remains unexplained, but it was not repeated in June 2002 sample W16. It could reflect the ordinary analytical uncertainty of measurements near the RL. Or it could reflect a selenium source along lower Big Boulder Creek that was diluted by June 2002 flows.

Table 2. Surface Water Flows

Site ¹	Date	Flow (cfs)	Date	Flow (cfs)
upper Jim Creek #3 (UJC3)	17-Oct-2001	2.08	19-Jun-2002	8.18
upper Jim Creek #2 (W5)	17-Oct-2001	1.01	—	—
Tailings Area 5 effluent (W8,W9)	estimated	0.001–0.1	19-Jun-2002	>0.01
Jim Creek above beaver ponds (JC4)	—	—	19-Jun-2002	6.90
Jim Creek #3 (JC3)	17-Oct-2001	1.30	19-Jun-2002	6.71
Jim Creek #2 (JC2)	17-Oct-2001	1.86	—	—
Jim Creek #1 (W4,W12)	17-Oct-2001	1.08	19-Jun-2002	6.94
upper Big Boulder Creek (W6,W11)	17-Oct-2001	7.83	19-Jun-2002	90.92
Big Boulder Creek near Tailings 2 (W14)	—	—	19-Jun-2002	62.17
Big Boulder Creek below Tailings 1 (W15)	—	—	19-Jun-2002	58.40
Big Boulder Creek #3 (W1)	16-Oct-2001	5.30	—	—
Big Boulder Creek #2 (W2)	16-Oct-2001	5.56	—	—
Big Boulder Creek #1 (W3,W16)	16-Oct-2001	5.84	19-Jun-2002	61.98

Note 1: The associated water quality sample(s) or other map labels are identified in parentheses.

Flow measurements are presented in Table 2. The uncertainty in the measurements can be estimated by comparing nearby flows, which might be expected to be similar. The two upper Jim Creek measurements for October 2001 differ by 1 cfs, which is indicative of the difficulty of measuring stream velocities in a narrow channel containing large rocks. In contrast, the three lower Big Boulder Creek measurements during October 2001 are very similar, with a standard deviation of 0.27 cfs and 5% relative standard deviation (RSD). The middle Jim Creek measurements showed a standard deviation of 0.40 cfs (28%

RSD) in October 2001 and 0.12 cfs (2% RSD) in June 2002. This reflects the relative ease of obtaining good flow measurements in a uniform channel.

The effluent flow from Tailings Area 5 was too low to measure with the velocity meter in both October and November 2001. The difference of the October flows measured at upper Jim Creek #2 and Jim Creek #1 provides a rough estimate of 0.07 cfs for the Tailings Area 5 flow. Estimates of this flow from the mass balances for hardness, zinc and selenium are 0.10 cfs, 0.02 cfs and 0.07 cfs, respectively, which are in rough agreement with the estimate based on flow measurements. Flow estimates based on arsenic and lead mass balances are below 0.001 cfs. The June 2002 flow was visually similar, and a 0.01 cfs lower limit for this flow was estimated by measuring the time to fill a 500mL sample bottle.

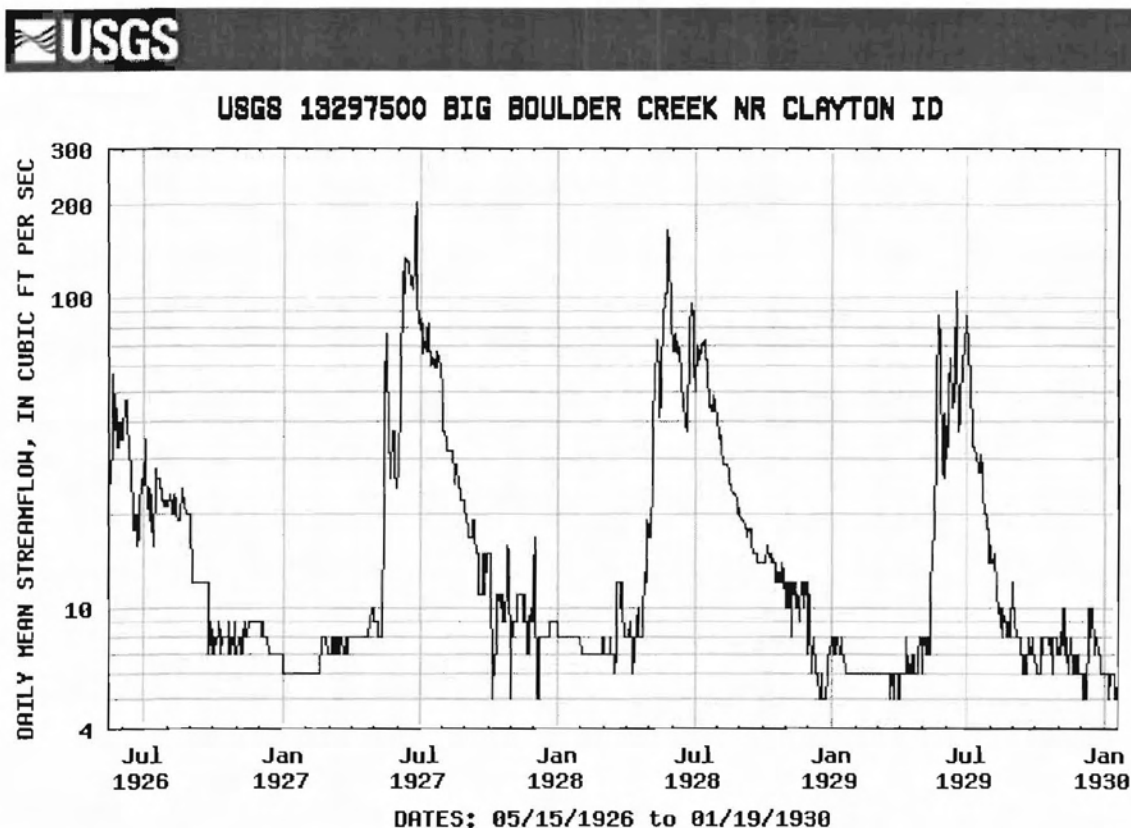


Figure 15. Historical USGS Flow Data for Big Boulder Creek, 1926–30.

The flow data for both seasons indicate that both Jim Creek and Big Boulder Creek are losing streams within the study area. A three-inch thick zone of moist tailings was encountered at an auger depth of about 2½ feet in the northeastern part of Tailings Area 2A. A free water surface was also encountered in one of the deeper auger borings (at a depth of about 8 ft) near the southeast corner of Area 2B. Tailings were observed to be dry at other sampling locations. The piezometer in Tailings Area 2A (Map 2B) was observed to be dry in both the autumn of 2001 and June 2002. Moist soil was observed at a single location on the north bank of the man-made channel in Tailings Area 3 during June 2002, but no other moisture was apparent in any of the other tailings areas, except Tailings Area 5.

All of these observations suggest that moisture content in Tailings Areas 1–4 is low, and therefore that leaching of metals from Tailings Areas 1–4 by subsurface flow would not have contributed a significant

metals load to Big Boulder Creek within the study area. This is supported by the fairly consistent metals concentrations in lower Big Boulder Creek. However, flows in lower Big Boulder Creek were observed to be five to twelve times those in Jim Creek, and this dilution could serve to minimize the affects of metals loading from Tailings Areas 1–3.

Available historical flow data were limited to a four–year period in the 1920s (USGS 2002). These data are presented in Figure 15. It can be seen that the October 2001 flows measured in lower Big Boulder Creek were similar to the minimum seasonal flows observed at the USGS gauge. The annual maximum flows were 67 cfs, 206 cfs, 184 cfs and 115 cfs in May 1926, June 1927, May 1928 and June 1929, respectively. These are 13 to 41 times the minimum flow of 5 cfs. Since the 1927 flow corresponded to a gauge height of 2.04 ft, it appears likely that bank overflows at the project site will occur.

Macroinvertebrates Results

Results of macroinvertebrate sampling indicate that the macroinvertebrate assemblages were not impaired at any of the sampling sites. Interpretation of the data followed the Idaho Department of Environmental Quality (DEQ) protocols outlined in the *1996 Waterbody Assessment Guidance* (IDEQ 1996). This is the most recent published guidance, although DEQ is in the process of updating its assessment protocols for surface waters.

DEQ uses the macroinvertebrate biotic index (MBI) to assess aquatic life use support (ALUS). The MBI is a multimetric index and consists of seven metrics: percent Ephemeroptera, Plecoptera, and Trichoptera (EPT), Hilsenhoff Biotic Index, Percent Scrapers, Percent Dominance, EPT Richness, Taxa Richness, and Shannon’s H’ Diversity Index. These seven metrics and the MBI are presented in Table 3. If the MBI is greater than or equal to 3.5, the macroinvertebrate assemblage is determined to be non-impaired. If the MBI is less than or equal to 2.5, the macroinvertebrate assemblage is determined to be impaired. If the MBI is greater than 2.5 and less than 3.5, the assemblage needs further verification (such as fish, habitat, or water chemistry data). The MBI scores for each of our sample locations exceeded the 3.5 score; therefore, it can be concluded that the macroinvertebrate assemblages were not impaired.

Table 3. Macroinvertebrate Biotic Index

Index	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder Cr.	Upper Big Boulder Cr.	Duplicate Big Boulder Cr.
Taxa Richness	36.00	37.00	27.00	37.00	31.00
EPT Richness	20.00	22.00	18.00	22.00	19.00
% EPT	43.05	80.00	68.95	76.15	73.44
% Scrapers	6.07	24.09	50.88	48.85	46.68
% Dominance	34.83	17.73	23.86	29.42	27.39
Hilsenhoff Biotic Index	3.47	1.86	2.36	2.49	2.62
Shannon’s H’ Diversity Index	1.02	1.26	0.98	1.13	1.10
MBI	3.92	5.14	4.72	5.1	4.84

Notes: 1. EPT = Ephemeroptera, Plecoptera, Trichoptera

EcoAnalysts calculated numerous other metrics, which are presented in Appendix 2. They also supplied metals tolerance values for each taxon identified from the samples. The metals tolerance values were obtained from the Montana Department of Environmental Quality Planning (1998) and are included in Appendix 1. The values increase with increasing tolerance to metals.

A duplicate sample was collected from Big Boulder Creek upstream of its confluence with Jim Creek to obtain community information specific to Big Boulder Creek prior to potential influences from the Livingston Mill. EcoAnalysts, Inc. calculated a percent similarity index to determine if the samples came from the same population. The duplicate was calculated to be approximately 79% similar to the Upper Big Boulder Creek location. Gary Lester, president of EcoAnalysts, Inc., stated that samples that are greater than 50% similar are considered to be from the same community. The similarity index is calculated from the differences in abundance between the samples for a given taxon, integrated over all taxa in both samples. This sum is then multiplied by one-half, and then subtracted from unity to obtain the index.

Tailings Sampling Results

Table 4 shows the chemical composition of samples from Tailings Areas 1 through 5 and certain waste samples collected from outside Mill 1. The bar graph presented as Figure 16 shows that metals concentrations are generally highest in Tailings Area 5, and slightly lower in Areas 2 and 3 than in the other areas. This is consistent with the hypothesis that tailings in Areas 2 and 3 were reprocessed materials formerly in Areas 4 and 5.

Metals concentrations in the surface fines from Tailings Area 1 (T1F1 through T1F6) are higher than expected, and are generally similar to the concentrations in two of the mixed samples (T1M2 and T1M4). This suggests that these near-surface materials are better mixed than was indicated by visual observations. MSE personnel observed during November field activities that local winds were able to carry enough tailings to significantly reduce visibility. Thus, aeolian deposition may be as significant a transport mechanism for tailings as fluvial deposition (*e.g.*, through the breach in the tailings dam between Tailings Areas 2 and 3). Insufficient wind data are available to quantify aeolian transport. Sample T1M1 has distinctly lower concentrations than those found in other samples from Area 1, and may be taken as an upper bound on concentrations in native soils.

Table 4 also includes the BLM Human Health Risk Management Criteria (RMC) for soils (Ford 1996, 1998). Two criteria are presented, those for residents and the less restrictive criteria for campers. Arsenic concentrations exceeded both RMC in all 27 samples. Similarly, the camper RMC was exceeded for lead in 25 of the 27 samples. The camper RMC for copper, selenium and zinc were not exceeded in any of the samples. However, the resident RMC were exceeded in seven samples for copper, in 13 samples for selenium and 17 samples for zinc.

The concentrations presented in Table 4 were color-coded according to the degree of relative risk they pose to human residents. The BLM logarithmic classification system for relative risk (Ford 1996) is used, as shown in Table 4. It can be readily seen from the table that the risk to human health from tailings and soils is driven by their arsenic content, and to a lesser degree by their lead content. The risk from zinc, selenium and copper is low to moderate.

Four BLM Wildlife RMC are also included in Table 4 for comparison. BLM data are only available for about a dozen species, and those presented here may not be representative of those that actually live on or migrate through the site. They were selected to be representative of four animal types: small mammal, large mammal, terrestrial birds and migratory waterfowl. They may not represent actual species. It can be seen that risk to animals that feed on soil invertebrates (such as the robin) is higher than the risk to other species.

Table 4. Solids Composition (mg/kg)

Sample	Description	Collected	As	Cu	Pb	Se	Zn	% Solids
T1F1	Tailings Area 1 surface fines	11-Oct-2001	1190	132	12200	26.5	5570	—
T1F2	Tailings Area 1 surface fines	11-Oct-2001	2270	200	22300	46.9	3100	—
T1F3	Tailings Area 1 surface fines	11-Oct-2001	2040	179	23300	53.6	4430	—
T1F4	Tailings Area 1 surface fines	11-Oct-2001	1550	370	25400	46.6	4330	—
T1F5	Tailings Area 1 surface fines	11-Oct-2001	3000	322	24000	82.3	3820	—
T1F6	Tailings Area 1 surface fines	11-Oct-2001	1360	86.8	16300	42.0	3310	—
T1M1	Tailings Area 1 mixed upper 6"	11-Oct-2001	132	75.8	742	<10	903	—
T1M2	Tailings Area 1 mixed upper 6"	11-Oct-2001	1720	111	14700	51.0	3170	—
T1M4	Tailings Area 1 mixed upper 6"	11-Oct-2001	1430	333	20400	33.0	4430	—
T2A4	Tailings Area 2A	11-Oct-2001	1930	183	16300	31.0	2020	—
T2A5	Tailings Area 2A middle	11-Oct-2001	1010	102	6220	15.7	624	91.3%
T2B1	Tailings Area 2B	11-Oct-2001	1570	166	14800	25.7	1110	76.7%
T2B6	Tailings Area 2B	11-Oct-2001	714	101	8890	16.6	1290	89.6%
T303	Tailings Area 3	11-Oct-2001	768	168	11100	20.4	1700	85.9%
T304	Tailings Area 3 south side	11-Oct-2001	973	132	9030	17.7	1650	88.6%
T401	Tailings Area 4 south berm	11-Oct-2001	1350	213	20200	39.0	1480	93.8%
T403	Tailings Area 4 east berm	11-Oct-2001	2080	285	23900	41.9	6890	83.8%
T405	Tailings Area 4 floor	11-Oct-2001	1040	164	14000	25.1	1660	91.8%
T501	Tailings Area 5 center washout	11-Oct-2001	2240	236	21400	55.0	3300	—
T502	Tailings Area 5 lower trench	11-Oct-2001	1490	151	32800	30.0	3430	—
T506	Tailings Area 5 north wall	11-Oct-2001	8120	211	23300	43.0	1630	—
M001	Mill #1 southeast soils	11-Oct-2001	2190	309	29800	46.7	3550	86.8%
M002	Mill #1 east side tailings/soils	11-Oct-2001	1820	209	15800	37.3	5710	92.9%
M003	Mill #1 soils above mill	11-Oct-2001	152	79.3	2980	9.5	2460	83.5%
M004	Mill #1 soils	11-Oct-2001	2610	491	31500	51.7	22500	93.2%
M005	Mill #1 white mat'l in drum ¹	11-Oct-2001	25.1	5.8	165	<1.0	210	76.0%
M006	Mill #1 mat'l in drum	11-Oct-2001	1430	325	22000	69.7	7070	96.8%
M008	Blue crystalline material	29-Jul-2002	8.9	23.9%	117	<1.0	41.1	—
M009	White-gray powder	29-Jul-2002	195	114	3240	<1.0	59900	—
BLM Human Risk Management Criteria								
camper			20	5000	1000	700	40000	—
resident			1	250	400	35	2000	—
BLM Wildlife Risk Management Criteria								
deer mouse			230	640	142	nc	419	—
mule deer			200	102	106	nc	222	—
robin			4	7	6	nc	43	—
Canada goose			671	161	34	nc	271	—

Notes: 1. Calcium concentration = 292,000 mg/kg; cyanide concentration = 1.85 mg/kg
2. nm = not measured
3. nc = no criterion

Relative Risk vs. Contaminant Concentration in Solids

Concentration Range	Relative Risk
≤ residential RMC	Low
1–10× residential RMC	Moderate
10–100× residential RMC	High
>100× residential RMC	Extremely high

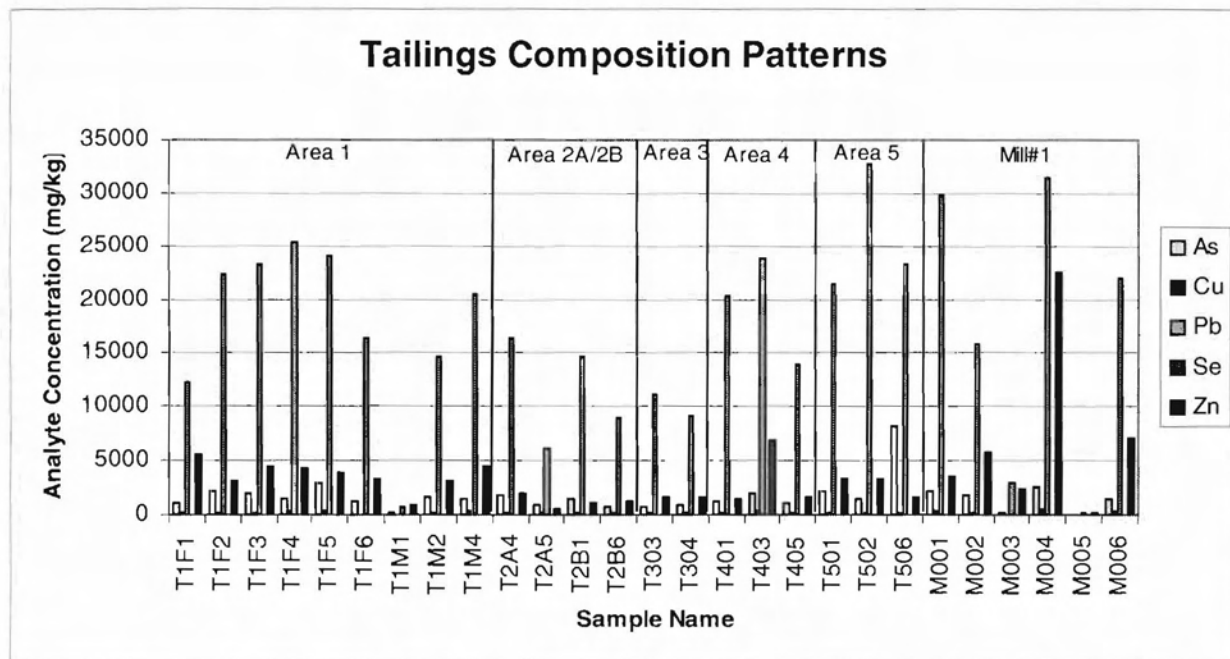
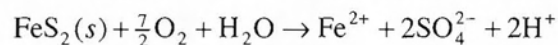


Figure 16. Chemical composition of tailings and process residuals.

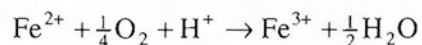
Acid Generating Potential

A common concern at mine sites is the potential for release of Acid Mine Drainage (AMD). The oxidation of sulfur-bearing minerals, especially pyrites, can result in a release of acids and dissolved metals to receiving waters. The process is illustrated for the oxidation of the most common pyrite mineral, iron pyrite, FeS_2 (Stumm and Morgan 1981).

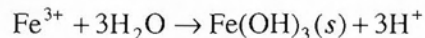
- oxidation of mineral iron pyrite to dissolved ferrous sulfate, with the release of hydrogen ions;



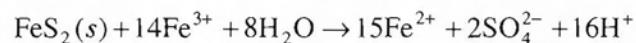
- slow oxidation of ferrous iron to ferric iron, in a reaction mediated by microbes such as the iron autotrophs *Thiobacillus* and *Ferrobacillus ferrooxidans*; and



- precipitation of amorphous "ferric hydroxide" with the release of hydrogen ions;



- fast reduction of ferric iron to regenerate dissolved ferrous iron, with additional release of hydrogen ions and sulfate;



Once the process has started, an iron cycle is established, with a net production of hydrogen ions. Ferrous iron is oxidized slowly by microbes to ferric iron, which rapidly regenerates ferrous iron. Any ferric iron that precipitates out as amorphous “ferric hydroxide” forms a reservoir of available ferric ions. These enable the cycle to continue, even after pyrite is no longer available (Stumm and Morgan 1981).

Factors affecting the potential for a solid waste to generate acid include:

- amount of sulfur-containing minerals present;
- amount of neutralizing minerals present; and
- composition and physical state of acid neutralizing minerals present

The *rate* of acid generation is dependent upon:

- the types of sulfide minerals present and their crystal forms;
- the types of carbonate and other neutralizing minerals present;
- the waste particle size and surface area;
- the presence of mineral grains and their surface areas;
- available water and oxygen;
- appropriate bacteria populations

Static testing predicts the potential for acid to be generated, based on the sulfur and carbonate content of the mineral (EPA 1994). For actual acid mine drainage to occur, the other conditions noted above must be met. The static testing performed by SVL is known as Modified Acid–Base Accounting (ABA). In these tests, a sample’s Acid Generating Potential (AGP) is calculated from its pyritic sulfur (*i.e.*, sulfide) content and the Acid Neutralization Potential (ANP) is measured from its ability to react with acid. The result of the test is a figure of merit known as the Net Neutralization Potential (NNP):

$$\text{Net Neutralization Potential} = \text{Acid Neutralization Potential} - \text{Acid Generating Potential}$$

If the NNP is negative, there is a risk of acid mine drainage. Values of NNP more negative than –20 kilograms of calcium carbonate per ton (kg CaCO₃/ton) indicate a material that is likely to form acid. Values greater than +20 kg CaCO₃/ton indicate that the material is unlikely to form acid. Values between –20 and +20 kg CaCO₃/ton fall into a zone of uncertainty, and kinetic testing is required for AMD prediction. Alternatively, the result can be evaluated in terms of the ratio ANP/AGP. Ratios greater than 3 represent a low risk, and ratios less than 1 represent a high risk. Ratios between 1 and 3 fall into a zone of uncertainty. It should be noted that the accuracy of the Modified ABA procedure can be adversely affected by the presence of acid-producing sulfate minerals, iron or magnesium carbonates, or metals which form hydroxide precipitates.

The results of ABA testing performed on tailings composites are displayed in Table 5. For each sample, the NNP is strongly negative and the ANP/AGP ratio is very low. This indicates that the potential for AMD generation is high, if the appropriate conditions of water, oxygen and microbial populations are met.

The water quality testing results previously described indicate that acid generation is not actually occurring in Tailings Areas 1 through 4 at rates that impact metals concentrations and pH values in Jim Creek and Big Boulder Creek. The alkalinity and pH value in the Tailings Area 5 effluent appear to be inconsistent with net acid generation. The sulfate concentration is also lower in that effluent than in Jim Creek. However, the metals loading in the Tailings Area 5 effluent indicates that leaching is probably occurring from these tailings, whatever the mechanism causing it.

Table 5. Acid-Base Accounting

Sample ¹	Description	NNP ²	AGP ²	ANP ²	Sulfur (% by weight)			
					Residual	Pyritic	Sulfate	Total
T1C	Tailings Area 1	-41.3	41.3	<0.3	0.01	1.32	0.92	2.25
T2C	Tailings Area 2	-25.0	25.0	<0.3	<0.01	0.80	0.89	1.69
T3C	Tailings Area 3	-28.1	28.1	<0.3	0.05	0.90	0.75	1.70
T4C	Tailings Area 4	-38.4	38.4	<0.3	<0.01	1.23	0.63	1.86
T5C	Tailings Area 5	-28.1	28.1	<0.3	<0.01	0.90	1.13	2.03

Notes: 1. The subsamples were collected on 11-Oct-2001 and combined into composites later.
2. NNP, AGP and ANP are reported in tons of CaCO₃ equivalent per ton of rock.

Tailings Volumes

Map 3 displays the results of augering in Tailings Areas 2 and 3. Tailings thickness varied from six inches to 9 feet, which is consistent with the results of the 1993 study. A tailings thickness contour map was generated using ArcView and superimposed on top of the aerial photograph. GPS coordinates (shown in black) were used to outline the tailings area, and ArcView was used to calculate the resulting tailings volume. The tailings outline offers a visual estimate of the positional uncertainty of artifacts on the aerial photograph. The volumes of other tailings areas were estimated from their geometry, as shown in Table 6.

Table 6. Tailings Areas and Volumes

Tailings Area	Area (ac.)	Geometry	Volume (cu. yd.)
1	2.556	<2'D	6,200 ^a
2A	1.260	0.5–8.9' THICK	32,905 ^b
2B	6.710		
3	2.084		
4	3.942	<1'D (floor) <10'D? (periphery) 15'D (berm)	6,360 ^c 10,175 ^d 6,944 ^e
5	0.339	<1'D (floor) 26'wx8'Hx85'L dike 16'wx8'Hx48'L dike 25'Hx5'Dx80'L	550 ^c 327 114 370
Total	16.891		63,945

NOTES: a. Based on an assumed average depth of 18 inches.
b. Based on auger results and contour map.
c. Based on an assumed average depth of 1 ft.
d. Based on 20% of the total area at assumed average depth of 8 ft.
e. Based on approx. 1000 ft long berm, assumed average height 15 ft and width 25 ft at the base.

The extreme variation in topography at the surface of and underlying the Tailings Areas makes accurate volume estimates difficult. This is particularly true in Area 4. The effect is somewhat mitigated in Areas 2 and 3 by the use of the augering technique, but the wide variation in measured thickness over an area that looks fairly flat on the surface demonstrates the variation in underlying topography. The volume estimates presented here are not suitable for detailed engineering design, but should be usable in evaluating gross removal action alternatives. Accurate topographic surveys (not available at the time of this study), combined with limited field mapping and estimation of tailings depth would provide a basis for better volumetric estimation.

Based on this initial estimate, the total tailings volume is 63,900 cubic yards. The volume of Tailings Areas 1-3 is estimated to be 39,105 cubic yards. If the density is assumed to average 116.5 pounds per cubic foot (see Table 7 below), this corresponds to 61,500 tons. This is very close to the 60,000 tons of tailings that Mitchell estimated were reprocessed. We estimate that approximately 40,500 cubic yards of tailings are located outside of Tailings Area 4. If all of these tailings were placed within the berm of Area 4, it would raise the floor by only 7.5 feet, allowing for an 18% swell factor. There is adequate room to stack tailings much higher if the volume estimate turns out to be low, particularly if the tailings are compacted during construction. In addition, this area is relatively isolated from streams, and is not likely to be impacted by flooding along Jim Creek. However, a landslide from Railroad Ridge Road down to the west end of Tailings Area 4 was identified during the June 2002 site inspection (Figures 17–18). Tailings Area 4 remains likely candidate for a repository for all materials in Areas 1,2, 3 and 5, but the west end should be avoided, and care should be taken in cell design to provide adequate protection from sheet flow.



Figure 17. Landslide into Tailings Area 4.



Figure 18. Landslide into Tailings Area 4.

Results of Mill #1 Inspection and Sampling

The inventory of waste materials in and around Mill 1 is summarized in Table 7. The full analytical results for the “unknown” materials (samples M005, M008 and M009) are displayed in Table 8. It should be noted that different analyses were performed on different samples, based on their physical appearance and condition.

Table 7. Mill Waste Inventory

Item	Sample ID	Result/Comment
Mill #1 southeast soils	M001	similar to tailings
Mill #1 east side tailings/soils	M002	similar to tailings
Mill #1 soils above mill	M003	moderate risk soil/tailings mix
Mill #1 soils	M004	similar to tailings
Mill #1 white mat'l in drum	M005	probably lime with 1.85 mg/kg CN ⁻
Mill #1 mat'l in drum	M006	similar to tailings
3 transformers	M007	no PCBs found in east transformer
Blue crystalline material	M008	cupric sulfate
White-gray powder	M009	probably lime with 63.5 mg/kg CN ⁻
2 Pyranol™ capacitors, 1.9 gal, Cat. 15P131, No. J35543 and J35544	none	may contain PCBs
Aeroflot 211, 55 gal	none	promoter and collector
Aeroflot 404, 55 gal	none	promoter and collector
Sodium isopropyl xanthate	none	frother and secondary collector
Sodium sulfide, flake, 400# (55gal), 60-62% Na ₂ S	none	probably used with NaCN
Sodium cyanide, 55 gal, corroding drum	none	reagent

As can be readily seen from the bar chart (Figure 16), soil samples M001, M002 and M004 and drum sample M006 from around Mill 1 were chemically similar to tailings, and are probably soils mixed with tailings. Sample M003 is similar, but contains a lower concentration of tailings, and represents a moderate relative risk to human residents.

The white powdery sample collected from a drum outside Mill 1 (M005) contained lower concentrations of metals than in the other process residuals or tailings samples. However, it was found to be 29.2% calcium by weight, suggesting that it is primarily some form of lime. Both quicklime and hydrated lime are used in the flotation process for zinc-, copper- and lead-bearing ores. Lime is also used in the cyanide leaching process of silver and gold ores, both for control of pH and as a cyanide recovery aid (National Lime Association, undated). The white-gray powder found inside Mill 1 (M009) is probably also a form of lime, as indicated by the high calcium content and slightly alkaline pH value.

Samples M005 and M009 also contained cyanide ion, in concentrations of 1.85 mg/kg and 63.5 mg/kg, respectively. There is no Toxicity Characteristic concentration for cyanide (40 CFR 261.24). However, this waste could be classified as a D003 Reactive Hazardous Waste if, "when exposed to pH conditions between 2 and 12.5, [it] can generate toxic gases, vapors or fumes in a quantity sufficient to present a danger to human health or the environment" (40 CFR 261.23(a)(5)). EPA has withdrawn its analytical method for determining the reactivity of cyanide and sulfide wastes, but the regulatory definitions remains in effect. This complicates the assessment of whether cyanide-containing wastes are hazardous wastes under RCRA. Since the EPA guidance level for reactive cyanide is 250 mg/kg (as HCN; SW-846 §7.3.3.1), and the Treatment Standard for Hazardous Waste D003 is 590 mg/kg total cyanide or 30 mg/kg cyanide amenable to chlorination (40 CFR 268.40), the drum contents represented by M005 would not be classified as a RCRA hazardous waste on the basis on their cyanide content. However, the total cyanide concentration in M009 is 63.5 mg/kg and the zinc concentration is nearly 6%. Since zinc cyanides are highly amenable to chlorination (EPA 2000), the amenable cyanide concentration is expected to exceed the 30 mg/kg treatment standard. It would be prudent to handle this material as a RCRA hazardous waste.

No PCBs were detected in the sample from the east transformer (M007). Small chromatographic peaks were observed in the PCB elution range, but these peaks were below the 1.0 mg/kg Method Detection Level, and the characteristic Arochlor patterns were not present.

Table 8. Composition of Unknown Materials

Parameter	M005	M008	M009
physical description	partially cemented white powder	blue crystals	white-gray powder
corrosivity (pH)	—	3.1	7.9
total sulfur	—	11.8%	0.98%
calcium	29.2%	33.5 mg/kg	30.4%
magnesium	—	7.7 mg/kg	2750 mg/kg
sodium	—	<50 mg/kg	2490 mg/kg
potassium	—	<100 mg/kg	240 mg/kg
arsenic	25.1 mg/kg	8.9 mg/kg	195 mg/kg
copper	5.8 mg/kg	23.9%	114 mg/kg
mercury	—	<0.033 mg/kg	0.422 mg/kg
lead	165 mg/kg	117 mg/kg	3240 mg/kg
selenium	<1.0 mg/kg	<1.0 mg/kg	<1.0 mg/kg
zinc	210 mg/kg	41.4 mg/kg	5.99%
total cyanide	1.85 mg/kg	<0.5 mg/kg	63.5 mg/kg
chloride	—	<200 mg/kg	—
nitrate	—	<50 mg/kg	—
sulfate	—	35.0%	—

The blue crystalline material (M008) is copper sulfate. The distinctive blue color is typical of hydrated cupric salts, and the copper and sulfate compositions are consistent with a 92% cupric sulfate. Cupric sulfate is a sulfadizing agent used to improve the recovery of zinc sulfides (American Cyanamid 1976).

Results of Agronomic and Geotechnical Sampling

The detailed results of agronomic analyses of samples from Tailings Area 1 are presented in Appendix 4. Some of the key results are discussed here. In general, they demonstrate that the mixed soils and tailings from Tailings Area 1 are not suitable as a plant growth medium. The alluvial soils are probably usable, with some soil amendments. It should be noted that the recommendations made by Western Laboratories are based on generic agricultural practice in Southwestern Idaho, not to alpine habitat. Forest Service botanists should review these results for their applicability to candidate vegetative cover species.

Soil hydrogen ion activity is reported as pH. Maximum availability of plant nutrients generally occurs between pH 6.5 and 7.5. The SMP pH (named after Shoemaker, MacLean and Pratt; Marx, *et al.*, 1999) is the equilibrium pH observed after adding 20 mL of SMP buffer solution (pH 7.5) to ten grams of soil. The SMP pH is used to estimate the amount of lime needed to neutralize the soil. The samples from Tailings Area 1 (T1M1, T1M2 and T1M4) were all strongly acidic, with SMP pH values ranging from 5.4 to 5.5. Based on these results, Western Laboratories recommended adding 13,000–22,000 pounds of lime per acre to neutralize the soils. However, the alluvial soils (SOIL–1, SOIL–2, SOIL–3 and SOIL–4) were slightly acidic to moderately basic, and Western Laboratories' lime amendment recommendations ranged from zero to 1,000 pounds per acre.

Electrical conductivity of the soil extract (ECe) in decisiemens per meter (dS/m) is a measure of the amount of dissolved salts in the soil solution. High salt content can interfere with plant growth. The ECe readings for both Tailings Area 1 samples and alluvial soil samples were in the range of no cropping limitations (less than 0.4 dS/m) or negligible limitations (0.4–0.8 dS/m). Results were based on actual measurements, rather than calculations from cation concentrations.

Percent lime is the measurement of free calcium carbonate and free magnesium carbonate in the soil. Free lime increases the potential for soil crusting, reduces the availability of phosphorus and micronutrients and can interfere with uptake of potassium and magnesium. It can be neutralized with elemental sulfur or acid-residue fertilizers.

Fertilizing with the major nutrients will probably be desirable. Nitrogen content ranges from “very low” to “medium,” and phosphorus, potassium and sulfate range from “low” to “high.”

Concentrations of the micronutrients iron and manganese in the alluvial samples were “adequate,” and concentrations for micronutrients boron, copper and zinc ranged from “low” to “good.” Iron concentrations in the Tailings Area 1 samples were high, ranging from 188–581 mg/kg, compared to an “ideal” agronomic range of 15–135 g/kg. The requirements for iron vary, but levels over 300 mg/kg would be expected to be antagonistic to other nutrients, thus inducing nutrient deficiencies.

Geotechnical results are displayed in Table 9. The *in situ* density and moisture content of the brass tube tailings samples (BT-2A through BT-4) are below the optimal values determined for the composite tailings sample (TC). This indicates that they could be compacted significantly, if they were to be placed in a containment cell. Sieve analysis of the potential cover material (SOIL) determined that the fines content was somewhat high, leaving concern that it might be too erosive. Atterberg Limits were therefore determined for this sample. These limits indicate that the risk of erosion is low.

Table 9. Results of Geotechnical Analyses

Sample	Classification	Max. Dry Density (pcf)	Optimum Moisture	<i>in situ</i> Density (pcf)	<i>in situ</i> Moisture	Atterberg Limits	
						LL	PI
BT-2A	sand	—	—	82.3	7.4%	—	—
BT-2B	sand silt	—	—	82.2	12.6%	—	—
BT-3	fine silt	—	—	87.2	9.9%	—	—
BT-4	silty sand	—	—	90.6	3.3%	—	—
TC	sand	116.5	12.5%	—	—	—	—
SOIL	clayey sand w/ gravel and organics	125.0	10.0%	—	—	46%	20%

CONCLUSION AND RECOMMENDATIONS

Metals concentrations in tailings and acid-base accounting results indicate that the site presents some risk to human health or the environment, and that a removal action of some kind appears to be warranted. However, the surface water quality and flow results indicate that most of the impact to streams is in the vicinity of Tailings Area 5. Water in lower Jim Creek and Big Boulder Creek present only a low risk at this time. This suggests that a removal action might take a lower priority than at some other sites.

Saturated conditions clearly exist within Tailings Area 5, even during the dry season. This is contributing a metals load to Jim Creek via leaching. Limited moist conditions were encountered in Tailings Areas 2 and 3, but not found to be widespread. Tailings subject to subsurface flows should not be left in place, unless proper drainage is installed. Tailings could be removed and placed in a designed repository, possibly at the location of Tailings Area 4.

The historic Jim Creek channel was observed to be dry during both autumn 2001 and June 2002. However, an increase in water levels of about one foot would be sufficient to defeat the diversion efforts and rehydrate the historic channel. The very limited historic data suggest that this increase is likely to occur often. This would increase the potential for subsurface leaching from the tailings, and would also be likely to cause surface flows into Tailings Area 3, and thus through the breached dam into Tailings Area 2B. Similarly, water flow in M1 Creek may cause surface flow on top of Tailings Area 2A, as well as possible subsurface flow. These considerations suggest that a removal action to address the consequences of flooding would be prudent.

The tailings themselves present an extremely high risk to human residents due to arsenic, and a high risk due to lead. The risk from other constituents is less. These factors, coupled with the observation of windblown tailings during a site visit, indicate that a removal action should include even dry tailings. Possible removal actions could include capping in place, or placement in a designed repository. There is sufficient volume available in Tailings Area 4 to accommodate the tailings identified in all five tailings areas.

Some waste materials were found at Mill 1, including electrical equipment, a few unlabelled drums and a box containing blue crystals. One sample taken from a large transformer showed it to be free of detectable PCBs. Small concentrations of cyanide salts were found in two drums. General knowledge of cyanide salts suggests that the cyanide concentration in one drum is above the Treatment Standard for D003 wastes. Prudence indicates that this drum be handled as a RCRA hazardous waste. A limited amount of other reagents should be disposed of if Mill 2 is closed.

We recommend that an aerial photographic survey of the site be performed at a scale that could generate one-foot elevation contours. A day or two of a survey crew's time would probably provide sufficient data for calibrating the photographic contours. This would support engineering design, as well as provide data for an additional flood plain study, if desired. The Forest Service should also consider other sensing techniques, such as infrared photography, if the incremental cost can be kept low. This could provide additional data regarding subsurface water paths and/or tailings thickness that would be useful for evaluation and design of removal action alternatives.

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Appendices

Appendix 1. Macroinvertebrate Taxonomic List

Order	Organism	Metals Tolerance Values	Stream	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder	Upper Big Boulder	Big Boulder (duplicate)
			Site	above Big Boulder	Above Tailings #5	below Tailings #1	upstm of mill	upstm of mill
			Date	10-11-2001	10-11-2001	10-10-2001	10-11-2001	10-11-2001
			% Subsampled	16.67	100.00	41.67	33.33	25.00
Ephemeroptera	<i>Ameletus</i> sp.	1		1	1	0	2	0
	<i>Baetis bicaudatus</i>	4		9	78	9	43	38
	<i>Caudatella hystrix</i>	0		0	0	0	2	1
	<i>Caudatella</i> sp.	U		0	0	2	0	0
	<i>Cinygmula</i> sp.	0		6	0	0	0	18
	<i>Drunella doddsi</i>	0		2	2	4	9	4
	<i>Drunella spinifera</i>	0		0	0	0	0	1
	<i>Epeorus grandis</i>	U		0	37	0	1	0
	<i>Ephemerellidae</i>	U		106	8	38	3	16
	<i>Nixe</i> sp.	1		0	0	0	7	0
	<i>Paraleptophlebia</i> sp.	U		0	0	0	1	0
	<i>Rhithrogena</i> sp.	2		6	13	58	21	31
Plecoptera	<i>Capniidae</i>	0		0	1	0	0	1
	<i>Cultus</i> sp.	2		1	0	2	0	0
	<i>Despaxia augusta</i>	U		0	5	0	0	0
	<i>Megarcys</i> sp.	1		5	1	0	5	0
	<i>Nemouridae</i>	U		9	0	0	0	0
	<i>Perlidae</i>	U		0	0	0	1	0
	<i>Perlodidae</i>	U		16	26	16	16	27
	<i>Sweltsa</i> sp.	U		3	8	0	0	0
	<i>Visoka cataractae</i>	0		0	4	0	0	0
	<i>Zapada cinctipes</i>	3		9	0	4	5	3
	<i>Zapada columbiana</i>	1		0	6	0	0	0
	<i>Zapada oregonensis</i> gr.	1		2	0	3	12	9
	<i>Zapada</i> sp.	U		1	0	0	0	0

Appendix 1, continued. Macroinvertebrate Taxonomic List

Order	Organism	Metals Tolerance Values	Stream	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder	Upper Big Boulder	Big Boulder (duplicate)
Coleoptera	<i>Heterlimnius</i> sp.	3		3	0	0	1	1
	<i>Heterlimnius</i> sp. - adult	U		1	0	0	0	0
Trichoptera	<i>Brachycentrus americanus</i>	4		0	0	3	0	0
	<i>Glossosoma</i> sp.	2		12	19	94	63	39
	<i>Micrasema</i> sp.	2		0	0	1	0	0
	<i>Neothremma alicia</i>	U		22	33	3	5	1
	<i>Oligophlebodes</i> sp.	1		5	35	134	153	132
	<i>Parapsyche elsis</i>	1		2	53	6	18	3
	<i>Rhyacophila betteni</i> gr.	1		0	6	3	0	2
	<i>Rhyacophila brunnea</i> gr.	1		1	3	0	2	1
	<i>Rhyacophila coloradensis</i> gr.	1		0	2	0	0	0
	<i>Rhyacophila hyalinata</i> gr.	1		0	10	1	3	3
	<i>Rhyacophila narvae</i>	U		0	1	0	2	0
	<i>Rhyacophila vofixa</i> gr.	1		2	0	12	22	24
Diptera	<i>Chelifera</i> sp.	4		2	10	0	1	1
	<i>Dicranota</i> sp.	2		0	1	0	1	0
	<i>Glutops</i> sp.	U		0	1	0	0	0
	<i>Limnophila</i> sp.	U		0	0	0	0	1
	<i>Pericoma</i> sp.	4		1	9	0	0	0
	<i>Prosimulium</i> sp.	2		0	1	0	0	1
	<i>Simulium</i> sp.	5		0	1	0	0	0
	<i>Wiedemannia</i> sp.	U		0	1	0	0	0

Appendix 1, continued. Macroinvertebrate Taxonomic List

Order	Organism	Metals Tolerance Values	Stream	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder	Upper Big Boulder	Big Boulder (duplicate)
Chironomidae (fam.)	<i>Brillia</i> sp.	4		1	1	1	1	1
	<i>Cricotopus (Nostococladius)</i> sp.	5		0	0	0	1	0
	<i>Eukiefferiella brehmi</i> gr.	U		0	16	3	1	1
	<i>Eukiefferiella brevicar</i> gr.	U		2	0	0	0	0
	<i>Eukiefferiella gracei</i> gr.	U		2	1	8	14	9
	<i>Heleniella</i> sp.	U		5	0	0	0	0
	<i>Orthoclaadiinae</i>	U		0	0	0	1	0
	<i>Orthocladus</i> (Symp.) <i>lignicola</i>	U		0	0	0	1	0
	<i>Orthocladus</i> Complex	U		1	0	0	0	0
	<i>Orthocladus</i> sp.	5		0	0	0	2	0
	<i>Pagastia</i> sp.	9		0	0	0	1	0
	<i>Polypedilum</i> sp.	4		1	0	0	0	0
	<i>Tanytarsus</i> sp.	3		178	8	136	29	61
	<i>Tvetenia bavarica</i> gr.	4		39	16	6	24	17
Oligochaeta (class)	<i>Enchytraeidae</i>	1		0	1	2	44	30
	<i>Rhyacodrilus</i> sp.	U		31	3	0	0	0
	Tubificidae w/o cap setae	U		4	0	1	0	0
Tricladida	<i>Polycelis</i> sp.	U		15	18	12	2	3
	Acari (=Acarina)	5		5	0	8	0	2
				511	440	570	520	482

Notes:

1. Identification performed by EcoAnalysts, Inc.
2. Data are NOT adjusted for subsampling.
3. U = unknown.
4. Tolerance values increase with increasing tolerance to metals.
5. Tolerance obtained from Montana Department of Environmental Quality (1998).

Appendix 2. Macroinvertebrate Metrics

Sample	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder Cr.	Upper Big Boulder Cr.	Big Boulder Cr. (Duplicate)
Date	10-11-2001	10-11-2001	10-10-2001	10-11-2001	10-11-2001
Percent Subsampled	16.67	100.00	41.67	33.33	25.00
Abundance Measures					
Corrected abundance	3066.00	440.00	1368.00	1560.00	1928.00
EPT abundance	1320.00	352.00	943.20	1188.00	1416.00
Dominance Measures					
1st dominant taxon	Tanytarsus sp.	Baetis bicaudatus	Tanytarsus sp.	Oligophlebodes sp.	Oligophlebodes sp.
1st Dominant Abundance	1068.00	78.00	326.40	459.00	528.00
2nd dominant taxon	Ephemerellidae	Parapsyche elsis	Oligophlebodes sp.	Glossosoma sp.	Tanytarsus sp.
2nd Dominant Abundance	636.00	53.00	321.60	189.00	244.00
3rd dominant taxon	Tvetenia bavarica gr.	Epeorus grandis	Glossosoma sp.	Enchytraeidae	Glossosoma sp.
3rd Dominant Abundance	234.00	37.00	225.60	132.00	156.00
% 1 dominant taxon	34.83	17.73	23.86	29.42	27.39
% 2 dominant taxa	55.58	29.77	47.37	41.54	40.04
% 3 dominant taxa	63.21	38.18	63.86	50.00	48.13
Richness Measures					
Species richness	36.00	37.00	27.00	37.00	31.00
EPT richness	20.00	22.00	18.00	22.00	19.00
Ephemeroptera richness	6.00	6.00	5.00	9.00	7.00
Plecoptera richness	8.00	7.00	4.00	5.00	4.00
Trichoptera richness	6.00	9.00	9.00	8.00	8.00
Chironomidae Richness	8.00	5.00	5.00	10.00	5.00
Oligochaeta Richness	2.00	2.00	2.00	1.00	1.00
NCO Richness	26.00	30.00	20.00	26.00	25.00
Rhyacophila richness	2.00	5.00	3.00	4.00	4.00

Appendix 2, continued. Macroinvertebrate Metrics

Sample	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder Cr.	Upper Big Boulder Cr.	Big Boulder Cr. (Duplicate)
Community Composition					
% Ephemeroptera	25.44	31.59	19.47	17.12	22.61
% Plecoptera	9.00	11.59	4.39	7.50	8.30
% Trichoptera	8.61	36.82	45.09	51.54	42.53
% EPT	43.05	80.00	68.95	76.15	73.44
% Coleoptera	0.78	0.00	0.00	0.19	0.21
% Diptera	45.40	15.00	27.02	14.81	19.09
% Oligochaeta	6.85	0.91	0.53	8.46	6.22
% Baetidae	1.76	17.73	1.58	8.27	7.88
% Brachycentridae	0.00	0.00	0.70	0.00	0.00
% Chironomidae	44.81	9.55	27.02	14.42	18.46
% Ephemerellidae	21.14	2.27	7.72	2.69	4.56
% Hydropsychidae	0.39	12.05	1.05	3.46	0.62
% Odonata	0.00	0.00	0.00	0.00	0.00
% Perlidae	0.00	0.00	0.00	0.19	0.00
% Pteronarcyidae	0.00	0.00	0.00	0.00	0.00
% Simuliidae	0.00	0.45	0.00	0.00	0.21
Diversity/Evenness Measures					
Shannon-Weaver H' (log 10)	1.02	1.26	0.98	1.13	1.10
Shannon-Weaver H' (log 2)	3.40	4.20	3.24	3.75	3.66
Shannon-Weaver H' (log e)	2.35	2.91	2.25	2.60	2.54
Margalef's Richness	4.36	5.91	3.60	4.90	3.97
Pielou's J'	0.66	0.81	0.68	0.72	0.74
Simpson's Heterogeneity	0.82	0.92	0.84	0.87	0.88

Appendix 2, continued. Macroinvertebrate Metrics

Sample	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder Cr.	Upper Big Boulder Cr.	Big Boulder Cr. (Duplicate)
Functional Group Composition					
% Filterers	34.83	2.27	24.39	5.58	12.86
% Gatherers	33.86	29.55	12.11	26.92	23.44
% Predators	10.18	32.05	10.53	14.04	13.90
% Scrapers	6.07	24.09	50.88	48.85	46.68
% Shredders	4.50	3.86	1.58	3.65	2.90
% Piercer-Herbivores	0.00	0.00	0.00	0.00	0.00
% Unclassified	10.57	8.18	0.53	0.96	0.21
Filterer richness	1.00	3.00	2.00	1.00	2.00
Gatherer richness	11.00	8.00	8.00	14.00	8.00
Predator richness	10.00	14.00	8.00	11.00	10.00
Scraper richness	5.00	5.00	4.00	6.00	6.00
Shredder richness	6.00	5.00	4.00	4.00	4.00
Piercer-Herbivore Richness	0.00	0.00	0.00	0.00	0.00
Unclassified	3.00	2.00	1.00	1.00	1.00
Biotic Indices					
Hilsenhoff Biotic Index	3.47	1.86	2.36	2.49	2.62
Metals Tolerance Index	1.69	1.53	1.77	1.62	1.62
FSBI - summed	105.00	110.00	89.00	106.00	98.00
FSBI - average	2.92	2.97	3.30	2.86	3.16
FSBI - weighted average	0.78	3.80	3.95	4.63	4.27
TPM - average	6.08	6.46	5.74	5.51	6.48
TPM - weighted average	4.17	7.31	5.85	6.47	6.47
Karr BIBI Metrics					
Long-Lived taxa richness	4.00	6.00	4.00	6.00	4.00
Clinger richness	19.00	21.00	17.00	20.00	19.00
Intolerant taxa richness	19.00	22.00	18.00	21.00	18.00
% Tolerant taxa	0.13	0.23	0.22	2.82	1.56

Appendix 2, continued. Macroinvertebrate Metrics

Sample	Lower Jim Creek	Upper Jim Creek	Lower Big Boulder Cr.	Upper Big Boulder Cr.	Big Boulder Cr. (Duplicate)
Montana DEQ Metrics					
MT Biotic Index	-0.75	-5.49	1.84	1.54	2.42
C-Gatherers + C- Filterers	68.69	31.82	36.49	32.50	36.31
% Scraper + %Shredder	10.57	27.95	52.46	52.50	49.59
% Univoltine	75.54	48.86	74.04	66.73	73.03
% Multivoltine	5.68	6.59	18.60	13.27	9.34
% Semivoltine	2.35	17.95	3.51	9.62	6.43
Community Tolerance Quotient	-99.00	-99.00	-99.00	-99.00	-99.00
% Hydropsychinae	0.00	0.00	0.00	0.00	0.00
Idaho DEQ MBI	3.92	5.14	4.72	5.10	4.84

Notes: 1. Calculations were performed by EcoAnalysts, Inc.
2. Data are adjusted for subsampling.

Appendix 3. QA Results for Water Quality Analyses

Sample	Description	Collected	pH	H mg/L	Ca mg/L	Mg mg/L	Cu µg/L	Zn µg/L	As µg/L	Pb µg/L	Se µg/L
W1	Big Boulder Creek #3	16-Oct-2001	7.84	48.4	17.1	1.41	<3	17	<1	<1	<2
W2	Big Boulder Creek #2	16-Oct-2001	7.87	48.9	17.2	1.46	<3	16	<1	<1	<2
W3	Big Boulder Creek #1	16-Oct-2001	7.86	49.1	17.3	1.47	<3	16	<1	<1	8
W4	Jim Creek #1	16-Oct-2001	8.09	83.2	28.3	3.03	<3	102	1	1	2
W5	upper Jim Creek #2	16-Oct-2001	8.06	81.9	28.0	2.90	<3	97	1	<1	<2
W6	upper Boulder Creek	16-Oct-2001	7.83	41.1	14.7	1.05	<3	<5	<1	<1	<2
W7	duplicate of W1	16-Oct-2001	7.86	49.3	17.3	1.50	<3	17	<1	<1	<2
W8	Tailings #5 effluent	20-Nov-2001	—	66.6	22.1	2.76	7	490	36	705	<2
	lab duplicate of W8			66.2	22.1	2.71	6	467	37	590	<2
	RPD			1%	0%	2%	15%	5%	3%	18%	
	W8MS			207	44.5	23.3	1020	1610	100	558	50
W4MS	spike added to W8			132	20.0	20.0	1000	1000	50	50	50
	spike recovery			106%							

Appendix 4. Agronomic Testing Results

Sample	Description	pH	SMP pH	Conductivity mS/cm	CEC meq/100g	Lime
T1M1	Tailings Area 1 mixed upper 6"	4.2	5.4	0.34	8	0%
		strongly acidic		good	v. low	v. low
T1M2	Tailings Area 1 mixed upper 6"	3.4	4.5	0.59	10	0
		strongly acidic		good	low	v. low
T1M4	Tailings Area 1 mixed upper 6"	3.2	5.5	0.58	10	0%
		strongly acidic		good	low	v. low
SOIL-1	Alluvium N of Tailings Area 2	7.8		0.61	16	0.3%
		moderately basic		good	medium	low
SOIL-2	Alluvial fan near Tailings 1 and 2	6.3	6.6	0.22	17	0%
		slightly acidic		good	medium	v. low
SOIL-3	15ft N of road	6.5		0.20	17	0%
		slightly acidic		good	medium	v. low
SOIL-4	25-30ft above tailings	6.8		0.20	17	0%
		neutral		good	medium	v. low

	Texture	Nitrates	Phosphorus	Potassium	Sulfate	Organic Matter
T1M1	loamy sand	3	28	123	6	2.6%
		v. low	high	low	low	high
T1M2	sandy loam	6	20	102	21	0.8%
		low	medium	low	adequate	v. low
T1M4	sandy loam	6	30	106	42	1%
		low	high	low	high	low
SOIL-1	loam	23	22	175	12	5.8%
		medium	medium	low	adequate	v. high
SOIL-2	loam	7	6	368	7	12.2%
		low	low	medium	low	v. high
SOIL-3	loam	2	7	457	11	6.8%
		v. low	low	high	adequate	v. high
SOIL-4	loam	5	7	355	10	6.3%
		v. low	low	medium	adequate	v. high

	Ca	Al	Mg	Na	B	Cu	Fe	Mn	Zn
ideal level ^a					8-1.5	1.0-2.5	15-135	10-55	1.5-3.0
T1M1	928 low	6.2 too high	149 v. low	52 low	0.1	7.4	188	26	10.5
T1M2	877 v. low	0.7 ok	102 v. low	62 medium	0.1	1.5	497	10	20.8
T1M4	811 v. low	0.7 ok	101 v. low	66 medium	0.1	1.1	581	11	4.5
SOIL-1	3088 medium	0.9 ok	349 low	104 medium	0.5 adequate	0.5 low	14 adequate	3 adequate	0.6 low
SOIL-2	2035 medium	0.8 ok	247 low	92 medium	0.2 low	0.3 low	33 adequate	5 adequate	2.0 good
SOIL-3	1626 medium	1.1 ok	474 medium	126 medium	0.2 low	0.8 adequate	32 adequate	6 adequate	1.5 good
SOIL-4	1999 medium	0.9 ok	442 medium	48 low	0.2 low	0.4 low	25 adequate	4 adequate	1.3 good

Note: a. specified for acidic soils (pH<7)

Bases	Base Sat'n	Calcium	Magnesium	Potassium	Sodium	Aluminum (mg/kg)	Hydrogen
ideal level ^a		65-80%	10-20%	2-6%	<5%	<6	<15%
T1M1	80% low	58%	16%	4%	3%	6.2	20%
T1M2	58% v. low	44%	9%	3%	3%	0.7	42%
T1M4	55% v. low	41%	8%	3%	3%	0.7	45%
SOIL-1	120% high	97%	18%	3%	3%	0.9	
SOIL-2	80% low	60%	12%	6%	2%	0.8	20%
SOIL-3	81% ideal	48%	23%	7%	3%	1.1	19%
SOIL-4	87% ideal	59%	22%	5%	1%	0.9	13%