ANALYTICAL RESULTS FOR MINE DUMP SAMPLES AND LEACHATE SOLUTIONS, UPPER ANIMAS RIVER WATERSHED, SAN JUAN COUNTY, COLORADO

by **David L. Fey[1], J. Thomas Nash[1],**
Douglas B. Yager, and George A. Desborough[1]

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This report contains text, linked to Excel spreadsheet data files. The following list provides the names and describes the contents of the files comprising this report.

LIST of FILES

1: **SDCHEMOF.DOC** Text of Open-File Report: MS-WORD format

2: **SDCHEMOF.PDF** Text of Open-File Report: Adobe PDF format

3: **SDSITE.xls** Sample localities and descriptions: EXCEL format

4: **SDGX97.xls** Total-digestion analyses of mineralized rock samples by ICP-AES: EXCEL format

5: **SDPL97.xls** Analyses of passive leach solutions (1997) by ICP-MS: EXCEL format

6: **SDTL97.xls** Analyses of EPA-1312 (SPLP) solutions by ICP-AES: EXCEL format

7: SDPL99.xls Analyses of passive leach solutions (1999) by ICP-MS: EXCEL format

8: **QAQC.xls** Compilation of analytical qc data: EXCEL format

Note: When linking to an Excel file, your web browser will launch Excel, which will automatically open the referenced file. To return to the text file, use the browser's "back" button. This will return you to the first page of the text file.

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INTRODUCTION

This report provides analytical results for samples of mine dumps, mill tailings, and some unmined altered rocks. The analyses are intended to be used to characterize mineralized rocks in the Upper Animas River watershed. This study represents one component in the U.S. Geological Survey (USGS) program of integrated geological-hydrological-biological-chemical studies underway in the Upper Animas River watershed as part of the Abandoned Mine Lands Initiative (AMLI) to provide Federal land management agencies a scientific rationale for cost-effective restoration of public lands affected by historic mining (Buxton and others, 1997; Nimick and von Guerard, 1998). Information reported here is part of the mine site, or metal source, component of the project. Other personnel on the AMLI team are investigating diverse aspects of geology, geochemistry, hydrology, and biology that are pertinent to establishing pre-mining and existing conditions, as well as attainable reclamation goals.

Field studies in the summers of 1997 and 1998 focussed chiefly on historic mines and prospects identified by others as being partly or entirely on public lands administered by the U.S. Bureau of Land Management (BLM) or the USDA-Forest Service (USFS); a limited number of sites on private property were studied for comparison when the owner provided access and permission to sample. Previous reports (Nash, 1999a; 1999b) presented interim recommendations for establishing priorities or rankings of mine sites for removal or remediation. These two reports, OFR-99-170 and OFR-99-323, have been included in Nash (2000), a CD-ROM compilation of descriptions and photos of mines, mine waste dumps, mills, and mill tailings and interim interpretations of their significance as sources of acid or metals in the upper Animas River watershed.

Acknowledgements: Many people with the BLM and USGS have been helpful during this study, in particular Barbara Hite, Stephanie Odell, and Rob Robinson of the BLM, and Daryl Gussey of the USFS. They have provided helpful information and suggestions. The friendly advice of the many scientists on the USGS AMLI team has expanded the breadth and depth of our geochemical investigations, but the authors are solely responsible for any errors reported here.

METHODS OF STUDY

Field and laboratory studies for this investigation utilized methods that were developed for the AMLI program, and efforts have been made to maintain consistency among the scientists working in the Colorado (Animas watershed) and Montana (Boulder River watershed) study areas. In the Upper Animas study area, sites were first selected for study using information gathered by previous investigators who had made inventories for the BLM (Hite, 1995) or U.S. Forest Service (Lovekin and others, 1997). Because of the limited amount of field time available in 1997 and 1998, and the large number of potential sites, we focussed on sites that were reasonably accessible, within two miles of major streams, and had waste piles or dumps larger than about 70 cubic yards. Of the more than 500 sites identified by previous investigators, the majority are smaller than 70

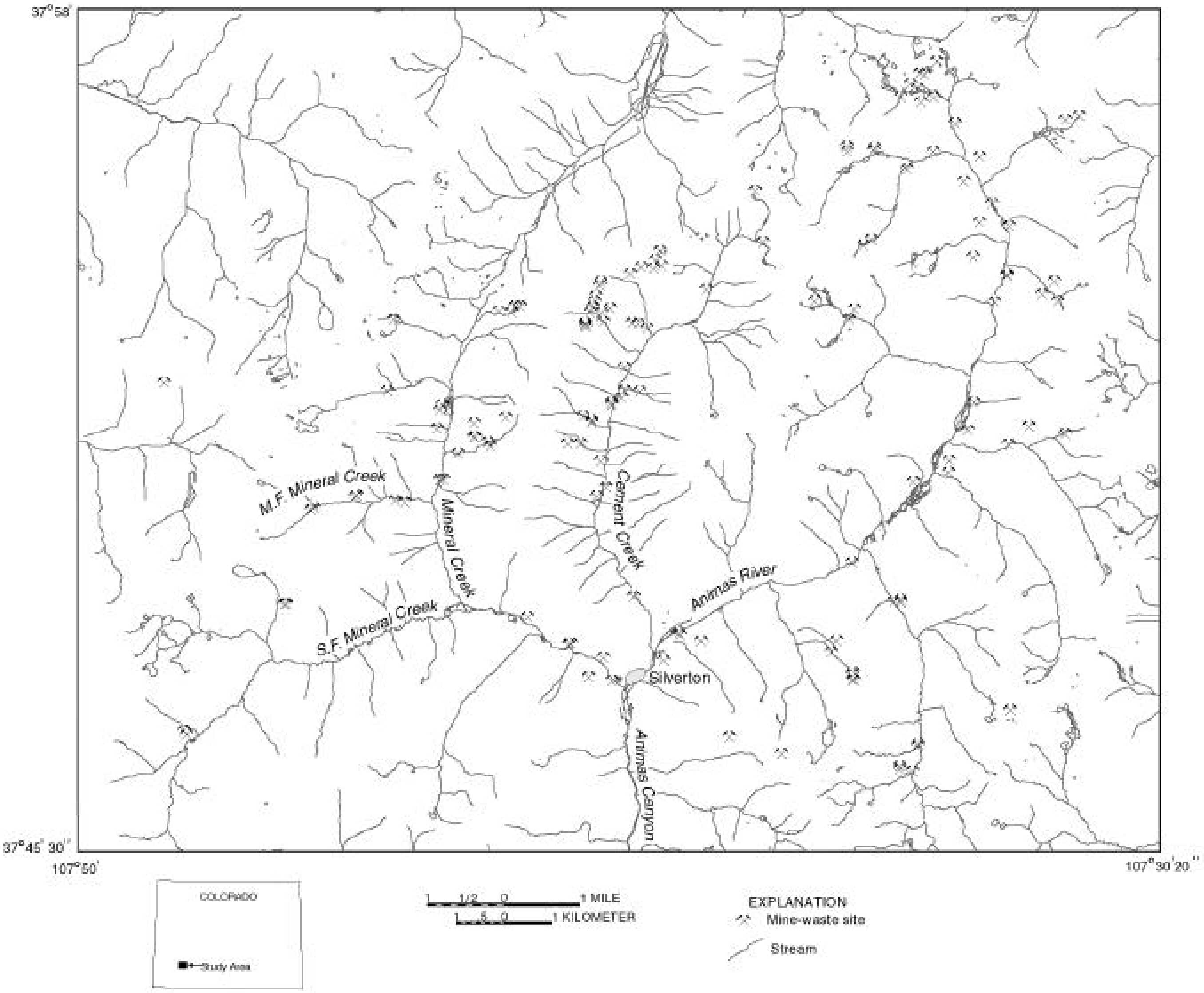

Figure 1. Index map of upper Animas Watershed study area, with mine-waste sample localities shown by pick symbols. Sites not labeled due to space. All site localities and descriptions are in Table 1 of the text.

cubic yards, and were considered unlikely to be significant contributors to water quality problems in the watershed (Nash, 1999a; 1999b). These sites were not sampled and are not included in this study. Site localities were identified on USGS 1:24,000 topographic maps and recorded using a standard global position system (GPS) instrument with an estimated accuracy of "100 meters (based on real tests). Figure 1 shows the upper Animas Basin study area with the localities of mine dumps sampled. The coordinates and sample names are given in the Excel file SDSITE.xls, and Table 1 of this text.

Sampling Methods

On-site work included a brief description of the site, rock types, rock alteration and ore mineralogy, a measurement or estimate of size of the dump pile, and the collection of a representative sample of the entire dump or waste pile surface. Samples of waste-rock from mine dumps were taken from more than 150 inactive mine sites in the upper Animas River study area. Material was collected from 30 or more subcells, each having an area of about one half square meter, across the top and sides of the dumps to a depth of about 5 cm using four to six randomly selected 50-80 g scoops. The material was mixed, and a portion passed through a 2-mm sieve to yield about 100 g from each subcell. The minus-2 mm fraction was saved, as this was deemed to be the most reactive to water in short-term exposures (Desborough and Fey, 1997; Nash, 1999a; 1999b; Smith and others, 2000). The composite sample, split from the total sieved material, amounted to one to two kg.

Samples with field numbers starting with 97ABS were collected by Fey, those starting with A97W were collected by Desborough, and those starting with NA were collected by Nash. In the series of samples collected by Nash, the third letter indicates the type of material: D, dump; F, iron flocculate-dominated sample; H, drill hole cuttings; G, smelter slag; R, unmined altered rock; S, soil; and T, mill tailing. Unless otherwise noted, all dump samples were sieved to minus-2 mm. Information on the sample sites, their localities, and which sample analyses are contained in which data spreadsheet are in an Excel spreadsheet labeled SDSITE.xls that can be read by most spreadsheet programs. Not all samples were subjected to the complete suite of analytical chemistry methodology. This information is also in Table 1 of this text.

Sample Preparation

In the laboratory, the composite samples were dried at 40^{o} C, split with a Jones splitter, and recombined several times to achieve thorough mixing. Splits from the homogenized material were made for: 1) ICP-AES total-digestion analysis, 2) EPA-1312 leach test, 3) passive leach test, and 4) net acid production (NAP) test. Splits for the EPA-1312 leach and the passive leach did not require further preparation; splits for total-digestion analysis and for NAP measurements were ground in a vertical pulverizer with ceramic plates to minus-200-mesh (75 microns).

Analytical Methods

Total-digestion ICP-AES analysis for 30 elements

A 0.2 g. portion of minus-200-mesh material was subjected to a mixed-acid total digestion using HCl, HNO_3, $HCLO_4$ and HF acids (Briggs, 1996). The resulting solution was analyzed for 40 elements using inductively coupled-plasma atomic emission spectroscopy (ICP-AES); 30 elements are reported in this report. This analysis was performed on samples collected in 1997, but not on later samples. The analytical results are contained in the spreadsheet program SDGX97.xls.

EPA-1312 Leach Method *(Synthetic Precipitation Leach Procedure-SPLP)*

A 100-g. sample of mine waste was placed in a 2.3L polyethylene bottle. Two liters of extract solution were added, resulting in a 1:20 sample/extract ratio, with 300 cc of head space. The SPLP method mandates that an extract solution of pH 4.2 be used on soils from east of the Mississippi River, and solution with pH of 5.0 be used on soils from west of the Mississippi River, and the more acidic pH 4.2 solution be used on mine-waste material. Because all of these samples were mine waste or altered rock, we used the pH 4.2 extract solution. The extract solution was made from de-ionized water acidified to a pH of 4.2 with a one percent solution of 60/40 $H2SO_4/HNO_3$. The capped bottles were placed on an end-over-end (tumbling) rotating agitator at 30 rpm for 18 hours. The leachates were then pressure-filtered through a 142 mm diameter-0.7 micron glass-fiber filter (US-EPA, 1986). A 100 mL aliquot of filtered solution was acidified with ultra-pure HNO_3 for analysis for 25 elements by ICP-AES (Briggs and Fey, 1996) and for sulfate by ICP-AES as sulfur. Conductivity and pH were determined on the bulk filtered leachate. This leach and analysis was performed on samples collected in 1997, but not on later samples. The analytical results for the EPA-1312 (SPLP) leach are contained in the spreadsheet program SDTL97.xls.

Passive Leach Method

A 100-g. sample of mine waste was exposed to 2L of laboratory de-ionized water (pH of 5.0 "0.2) in an open 4L beaker. Samples were left at rest for one hour, and then gently stirred for five seconds to prevent stratification of the leachate. The pH of the the leachate of the 1997 samples, and the pH and conductivity of the leachate of the 1999 samples was (were) measured after 24 hours. A 60 mL aliquot was then filtered through a Gelman 0.45-micron filter using a disposable syringe (Desborough and Fey, 1997), acidified with ultra-pure HNO_3, and refrigerated prior to analysis by inductively coupled-plasma-mass spectroscopy (ICP-MS).

Filtered, acidified solutions from the passive leach tests were analyzed by ICP-MS because this method provides information on more than 40 elements of possible interest, with good results to one part per billion (ppb, or microgram per liter), or lower for some elements (Crock and others, 1999). All of the samples of this study were subjected to the passive leach test. Samples collected in 1997 and processed in 1998 were analyzed by a commercial laboratory (results contained in spreadsheet file SDPL97.xls). This file also contains pH but not conductivity measurements of the passive leach solutions. Samples collected in 1998 and processed in 1999 were analyzed with a similar instrument in the USGS laboratories in Lakewood, Colorado (results contained in spreadsheet file SDPL99.xls). This file includes pH and conductivity measurements of the passive leach solutions. Replicate samples and standards were submitted with the leachates to evaluate precision and quality control.

Results of ICP-MS analyses of leachate solutions are best considered semi-quantitative, as is well understood by geochemists who routinely use this method for solutions of highly variable composition. As demonstrated by Fey and others (1999), data from analyses of leachates are inherently less reproducible than those from total digestion analyses. Our laboratory-produced solutions span a wide range in pH, conductivity, and elemental composition, and one should not expect precision to be constant across five orders of magnitude of concentration. For base metals such as copper, lead, and zinc, the precision is about "20 percent for solutions whose concentrations resemble typical surface waters; the precision is lower for solutions whose concentrations are 1,000 times or more higher than normal surface waters. High and very high concentrations are clearly delineated from low concentrations, and the semi-quantitative nature of the results is appropriate for these tests. The file QAQC.xls included in this report presents data for duplicates, blanks, and standards for the ICP-40 element method, the EPA-1312 method, and the passive leach method. Further comments are made elsewhere (Nash, 1999a; 1999b).

Net Acid Production (NAP) method

A 1.0-gram sample of pulverized, minus-200-mesh material was digested with a solution of 30 percent hydrogen peroxide to oxidize pyrite, thereby producing sulfuric acid (Lapakko and Lawrence, 1993). This acidic solution reacted with the bulk of the sample, released additional acidity from water-soluble acid salts (such as iron-sulfates), and reacted with acid-consuming minerals such as carbonates, and some non-carbonates (e.g. biotite, chlorite and epidote). The solutions were heated for one hour, cooled, and filtered. The acidic filtrate was then titrated to a pH of 7 with 0.1M NaOH. A calculated net acid production (NAP) is expressed in terms of kg-equivalent $CaCO_3$ per metric ton of mine waste. This NAP is meant to represent the net long-term or total potential of a material to produce acid over an unspecified period of weathering. This test was applied to samples collected in 1997, and the results are contained in the same spreadsheet file as the EPA-1312 leach analyses, SDTL97.xls.

X-ray diffraction (XRD) studies

X-ray diffraction studies were made to determine major minerals in the minus-2 mm sample material. Detailed results of the XRD studies are not presented here, but a summary indicates that sulfide minerals are common in these samples: 25 percent of the samples contain pyrite (FeS_2), 30 percent contain sphalerite (ZnS), and 30 percent contain galena (PbS). Calcite ($CaCO_3$), an important acid-buffering phase, was detected by XRD in only three samples.

DISCUSSION OF EPA-1312 (SPLP) LEACH AND PASSIVE LEACH RESULTS

A comparison between the results of the EPA-1312 leach and the passive leach is reported in Fey and others (2000), which discussed the EPA-1312 leach and the passive leach and their application to the same samples as those from 1997 in this report, plus eighteen mine-waste samples from Montana. In figure 1 of Fey and others (2000), the pH of the passive leach was plotted versus the pH of the EPA-1312 leach. The data points cluster quite closely around a diagonal line of 1 to 1 correspondence. The same is true for many of the trace elements presented in the tables of this report. We applied both leach procedures to samples collected in 1997 (files SDTL97.xls and SDPL97.xls). However, we did not apply the EPA-1312 leach to the later samples, because using the passive leach procedure is simpler and faster, yields similar results, and more closely simulates the processes that occur at the surface of waste piles exposed to rainwater and snowmelt runoff. (Fey and others, 2000).

The relation between the net acid production (NAP) and the sum of dissolved metals As+Cd+Cu+Pb+Zn (in µg/L) from the EPA-1312 leach has also been examined (Fey and others, 2000). The mine wastes studied can be segregated into groups based on their NAP and summed metals, where samples with NAP greater than 10 kg $CaCO_3$ per ton and the above summed metals greater than 5,000 µg/L would rank as having the greatest potential for causing water quality problems. The passive leach samples discussed in Fey and others (2000) also exhibit a systematic relationship between summed metals and NAP. Although the passive leach releases a lower concentration of metals, a similar grouping of the waste samples results. Here, the group with greatest potential for causing water quality problems (highest rank) have NAP greater than 10 $CaCO_3$ and summed metals greater than 3,000 µg/L. We did not determine the NAP for the later samples, but did perform the passive leach on all samples in this report, and so some measure of ranking can be achieved by using the 3,000 µg/L value for the sum of the metals As+Cd+Cu+Pb+Zn in the passive leach solutions. Dissolved iron in the EPA-1312 solutions can also be used to delineate wastes with high potential for water quality degradation. A value of 1,000 µg/L iron in leach solutions can be used to separate the samples, for reasons also discussed in Fey and others (2000).

EXPLANATORY NOTES FOR FILES OF ANALYTICAL RESULTS

1. In the file SDPL97.xls, the number of figures carried in the spreadsheet tends to exceed the significant figures reported by the analyst. In most cases, only two figures are significant. The other spreadsheet files have been formatted to present the correct number of significant figures.

2. In all files, additional elements may have been determined but not reported here because the results were either at or below the limit of determination (e.g. Cr and Ti in leachates), or the element is not being used in the geochemical characterization of the watershed.

3. Explanations for each specific file are included in notes found at the bottom of each file, below the analytical data. Especially important are the extra characters attached to some field numbers in the file SDPL99.xls, which indicate that additional or unusual steps were taken in the passive leach of those samples. Some samples were leached for more than the standard 24 hour period. Those sample leachates carry extra letters including: B, 48 hour leach period; C, 72 hours; D, 96 hours; G, 168 hours. Some solutions were collected using different filtering techniques. The extra character U indicates the leachate was not filtered prior to analysis, and a V indicates the leachate was filtered through a 0.1 micrometer filter instead of the usual 0.45 micrometer filter. The extra character Y or X indicates a replicate analysis. Other letter suffixes (e.g. F, L, P, R, S) refer to sample field attributes, and can be ignored.

4. In the file SDSITE.xls, sample locations shown were mostly determined by standard GPS (global positioning satellite), with no subsequent corrections. Some site locations were determined from USGS 1:24,000 topographic maps where the GPS

could not operate. Field tests show that the GPS is accurate to about " 100 meters in the San Juan mountains.

References Cited

Briggs, P.H., 1996, Forty elements by inductively coupled plasma-atomic emission spectrometry, *in* Arbogast, B.F., ed., Analytical methods manual for the Mineral Resource Surveys Program, U.S. Geological Survey Open-File Report 96-525, p. 77-94.

Briggs, P.H., and Fey, D.L., 1996, Twenty-four elements in natural and acid mine waters by inductively coupled plasma-atomic emission spectrometry, *in* Arbogast, B.F., ed., Analytical methods manual of the Mineral Resource Surveys Program, U.S. Geological Survey Open-File Report 96-525, p. 95-101.

Buxton, H.T., Nimick, D.A., and others, 1997, A science-based, watershed strategy to support effect remediation of abandoned mine lands: Proceedings of the Fourth International Conference on Acid Rock Drainage, Vancouver, B.C., p. 1869-1880.

Crock, J.G., Arbogast, B.F., and Lamothe, P.J., 1999, Laboratory methods for the analysis of environmental samples, *in* G.S. Plumlee and M.J. Logsdon, eds., The Environmental Geochemistry of Mineral Deposits, part A: Society of Economic Geologists, Rviews in Economic Geology, vol. 6A, p. 265-287.

Desborough, G.A., and Fey, D.L., 1997, Preliminary characterization of acid-generating potential and toxic metal solubility of some abandoned metal-mining related wastes in the Boulder River headwaters, northern Jefferson County, Montana: U.S. Geological Survey Open-File Report 97-478, 21 p.

Fey, D.L., Unruh, D.M., and Church, S.E., 1999, Chemical data and lead isotopic composition in stream-sediment samples from the Boulder River watershed, Jefferson County, Montana: U.S. Geological Survey Open-File Report 99-575, 147 p.

Fey, D.L., Desborough, G.A., and Church, S.E., 2000, Comparison of two leach procedures applied to metal-mining related wastes in Colorado and Montana and a relative ranking method for mine wastes, in Proceedings of the Fifth International Conference on Acid Rock Drainage, May 20-23, 2000, Denver, Colorado, Society of Mining Engineering, Lakewood, Colo., p. 1477-1487.

Hite, B.J., 1995, Abandoned mine land inventory of BLM Administered land in Upper Animas River watershed, Colorado: U.S. Bureau of Mines, report for Colorado State BLM Office, 15 p. plus appendices; data for 304 sites on diskette.

Lapakko, K., and Lawrence, L.W., 1993, Modification of the net acid production (NAP) test. Paper presented at the Seventeenth Annual British Columbia Mine Reclamation Symposium, May 4-7 at Port Hardy, B.C.

Lovekin, J.R., Satre, M.J., Sheriff, W.M., and Sares, M.A., 1997, USFS-Abandoned mine land inventory project final summary report, San Juan National Forest, Columbine Ranger District: Colorado Geological Survey, 45 p. plus tables.

Nash, J. T., 1999a, Geochemical investigations and interim recommendations for priority abandoned mine sites on U.S.D.A. Forest Service lands, Mineral Creek watershed, San Juan County, Colorado; paper edition: U.S. Geological Survey Open-File Report 99-170, 40 p.

Nash, J.T., 1999b, Geochemical investigations and interim recommendations for priority abandoned mine sites on USBLM lands, Upper Animas River watershed, San Juan County, Colorado; paper edition: U.S. Geological Survey Open-File Report 99-323, 45 p.

Nash, J.T., 2000, Geochemical studies of mines, dumps, and tailings as sources of contamination, Upper Animas River Watershed, Colorado, U.S. Geological Survey Open-File Report 00-104, CD-ROM

Nimick, D. A., and von Guerard, Paul, 1998, editors, Science for Watershed Decisions on Abandoned Mine Lands: Review of Preliminary Results, Denver, Colorado, February 4-5, 1998: U.S. Geological Survey Open-File Report 98-297, 70 p.

Smith, K.S., Ramsey, C.A., and Hageman, P.L., 2000, Sampling strategy for the rapid screening of mine-waste dumps on abandoned mine lands, in Proceedings of the Fifth International Conference on Acid Rock Drainage, May 20-23, 2000, Denver, Colorado, Society of Mining Engineering, Lakewood, Colo., p 1456-1462.

U.S. Environmental Protection Agency, 1986, Test Methods for Evaluating Solid Waste, Vol. I and II (SW-846) 3rd Edition, November. Updates are available through Revision 2B, published April 4, 1995.

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
97ABS101	x	x	x		B060	37.8356	107.6858	>50,000	Lower level, tan, high clay, low sulfide
97ABS102	x	x	x		B060	37.8358	107.6864	>50,000	Upper level, tan, high clay, med pyrite
97ABS103	x	x	x		--	37.8233	107.6656	100	Small dump, weakly mineralized volcanics
97ABS104	x	x	x		B160	37.8131	107.6444	5,000	Gray, weakly altered volcanics, wet by mine drain
97ABS105	x	x	x		B070	37.8083	107.6650	5,000	Tan and green weakly mineralized volcanics
97ABS106	x	x	x		B248	37.8117	107.6939	nd	Red-ocher altered, high pyrite, mixed talus
97ABS107	x	x	x		--	37.8672	107.6839	2,000	High pyrite waste from shaft, galena-sphalerite
97ABS108	x	x	x		--	37.8656	107.6811	10,000	High sulfide pyrite-galena-sphalerite from adit
97ABS109	x	x	x		--	37.8678	107.6750	10,000	Rusty stained low sulfide dump; high flow drainage
97ABS110	x	x	x		--	37.7872	107.6233	>50,000	Dark manganese-stained, oxides, some pyrite-chalcopyrite
97ABS111	x	x	x		--	37.7942	107.6356	2,000	Oxides of iron-mangangese-copper, low pyrite
97ABS112	x	x	x		Bonner	37.8431	107.7383	>50,000	Tan altered volcanics, medium pyrite, some sphalerite
97ABS260	x	x	x		Ferricrete mine	37.8683	107.7269	500	Iron-oxide cemented talus, no sulfides; wet
97ABS261	x	x	x		--	37.8672	107.7275	>5,000	Ocher ferricrete, friable, trenched
97ABS262	x	x	x		--	37.8497	107.7258	2,000	Brown iron-oxide coated weakly altered volcanics, no pyrite
97ABS263	x	x	x		Imogene	37.8622	107.7292	15,000	Rusty iron-oxide coatings, low pyrite; wet
97ABS264	x	x	x		Silver Crown	37.8717	107.8111	20,000	High sulfide-pyrite-galena-sphalerite, medium clay, wet by mine drain
A97W001	x	x	x		Carbon Lake	37.8977	107.7163	12,000	High pyrite-galena-sphalerite, enargite; wet
A97W002	x	x	x		Congress	37.8861	107.7023	7,000	High sulfide, high clay, inhomogeneous
A97W003	x	x	x		--	37.8910	107.7066	2,500	High sulfide, high clay dump
A97W004	x	x	x		--	37.8915	107.7102	<500	Sulfidic dump from prospect
NAD084	x	x	x		--	37.9036	107.5564	--	Private; high pyrite dump, makes yellow sulfates
NAD085	x	x	x		B144	37.8961	107.6144	1,000	High pyrite-galena-sphalerite-chalcopyrite, weathers yellow; high clay
NAD086	x	x	x		B152	37.8044	107.5983	20,000	Sulfidic granitic rocks, galena-sphalerite, is unusual
NAD089	x	x	x		--	37.8244	107.5864	>100,000	Private; medium pyrite-galena-sphalerite, ore pile?
NAD090	x	x	x		B156	37.8658	107.5667	2,000	Messy mine drainage makes iron flocculate
NAD091	x	x	x		--	37.8792	107.6728	10,000	Messy mine drainage, much red iron flocculate
NAD092	x	x	x		B052	37.8914	107.6789	500	Only part mine dump, is high sulfide; debris

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAD094A	x	x	x		--	37.8922	107.6808	10,000	Lark lower, medium-high sulfide, galena-sphalerite
NAD094B	x	x	x		B072	37.8944	107.6806	100,000	Lark upper level, alluvium and high sulfide
NAD095	x	x	x		B021	37.9014	107.6700	300	Very high pyrite, some galena-sphalerite, water in shaft
NAD096	x	x	x		B123	37.9103	107.6306	30,000	Big dump, high pyrite-galena-sphalerite, drain through dump
NAD098	x	x	x		B234	37.9519	107.5833	3,000	Very high sulfide, big vein; water in trenches
NAD099	x	x	x		--	37.9428	107.5344	2,000	Oxidized, high quartz, small dump
NAD121	x	x	x		B088	37.9336	107.5972	2,000	Dump from adit; high clay, medium sulfide
NAD123	x	x	x	x	B213	37.9286	107.5864	1,000	High clay and black manganese, medium pyrite-sulfide dump, small
NAD132				x	B229	37.9264	107.5697	1,000	Mostly green-gray altered volcanic rock, background?
NAD134	x	x	x		B183	37.9428	107.5344	2,000	Oxidized, high quartz, small dump
NAD137	x	x	x		B184	37.9417	107.5386	7,000	Yellow sulfate from weathering, high silica
NAD142	x	x	x		B182	37.9322	107.5644	6,000	High quartz-carbonate (tan), low sulfide
NAD144	x	x	x		B169	37.9400	107.5722	3,000	Coarse abundant pyrite-quartz, some mine drainage
NAD146	x	x	x		B236	37.9494	107.5861	<100	Abundant pyrite and sulfate, big quartz veins
NAD148	x	x	x		--	37.9461	107.5889	8,000	Stockpile? High pyrite-galena-sphalerite; looks like ore pile
NAD149	x	x	x		--	37.9483	107.5839	10,000	High pyrite-sericite altered volcanics; coarse quartz
NAD150	x	x	x		B238	37.9450	107.5828	12,000	Pyrite-clay rich, some galena-sphalerite; adit on large vein
NAD151	x	x	x	x	B237	37.9461	107.5789	2,000	Coarse pyrite with clay, big quartz-pyrite vein chunks, small dump
NAD155	x	x	x		B234	37.9519	107.5833	3,000	Very high sulfide, big vein; water in trenches
NAD160	x	x	x		B233	37.9550	107.5783	5,000	High sulfide, coarse pyrite; some mine drainage
NAD166				x	--	37.9158	107.5642	<1,000	Mostly green altered volcanics ; background?
NAD167	x	x	x		B180	37.9147	107.5542	5,000	Mixed oxidized sulfide and green altered volcanics
NAD172				x	B120	37.9222	107.6328	<100	Very small but high sulfide
NAD175	x	x	x	x	B123	37.9103	107.6306	30,000	Big dump, high pyrite-galena-sphalerite, clay, drain through dump

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAD177				x	B010	37.9036	107.6606	<100	Mostly pyrite-sericite altered volcanics ; background?
NAD181	x	x	x		--	37.9069	107.6608	4,000	High sulfide dump near lake at pass, clay?
NAD184	x	x	x		--	37.8981	107.6467	3,000	Mixed high pyrite and low pyrite waste; tram
NAD187	x	x	x		B006	37.9028	107.6631	500	Small, pyrite-altered volcanics, any ore?
NAD192	x	x	x		B021	37.9014	107.6700	300	Very high pyrite, some galena-sphalerite, water in shaft
NAD196	x	x	x		B103	37.8892	107.6689	800	Coarse pyrite-quartz veins, steep avalanche path
NAD201	x	x	x		B105	37.8881	107.6650	200	Low sulfide, high iron-oxide on dump, ferricrete
NAD204	x	x	x		B072	37.8944	107.6806	100,000	Lark upper level, alluvium and high sulfide
NAD210	x	x	x		--	37.8922	107.6808	10,000	Lark lower, medium-high sulfide, galena-sphalerite
NAD211	x	x	x	x	--	37.8922	107.6808	10,000	High pyrite-sphalerite-galena, fresh, few fines; sulfide picks
NAD216	x	x	x		--	37.8914	107.6828	100,000	High sulfide, high clay, weathered?, large
NAD218	x	x	x		B052	37.8914	107.6789	500	Only part mine dump, is high sulfide; debris
NAD219	x	x	x		B053	37.8931	107.6761	<100	Small diggings, oxidized sulfides
NAD221	x	x	x		B271	37.8886	107.6789	5,000	Recent mining, low pyrite, slides into creek
NAD225	x	x	x		B001	37.8792	107.6728	10,000	Messy mine drainage, much red iron flocculate
NAD227	x	x	x		--	37.8792	107.6728	10,000	High pyrite part of dump, atypical sample
NAD227P				x	--	37.8792	107.6728	10,000	Sulfidic picks from mostly oxide dump
NAD231	x	x	x		B156	37.8658	107.5667	2,000	Messy mine drainage makes iron flocculate
NAD235	x	x	x		B022	37.8653	107.5381	12,000	Low sulfide gray rocks, wet by mine drainage
NAD237	x	x	x		B157	37.8672	107.5478	10,000	Yellow sulfate colors on high pyrite waste, galena-sphalerite
NAD249	x	x	x		B127	37.8572	107.5742	1,500	Overgrown, variable sulfide, some water
NAD252	x	x	x		--	37.8231	107.5853	>100,000	Private; oxide-sulfide-clay mix
NAD253	x	x	x		--	37.8244	107.5864	>100,000	Private; medium pyrite-galena-sphalerite, ore pile?
NAD254	x	x	x		--	37.8244	107.5856	>100,000	Private; low sulfide, wallrock only?
NAD262	x	x	x		Highland Mary	37.7844	107.5839	>100,000	Clay-altered volcanics, calcite veins
NAD265	x	x	x		--	37.7828	107.5806	10,000	Altered pre-Cambrian amphibolite, calcite veins
NAD286				x	--	37.8061	107.5992	2,000	Quartz-sulfide vein, old mine, calcite, -2 mm

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAD298	x	x	x		B152	37.8044	107.5983	20,000	Sulfidic granitic rocks, galena-sphalerite, is unusual
NAD300	x	x	x		B248	37.8108	107.6856	5,000	Highly altered rocks, high pyrite, mixed talus and dump
NAD308	x	x	x		B108	37.8722	107.6719	1,500	Gray volcanics, low pyrite, some iron-oxide, small
NAD309	x	x	x		B116	37.8722	107.6678	1,500	Dump is tan, oxide coatings, pyrite, mine water on dump
NAD310	x	x	x		B115	37.8728	107.6708	4,000	Gray volcanics, low sulfide, no Acid Rock Drainage (ARD)
NAD311	x	x	x		B009	37.8700	107.6747	3,000	Much ocher-red iron flocculate from Acid Mine Drainage (AMD)
NAD320	x	x	x		B262	37.8594	107.6872	3,000	Moderate pyrite, tan clays, AMD on dump
NAD323	x	x	x		--	37.8603	107.6853	4,000	Sulfidic dump with yellow sulfates, high clay
NAD327	x	x	x		B114	37.8747	107.6878	8,000	Low pyrite, low iron-oxide, no ARD
NAD339	x	x	x		B144	37.8961	107.6144	1,000	High pyrite-galena-sphalerite-chalcopyrite, weathers yellow; high clay
NAD347	x	x	x		B149	37.8919	107.6033	600	Mix of sulfidic and green altered volcanics
NAD351	x	x	x		--	37.8972	107.5403	--	Klondyke; much black manganese, low iron-oxide, low pyrite
NAD352	x	x	x		--	37.8992	107.5442	--	Coarse pyrite-quartz veins, weathers yellow
NAD353	x	x	x		--	37.9025	107.5411	--	Coarse pyrite-galena-sphalerite, talus mixed in with dump
NAD355	x	x	x		--	37.9036	107.5564	--	Private; high pyrite dump, make yellow sulfates
NAD357	x	x	x		--	37.9044	107.5561	--	Private; upper dump like NAD355.
NAD361	x	x	x		--	37.8103	107.6053	--	Private; mostly green altered volcanics, some quartz
NAD362	x	x	x		--	37.8139	107.6039	--	Private, small; mixed pyrite and yellow sulfates
NAD364	x	x	x		B160	37.8919	107.6033	5,000	Tan dump, high clay, high water flow, no ARD
NAD365	x	x	x		--	37.8142	107.6517	--	Stockpile at mill; high pyrite ore (?)
NAD380	x	x	x		B318	37.9078	107.5656	10,000	Recent mining; low sulfide dump
NAD381				x	--	37.9331	107.6058	500	Stockpile, rich in sphalerite-galena-pyrite
NAD387				x	--	37.8969	107.5589	10,000	Sulfidic part of dump, chunks?
NAD396	x	x	x		B249	37.9319	107.6056	1,000	Upper dump, moderate pyrite-ocher oxides
NAD399	x	x	x		--	37.7869	107.8003	>100,000	Gray siltite, oxide coatings, low sulfide

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAD414	x	x	x		--	37.8494	107.6764	--	Private; high pyrite-galena-sphalerite dump, high clay
NAD423	x	x	x		--	37.8561	107.7208	500	Quartz-pyrite-sericite altered rocks, moderate sulfides
NAD427	x	x	x		--	37.8747	107.7325	5,000	Rusty altered rocks, low sulfide?, much mine water
NAD501				x	--	37.8653	107.7072	300	Yellow, high clay, pyritic dump
NAD504				x	--	37.8639	107.7169	500	Sulfidic waste from old shaft, bulldozed
NAD511				x	Imogene	37.8622	107.7286	10,000	Gray silicic volcanics, iron-oxide coatings, low pyrite
NAD516				x	Bonner	37.8431	107.7383	10,000	Middle dump, low pyrite, silicic volcanics, iron-oxide
NAD517				x	Bonner	37.8436	107.7383	10,000	Lower dump, low pyrite, high iron-oxide matrix
NAD519				x	West Bonner	37.8444	107.7403	7,500	West of Bonner, low pyrite, high iron-oxide dump
NAD520				x	Paradise	37.8425	107.7644	10,000	Paradise, low pyrite, high iron-oxide and white crust
NAD524				x	Ruby Trust	37.8458	107.7528	20,000	High clay, medium pyrite, iron-oxide coatings on volcanic rocks
NAD530				x	B123	37.9103	107.6306	30,000	High pyrite-sphalerite-galena; repeat sample
NAD555				x	B116	37.8728	107.6675	1,600	Tan, low-medium pyrite, iron-oxide coatings
NAD557				x		37.8878	107.6842	500	Very high sulfide, fine grained in clay
NAD563				x	N204	37.8928	107.6811	50,000	Upper Lark, on average is low sulfide with alluvium
NAD564				x	N210	37.8925	107.6808	50,000	Lower Lark re-sample, medium sulfide, pyrite-sphalerite-galena
NAD577				x	Silver Crown	37.8717	107.7444	20,000	Waste rich in clay and fine pyrite
NAD588				x	Brooklyn	37.8722	107.6972	100,000	Gray dump, high in fine pyrite and clay
NAD594				x	Bullion King	37.8881	107.7422	30,000	Tan color, high clay and iron-oxide, fine pyrite inside
NAD601				x	B152	37.8025	107.6797	20,000	Granitic rocks, medium pyrite, medium iron-oxide
NAD603				x	Burbank	37.8189	107.7725	10,000	Green altered volcanics, oxide coatings
NAD648				x	Bandora	37.7867	107.8011	50,000	Lower Bandora, tan siltite, iron-oxide coatings, low pyrite
NAD650				x	Bandora	37.7875	107.8019	50,000	Upper dump, tan siltite, has low sulfide
NAD696				x	NAD211	37.8925	107.6814	10,000	High sulfide dump, coarse, few fines; re-sample
NAD726				x	B234	37.9517	107.5819	3,000	High pyrite dump, re-sample
NAD817				x	--	37.8608	107.7163	>50,000	High pyrite-sphalerite-galena dump, high clay, recent
NAD818				x	--	37.8592	107.7013	10,000	High pyrite-sphalerite-galena dump, high clay, recent

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAD845				x	B249	37.8525	107.5819	2,000	Ocher, mixed sulfide-oxide materials
NAD878				x	B014	37.8653	107.6806	2,000	From adit, high pyrite-sphalerite-galena dump
NAD879				x	B014	37.8650	107.6811	3,000	From shaft, very high pyrite, sphalerite-galena
NADW520				x	Paradise	37.8425	107.7644	10,000	Mostly white crust on iron-oxide soil
NAF520				x	Paradise	37.8425	107.7644	10,000	Mostly red and brown fine iron-oxide soil
NAF521				x	Paradise West	37.8419	107.7653	5,000	Fine red iron-oxide soil in matrix
NAF687				x	--	37.8783	107.6714		Rusty brown iron-oxide from mine drainage
NAG299	x	x	x		--	37.8078	107.6750	--	Glassy black smelter slag, ground sand size
NAH188				x	--	37.9031	107.6669	na	Drill cuttings, high clay, high pyrite
NAH189				x	--	37.9033	107.6672	na	Drill cuttings, high clay, high pyrite
NAH558				x	--	37.8886	107.6844	na	Drill cuttings, high clay, high pyrite
NAH559				x	--	37.8892	107.6847	na	Drill cuttings, high clay, high pyrite, and oxides
NAH560				x	--	37.8894	107.6847	na	Drill cuttings, high pyrite and iron-oxide
NAR130	x	x	x		--	37.9114	107.5967	--	Red-black soil along quartz-sulfide vein, -2 mm
NAR180	x	x	x		--	37.9044	107.6633	--	Pyrite-jarosite altered volcanic, Red Mtn type, -2 mm
NAR190	x	x	x		--	37.9031	107.6669	--	Drill cuttings in red altered volcanics, -2 mm
NAR197				x	--	37.8894	107.6672	na	Iron-oxide-pyrite altered volcanic rocks, -2 mm
NAR205				x	--	37.8950	107.6811	na	Rusty alluvium at Lark mine
NAR207S	x	x	x		--	37.8983	107.6789	--	Red soil from pyrite-altered volcanics, -2 mm
NAR261	x	x	x		--	37.7831	107.5839	--	Soil from gray clay-carbonate altered volcanics
NAR301	x	x	x		--	37.8106	107.6861	--	Red weathered pyrite-altered volcanics, -2 mm
NAR366				x	B218	37.9078	107.5656	na	Small dump, mostly gray volcanics
NAR391				x	B288	37.7981	107.5508	na	Mostly gray fresh volcanics, low pyrite
NAR421	x	x	x		--	37.8186	107.6983	--	Red pyrite-altered volcanics in County pit, -2 mm
NAR603				x	--	37.8189	107.7719	na	Green altered volcanic agglomerate
NAR691				x	--	37.8992	107.6789	na	Soil in red altered volcanics, from acid sulfate alteration?

Table 1. Sample Identification numbers, Excel files containing analytical data, site names, site localities, estimated dump size, and site/sample descriptions (cont.)

Sample ID	FILE SD GX97	FILE SD TL97	FILE SD PL97	FILE SD PL99	Name or BLM site #	Latitude N (deg)	Longitude W (deg)	Size Est. Tons	Site and/or sample description
NAS638				x	--	37.8983	107.6792	na	Soil in red altered volcanics, from acid sulfate alteration?
NAS699F				x	--	37.8558	107.6775	na	Schwertmannite (?) ocher crust in Cement Creek
NAT088	x	x	x		Highland Mary tails	37.7886	107.5789	>100,000	Highland Mary mill tails, light tan, carbonate?
NAT230	x	x	x		Kitti-Mack tails	37.8606	107.5706	>100,000	Kitti-Mack tails, pale yellow
NAT234	x	x	x		Old Kitti-Mack	37.8622	107.5533	<100	Old Kitti-Mack millsite, ocher tailings
NAT258	x	x	x		Highland Mary tails	37.7886	107.5789	>100,000	Highland Mary mill tails, light tan, carbonate?
NAT270	x	x	x		Old Hundred	37.8244	107.5864	500?	Old Hundred mill tails, ocher
NAT287				x	--	37.8061	107.5992	1,000	Tails from stamp mill L. Giant
NAT378	x	x	x		Vermillion mill	37.9325	107.5961	<100	Vermillion mill tails, light gray
NAT389	x	x	x		South Howard. Mill?	37.8325	107.6003	<100	South Howardsville mill site, rusty tails at mill
NAT501				x	Brooklyn	37.8581	107.7111	1,000	Brooklyn tails, gray, high pyrite
NAT525				x	Ruby Trust	37.8447	107.7519	<100	Ruby Trust tails in foundation
NAT600				x	--	37.8511	107.7264	<100	Tailings in burned foundation, pale gray
NAT602				x	Lodore	37.8022	107.6728	1,000	Ocher tailings near Lodore mill
NAT622				x	Lackawanna	37.8447	107.7533	30,000	Gray and ocher tailings, Lackawanna
NAT623				x	--	37.8678	107.5664	fluvial	Ocher layer of tailings, upper layer
NAT624				x	--	37.8678	107.5664	fluvial	Gray layer of mill tailings, below ocher
NAT628				x	--	37.9208	107.5597	fluvial	Ocher tailings on sandbar
NAT706				x	Bagley	37.9328	107.5789	10,000	Bagley tails, ocher, in pond
NAT720				x	--	37.8044	107.5994	1,000	Below stamp mill, in creek, coarse
NAT742				x	Highland Mary	37.7883	107.5800	100,000	Highland Mary tails, light, calcite?
NAT830				x	Mastodon	37.9100	107.6003	na	Ocher tailings, reclaimed 1997