In cooperation with the U.S Department of Agriculture Forest Service

HYDROGEOLOGIC, WATER-QUALITY, AND GEOCHEMICAL DATA FOR THE FROHNER MEADOWS AREA, UPPER LUMP GULCH, JEFFERSON COUNTY, MONTANA

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This report is preliminary and has not been reviewed for conformity with the U.S. Geological Survey editorial standards or with the North American Stratigraphic Code.

Open-File Report 2003-03-248

U.S. Department of the Interior
U.S. Geological Survey

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CONVERSION FACTORS, ABBREVIATED UNITS, AND ACRONYMS

Multiply	by	to obtain
cubic foot per second (ft^3/s)	0.028317	cubic meters per second (m^3/s)
foot (ft)	0.3048	meter (m)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer

Temperature can be converted to degrees Celsius (°C) or degrees Fahrenheit (°F) by the following equations:

$$°C = 5/9\ (°F - 32)$$
$$°F = 9/5\ (°C) + 32$$

Abbreviated units used in this report:

<, less than
>, greater than
--, no data
°C, degrees Celsius;
$CaCO_3$, calcium carbonate
cm, centimeter
E, estimated
ft, feet
ft^3/s, cubic feet per second
g, gram
GPS, Global Positioning System
HCl, hydrochloric acid
$HClO_4$, perchloric acid
HF, hydrofluoric acid
HNO_3, nitric acid
H_2O_2, hydrogen peroxide
HMI, Huntingdon Engineering and Environmental, Inc.
ICP-AES, inductively coupled plasma-atomic emission spectroscopy
I.D.. inside diameter
kg, kilogram
L, liter
LRL, laboratory reporting level
MDEQ, Montana Department of Environmental Quality
mg/L, milligrams per liter;
mL, milliliter TD, total depth]
mm, millimeters
NAP, net acid production
NaOH, sodium hydroxide
n.d., not detected
NWQL, USGS National Water Quality Laboratory (Denver, Colorado)
ppb, parts per billion
ppm, parts per million
PTS, Pioneer Technical Services
PVC, polyvinyl chloride
SRM, standard reference material
su, standard units
TD, total depth
uS/cm, microsiemens per centimeter at 25 degrees Celsius;
ug/L, micrograms per liter.

INTRODUCTION

The Frohner Meadows are located within the headwaters of Lump Gulch, about 15 miles west of the town of Clancy, Montana in the Helena National Forest (fig 1). They are located in the western part of the upper Prickly Pear Creek watershed about 12 miles southwest of Helena, Montana. Two abandoned mines and mill sites, the Frohner and Nellie Grant, are located within the Frohner Meadows study area (fig. 2). These mine and mill sites are considered to be potential sources of trace elements to the Frohner Meadows. Water chemistry and streambed sediment geochemical data (Klein and others, 2001; Klein and others, 2003) show that high concentrations of trace metals are contributed to upper Lump Gulch by streams flowing from the outlets of Frohner Meadows

Although remediation activities at the Frohner and Nellie Grant Mine sites have been undertaken several times between the early-1980s and 1998, the State of Montana has listed the Frohner Mine for additional future remediation (Montana Department of Environmental Quality, 2002). The USDA-Forest Service is currently (2003) in the process of determining remediation efforts for their agency in the Frohner Meadows area (Beth Ihle, USFS, Townsend, oral commun., 2003). To aid in this determination, the U.S. Geological Survey and USDA-Forest Service conducted a comprehensive study during 2001-02 of the hydrogeology, water quality, and geochemistry of the Frohner Meadows.

Purpose and scope

The purpose of this report is to present data from a comprehensive study of the hydrogeology, surface- and ground-water quality, and geochemistry of surficial geologic materials from the Frohner Meadows area. This report presents hydrogeologic, water-quality, and geochemical data for the Frohner Meadow. Data presented in this report were collected during 2001 and 2002 for the following objectives: 1) characterize ground-water flow and quality in the Frohner Meadows area, 2) characterize stream flow and quality in Frohner Meadows and upper Lump Gulch, 3) identify sources and loads of trace elements to Frohner Meadows, 4) characterize physical and chemical properties of mill tailings in Frohner Meadows and 5) characterize the geochemistry of streambed sediments and core samples in the wetlands and waterways of Frohner Meadows and in upper Lump Gulch.

HYDROGEOLOGIC AND WATER–QUALITY DATA

Seven shallow monitoring wells were installed in upper Frohner Meadows and three were installed in lower Frohner Meadows for ground-water sampling sites (fig 2). Location, lithologic description, and completion data for each well are reported in Table 1.

Water-quality samples were collected from both surface-water and ground-water sites in upper and lower Frohner Meadows (fig. 2). Ground-water samples were collected from monitoring wells using a peristaltic pump and filtered samples were pumped through a 0.45-micron capsule filter. Methods for monitoring of onsite measurements, well purging, and sample collection are described in Wilde and others (1998). Surface-water samples typically were collected using dip methods described by Wilde and others (1998) because streamflow was too small to allow the use of a depth-integrating sampler. Filtered samples were processed on-site using a 0.45-micron syringe filter. Samples were processed according to procedures described in Wilde and others (1998) and were analyzed by the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Analytical methods are described by Fishman and Friedman (1989), Faires (1993), Fishman (1993), Hoffman and others (1996), Garbarino and Struzeski (1998),Garbarino (1999), and Jones and Garbarino (1999).

The NWQL collects quality-control data on a continuing basis to evaluate selected analytical methods to determine the laboratory reporting levels (LRL). Accordingly, concentrations are reported as <LRL for samples in which the analyte was either not detected or could not be reliably identified. Analytes that are detected at concentrations less than LRL and that pass identification criteria are reported with an estimated concentration. Estimated concentrations are noted in data tables with a remark code of "E". Those data should be used with the understanding that their uncertainty of quantification is greater than data reported without the "E" remark code.

Figure 1. Location of the Frohner Meadows area and the upper Prickly Pear Creek watershed.

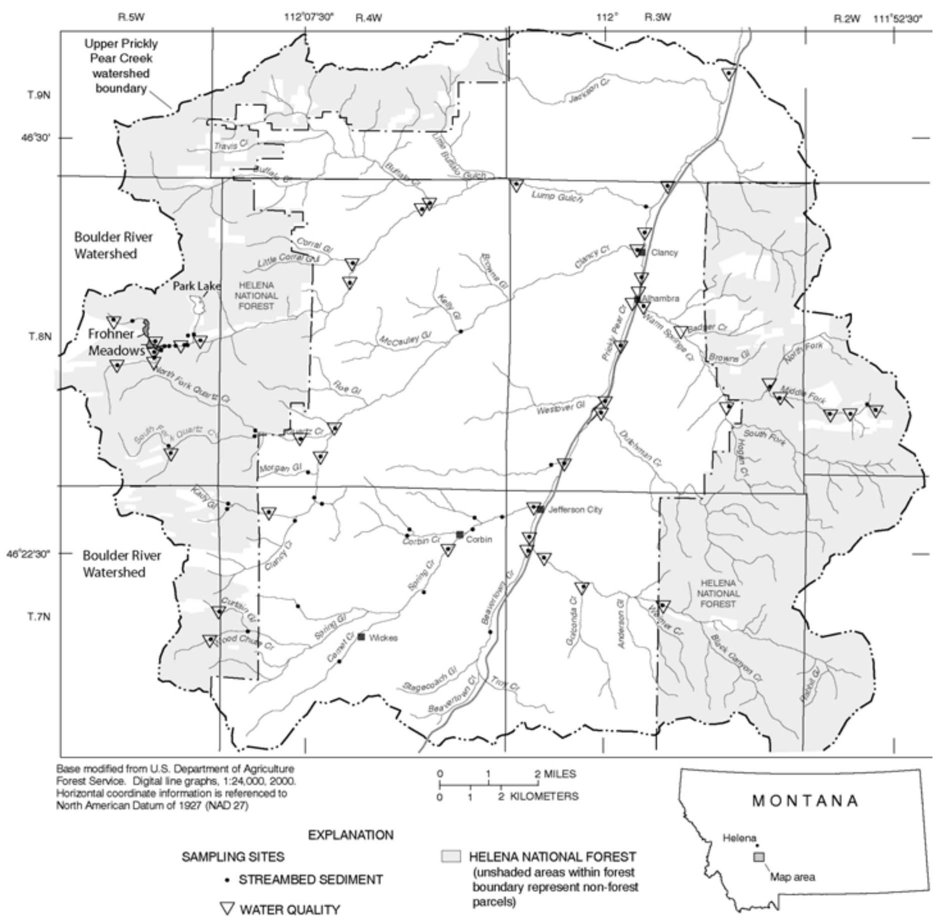


Figure 2. Location of monitoring wells and surface-water sites in the Frohner Meadows study area.

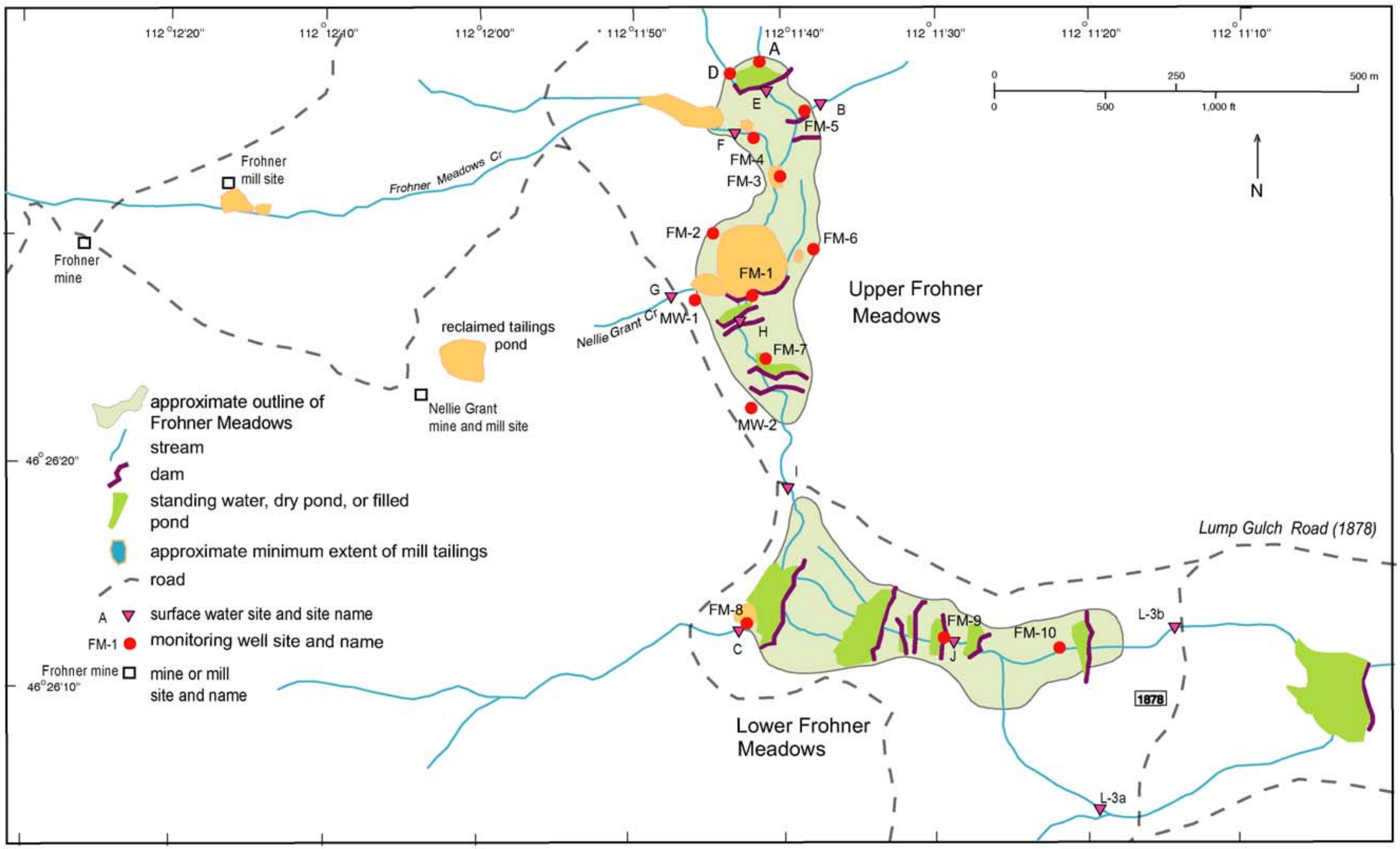


Table 1. Lithologic logs and completion data for monitoring wells installed during 2001 in the Frohner Meadows.

[All wells were installed with a 3.25 in. diameter hand auger. All depths are in feet below land surface, except where + indicates feet above land surface. Site ID numbers are latitude and longitude in degrees, minutes, and seconds, plus a two-digit sequence number. Locations were rounded to the nearest second and are referenced to the NAD 27 datum.]

MONITORING WELL FM-1
Site ID: 462627112114301
Date Drilled: 7-11-2001

Depth	**Description**
0-1	Sand; fine to coarse, reddish brown, oxidized tailings
1-1.8	Sand; medium to coarse, light gray, saturated
1.8-3.3	Clay; silty, black, organic-rich, with lenses of peat and sand
3.3-6.4	Peat: sandy, clayey, dark brown
6.4-7.1	Clay; dark brown, organic-rich, sandy
7.1-8.6	Sand; medium, silty with some fine angular gravel, gray, caving sand lens at 8.5 feet
8.6-9.0	Clay; brown and gray, organic-rich, silty
9.0	TD

Completion Data

+3-0	2-inch PVC casing, with threaded cap
0-7.1	2-inch PVC casing
7.1-8.6	2-inch PVC factory-slotted screen (0.025-inch slot size), with end cap

Bentonite chips from 1-5.0 ft
Packed with #10-20 filter sand from 5.0-7.5 ft
Natural sand pack from 7.5 ft to bottom of hole

MONITORING WELL FM-2
Site ID: 462630112114501
Date Drilled: 7-11-2001

Depth	**Description**
0-1.1	Peat; dark brown (no tailings)
1.1-2.3	Clay; organic-rich, dark gray
2.3-4.0	Sand and silt; light gray, fine- to medium-grained, , lenticular, some lenses of medium-grained sand
4.0-5.0	Till; light gray, highly weathered, with granitic pebbles to 3 inches
5.0	Rock; unable to penetrate
5.0	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-3.5	2-inch PVC casing
3.5-5.0	2-inch PVC factory-slotted screen (0.025-inch slot size), with end cap

Bentonite chips from 0-2.8 ft
Packed with #10-20 filter sand from 2.8-5.0 ft

Table 1 (continued)

MONITORING WELL FM-3
Site ID: 462632112114101
Date Drilled: 7-11-2001

Depth	**Description**
0-0.4	Silt; reddish brown, some fine-grained tailings
0.4-3.0	Clay; dark gray, organic-rich, some thin sandy lenses
3.0-3.2	Sand; silty, light gray, fine- to medium-grained
3.2-4.8	Clay; dark gray, organic-rich, some sandy lenses
4.8-7.0	Sand; light gray, fine- to medium-grained with volcanic ash and clay
7.0-9.0	Sand; gray, fine- to coarse-grained, some silt, , water
9.0-9.3	Granite pebbles (1- to 2.5-inch diameter) and gray, medium- to coarse-grained sand
9.3	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-7.0	2-inch PVC casing
7.0-9.0	2-inch PVC factory-slotted screen (0.025-inch slot size), with end cap

Bentonite chips from 0-2.0 ft
bore-hole cuttings from 2.0-5.0 ft
Packed with #10-20 filter sand from 5.0-9.0 ft

MONITORING WELL FM-4
Site ID: 462634112114301
Date Drilled: 7-16-2001

Depth	**Description**
0-0.8	Sand; reddish brown and yellowish brown, medium-to coarse-grained, silty
0.8-2.6	Clay; dark gray, organic-rich, plant roots, silty
2.6-5.3	Clay and peat lenses; dark brown and gray, sandy
5.3-6.2	Sand; gray, fine- to coarse-grained, silty
6.2-6.5	Till; gray, sandy, weathered, with angular pebbles
6.5	Rock; unable to penetrate
6.5	TD

Completion Data

+2.5-0	2-inch PVC with threaded cap
0-5.2	2-inch PVC casing
5.2-6.2	2-inch PVC slotted screen (0.025-inch slot) with end cap

Bentonite chips from 0-2.2 ft
Packed with #10-20 filter sand from 2.2-6.2 ft

Table 1 (continued)

MONITORING WELL FM-5
Site ID: 462635112114001
Date Drilled: 7-16-2001

Depth	**Description**
0-1.5	Clay; with peat, brown and dark brown
1.5-5.0	Sand; gray with streaks of reddish gray, fine- to coarse-grained with pebbles and cobbles, derived from granite, (derived from glacial sediments and colluvium; large boulders on land surface within 20 ft of hole)
5.0-5.3	Till; light brown
5.3	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-3.0	2-inch PVC casing
3.0-5.0	2-inch PVC factory-slotted screen (0.025-inch slot size), with end cap

Bentonite chips from 0-2.5 ft
Packed with #10-20 filter sand from 2.5-5.0 ft

MONITORING WELL FM-6
Site ID: 462629112113901
Date Drilled: 7-17-2001

Depth	**Description**
0-1.1	Clay; high organic content, dark gray with streaks of brown peat
1.1-2.0	Sand; gray fine- to coarse-grained, silty
2.0-2.8	Clay; dark gray, organic-rich sandy streaks,
2.8-3.0	Volcanic ash; light gray (likely from Mount Mazama, Washington)
3.0-4.1	Sand; gray fine- to medium- grained, with clay and volcanic ash
4.1-4.9	Sand; gray, fine- to medium- grained, silty, compact, angular
4.9-5.0	Till
5.0	Rock; unable to penetrate
5.0	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-4.0	2-inch PVC casing
4.0-5.0	2-inch PVC factory-slotted screen (0.025-inch slot size), with end cap

Bentonite chips from 0-2.5 ft
Packed with #10-20 filter sand from 2.5-5.0 ft

Table 1 (continued)

MONITORING WELL FM-7
Site ID: 462624112114201
Date Drilled: 7-17-2001

Depth	**Description**
0-0.3	Peat; brown
0.3-2.9	Clay; dark gray, organic-rich
2.9-3.2	Volcanic ash (Mount Mazama, Washington): light gray
3.2-4.1	Clay; organic-rich, dark gray
4.1-6.0	Sand; gray, fine- to coarse- grained, angular, silty, with lenses of brown peat
6.0-7.8	Sand; gray with streaks of reddish gray, medium to coarse grain, granitic, with angular pebbles
7.8-8.3	Sand and gravel; gray, medium- to coarse-grained sand, fine gravel, granitic,
8.3	Rock; unable to penetrate
8.3	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-6.2	2-inch PVC casing
6.2-8.2	2-inch PVC factory-slotted screen (0.020-inch slot size), with end cap

Bentonite chips from 0-3.5 ft
Packed with #10-20 filter sand from 3.5-8.2 ft

MONITORING WELL FM-8
Site ID: 462612112114301
Date Drilled: 7-17-2001

Depth	**Description**
0-2.0	Clay; dark gray, organic-rich (about 1 inch of yellow and gray slimy clay in top of root zone, could be fines from tailings)
2.0-3.5	Interbedded sand and clay; mottled gray and reddish brown, sand is fine- to medium-grained, silty, clay is dark gray and organic-rich
3.5-4.9	Sand; gray, fine- to medium-grained, silty, clayey
4.9-5.7	Sand; gray with streaks of reddish gray, medium- to coarse-grained, silty,
5.7-8.0	Clay and silt; gray and dark brown, with thin beds of peat
8.0	Boulder
8.0	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-3.5	2-inch PVC casing
3.5-6.0	2-inch PVC factory-slotted screen (0.020-inch slot size), with end cap

Bentonite chips from 0-1.0 ft
Packed with #10-20 filter sand from 1.0-6.0 ft

Table 1 (continued)

MONITORING WELL FM-9
Site ID: 462612112113002
Date Drilled: 7-18-2001

Depth	**Description**
0-0.8	Peat; brown
0.8-4.6	Clay; gray. sandy, organic-rich
4.6-5.0	Sand; gray, medium-grained, some fine gravel, granitic
5.0	Boulder; unable to drill
5.0	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-4.0	2-inch PVC casing
4.0-5.0	2-inch PVC factory-slotted screen (0.020-inch slot size) with end cap

Bentonite chips from 0-3.0 ft
Packed with #10-20 filter sand from 3.0-5.0 ft

MONITORING WELL FM-10
Site ID: 462611112112201
Date Drilled: 7-18-2001

Depth	**Description**
0-0.3	Peat and plant roots; brown, sandy
0.3-0.8	Sand and clay; gray
0.8-1.2	Sand; gray, fine- to medium-grained
1.2-4.5	Clay; dark gray, firm, organic-rich, sandy lenses
4.5-6.0	Sand; gray, fine- to coarse-rained, some fine gravel, granitic, silty, firm
6.0	Cobbles; unable to penetrate
6.0	TD

Completion Data

+2.5-0	2-inch PVC casing, with threaded cap
0-4.0	2-inch PVC casing
4.0-6.0	2-inch PVC factory-slotted screen (0.020-inch slot size), with end cap

Bentonite chips from 0-3.0 ft
Packed with #10-20 filter sand from 3.0-6.0 ft

Table 2. Ground-water quality from monitoring wells in the study area.
[Samples from monitoring wells FM-1 through FM-10 were collected and analyzed by the U.S. Geological Survey. Samples from monitoring wells MW-1 and MW-2 were collected and analyzed for the MDEQ as summarized in Pioneer (1996). Site ID numbers are latitude and longitude in degrees, minutes, and seconds, plus a two-digit sequence number. ** average of 5 samples, ** average of 3 samples]*

Site ID	**Well name**	**Date**	**Time**	**pH, field**	**Specific conduct-ance**	**Calcium, dissolved**	**Magnes-ium, dissolved**	**Potass-ium, dissolved**	**Sodium, dissolved**	**Alkal-inity, lab**	**Chloride, dissolved**	**Silica, dissolved**	**Sulfate, dissolved**	**Arsenic, dissolved**	**Cadmium, dissolved**	**Copper, dissolved**	**Lead, dissolved**	**Mangan-ese, dissolved**	**Zinc, dissolved**
				standard units	us/cm	mg/L as Ca	mg/L as Mg	mg/L as K	mg/L as Na	mg/L as $CaCO_3$	mg/L as Cl	mg/L as SiO_2	mg/L as SO_4	ug/L as As	ug/L as Cd	ug/L as Cu	ug/L as Pb	ug/L as Mn	ug/L as Zn
462627112114301	**FM-1**	7/26/2001	1225	6.8	171	19.3	2.63	0.92	6.4	75	0.4	17.3	1.4	1,600	0.08	0.3	2.6	590	390
	FM-1	10/17/2001	1130	6.9	182	19.4	2.73	0.98	6.3	76	1	17.5	1.5	3,400	0.08	0.4	4.2	800	240
462630112114501	**FM-2**	7/26/2001	940	6.4	175	20.5	2.89	0.88	6.9	79	0.3	28.4	1.5	4.5	0.07	E0.2	E0.07	110	7.0
462632112114101	**FM-3**	7/26/2001	1005	7.3	172	23.6	3.13	1.00	6.3	85	0.4	13.1	4.3	42	<0.04	<0.2	<0.08	100	3.0
	FM-3	10/17/2001	1100	7.1	170	23.8	3.09	1.00	6.1	86	0.9	13.5	4.7	18	E0.02	E0.2	E0.06	94	<1.0
462634112114301	**FM-4**	7/26/2001	1035	7.6	189	26.6	3.59	1.26	6.5	95	0.6	14.0	4.4	410	0.04	<0.2	0.34	34	1.0
462635112114001	**FM-5**	7/26/2001	1100	7.0	144	18.9	3.07	1.22	5.4	68	0.4	20.6	6.0	1.0	0.07	E0.1	<0.08	11	4.0
462629112113901	**FM-6**	7/26/2001	1145	6.0	154	11.5	2.81	0.86	8.4	37	0.4	56.3	20	13	0.10	1	0.09	170	22
462624112114201	**FM-7**	7/26/2001	1205	6.9	154	19.1	2.45	0.73	6.8	68	0.5	14.4	4.6	100	0.11	0.3	0.15	210	52
	FM-7	10/17/2001	1225	7.1	164	21.3	2.75	0.91	6.7	78	1	14.4	3.6	30	<0.04	E0.2	E0.04	250	3.0
462612112114301	**FM-8**	7/26/2001	1310	6.8	233	29.8	4.87	1.76	7.1	110	0.4	25.5	5.2	160	E0.03	E0.1	0.42	6,500	12
462612112113002	**FM-9**	7/26/2001	1340	6.3	162	20.1	3.12	0.48	5.3	81	0.6	30.3	1.0	75	0.44	1	2.7	2,300	420
462611112112201	**FM-10**	7/26/2001	1410	6.5	150	14.4	2.28	1.00	5.7	54	0.6	25.9	11	46	0.04	0.4	0.42	2,500	93
	FM-10	10/17/2001	1330	7.0	182	14.0	2.10	0.91	6.1	58	1	27.4	6.5	210	<0.04	0.2	<0.08	3,400	3.0
State Observation well	**MW-1**	1989-94												4.1 *	79 *	5.8 *	4.1 *		9,300 *
Sparrow Resources well	**MW-2**	1993-94												1.6 **	0.5 **	1.4 **	0.6 **		3.5 **

Table 3. Surface-water quality data for sites in the Frohner Meadows area. [Surface-water samples were collected and analyzed by the U.S. Geological Survey. Site ID numbers are latitude and longitude in degrees, minutes, and seconds, plus a two-digit sequence number.]

Site ID	site name	Date	Time	Streamflow	pH, field	Specific conductance field	Water temperature field	Hardness	Calcium, dissolved	Magnesium, dissolved	Potassium, dissolved	Sodium, dissolved	Alkalinity, lab	Chloride, dissolved	Silica, dissolved	Sulfate, dissolved
				ft^3/second	standard units	us/cm	°C	mg/L as $CaCO_3$	mg/L as Ca	mg/L as Mg	mg/L as K	mg/L as Na	$CaCO_3$ mg/L	mg/L as Cl	mg/L as SiO_2	mg/L as SO_4
462638112114201	**A**	6/25/2001	1255	0.035	6.8	49	14.5	--	--	--	--	--	--	--	--	--
		8/1/2001	945	0.004	7.1	80	8.0	36	10.3	2.39	0.68	3.3	41	0.4	14.3	0.30
462636112113801	**B**	6/25/2001	1340	0.004	7.1	52	14.0	--	--	--	--	--	--	--	--	--
		8/1/2001	910	Dry	--	--	--	--	--	--	--	--	--	--	--	--
462613112114401	**C**	6/25/2001	1020	0.067	7.3	33	11.0	--	--	--	--	--	--	--	--	--
		8/1/2001	945	0.010	6.7	46	16.0	17	5.21	0.91	0.40	3.1	21	0.1	13.9	2.4
462637112114401	**D**	6/26/2001	1050	0.016	7.2	47	8.7	--	--	--	--	--	--	--	--	--
		8/1/2001	1035	0.027	7.4	68	9.1	28	9.07	1.33	0.32	3.5	34	0.1	13.1	1.2
462637112114101	**E**	6/26/2001	1005	0.207	7.2	52	12.7	--	--	--	--	--	--	--	--	--
		8/1/2001	1135	0.025	7.6	69	13.6	29	9.00	1.52	0.35	3.5	34	0.1	9.50	2.1
462635112114401	**F**	6/26/2001	1040	0.605	7.2	55	8.0	--	--	--	--	--	--	--	--	--
		8/1/2001	1240	0.138	7.2	88	12.0	28	8.85	1.42	0.80	3.3	7	0.2	18.7	29
462627112114701	**G**	6/26/2001	1115	0.063	7.0	486	16.6	--	--	--	--	--	--	--	--	--
		8/1/2001	1205	0.006	7.4	500	20.7	210	74.3	6.40	2.10	5.7	16	1.3	18.5	230
462626112114301	**H**	6/26/2001	1105	0.760	7.2	95	13.5	--	--	--	--	--	--	--	--	--
		8/1/2001	1200	0.203	7.0	130	16.5	46	15.1	1.99	0.81	3.6	13	0.3	16.4	44
		10/16/2001	1350	0.090	7.4	167	0.6	--	--	--	--	--	--	--	--	--
462619112114001	**I**	6/26/2001	1140	0.860	7.2	97	13.0	--	--	--	--	--	--	--	--	--
		8/1/2001	1540	0.212	7.7	135	14.7	49	16.1	2.09	0.82	3.7	16	0.3	16.0	44
		10/16/2001	1420	0.150	7.3	186	1.5	--	--	--	--	--	--	--	--	--
462612112113001	**J**	6/26/2001	1300	0.910	7.3	91	14.7	--	--	--	--	--	--	--	--	--
		8/1/2001	1500	0.311	7.1	136	19.4	52	17.1	2.23	0.85	3.6	16	0.4	15.2	44
462603112112101	**L-3a**	6/16/2000	1415	0.620	7.2	119	10.0	41	13.2	2.03	--	--	--	--	--	--
		10/11/2000	1345	0.0003	6.3	483	1.5	210	67.0	9.23	--	--	--	--	--	--
		5/10/2001	1100	0.260	6.3	88	4.5	29	9.35	1.38	--	--	--	--	--	--
		8/1/2001	1130	0.004	7.7	94	8.5	33	10.8	1.52	--	--	21	--	--	--
462612112111501	**L-3b**	6/16/2000	1445	1.17	7.2	138	12.0	47	15.4	2.16	--	--	--	--	--	--
		10/11/2000	1630	0.110	6.0	398	2.0	150	49.3	6.14	--	--	--	--	--	--
		3/15/2001	1130	0.06	7.5	193	0.1	72	23.6	3.19	--	--	--	--	--	--
		5/10/2001	1120	0.78	6.3	100	5.0	32	10.4	1.42	--	--	--	--	--	--
		8/1/2001	0950	0.233	8.2	121	10.0	42	13.6	1.91	--	--	20	--	--	--

Table 3 (continued)

Site ID	Site name	Arsenic, dissolved	Arsenic, total recoverable	Cadmium, dissolved	Cadmium, total recoverable	Copper, dissolved	Copper, total recoverable	Lead, dissolved	Lead, total recoverable	Manganese, dissolved	Zinc, dissolved	Zinc, total recoverable
		ug/L as As	ug/L as As	ug/L as Cd	ug/L as Cd	ug/L as Cu	ug/L as Cu	ug/L as Pb	ug/L as Pb	ug/L as Mn	ug/L as Zn	ug/L as Zn
462638112114201	**A**	1.4	E1	<0.04	E0.03	2.9	3.2	E0.07	<1	--	4	4
		1.5	2	<0.04	E0.03	1.6	2.2	E0.08	<1	42.7	4	5
462636112113801	**B**	.9	<2	0.06	0.07	2.9	3.0	0.16	<1	--	3	3
462637112114401	**D**	2.5	3	E0.03	0.05	3.8	4.1	1.48	2	--	6	7
		7.6	9	0.04	0.07	3.0	3.3	2.00	3	15.0	10	11
462613112114401	**C**	1.4	E1	<0.04	E0.03	3.0	3.0	0.74	<1	--	2	2
		2.2	4	<0.04	0.06	2.3	2.8	0.40	3	8.4	3	6
462637112114101	**E**	13.5	16	0.10	0.12	4.4	5.1	2.55	4	--	18	20
		45.5	55	0.05	0.13	4.4	5.0	7.47	12	4.9	19	21
462635112114401	**F**	13.4	17	1.39	1.40	6.9	7.3	6.20	9	--	267	284
		20.1	25	2.45	2.49	7.0	8.0	7.60	11	374	549	505
462627112114701	**G**	9.0	210	114	121	14.1	83.9	0.32	72	--	14,100	15,100
		7.0	45	94.8	94.0	7.8	15.9	0.17	13	5,180	12,400	13,400
462626112114301	**H**	30.8	39	7.08	7.16	7.4	8.0	6.69	10	--	1,090	1,110
		61.8	81	6.14	6.23	6.7	8.0	8.62	15	524	1,170	1,130
		30.4	52	7.93	7.92	5.1	6.4	1.90	9	--	1,890	1,920
462619112114001	**I**	30.3	38	6.96	6.94	8.1	8.9	6.05	8	--	1,110	1,180
		47.4	71	5.87	6.00	6.2	7.7	7.95	13	399	1,110	1,120
		9.1	23	9.08	8.96	4.0	5.4	1.17	4	--	2,310	2,320
462612112113001	**J**	26.6	34	6.87	6.89	7.7	8.4	7.35	10	--	1,130	1,110
		35.2	64	5.38	5.66	4.6	7.6	15.4	42	205	1,020	1,020
462603112112101	**L-3a**	5.3	6	6.87	6.31	8.2	7.4	1.34	2	--	1,570	1,450
		7.8	10	9.90	9.76	2.1	2.7	<0.08	<1	--	4,090	3,970
		4.4	7	6.33	6.67	6.9	7.3	0.85	2	--	1,660	1,630
		3.2	11	4.58	5.21	5.1	6.9	E0.07	2	--	1,190	1,360
462612112111501	**L-3b**	9.7	15	13.9	13.1	11.2	11.0	3.74	8	--	2,750	2,650
		1.6	6	47.7	47.1	4.1	5.8	0.19	4	--	15,100	15,400
		4.8	17	15.5	15.6	5.3	10.3	2.37	9	--	4,810	4,720
		8.0	14	13.3	13.1	10.5	11.4	2.41	7	--	2,590	2,510
		10.5	33	4.13	4.99	3.3	6.5	1.53	8	--	1,070	1,190

GEOCHEMICAL DATA

Field Sampling and Sample Preparation Methods

Streambed sediments were systematically sampled throughout upper and lower Frohner Meadow to determine the sources of streambed sediment metal enrichments observed in streambed sediments at the outlet of Frohner Meadows during regional streambed sediment investigations (Klein and others, 2001). Most sites were sampled within a three-day period during July, 2001. This short duration sampling program minimized the short-term variation of elemental concentrations that might result from changes in stream discharge and seasonal changes in water chemistry. The locations of the streambed sediment sample sites are shown in figure 4. Two samples, L-1 and L-2 were sampled in September 2000, when stream discharge was somewhat lower than the July 2001 levels.

Composite samples of mill tailings in upper and lower Frohner Meadows were collected to determine chemical characteristics, including bulk chemical composition and acid-producing potential. Composite mill-tailings samples were collected at seven sites to characterize each of the major mill-tailings deposits. Data from previous studies of the Frohner and Nellie Grant mine sites were used to supplement data obtained during this study (Metesh and others, 1998; Pioneer Technical Services, Inc., 1996; Pioneer Technical Services, Inc., 2000).

Shallow cores were used to determine the thickness and extent of mill tailings, stratigraphy, physical characteristics, and chemistry. Most cores were sampled along profile lines at intervals that ranged from 50 to 100 ft. The locations of profile lines and individual core sample sites are shown in figure 3. The locations of shallow core sites that were sampled along the profile lines are shown in figures 5-7.

Streambed-sediment samples

An integrated streambed-sediment sample was collected at eighteen sites and weighed approximately 2 kg. Samples were obtained as composites from 10-20 sub-sites within 15 m (50 ft) of the sample site and sediment was collected from the active channel alluvium. Onsite measurements of surface water (temperature, pH, and specific conductance) were determined at each streambed-sediment sample site with calibrated instruments. The site locations were determined using a portable Global Positioning System unit. Locations were marked on a 7.5’ topographic map and orthophoto quadrangle map. Each sample composite was sieved in the field through a 2 mm (10-mesh) stainless steel screen. The fractions less than 2-mm were retained and the fractions greater than 2-mm were discarded. Streambed-sediment site locations and onsite measurements of surface water at each sample site are listed in Table 4.

Samples were air-dried in the laboratory and sieved to less than 80-mesh (<0.18 mm). The less than 80-mesh fraction was ground to less than 150-mesh before laboratory analysis. The greater than 80-mesh fraction was not analyzed.

Figure 3. Location of streambed sediment sites, individual cores sites, and composite mill-tailings sample sites, and shallow core profile lines in the study area.

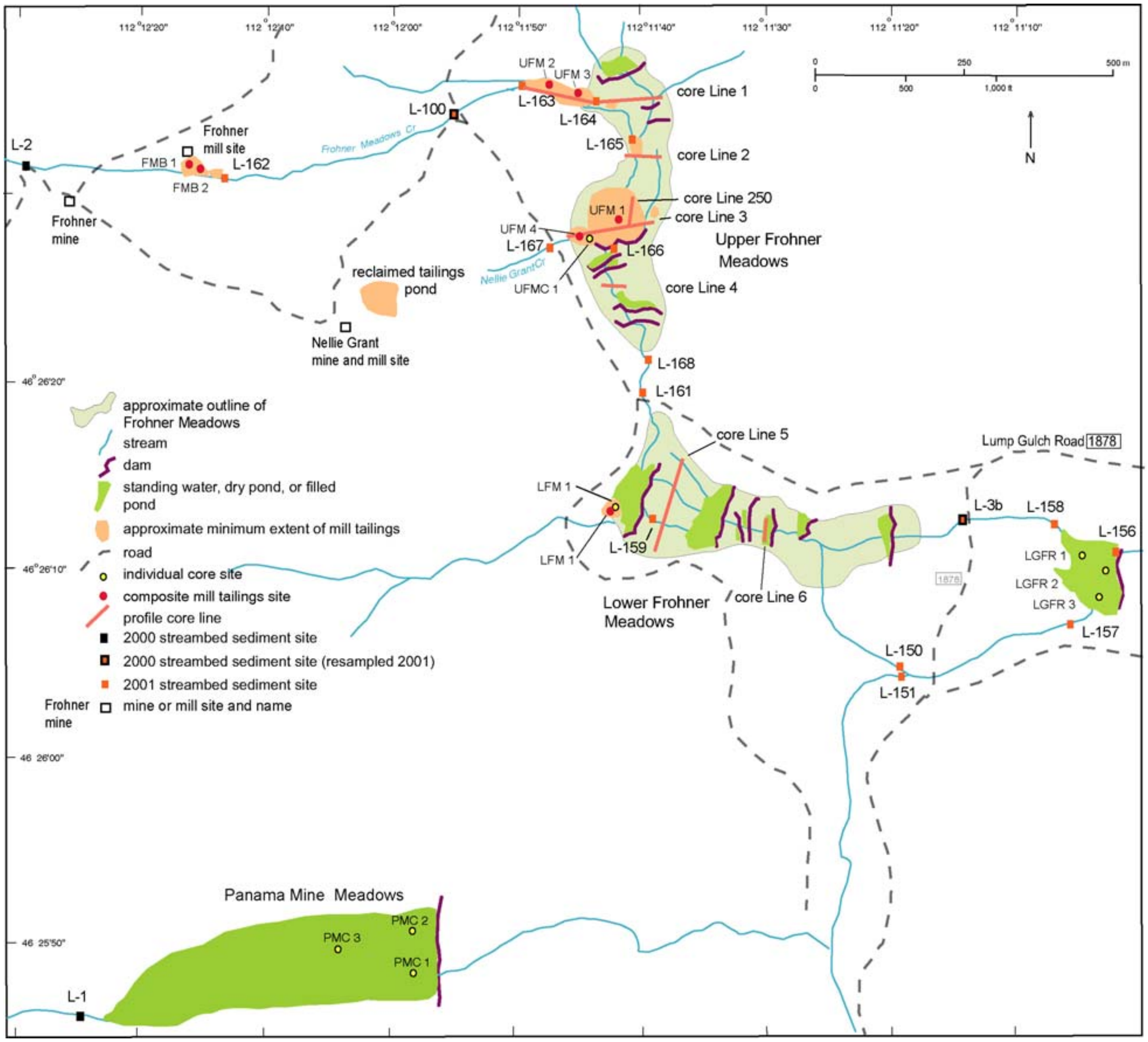


Table 4. Streambed sediment site locations and onsite measurements of surface water.
[Latitude and longitude are measured with portable Global Positioning System using NAD 27 datum. pH is measured in standard units and specific conductance in µ siemens/cm]

Site number	Sample description	Latitude	Longitude	pH	Specific conductance	Date
L-1	sand and gravel	46.4291	-112.2061	6.92	76	10/04/2000
L-2	sand	46.4415	-112.2064	6.97	84	10/04/2000
L-3b	sand	46.43667	-112.18790	6.15	97	7/13/2001
L-100	sand	46.44302	-112.19855	6.26	66	7/15/2001
L-150	sand	46.43411	-112.48955	6.00	81	7/13/2001
L-151	sand	46.43395	-112.18934	6.25	53	7/13/2001
L-156	sand and gravel	46.43628	-112.18438	6.90	67	7/13/2001
L-157	sand and gravel	46.43504	-112.18664	7.07	56	7/13/2001
L-158	sand and gravel	46.43665	-112.18594	6.84	96	7/13/2001
L-159	sand	46.43664	-112.19405	6.56	121	7/14/2001
L-161	sand and gravel	46.43842	-112.19408	6.60	206	7/14/2001
L-162	sand and gravel	46.44163	-112.20333	6.04	70	7/15/2001
L-163	sand	46.44323	-112.19746	6.20	69	7/15/2001
L-164	sand	46.44292	-112.19551	6.45	69	7/15/2001
L-165	sand	46.44229	-112.19487	6.51	73	7/15/2001
L-166	sand	46.44073	-112.19516	6.39	99	7/15/2001
L-167	sand	46.44072	-112.19659	6.41	520	7/15/2001
L-168	sand	46.43932	-112.19451	5.30	111	7/15/2001

Composite samples of mill tailings

Composite samples of mill tailings were collected from seven sites (table 6). The tailings were collected from 30 or more randomly selected sub-sites in the vicinity of the sample site to a depth of about three inches. Between four and six sub-samples were collected at each sub-site. Sub-sample size ranged between 2 and 3-ounces. This sample-collection method is designed to reduce possible sample-collection error (Smith and others, 2000). Samples were dry-sieved onsite to obtain a less than 0.08 in (<2 mm) fraction. The less than 0.08 in fraction generally is the most reactive to water during short-term exposure. The greater than 0.08 in fractions were discarded at all sites except for site UFM-2. The resulting composite sample of mill tailings typically weighed approximately 2 kg. The less than 0.08 in fraction was sieved in the laboratory to less than 80-mesh (<190 µm) and subsequently ground to minus-200 mesh (<75 µm). The sample was then subjected to (1) bulk chemical analysis; (2) leaching tests to determine amounts of water soluble deposit-related elements present; and (3) net acid production (NAP) tests to determine acid-producing potential. The locations of composite mill-tailings sites are shown in figure 3.

At site UFM-2, an un-sieved composite sample was processed in the laboratory. This sample was first thoroughly mixed and then split into three aliquots. The first aliquot was un-sieved and contained the original bulk sample. The second aliquot was composed of the less than 2-mm fraction. The third aliquot was composed of the greater than 2-mm fraction. By segregating the composite sample into these three aliquots, the geochemistry and acid-producing potential of the bulk sample was compared with the geochemistry and acid-producing potential of the two size fractions.

Shallow core samples

Thick-walled, 2 in (I.D.) PVC casing was driven into the surface and underlying geologic material with an 8-pound sledgehammer to obtain 2-inch diameter shallow cores. The core tube was retrieved with a hand winch attached to a portable tower (fig. 4). The core tubes were driven to the maximum depth possible. At the field site, the depth of penetration and the length of the recovered core were recorded and the locations determined with a differential GPS unit. Non-differential GPS was used when the differential signal was not available. In the laboratory, the PVC casing was scored with a circular saw and split in two parts lengthwise with the aid of a stainless-steel laboratory spatula. The cores were then photographed and one part was retained for physical description and reference while the other part was available for geochemical analyses. The locations of shallow cores sampled along the lines shown in figure 3 are shown in figure 5 (line 1 and 2), figure 6 (lines 3, 4, and 250) and figure 7 (lines 5 and 6); site parameters are in Appendix 1a. Descriptions of the geologic material sampled in the shallow cores are in Appendix 1b.

Figure 4. Core retrieval apparatus. The PVC core barrel that is attached to the chain is approximately 4 ft in length.

Figure 5. Location of shallow core and streambed sediment sites along profile lines 1 and 2.

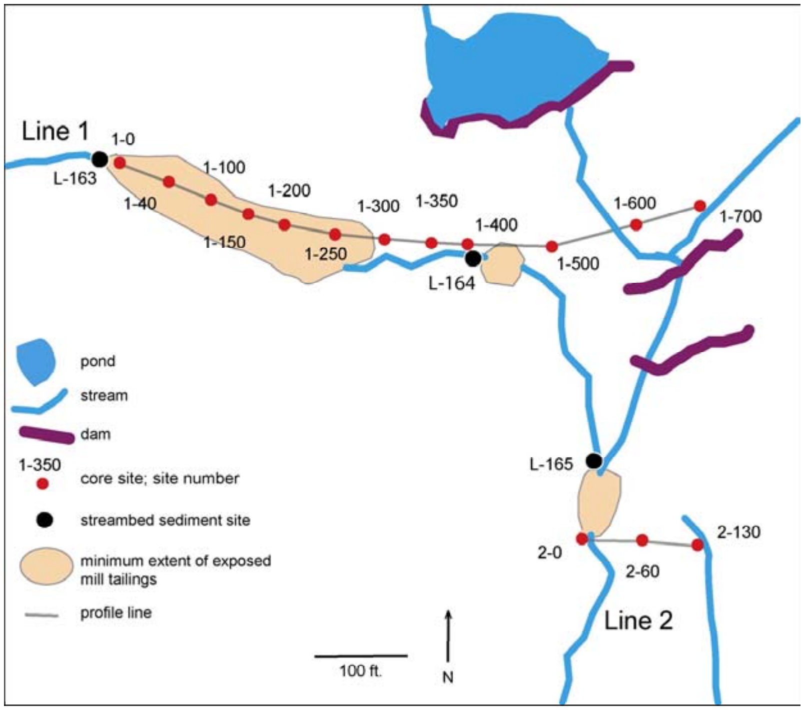


Figure 6. Location of shallow core and streambed sediment sites along profile lines 3, 4, and 250.

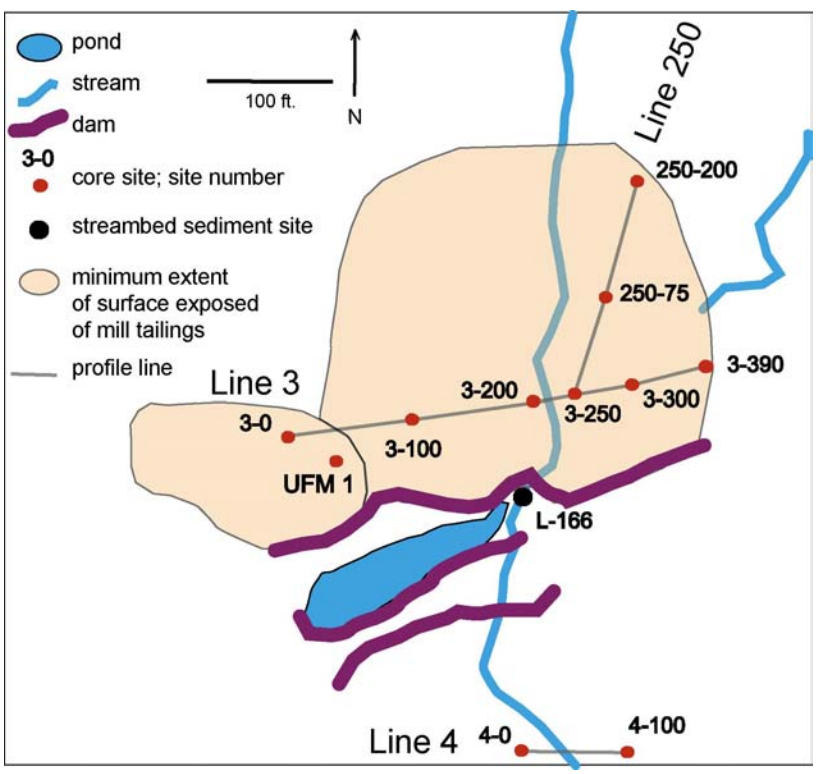
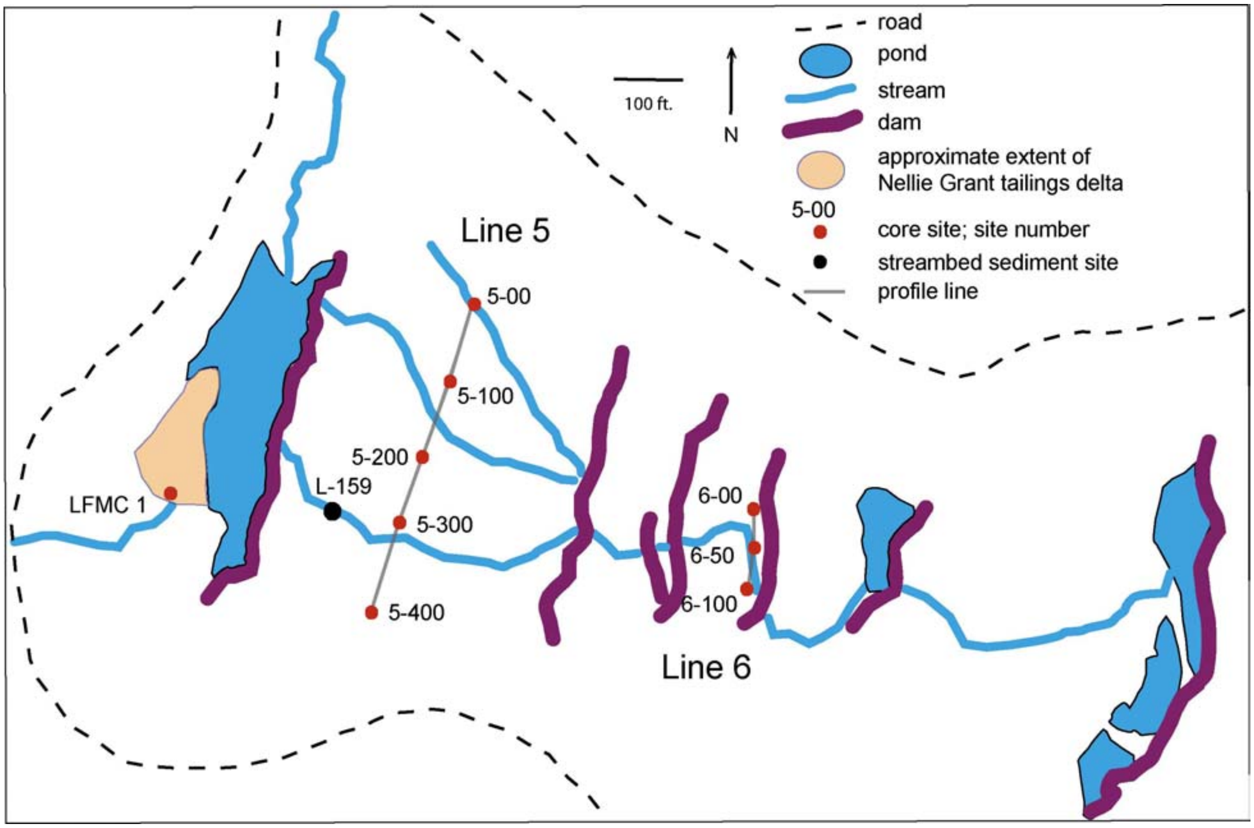


Figure 7. Location of shallow core and streambed sediment sites along profile lines 5 and 6.



Laboratory Methods

Total digestion of streambed sediments, tailings, and shallow cores

Streambed-sediment samples, mill-tailings composite- samples, and shallow-core samples were weighed into 0.2 g aliquots and digested in a mixed-acid medium of HCl, HNO_3, $HClO_4$, and HF. The resulting solutions were analyzed as described by Briggs (1996) for 40 elements by inductively coupled plasma-atomic emission spectroscopy (ICP-AES). This digestion procedure completely dissolves most minerals, including silicates, oxides and sulfides; and partially dissolves resistant or refractory minerals such as zircon, chromite, and some tin oxides. Previous investigations using a variety of geologic materials confirm the completeness of this digestion procedure (Church and others, 1987; Wilson and others, 1994). The analytical results using the total digestion procedure for streambed-sediment samples, mill-tailings composite samples, and shallow-core samples are presented in tables 5 through 7, respectively. Intervals that were sampled at each shallow core site are described in Appendix 1b. QA/QC data for the total digestion analyses are summarized in Appendices 2 a through 2 c.

Partial digestion of streambed sediments

Partial-digestion extraction was used to determine concentrations of trace elements bound within different mineral phases, (Chao, 1984). Streambed-sediment samples were the only sample type in this study that were analyzed using the partial-digestion procedure. The samples were weighed into 2 g aliquots and digested in 15 mL of daily-prepared acid mixture of 2M HCL and

1 percent hydrogen peroxide (H_2O_2). This partial-digestion procedure dissolves trace elements associated with hydrous amorphous iron-, manganese-, and aluminum-oxide minerals, as well as some crystalline iron- and manganese-oxyhydroxides (Church and others, 1993). This procedure also dissolves water-soluble, ion-exchangeable, and carbonate species. The resulting solutions were placed in 90-mL Teflon FEP jars, sealed, and agitated in a 50^{o} C water bath for three hours to allow complete removal of the iron- and manganese-oxyhydroxide coatings from the sediment grains. The solutions were subsequently analyzed by ICP-AES. The analytical results using the partial-digestion procedure for streambed-sediment samples are shown in table 8. QA/QC data for the partial-digestion analyses are summarized in Appendix 2d.

Synthetic precipitation leach procedure (SPLP) for mill tailings

This procedure, also know as EPA 1312 leach (USEPA, 1986), was used to process composite samples of mill tailings. This procedure simulates the effect of rainfall or runoff on a dump surface. An extract solution was prepared by acidifying deionized water to a pH of 4.2 with 1-percent acid mixture of H_2SO_4 and HNO_3 (at a ratio of 60-percent H_2SO_4 and 40-percent HNO_3). The mill tailings sample (less than 2 mm fraction) was weighed into a 100 g aliquot and placed in a 2.3 L polyethylene bottle. Two liters of extract solution were added, resulting in a 1:20 sample/extract ratio, with 300 cm^3 of headspace. 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 µm glass-fiber filter. A 100 mL aliquot of filtered leachate was acidified with ultra-pure HNO_3 for analysis of 25 elements by ICP-AES (Briggs and Fey, 1996) and for analysis of sulfate as sulfur also ICP-AES. The results of the synthetic precipitation leach test are in Table 9. QA/QC data are summarized in Appendix 2e.

Net acid production (NAP) for mill tailings

This procedure was used to analyze composite samples mill tailings for acidity. This procedure simulates the net long-term or total potential of a material to produce acid during an unspecified period of weathering. Each mill-tailings sample was pulverized into less than 200-mesh material, weighed into a 1.0 g aliquot, and exposed to 100 mL of 30% hydrogen peroxide. The sulfide minerals (mostly pyrite) in the sample are oxidized by the peroxide, producing sulfuric acid (Lapakko and Lawrence, 1993).

The sulfuric-acid solution reacts with the composite tailings sample, releasing additional acidity from water-soluble salts that are usually present as a result of wetting-drying cycles on the tailings, and also reacts with acid-consuming minerals such as carbonates, biotite, chlorite, and epidote. The solutions of acid and tailings samples were heated to near-boiling for 1 hour, cooled, and filtered. The acidic filtrates were 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.

Quality assurance and Quality control data

Tables 2a through 2e present quality control data for solid-material samples (non-water) analyzed in the USGS laboratories in Lakewood, Colorado. All sample solutions, regardless of digestion or leach pre-treatment, were analyzed by inductively-coupled plasma optical spectroscopy, using the same Perkin-Elmer Optima 3000 instrument. All samples were run in batches of 40 or fewer and each batch contained two or more reference materials or water-quality standards.

When analyzing material from streambed sediment and meadow cores in this study, the mixed-acid digestion was applied to samples and to standard reference materials (SRM). These materials, available from the National Institute of Standards and Technology, were NIST 2704, NIST 2709, and NIST 2711 (NIST 1993a, 1993b, 1993c)
.

Over the course of the upper Prickly Pear watershed and Frohner Meadows studies, a total of ten separate analyses of each standard were completed. Table 1a presents the statistical results of the multiple analyses, including the mean, percent relative standard deviation (RSD), and the percent recovery compared to the SRM certified values. The RSD for the major elements were generally below 5 percent, except for titanium. The percent recovery for the major elements was within 3 percent, except for titanium. The mixed-acid digestion, as mentioned in the analytical methods section, is not wholly successful in dissolving titanium oxides.

For the trace elements, where the standard concentration was sufficiently greater than the analytes' detection limit (greater than 5x), the RSD values were generally less than 10 percent and percent recoveries were within 10 percent. Tin typically occurs in these standards at low levels in refractory minerals, and so the RSD values are higher and the recovery in NIST 2704 is lower. The higher RSD values for the elements arsenic, cadmium, molybdenum, niobium, and yttrbium are due to the low standard concentrations relative to the detection limits.

Appendix table 2b presents data for 14 field-duplicate pairs collected from the upper Prickly Pear watershed (fig. 1), including Frohner Meadow Creek, Lump Gulch, and Prickly Pear Creek and its tributaries. These duplicate pairs were collected nearly one year apart. In each case, the first sample was collected in October 2000, and the second sample was collected from the same site in July 2001. Since the collection dates occur at different points on the yearly hydrograph, somewhat more variation in some elements' concentrations may be expected.

At sites where sample material is limited (for instance site L-3b), there is more variation in some element concentrations. This site showed the largest difference in manganese (30,000 ppm vs.10,000 ppm) between the two years. There was also a large difference in the iron concentrations. Since iron and manganese had strong correlations with cadmium, copper and zinc, those elements' concentrations also had large differences. The aluminum, calcium, sodium, potassium, and strontium concentrations in the 2001 sample were higher than the 2000 sample, indicating that the second sample had a higher lithic component, thus diluting the iron, manganese, and deposit-related trace elements. The difference in the major elements between the two samples can be due to both sample heterogeneity at the site and temporally related differences in streambed material.

At sites along larger stream reaches, more material is present, and is likely to be better mixed, for example at sites along Prickly Pear Creek (fig. 1). Here, variations between the two years is likely to be more related to temporal differences in iron, manganese, and trace elements due to flow regime differences over the hydrograph. For example, at site PP5, there is less variation in the major and trace elements than from site L-3b. However, there is still enough variation in iron

(14 vs. 12 percent) and manganese (2,200 vs. 1,700 ppm) to affect the zinc concentration, which is hydromorphically transported and deposited (910 vs. 680 ppm). The lead concentration, well mixed and detritally transported, is essentially the same from both years' samples (230 vs. 220 ppm).

Appendix table 2c contains analytical results for pairs of samples run as laboratory splits. Laboratory splits were made by weighing aliquots from the same well-mixed less than 100-mesh material at the time of sample digestion. Variation between pairs of laboratory splits is smaller than between field duplicates, since the sample material is from one sampling event and has been well mixed. This is essentially a test of laboratory reproducibility (repeated analyses of SRM is another- e.g. table 1a) and the degree to which the sample has been mixed during sample preparation. Inspection of Appendix table 2c reveals that the variation for most elements is generally within 10 percent, and usually less than 5 percent. One sample, 3-250-i, shows greater variation between analyses (Appendix table 2c). This was probably due to incomplete mixing during sample preparation.

Appendix Table 2d presents data for standards NIST 2709 and NIST 2711 leached using the 2M HCl-1 percent H_2O_2 digestion procedure. Since there are no certified values for the standards leached with this method, the results from this study are compared with the means obtained for the same SRM obtained in other studies over a four-year period (Fey and others, 1999). The efficacy of this method is affected by the strength of the H_2O_2, which can decline with age. Whereas, we took care to use peroxide less than 6 months old and stored in a refrigerator, the fraction of material dissolved in this study was systematically less than for the previous study. However, most elements for both standards were within two standard deviations of the first study, and the digestion generally returned about 85 percent of the concentrations from the first study.

Appendix Table 2e presents certified analyte concentrations for six standard reference material water standards from USGS Water Resources Division (Long and Farrar, 1994; Farrar, 1998; Farrar, 2000; Farrar and Copen, 2000) and one from NIST (National Institute of Standards and Technology 1999). These standards were run with the leachate solutions generated from the EPA-1312 procedure applied to the composite mine wastes. Below the certified values in the table are the analytical results from this study for those standards. The agreement is quite good, even for analytes analyzed near the instrumental detection limits (e.g. beryllium, cadmium, cobalt, copper, nickel, lead, zinc).

BACKGROUND GEOCHEMISTRY IN SHALLOW CORE SAMPLES

Local background geochemistry of meadow deposits was calculated to help quantify the concentrations of trace elements in pre-mining, non-tailings material. The shallow core samples used to estimate background values were selected from cored intervals in the study area or a nearby area that appear to be geologically isolated from sources of mining-related contaminants. These intervals were chosen from: 1) cores sites in an area that contains no physical signs of previous mining activity (Panama Mine Meadows) and 2) intervals from cores within the study area which underlie mine and mill waste and are separated by thick, non-permeable, clay layers. The samples used to define the local background geochemistry are listed in table 10.

Table 5. Streambed sediment analytical data using total digestion method for the study area.
[Analyzed by David Fey, USGS using ICP-AES. Major element data expressed in weight percent; trace element data expressed in ppm, dry weight basis.]

Field No.	Ag	Al %	As	Ba	Be	Ca %	Cd	Co	Cr	Cu	Fe %	K %	Li	Mg %	Mn	Mo	Na %	Ni	P %	Pb	Sn	Sr	Th	Ti %	V	Y	Zn
L-1	<2	9.3	18	940	2	1.6	3	<1	12	15	2.2	2.1	nd	.34	550	<2	3.0	7	0.06	44	<5	670	22	0.18	50	nd	140
L-2	< 2	8.9	20	900	2	1.9	3	< 1	12	25	2.4	1.9	30	0.44	810	<2	2.8	9	0.08	32	<5	660	16	0.19	51	17	76
L-3b	< 2	8.6	640	1,000	3	1.4	90	77	4	140	4.9	1.9	25	0.25	10,000	5	2.8	17	0.09	320	< 5	620	10	0.11	42	20	5,600
L-100	25	7.6	3,200	400	2	0.98	57	84	6	300	4.8	1.9	49	0.25	18,000	7	1.8	19	0.05	3,800	5	420	5	0.09	40	17	4,400
L-150	nd	8.9	260	1,300	2	1.7	42	14	7	52	3.5	2.3	15	0.23	9,000	11	3.0	13	0.07	130	< 5	680	11	0.11	49	15	3,200
L-151	< 2	9.2	20	860	2	1.7	3	< 1	21	9	3.6	2.4	20	0.25	570	3	2.9	7	0.08	37	< 5	640	24	0.16	100	14	120
L-156	<2	9.0	86	800	2	1.7	20	8	36	65	4.7	2.0	27	0.49	1,400	3	2.8	12	0.09	110	<5	600	26	0.23	120	19	1,800
L-157	<2	9.1	26	840	2	1.7	6	3	31	15	5.0	2.3	20	0.29	530	3	3.1	8	0.10	57	<5	630	26	0.18	140	16	470
L-158	<2	9.5	340	990	3	1.7	58	64	14	98	5.1	2.0	30	0.43	8,900	6	2.8	16	0.11	220	<5	670	16	0.17	90	20	4,700
L-159	2	8.6	900	860	2	1.3	44	25	6	160	2.9	1.9	27	0.24	3,000	4	2.6	10	0.05	1,200	< 5	560	12	0.11	27	20	2,400
L-161	2	8.9	790	830	2	1.2	58	44	16	130	4.2	2.4	30	0.44	4,000	4	2.6	12	0.07	720	< 5	520	29	0.17	79	16	2,600
L-162	34	7.5	3,300	720	2	0.82	22	44	5	190	3.3	2.2	58	0.25	10,000	6	1.6	11	0.05	5,400	< 5	370	11	0.10	39	12	2,000
L-163	24	8.2	3,300	820	3	1.1	53	99	4	280	5.1	2.0	55	0.27	17,000	6	2.0	19	0.06	3,700	6	470	8	0.10	46	18	4,300
L-164	6	9.2	1,000	900	2	1.4	10	4	12	130	2.9	2.2	32	0.28	2,000	8	2.7	8	0.06	1,500	< 5	610	13	0.15	62	12	830
L-165	12	9.8	2,100	900	2	1.6	15	12	8	220	3.0	2.2	40	0.33	2,400	4	3.0	9	0.06	2,000	< 5	650	14	0.17	47	15	1,400
L-166	20	8.0	2,000	710	2	1.1	19	< 1	6	300	2.7	2.0	36	0.27	750	3	2.2	7	0.05	2,400	7	470	9	0.12	34	11	1,800
L-167	< 2	9.0	410	690	3	1.9	24	34	14	180	4.2	2.3	28	0.66	2,800	22	2.2	12	0.11	490	< 5	440	29	0.26	95	26	3,500
L-168	< 2	7.4	580	710	2	1.1	19	11	4	100	1.8	1.7	22	0.23	1,200	3	2.2	6	0.04	500	< 5	500	8	0.11	24	12	1,600

Table 6. Composite mill tailings sample analytical data for the study area. [Analyzed by David Fey, USGS using total digestion method by ICP-AES. Al, Ca, Fe, K, Mg, Na, P, and Ti in wt. %, all other elements in ppm.]

Field No.	Sample Description	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Zn
This study																																		
UFM #1	upper Frohner Meadows, western part of upper tailings, Area 1	4.2	0.28	2.7	1.8	0.16	0.69	0.04	0.06	64	6,800	450	1	4	11	1	2	260	12	8	30	140	11	20	6	4	9,800	3	6	170	6	28	2	420
UFM #2 COMP	upper Frohner Meadows, eastern part of upper tailings, Area 1, composite	4.3	0.31	3.2	1.7	0.16	0.8	0.04	0.05	83	8,200	510	1	9	15	4		290	13	11	29	170	7	20	8	4	10,000	3		190	6	31	3	1,100
UFM #2 <2 mm	upper Frohner Meadows, eastern part of upper tailings, Area 1 <2 mm	4.9	0.38	3.8	1.9	0.18	0.98	0.04	0.07	64	8,900	570	1	4	15	1	1	250	14	11	30	160	8	22	8	4	9,400	4		240	6	33	3	420
UFM #2 >2mm	upper Frohner Meadows, eastern part of upper tailings, Area 1, >2 mm	2.7	0.11	2.5	1.2	0.11	0.3	0.02	0.03	120	8,500	290		19	6	6		300	9	5	30	150	6	11	4	3	9,600	2	6	73	4	24		2,600
UFM #3	upper Frohner Meadows, main tailings, Area 2	6.1	0.7	1.6	2.5	0.14	1.8	0.02	0.06	11	1,800	1000	1	6	20	nd	1	110	15	15	24	170	2	29	10	4	1,400	2		410	6	19	5	640
FMB #1	Frohner mill composite, Area 1	3.4	0.02	2.6	1.7	0.14	0.06	0.02	0.03	100	10,000	200	1	9	6	nd		320	11	5	36	110	8	15		3	17,000	2	7	38		22		1,100
FMB #2	Frohner mill composite, Area 1	3.7	0.16	1.9	1.7	0.14	0.41	0.02	0.04	90	7,100	340	1	4	8	nd	1	270	12	6	31	110	7	18		3	14,000	2	6	110	4	23		440
UFM #4	upper Frohner Meadows, Nellie Grant fluvial tailings delta, Area 2	6.8	0.65	1.5	2.6	0.2	1.9	0.02	0.1	2	620	1100	1	4	22	nd	3	33	16	16	24	210		34	10	4	480	3		450	7	22	5	390
LFM #1	lower Frohner Meadows, Nellie Grant tailings delta, Area 3	3	0.08	5.3	1.3	0.1	0.19	0.02	0.03	27	7,100	270		100	6	40	13	330	8	6	48	140	9	7	6	15	8,100	3	10	84		23	3	11,000
Previous studies																																		
22-243-TP-1	Frohner mill composite, PTS (2000), test pit			1.4						36	14,500			5				165									9,510							470
22-243-TP-1	Frohner mill composite; mean, n=6, PTS, 2000			1.6							11,800			<1				164									11,200							296
22-243-WR-1	Frohner mine waste, mean, n=4, PTS (2000)			1.1						27	6,050	52		<1				48									4,250							50
22-243-WR-2	Frohner mine waste, mean, n=2, PTS (2000)			0.4						3	372	27		<1				11								3	1,410							90
22-243-WR-3	Frohner mine waste, mean, n=2, PTS (2000)			0.8						1	802	76		<1				10									261							60
-----------	Nellie Grant waste rock, mean, n=10, PTS (2000)										1,319			3				72									4,593							441
22-244-WR1	Nellie Grant waste rock composite, HMI (1995)										969			9		1.3		87									15,500							934
22-244-WR3	Nellie Grant waste rock composite, HMI (1995)										2,570			8		10.8		143									7,410							417
22-244-TA-1	Nellie Grant tailings composite, HMI (1995)										4,210			11				51									9,380							763
22-244-TA2	Nellie Grant tailings composite, HMI (1995)										9,330			312				467									13,500							33,700
22-244-TA3	Nellie Grant tailings composite, HMI (1995)										9,500			190				321									9,670							21,200
Tailings Pond	Nellie Grant tailings composite- MDEQ (1993)										1,510			69													3,170							4,480
------------	Nellie Grant composite buried tailings, mean, n=8, PTS (2000)										2,165			28				163									4,376							2,905
------------	Nellie Grant transported tailings upper area, mean, n=8 PTS (2000)										1,492			2				40									2,625							261
22-244-SE2	Nellie Grant fluvial tailings, HMI (1995)										879			2				27									1,190							202

Table 7. Shallow core analytical data using total digestion method for the study area. [Sample numbers are a combination of the area, line number, core number, and interval from Appendix 1b. Analyzed by David Fey, USGS using ICP-AES. Al, Ca, Fe, K, Mg, Na, P, and Ti are given in weight %; the remainder of the elements are given in ppm.]

sample	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Co	Cr	Cu	Eu	Ga	Ho	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Yb	Zn
PMC 1-d	8.6	1.2	1.5	1.8	0.32	2.3	0.04	0.19	<2	38	840	2	3	60	<1	12	34	<2	23	<4	41	35	180	<2	27	32	7	79	6	<5	470	31	40	26	2	140
PMC 3-b	8	1.2	1.6	1.5	0.42	1.8	0.06	0.2	4	170	760	2	4	61	<1	14	56	<2	21	<4	41	39	260	2	26	33	9	370	7	<5	380	14	43	28	2	240
PMC 3-c	9.6	1.6	1.2	2.5	0.4	3.4	0.04	0.2	<2	31	1,100	2	2	44	<1	6	13	<2	25	<4	27	27	180	<2	34	17	6	70	4	<5	680	13	29	9	<1	99
UFMC 1-0-b	7.4	0.92	5.5	2.2	0.25	2.1	0.04	0.14	44	9,100	810	2	6	28	2	1	340	<2	22	<4	17	28	140	8	19	13	6	16,000	4	7	430	8	37	4	<1	520
UFMC 1-0-d	9.4	1.1	2.7	2	0.44	2.4	0.06	0.22	2	330	950	2	21	59	<1	13	170	<2	25	<4	36	55	180	3	30	28	9	320	7	<5	500	12	62	20	2	1,600
UFMC 1-150-a	5	0.31	5.3	2	0.18	0.75	0.07	0.08	130	18,000	450	1	11	21	8	<1	520	<2	15	<4	13	30	150	18	11	10	5	26,000	4	9	170	8	35	3	<1	990
UFMC 1-150-b	6.8	0.74	7.6	1.9	0.3	1.8	0.09	0.14	40	25,000	740	1	8	25	7	<1	440	<2	22	<4	16	30	130	9	19	13	7	20,000	6	7	360	14	41	4	<1	360
UFMC 1-150-c	8.8	1.4	2.8	2.4	0.23	3.3	0.05	0.15	3	2,200	1,100	2	3	41	<1	5	130	<2	23	<4	26	22	110	2	27	16	4	3,300	4	<5	670	14	57	6	<1	120
UFMC 1-150-d	9	0.8	3.2	1.8	0.53	1.8	0.08	0.28	<2	300	930	2	13	89	2	20	300	2	24	<4	61	63	240	2	31	52	12	410	10	<5	350	14	76	47	4	1,600
UFMC 1-150-e	9.8	1	2.1	2	0.55	2.3	0.05	0.3	2	80	980	2	10	95	4	18	440	2	25	<4	66	64	320	<2	32	52	11	300	9	<5	460	14	72	50	4	2,000
UFMC 1-150-f	9.3	1.2	1.6	2.1	0.41	2.8	0.03	0.22	<2	83	1,000	2	3	56	<1	10	38	<2	24	<4	34	43	290	<2	29	23	7	210	5	<5	570	11	46	16	1	1,200
UFMC 1-250-b	4.8	0.21	7.4	1.9	0.18	0.54	0.05	0.06	83	37,000	450	1	12	16	8	<1	420	<2	15	<4	10	30	130	23	9	9	4	35,000	4	19	130	9	35	2	<1	1,200
UFMC 1-250-c	6.3	0.53	1.5	2.2	0.19	1.3	0.02	0.09	29	4,600	530	1	2	23	<1	2	45	<2	19	<4	14	30	120	5	17	8	2	5,800	3	<5	270	6	25	2	<1	140
UFMC 1-250-d	8.9	1.1	2.4	1.9	0.43	2.4	0.06	0.22	5	810	1,000	2	2	38	<1	11	160	<2	25	<4	23	38	150	2	47	15	8	1,800	7	5	510	15	42	6	<1	200
UFMC 1-250-e	9.9	1.5	2	2.4	0.42	3.6	0.05	0.21	<2	81	1,200	2	2	37	<1	5	56	<2	28	<4	21	34	190	<2	47	15	6	180	5	<5	720	10	46	7	<1	190
UFMC 1-350-a	7.7	0.99	6.9	2	0.28	2.3	0.06	0.14	30	8,400	840	2	10	37	6	<1	210	<2	20	<4	23	35	340	7	18	19	6	2,800	6	<5	450	11	41	10	1	590
UFMC 1-350-b	7.3	0.84	3	1.3	0.3	1.4	0.09	0.1	8	9,800	660	2	31	80	6	16	1,400	<2	20	<4	53	47	230	3	30	44	11	6,300	7	<5	330	11	55	39	4	1,900
UFMC 1-350-c	8.9	1.3	1.7	2.1	0.29	2.9	0.04	0.18	2	650	1,000	2	6	39	<1	9	180	<2	26	<4	23	39	170	<2	41	19	6	710	4	<5	600	11	36	18	2	710
UFMC 1-40-a	6.3	0.45	5.1	2	0.27	1	0.07	0.1	96	14,000	520	1	11	24	4	3	420	<2	19	<4	14	34	190	12	15	11	6	18,000	5	11	220	10	40	4	<1	1,200
UFMC 1-40-b	7	0.82	5.5	2	0.24	1.9	0.06	0.12	28	7,100	740	1	5	26	4	1	150	<2	19	<4	16	34	300	8	17	12	6	3,600	4	6	400	10	40	4	<1	250
UFMC 1-40-c	6.8	0.78	6	2.1	0.25	1.7	0.06	0.12	46	9,500	750	1	8	28	5	2	230	<2	19	<4	17	34	230	10	17	14	6	6,000	5	10	360	12	42	5	<1	680
UFMC 1-40-d	7.1	0.74	4.6	2.6	0.22	1.9	0.05	0.08	100	6,200	250	1	11	26	3	<1	390	<2	20	<4	16	32	340	7	18	12	4	7,600	4	5	380	8	38	4	<1	1,100
UFMC 1-40-e	5.5	0.06	4.5	2.6	0.21	0.14	0.07	0.02	250	13,000	380	1	10	16	2	<1	920	<2	17	<4	10	39	140	19	12	8	4	29,000	5	13	56	10	39	3	<1	1,200
UFMC 1-40-f	7.8	0.9	3.7	2.9	0.21	2.6	0.05	0.1	52	4,900	400	2	6	30	<1	2	300	<2	20	<4	19	23	360	8	20	13	4	6,700	4	6	510	10	45	4	<1	580
UFMC 1-400-a	8.5	1.3	3.4	2.2	0.3	2.5	0.08	0.15	14	2,500	920	2	19	46	25	5	160	<2	22	<4	27	44	4,600	4	6	16	9	2,300	5	<5	530	9	39	13	1	1,300
UFMC 1-400-b,d	7.5	0.9	3.1	1.8	0.38	1.8	0.08	0.18	18	2,900	700	2	25	48	15	9	290	<2	20	<4	30	51	860	5	19	22	10	2,900	6	<5	380	10	50	19	2	1,800
UFMC 1-400-e	9.2	1.3	1.6	2.2	0.36	3	0.03	0.18	<2	440	1,000	2	7	45	<1	6	84	<2	24	<4	29	37	210	<2	27	18	5	480	5	<5	620	11	35	11	1	470
UFMC 1-400-g,h,i	9.3	1.5	1.4	2.2	0.41	2.9	0.03	0.2	<2	82	1,000	2	3	59	<1	10	39	<2	24	<4	40	46	270	3	28	30	7	170	6	<5	620	12	45	26	2	200
UFMC 1-500-b	8.5	1.2	1.8	2.2	0.34	2.6	0.05	0.18	18	1,400	860	2	15	46	4	7	190	<2	22	<4	27	43	470	3	27	18	7	2,300	5	<5	550	13	38	12	1	1,700
UFMC 1-500-c	7.3	0.89	2.7	2.1	0.25	2	0.04	0.08	110	5,600	450	2	60	38	5	5	850	<2	20	<4	22	30	250	13	28	15	6	4,600	4	9	420	11	40	6	<1	9,100
UFMC 1-500-d	9.2	1.3	1.6	1.7	0.43	2.1	0.03	0.25	2	47	900	2	2	57	<1	17	68	<2	25	<4	35	55	150	<2	50	28	10	160	8	<5	500	14	59	25	3	250

Table 7 (continued)

sample	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Co	Cr	Cu	Eu	Ga	Ho	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Yb	Zn
UFMC 1-500-e	9.2	1.6	1.4	2.2	0.44	2.8	0.04	0.21	<2	57	1,200	2	2	44	<1	12	23	<2	23	<4	27	36	170	13	47	18	10	86	5	<5	660	9	45	12	1	370
UFMC 1-600-b	9.1	1.1	2.3	1.7	0.42	2	0.06	0.21	6	400	840	2	6	69	<1	16	180	<2	23	<4	45	53	220	2	41	35	10	950	8	<5	430	20	55	31	3	690
UFMC 1-600-c	9.3	1.4	1.1	<0.01	0.34	3.1	0.04	0.16	<2	87	1,100	2	2	51	<1	12	40	<2	24	<4	33	33	140	<2	43	22	8	140	5	<5	650	12	32	16	2	170
UFMC 2-0-b	6.5	0.94	7	1.7	0.33	1.2	0.18	0.1	30	9,800	620	2	38	46	7	2	770	<2	17	<4	29	46	360	11	14	28	8	6,000	7	8	310	15	47	25	2	2,300
UFMC 2-0-c	10	1.3	1.9	1.7	0.5	1.7	0.04	0.24	2	64	900	2	3	77	<1	21	72	<2	27	<4	51	72	220	2	47	40	13	140	10	<5	420	19	62	38	4	740
UFMC 2-0-c-r	9.4	1.2	1.9	1.6	0.47	1.5	0.04	0.26	<2	59	880	2	3	70	<1	20	65	<2	24	<4	45	62	210	2	47	35	12	140	9	<5	390	16	60	35	3	720
UFMC 2-0-d	9.7	1.4	1.3	2.3	0.39	2.9	0.04	0.2	<2	29	1,100	2	<2	49	<1	13	26	<2	25	<4	30	42	150	<2	46	22	7	77	6	<5	620	11	38	17	2	260
UFMC 2-60-b	7.7	0.79	2.1	1.7	0.35	1.4	0.09	0.12	23	940	700	2	23	57	<1	13	600	<2	21	<4	38	49	160	5	21	32	8	2,500	7	7	310	13	53	32	3	1,100
UFMC 2-60-c	8.7	0.92	2.6	1.6	0.46	1.6	0.07	0.24	2	390	800	2	29	81	3	20	140	<2	23	<4	55	60	380	2	29	46	13	200	10	<5	350	17	64	44	4	1,800
UFMC 2-60-d	9.2	1.4	0.88	2.2	0.28	3	0.03	0.14	<2	89	1,100	2	4	45	<1	12	110	<2	22	<4	30	26	200	<2	39	17	7	82	4	<5	650	12	23	11	1	460
UFMC 2-60-e	8.7	1.2	1.8	1.6	0.48	1.7	0.04	0.23	<2	98	880	2	2	69	<1	18	61	<2	23	<4	46	51	330	2	40	37	12	100	8	<5	410	15	54	37	4	590
UFMC 2-130-b	8.9	1.4	1	2.1	0.3	2.8	0.04	0.15	<2	95	1,100	2	5	43	<1	7	33	<2	22	<4	27	27	160	<2	41	17	6	93	4	<5	610	10	27	11	1	380
UFMC 2-130-c	9.8	1.2	1.7	1.7	0.44	2	0.04	0.24	<2	51	960	2	<2	80	<1	20	62	<2	26	<4	53	58	280	3	48	41	15	100	10	<5	440	19	58	38	4	310
UFMC 250-200-a	8	1	4.3	2.1	0.29	2.3	0.06	0.13	31	4,800	800	2	16	38	2	3	360	<2	21	<4	23	38	210	6	20	18	6	4,000	5	5	480	10	37	12	1	1,300
UFMC 250-200-b	8.3	0.74	3.5	1.7	0.46	1.4	0.11	0.2	28	1,800	690	2	15	70	<1	15	530	<2	22	<4	43	58	220	6	24	37	10	3,300	9	<5	300	15	59	31	3	1,400
UFMC 250-200-c	9.2	1.4	1.2	2.1	0.3	2.9	0.02	0.21	<2	96	1,100	2	<2	55	<1	10	37	<2	24	<4	34	35	130	<2	43	26	6	110	5	<5	600	12	34	22	2	170
UFMC 250-200-d	9.5	1.2	1.9	1.6	0.4	1.7	0.02	0.24	2	72	940	2	2	93	<1	20	86	2	25	<4	64	58	130	<2	45	52	11	150	10	<5	400	15	64	53	5	290
UFMC 250-200-f	9.6	1.1	1.9	1.8	0.41	2.1	0.02	0.3	<2	33	1,000	2	2	63	<1	17	78	<2	26	<4	40	54	170	<2	48	31	10	140	8	<5	420	15	62	28	3	320
UFMC 250-75-a	7.5	1	3.8	2.1	0.3	2.1	0.06	0.12	62	6,000	750	2	30	40	5	4	570	<2	20	<4	23	41	320	6	19	18	7	5,900	5	<5	420	9	37	11	1	2,800
UFMC 250-75-b	8.2	1	3.8	2.1	0.31	2.3	0.06	0.15	32	3,600	800	2	14	44	4	4	320	<2	20	<4	26	43	440	6	22	20	6	4,600	5	<5	470	10	38	14	1	1,200
UFMC 250-75-c	7.7	0.97	2.9	2	0.32	2.2	0.05	0.15	35	5,600	760	2	12	42	<1	6	270	<2	21	<4	25	41	210	6	21	20	6	4,800	5	6	470	10	40	13	1	1,300
UFMC 250-75-d	7.6	0.66	3.2	1.7	0.34	1.4	0.1	0.13	43	6,200	630	2	51	56	3	11	820	<2	20	<4	34	51	220	8	19	29	9	6,200	7	5	300	14	46	27	3	3,400
UFMC 250-75-e	7.8	0.99	1.3	1.5	0.33	2	0.02	0.24	<2	25	790	2	<2	65	<1	15	31	<2	20	<4	42	40	150	<2	41	31	7	86	6	<5	400	15	43	25	2	170
UFMC 250-75-f	8	0.91	1.5	1.4	0.35	1.5	0.02	0.24	<2	56	790	2	2	69	<1	17	58	<2	21	<4	44	47	140	<2	43	34	8	160	7	<5	330	16	50	32	3	220
UFMC 250-75-g	10	1.5	1	2.5	0.32	3.4	0.02	0.16	<2	28	1,200	2	<2	46	<1	6	16	<2	25	<4	29	31	130	<2	44	19	6	55	4	<5	700	11	28	11	1	130
UFMC 3-0-a	8.3	0.78	3.1	2.2	0.32	2.2	0.05	0.13	10	2,600	820	2	46	37	<1	9	180	<2	20	<4	23	50	340	3	22	17	7	3,200	5	<5	450	9	36	12	1	1,400
UFMC 3-0-b	8.3	1	2.5	2.1	0.39	2.2	0.05	0.16	8	1,800	320	2	57	39	6	10	240	<2	21	<4	27	52	370	<2	25	19	11	2,000	5	<5	460	10	39	18	1	5,000
UFMC 3-0-c	9.5	1.2	2	2.4	0.47	2.5	0.06	0.2	2	160	1,100	2	4	40	<1	16	57	<2	25	<4	26	42	320	2	43	21	10	550	6	<5	520	12	56	20	2	1,200
UFMC 3-0-d	9.1	1.3	1.6	2	0.44	2.1	0.05	0.17	3	96	990	2	8	47	<1	13	78	<2	23	<4	36	44	300	<2	42	29	10	500	6	<5	510	12	48	31	3	1,000
UFMC 3-100-a	7.8	0.75	3.4	1.9	0.39	0.63	0.11	0.12	26	3,600	510	3	160	56	17	11	830	<2	19	<4	36	78	460	6	20	31	16	6,400	7	6	200	11	46	36	3	9,800

Table 7 (continued)

sample	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Co	Cr	Cu	Eu	Ga	Ho	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Yb	Zn
UFMC 3-100-b	8.5	1	2.6	1.6	0.48	1.3	0.04	0.18	7	260	1,000	3	21	52	<1	17	170	2	22	<4	52	61	470	<2	25	49	12	680	8	<5	320	10	54	59	5	1,500
UFMC 3-100-d	9.6	1.2	1.6	2.4	0.41	2.4	0.04	0.18	<2	240	1,200	2	3	46	<1	12	34	<2	25	<4	29	39	240	4	44	18	10	110	5	<5	520	10	41	12	1	370
UFMC 3-200-a,b	7.8	0.92	4.6	2	0.31	2	0.06	0.13	45	4,200	760	2	14	38	11	4	320	<2	20	<4	24	42	690	9	18	18	7	4,900	5	5	430	9	39	13	1	1,600
UFMC 3-200-c	7.7	0.66	5	1.8	0.43	1.2	0.09	0.16	63	7,700	380	2	46	53	18	10	800	<2	20	<4	32	56	670	7	20	27	13	7,200	8	7	250	14	55	24	2	5,800
UFMC 3-200-d	8.3	1	2.1	1.7	0.36	1.9	0.04	0.22	3	340	780	2	6	59	<1	14	62	<2	22	<4	38	44	230	<2	26	29	8	300	7	<5	420	12	45	23	2	690
UFMC 3-200-f	9.5	1.4	1.3	2	0.34	2.9	0.02	0.19	<2	150	940	2	4	60	<1	12	49	<2	24	<4	39	39	160	<2	31	29	7	170	6	<5	610	11	39	24	2	240
UFMC 3-200-g	10	1.5	1.2	2.4	0.36	3.2	0.03	0.2	<2	60	1,200	2	2	54	<1	10	34	<2	25	<4	34	36	150	2	32	23	7	110	5	<5	670	9	38	15	1	190
UFMC 3-250-a	7.9	1	2.9	2.1	0.29	2.1	0.05	0.14	19	3,300	870	2	20	45	15	5	240	<2	20	<4	27	37	1,800	3	16	20	7	2,600	5	<5	460	10	36	16	2	1,600
UFMC 3-250-b	8.3	0.83	3.7	2	0.42	1.8	0.06	0.2	28	2,400	750	3	24	58	6	10	470	<2	22	<4	36	59	400	3	26	29	11	3,800	8	6	370	15	52	27	2	2,300
UFMC 3-250-c	7.3	0.89	3	2.1	0.26	2.1	0.05	0.12	50	3,200	830	2	15	32	<1	7	250	<2	20	<4	20	33	200	5	21	15	5	5,200	4	<5	460	10	35	8	<1	1,700
UFMC 3-250-d	7.9	0.63	4.9	2.2	0.4	1.2	0.08	0.15	76	6,200	630	2	35	47	12	10	680	<2	22	<4	29	56	760	9	19	24	10	8,000	8	9	260	13	52	21	2	3,200
UFMC 3-250 g	9.4	1.4	1.2	2.2	0.28	3.2	0.01	0.18	<2	120	1,000	2	3	59	<1	9	36	<2	24	<4	38	28	140	<2	29	27	5	170	5	<5	630	11	42	19	2	240
UFMC 3-250-i	9.7	1.6	1.4	2.8	0.3	3.6	0	0.2	<2	110	1,200	3	3	38	<1	9	19	<2	28	<4	23	38	170	3	32	15	11	180	4	<5	680	10	42	9	1	300
UFMC 3-300-a	8.2	1	2.7	2	0.3	2.4	0.04	0.13	20	2,100	820	2	15	36	4	6	220	<2	21	<4	22	39	400	3	22	16	6	3,000	4	<5	500	9	35	11	1	1,400
UFMC 3-300 b	8.5	1	3.3	2.3	0.27	2.4	0.05	0.12	32	3,200	970	2	16	40	1	4	360	<2	21	<4	23	37	230	4	22	18	6	5,300	5	6	510	9	38	12	1	1,600
UFMC 3-300-c	8.1	0.95	3.5	1.8	0.38	1.9	0.07	0.16	32	2,900	710	2	35	46	10	9	490	<2	21	<4	29	46	700	5	22	23	11	4,200	6	7	410	10	46	21	2	3,400
UFMC 3-300-d	9.4	0.99	3.3	1.5	0.42	1.6	0.02	0.25	<2	59	940	2	3	83	<1	20	93	<2	25	<4	55	59	180	<2	48	47	13	130	10	<5	340	16	78	45	4	360
UFMC 3-300-e	8.3	1.3	2.1	1.7	0.37	2.8	0.05	0.34	2	120	960	2	2	42	2	4	37	<2	21	<4	22	47	320	<2	40	20	11	170	6	<5	310	8	35	23	2	220
UFMC 3- 300-f	8.6	0.9	2.7	1.6	0.4	1.6	0.02	0.27	<2	24	850	2	2	71	<1	25	58	<2	22	<4	45	46	160	<2	44	34	9	110	9	<5	340	18	93	31	3	270
UFMC 4-0-b	9.4	0.74	2.9	1.4	0.52	0.9	0.11	0.24	5	900	750	3	39	84	10	25	390	2	26	<4	58	73	320	3	31	49	17	690	12	<5	240	19	69	48	5	2,700
UFMC 4-0-c	10	0.86	2.4	1.3	0.5	0.87	0.04	0.24	3	90	780	2	4	70	<1	26	76	<2	28	<4	49	71	310	<2	48	40	14	160	12	<5	250	19	70	39	4	970
UFMC 4-0-d	8.2	0.97	1.2	1.7	0.28	2	0.02	0.19	<2	140	890	2	<2	46	<1	16	28	<2	21	<4	29	35	150	<2	39	20	7	110	5	<5	440	11	37	16	2	210
UFMC 4-100-c	9.5	1.3	1.2	2.1	0.32	2.8	0.02	0.2	<2	32	1,100	2	3	56	<1	10	29	<2	25	<4	36	41	120	<2	30	26	6	90	6	<5	590	10	39	20	2	220
LFMC 5- 100-d	9.9	1.3	1.3	2.4	0.44	2.8	0.02	0.24	<2	29	1,100	2	3	58	<1	14	28	<2	26	<4	34	42	180	<2	35	21	8	81	6	5	600	14	46	11	1	220
LFMC 5-200-b	7.3	0.92	1.7	1.1	0.32	1.2	0.05	0.16	2	370	580	2	9	61	2	17	97	<2	20	<4	40	46	250	2	20	35	13	240	8	<5	280	12	53	34	3	2,400
LFMC 5-200-c	9	1.3	1.2	2	0.3	2.9	0.02	0.19	<2	55	930	2	4	57	<1	11	38	<2	23	<4	35	35	150	<2	29	26	6	120	6	<5	590	12	38	20	2	220
LFMC 5-300-a	3.6	0.74	1.7	0.56	0.24	0.27	0.15	0.01	10	680	250	2	48	40	9	10	1,200	<2	8	<4	31	24	520	2	6	29	13	3,000	5	<5	130	6	29	43	4	3,300
LFMC 5-300-b	7.9	1.1	1.6	1.3	0.43	1.2	0.04	0.23	2	92	660	2	8	65	<1	20	69	<2	22	<4	44	54	250	<2	22	37	10	200	9	<5	290	14	53	36	3	1,100
LFMC 5-300-c	8.4	1.4	1.7	1.8	0.35	3.2	0.07	0.37	<2	52	1,000	2	2	55	<1	2	32	<2	24	<4	26	57	360	<2	23	27	7	83	7	<5	340	5	31	28	3	110
LFMC 6-0-a	6.5	0.56	2.1	1.2	0.27	1.1	0.12	0.08	13	2,200	520	3	58	56	18	14	930	<2	16	<4	36	38	720	8	15	34	12	3,600	7	<5	250	10	44	43	4	2,500

Table 7 (continued)

sample	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Co	Cr	Cu	Eu	Ga	Ho	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Yb	Zn
LFMC 6-0-b	9.2	1.1	1.8	1.7	0.35	2.2	0.02	0.23	<2	27	960	2	2	62	<1	16	38	<2	23	<4	38	45	170	<2	46	28	9	93	8	<5	480	20	52	25	2	280
LFMC 6-0-c	9.1	1.2	1.6	1.8	0.33	2.4	0.02	0.2	<2	32	1,000	2	<2	58	<1	14	49	<2	24	<4	35	40	150	<2	46	27	8	86	7	<5	510	16	48	22	2	220
LFMC 6-0-d	9.2	1.5	2	2.5	0.44	3.3	0.02	0.28	<2	63	1,300	2	3	34	<1	8	28	<2	29	<4	16	27	240	<2	53	11	6	83	4	<5	700	11	64	7	<1	190
LFMC 6-50-c	8.1	1.1	1.8	1.6	0.35	2	0.05	0.22	<2	100	790	2	11	61	<1	16	59	<2	23	<4	38	46	300	<2	24	32	9	160	7	<5	420	11	48	27	3	1,200
LFMC 6-50-d	8.8	1.3	1.4	2	0.3	2.7	0.03	0.19	<2	60	950	2	4	53	<1	10	37	<2	23	<4	34	33	200	<2	28	25	6	100	6	<5	570	11	36	20	2	270
LFMC 6-100-d	8.9	1.4	1	2	0.25	3.1	0.02	0.14	<2	17	1,100	2	<2	41	<1	7	18	<2	22	<4	26	26	140	<2	39	17	5	59	4	<5	650	9	29	12	1	180
LFMC 1-b	2.2	0.1	3.6	0.9	0.07	0.24	0.02	0.03	18	4,600	200	<1	63	8	22	4	250	<2	6	<4	5	40	100	7	<4	5	5	3,300	<2	7	72	<4	15	2	<1	6,800
LFMC 1-c	2.4	0.08	5.9	1	0.08	0.18	0.02	0.03	26	8,400	240	<1	120	10	37	9	370	<2	6	<4	7	44	160	8	<4	7	17	5,800	2	9	66	<4	18	3	<1	12,000
LFMC 1-d	3.9	0.62	2.4	0.49	0.22	0.28	0.12	0.07	5	990	300	2	94	60	18	13	430	3	10	<4	50	27	610	4	8	56	17	1,300	7	<5	120	6	38	51	5	10,000
LFMC 1-e	8.9	0.73	2.8	1.2	0.53	0.68	0.07	0.22	4	260	750	3	8	86	<1	27	120	4	25	<4	84	56	250	<2	27	77	17	320	13	<5	210	19	71	67	6	670
LFMC 1-f	9	1.2	1.6	2.2	0.43	2.7	0.03	0.2	<2	99	1,100	2	4	63	<1	13	57	<2	24	<4	49	30	190	<2	30	35	8	130	6	<5	580	13	40	26	2	310
LFMC 1-b	9.1	1.1	2.3	2.5	0.29	3.2	0.04	0.12	2	710	1,100	2	5	31	<1	3	38	<2	23	<4	19	25	320	<2	26	13	5	410	4	<5	640	10	27	6	<1	580
LFMC 1-c	8.5	0.66	2.4	2.1	0.4	1.5	0.07	0.13	13	1,900	590	2	140	49	14	10	570	<2	21	<4	32	68	300	4	21	26	15	3,300	6	5	320	10	41	28	3	11,000
LFMC 1-e	9.4	1.5	1.1	2.5	0.28	3.5	0.02	0.19	<2	68	1,100	2	4	32	<1	9	43	<2	26	<4	21	33	320	<2	28	17	8	220	4	<5	680	7	34	15	2	2,100
LGFR 1-a	7.7	0.95	4.1	1.6	0.42	1.6	0.12	0.18	2	400	820	3	54	69	30	12	410	<2	20	<4	43	41	1,900	3	17	36	14	780	8	5	350	14	61	37	4	3,300
LGFR 1-b	9.8	1.4	1.9	2.5	0.35	3.1	0.03	0.22	<2	55	1,100	2	3	60	<1	12	38	<2	27	<4	34	36	200	<2	30	25	7	110	5	<5	610	12	52	14	1	270
LGFR 1-c,d	9.4	1.5	1.8	2.2	0.34	2.8	0.04	0.2	<2	26	1,000	2	4	60	<1	12	40	<2	24	<4	35	36	210	<2	28	30	7	82	6	<5	560	10	50	24	2	280
LGFR 1-f	9.8	1.6	1.9	2.2	0.41	3.2	0.04	0.2	<2	120	1,100	3	5	78	<1	12	54	<2	26	<4	42	39	230	2	28	36	9	190	6	<5	630	13	64	27	3	400
LGFR 1-h	9	1.4	2.4	2.6	0.35	2.9	0.04	0.24	<2	120	1,100	2	5	63	3	14	42	<2	26	<4	34	39	210	16	29	28	9	120	6	<5	560	13	69	20	2	340
LGFR 2-a	8.8	1.7	1.2	3	0.19	3.5	0.04	0.14	<2	80	1,000	2	4	33	<1	5	22	<2	24	<4	18	18	280	<2	26	13	5	110	3	<5	640	8	28	6	<1	300
LGFR 2-b	8	1.5	2.6	2	0.35	2.5	0.07	0.17	<2	160	860	2	11	60	4	7	45	<2	20	<4	39	26	630	<2	24	29	8	160	6	<5	510	14	42	22	2	920
LGFR 2-c	9.1	1.4	1.4	2.2	0.32	2.9	0.03	0.19	<2	59	940	2	4	70	<1	10	35	<2	22	<4	41	32	300	<2	27	30	7	98	5	<5	590	12	41	20	2	240
LGFR 2-d	9.5	1.2	2.2	2.6	0.52	2.5	0.06	0.22	<2	95	900	2	7	69	5	13	50	<2	24	<4	40	48	210	8	33	27	10	87	7	<5	490	18	62	17	2	450
LGFR 3-a	8.8	1.6	1.7	2.4	0.3	2.9	0.05	0.16	<2	32	990	2	4	52	<1	6	22	<2	22	<4	32	22	440	<2	26	21	6	60	4	<5	590	11	37	12	1	380
LGFR 3-c	8.6	1.3	2.1	2	0.35	2.6	0.06	0.2	<2	47	810	2	6	73	<1	12	42	<2	22	<4	44	29	270	2	29	31	8	84	6	<5	520	15	54	21	2	520
LGFR 3-d	9.5	1.2	2.2	2.7	0.5	2.4	0.07	0.22	<2	280	310	2	4	68	4	19	48	<2	23	<4	39	35	170	6	32	26	11	290	7	<5	480	16	74	18	2	280
LGFR 3-e	9.2	1.1	2.4	2.5	0.54	2.2	0.08	0.24	<2	110	600	2	4	76	8	25	48	<2	23	<4	42	36	180	7	31	29	12	200	8	<5	450	18	97	20	2	250

Table 8. Streambed sediment analytical data using partial digestion method for the study area.
[Analyzed by David Fey, USGS using 2M HCL 1% hydrogen peroxide solution and ICP-AES. All values in ppm unless otherwise noted in the column headings. Sb values for all samples were less than the detection limit of 3 ppm.]

Site No.	Ag	Al %	As	B	Ba	Be	Ca %	Cd	Co	Cr	Cu	Fe %	K %	Li	Mg %	Mn	Mo	Na	Ni	P	Pb	Si %	Sr	Ti	V	Zn
L-1	<1	2.9	12	0.69	120	0.4	3.1	1.3	3	2	12	0.68	0.043	4.1	0.12	480	<1	38	2.8	560	26	0.14	31	140	9.0	100
L-2	<1	3.8	16	1.2	110	0.4	4.9	1	4.1	3	19	0.80	0.060	6.4	0.16	740	< 1	51	4	550	20	0.15	61	87	12	49
L-3b	1	3.2	460	3.1	270	1	2.1	73	61	< 0.6	93	3.0	0.023	2.0	0.063	8,600	2	40	12	600	220	0.095	30	< 30	11	4,600
L-100	19	5.2	2,100	< 3.0	210	1	1.9	46	83	< 0.6	200	2.3	0.033	3.2	0.047	16,000	3	30	14	280	2,900	0.11	37	< 30	5.7	3,500
L-150	< 1	2.2	230	< 3.0	390	< 0.6	2.1	40	26	< 0.6	47	2.0	0.030	3.0	0.088	8,800	8	40	8.5	620	120	0.12	29	< 30	9.9	3,100
L-151	< 1	2.3	9.0	< 3.0	92	< 0.6	2.4	< 1	4.8	1	8.0	0.69	0.028	3.0	0.088	460	< 1	63	2	600	18	0.084	19	50	7.7	85
L-156	<1	3.3	66	<3.0	120	<0.6	2.8	15	13	2	31	1.2	0.054	4.7	0.016	1,100	<1	69	4.2	630	73	0.10	26	98	12	1,400
L-157	<1	2.0	11	<3.0	70	<0.6	2.1	3	3.3	0.9	8.7	0.69	0.029	3.0	0.087	350	<1	55	2	610	27	0.080	15	61	7.4	310
L-158	2	4.8	2,100	4.6	97	2	3.4	76	180	<0.6	220	4.4	0.018	2.0	0.049	11,000	4	63	16	560	1,000	0.12	36	<30	10	5,900
L-159	2	3.2	720	< 3.0	110	0.9	2.0	38	35	< 0.6	120	1.8	0.016	2.0	0.048	2,700	1	41	5.8	360	960	0.094	30	< 30	4.9	2,000
L-161	2	3.0	510	< 3.0	100	0.6	1.8	43	32	< 0.6	79	1.2	0.055	3.7	0.11	3,200	1	34	5.0	420	480	0.096	20	34	6.6	2,000
L-162	17	3.0	2,100	< 3.0	100	0.7	1.2	16	44	< 0.6	120	1.5	0.033	2.0	0.036	8,000	2	< 30	6.4	250	3,500	0.088	21	< 30	3.7	1,400
L-163	15	4.1	1,600	< 3.0	170	0.9	1.6	33	59	< 0.6	140	1.9	0.031	3.0	0.046	12,000	2	30	11	260	2,200	0.093	29	< 30	4.7	2,600
L-164	5.0	2.1	600	< 3.0	53	< 0.6	1.3	6.1	6.8	< 0.6	74	0.58	0.028	2.0	0.061	1,400	1	46	2	330	940	0.084	16	< 30	6.6	480
L-165	8.0	2.9	1,400	< 3.0	95	< 0.6	2.1	9.1	15	< 0.6	110	1.1	0.032	3.0	0.065	1,900	1	66	3	360	1,300	0.090	28	< 30	7.8	760
L-166	16	2.9	1,500	< 3.0	56	< 0.6	1.4	13	8.6	< 0.6	200	1.3	0.028	2.0	0.058	610	2	40	2	350	1,800	0.093	19	< 30	6.2	990
L-167	1	5.1	290	< 3.0	110	1	3.3	24	45	1	140	1.5	0.19	5.6	0.24	3,000	6	85	6.5	880	420	0.14	38	100	22	3,700
L-168	2	3.6	730	< 3.0	110	0.9	2.2	26	32	< 0.6	130	1.6	0.033	3.4	0.10	1,700	2	68	5.3	390	600	0.11	30	< 30	7.8	2,000

Table 9. Mill tailings analytical data using synthetic precipitation leach method for the study area. [The following elements were below detection at the value shown in parentheses: Cr (10 ppb), Li (10 ppb), Mg (1 ppm), Mo (20 ppb), Na (1 ppm), P (50 ppb), Ti (50 ppb), V (10 ppb). Analyzed by David Fey, USGS using EPA 1312 leach method (USEPA, 1986).]

Field No	Description	Al ppm	As ppb	B ppb	Ba ppb	Be ppb	Ca ppm	Cd ppb	Co ppb	Cu ppb	Fe ppm	K ppm	Mn ppb	Ni ppb	Pb ppb	Si ppm	Sr ppb	Zn ppb	SO_4^{2-} ppm	pH su	Cond-uctivity µS/cm
UFM 1	upper Frohner Meadows tailings, western part, 1t.	0.35	340	22	60	< 10	2.3	< 10	< 10	70	1.5	2.8	220	< 10	1,700	2.0	17	560	16	3.73	104
UFM 2 COMP	upper Frohner Meadows tailings, western part, composite	0.29	<100	< 10	250	< 10	1.5	16	< 10	140	0.12	3.6	980	< 10	5,100	1.3	42	720	24	3.54	86
UFM 2 - 2 mm	upper Frohner Meadows tailings, western part, < 2 mm	0.13	<100	< 10	120	< 10	1.1	10	< 10	99	0.095	3.0	560	< 10	1,300	1.1	23	570	17	3.58	100
UFM 2 + 2mm	upper Frohner Meadows tailings, western part, <2 mm	0.32	160	< 10	120	< 10	< 1	< 10	< 10	80	1.2	2.4	230	< 10	17,000	1.2	24	330	23	4.00	88
UFM 3	upper Frohner Meadows tailings, main tailings impoundment	0.036	<100	< 10	100	< 10	3.3	73	14	250	< 0.05	2.4	990	< 10	280	1.4	59	5,900	25	3.82	67
UFM 4	upper Frohner Meadows tailings, main tailings impoundment, Nellie Grant tailings delta	0.42	130	16	140	< 10	2.3	35	< 10	72	0.79	3.5	210	< 10	230	2.1	47	2,700	18	2.99	252
FMB 1	Frohner mill composite sample	1.10	<100	< 10	< 5	< 10	< 1	12	< 10	160	4.0	2.8	33	< 10	13,000	< 1	20	1,200	47	3.39	94
FMB 2	Frohner mill composite sample	0.22	<100	< 10	57	< 10	< 1	< 10	< 10	32	0.091	2.7	42	< 10	19,000	1.1	20	450	21	4.77	76
LFM 1	lower Frohner Meadows tailings, Nellie Grant tailings delta	0.25	900	25	32	< 10	1.8	170	29	< 10	0.62	2.6	130	170	3,800	1.4	17	9,100	31	3.73	104

Table 10. Geochemical total digestion data used to calculate background concentrations of trace elements in shallow cores from the study area. [Values of Al, Ca, Fe, K, Mg, Na, P, and Ti are in weight %, all other elements are in ppm. Chemical data are from Table 7.]

Site number	type	Al	Ca	Fe	K	Mg	Na	P	Ti	Ag	As	Ba	Be	Cd	Ce	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sn	Sr	Th	V	Y	Yb	Zn
UFMC 1-500-d	clay	9.20	1.30	1.60	1.70	0.43	2.10	0.03	0.25	2	47	900	2.0	2	57	17	68	25	35	55	150	<2	50	28	10	160	8	<5	500	14	59	25	3.0	250
UFMC 2-130-c	clay	9.80	1.20	1.70	1.70	0.44	2.00	0.04	0.24	<2	51	960	2.0	<2	80	20	62	26	53	58	280	3	48	41	15	100	10	<5	440	19	58	38	4.0	310
UFMC 250-200-c	clay	9.20	1.40	1.20	2.10	0.30	2.90	0.02	0.21	<2	96	1,100	2.0	<2	55	10	37	24	34	35	130	<2	43	26	6	110	5	<5	600	12	34	22	2.0	170
UFMC 250-200-d	clay	9.50	1.20	1.90	1.60	0.40	1.70	0.02	0.24	2	72	940	2.0	2	93	20	86	25	64	58	130	<2	45	52	11	150	10	<5	400	15	64	53	5.0	290
UFMC 250-200-f	clay	9.60	1.10	1.90	1.80	0.41	2.10	0.02	0.30	<2	33	1,000	2.0	2	63	17	78	26	40	54	170	<2	48	31	10	140	8	<5	420	15	62	28	3.0	320
UFMC 250-75-e	clay	7.80	0.99	1.30	1.50	0.33	2.00	0.02	0.24	<2	25	790	2.0	<2	65	15	31	20	42	40	150	<2	41	31	7	86	6	<5	400	15	43	25	2.0	170
UFMC 250-75-f	clay	8.00	0.91	1.50	1.40	0.35	1.50	0.02	0.24	<2	56	790	2.0	2	69	17	58	21	44	47	140	<2	43	34	8	160	7	<5	330	16	50	32	3.0	220
UFMC 3-300-d	clay	9.40	0.99	3.30	1.50	0.42	1.60	0.02	0.25	<2	59	940	2.0	3	83	20	93	25	55	59	180	<2	48	47	13	130	10	<5	340	16	78	45	4.0	360
UFMC 3-300-f	clay	8.60	0.90	2.70	1.60	0.40	1.60	0.02	0.27	<2	24	850	2.0	2	71	25	58	22	45	46	160	<2	44	34	9	110	9	<5	340	18	93	31	3.0	270
UFMC 6-0-b	clay	9.20	1.10	1.80	1.70	0.35	2.20	0.02	0.23	<2	27	960	2.0	2	62	16	38	23	38	45	170	<2	46	28	9	93	8	<5	480	20	52	25	2.0	280
UFMC 6-0-d	clay	9.20	1.50	2.00	2.50	0.44	3.30	0.02	0.28	<2	63	1,300	2.0	3	34	8	28	29	16	27	240	<2	53	11	6	83	4	<5	700	11	64	7	<1	190
LFMC-1f	clay	9.00	1.20	1.63	2.16	0.43	2.73	0.03	0.20	1	99	1,078	2.2	4	63	13	57	24	49	30	192	1	30	35	8	129	6	3	579	13	39	26	2.4	307
PMC-1d	clay	8.59	1.18	1.48	1.72	0.32	2.27	0.03	0.19	1	38	835	1.9	3	60	12	34	23	41	35	173	1	27	32	7	78	6	1	466	12	40	26	2.3	133
UFMC 1-250-e	clastic	9.90	1.50	2.00	2.40	0.42	3.60	0.05	0.21	<2	81	1,200	2.0	2	37	5	56	28	21	34	190	<2	47	15	6	180	5	<5	720	10	46	7	<1	190
UFMC 1-400-g,h,i	clastic	9.32	1.49	1.41	2.24	0.41	2.88	0.03	0.20	1	82	1,041	2.2	3	59	9	39	24	40	46	273	3	28	30	7	172	6	3	616	12	45	25	2.4	205
UFMC 1-500-e	clastic	9.20	1.60	1.40	2.20	0.44	2.80	0.04	0.21	<2	57	1,200	2.0	2	44	12	23	23	27	36	170	13	47	18	10	86	5	<5	660	9	45	12	1.0	370
UFMC 1-600-c	clastic	9.30	1.40	1.10	<.01	0.34	3.10	0.04	0.16	<2	87	1,100	2.0	2	51	12	40	24	33	33	140	<2	43	22	8	140	5	<5	650	12	32	16	2.0	170
UFMC 2-0-d	clastic	9.70	1.40	1.30	2.30	0.39	2.90	0.04	0.20	<2	29	1,100	2.0	<2	49	13	26	25	30	42	150	<2	46	22	7	77	6	<5	620	11	38	17	2.0	260
UFMC 250-75-g	clastic	10.00	1.50	1.00	2.50	0.32	3.40	0.02	0.16	<2	28	1,200	2.0	<2	46	6	16	25	29	31	130	<2	44	19	6	55	4	<5	700	11	28	11	1.0	130
UFMC 3-200-g	clastic	10.25	1.51	1.19	2.41	0.36	3.20	0.03	0.20	1	60	1,181	2.0	2	54	10	34	25	34	36	149	2	32	23	7	108	5	2	667	9	38	15	1.4	187
UFMC 3-250-g	clastic	9.41	1.45	1.20	2.20	0.28	3.15	0.01	0.18	1	116	1,016	2.0	3	59	9	36	24	38	29	136	1	29	27	5	166	5	4	633	11	42	19	1.8	237
UFMC 3-250-i	clastic	9.89	1.57	1.37	2.77	0.34	3.62	0.03	0.22	1	114	1,140	2.2	3	38	9	19	28	22	38	163	3	32	15	11	178	4	3	679	10	42	8	0.9	298
UFMC 4-0-d	clastic	8.20	0.97	1.20	1.70	0.28	2.00	0.02	0.19	<2	140	890	2.0	<2	46	16	28	21	29	35	150	<2	39	20	7	110	5	<5	440	11	37	16	2.0	210
UFMC 4-100-c	clastic	9.53	1.33	1.21	2.06	0.32	2.83	0.02	0.21	<2	32	1,055	1.8	3	56	10	29	25	36	41	124	1	30	26	6	90	5	1	588	10	39	20	1.9	220
LFMC 5-100-d	clastic	9.88	1.34	1.32	2.38	0.44	2.83	0.03	0.24	<2	29	1,059	1.9	3	58	14	28	26	34	42	184	1	35	21	8	81	6	5	596	14	46	11	1.1	221
LFMC 5-200-c	clastic	9.04	1.31	1.18	1.96	0.30	2.90	0.02	0.19	1	55	934	1.9	4	57	11	38	23	35	35	154	1	29	26	6	121	6	2	594	12	37	20	1.8	224
LFMC 6-0-c	clastic	9.10	1.20	1.60	1.80	0.33	2.40	0.02	0.20	<2	32	1,000	2.0	<2	58	14	49	24	35	40	150	<2	46	27	8	86	7	<5	510	16	48	22	2.0	220
LFMC 6-50-d	clastic	8.83	1.33	1.39	2.01	0.30	2.74	0.03	0.19	1	60	946	2.0	4	53	10	37	23	34	33	205	2	27	25	6	104	6	3	572	11	37	19	1.9	270
LFMC 6-100-d	clastic	8.90	1.40	1.00	2.00	0.25	3.10	0.02	0.14	<2	17	1,100	2.0	<2	41	7	18	22	26	26	140	<2	39	17	5	59	4		650	9	29	12	1.0	180
PMC-3c	clastic	9.58	1.57	1.19	2.50	0.40	3.37	0.04	0.20	<2	31	1,065	2.0	2	44	6	13	25	27	27	182	1	33	17	6	70	4	2	676	13	29	9	0.8	99

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Appendix 1. Locations, field parameters, and core descriptions for shallow core sites.

1a. Locations and field parameters of shallow core sites.

[Locations were determined using a portable Global Positioning System (diff indicates that differential mode was used) (NAD 27 datum). Two samples sites were determined from digitizing their locations from USGS orthophoto 7.5' quadrangle map. PMC cores are from "Panama Mine" meadows, ULGFR from a sediment-filled reservoir below the outlet to Frohner Meadows, LFMC from the lower Frohner Meadows and UFMC from the upper Frohner Meadows.]

area	line	site	type	total length (cm)	recovered length (cm)	compaction (%)	latitude (N)	longitude (W)	GPS error (m)	sampling date	GPS type
PMC		1	meadow	107	56	52	46.42962	-112.1992	23	7/19/01	
PMC		2	meadow	91	63.5	70	46.43028	-112.1992	24	7/19/01	
PMC		3	meadow	112	79	71	46.43008	-112.20089	16	7/19/01	diff
LFMC		1	tailings	125.5	84	67	46.43682	-112.19505	14	7/19/01	diff
LFMC	5	0	meadow	123	92	75	46.43734	-112.19328	6	7/19/01	diff
LFMC	5	100	meadow	137	97	71	46.43706	-112.19343	6	7/19/01	diff
LFMC	5	200	meadow	137	96	70	46.43681	-112.19353	8	7/19/01	diff
LFMC	5	300	meadow	122	71	58	46.43658	-112.1937	9	7/19/01	diff
LFMC	5	400	meadow	73	64	88	46.43627	-112.19382	17	7/19/01	
LFMC	6	0	meadow	115	75	65	46.43669	-112.19186	8	7/19/01	diff
LFMC	6	50	meadow	98.5	69	70	46.43644	-112.19191	7	7/19/01	diff
LFMC	6	100	meadow	55.5	44	79	46.43656	-112.19189	20	7/19/01	diff
UFMC		1	tailings	82.5	52	63	46.44083	-112.195	13	7/18/01	diff
UFMC	1	0	tailings	82.5	52	63	46.44323	-112.19713	15	7/17/01	
UFMC	1	40	tailings	52	46	88	46.44323	-112.19688	17	7/17/01	
UFMC	1	100	tailings	87	74	85	46.44321	-112.19667	15	7/17/01	
UFMC	1	150	tailings	111	92	83	46.4432	-112.19651	17	7/15/01	
UFMC	1	200	tailings	118	95	81	46.44316	-112.19631	17	7/17/01	
UFMC	1	250	tailings	144	115	80	46.4431	-112.19612	16	7/17/01	
UFMC	1	300	tailings	136	121	89	46.44299	-112.19587	11	7/17/01	
UFMC	1	350	tailings/meadow	48	36	75	46.44295	-112.19565	13	7/17/01	
UFMC	1	400	tailings/meadow	168	106	63	46.44298	-112.19549	13	7/17/01	
UFMC	1	500	tailings/meadow	154	122	79	46.44303	-112.19508	13	7/17/01	
UFMC	1	600	tailings/meadow	148	116	78	46.44307	-112.19467	12	7/16/01	
UFMC	1	700	tailings/meadow	86	44	51	46.44314	-112.19429	13	7/17/01	
UFMC	2	0	tailings/meadow	106	54	51	46.44217	-112.1948	11	7/18/01	diff
UFMC	2	60	tailings/meadow	86	53	62	46.44215	-112.19452	14	7/18/01	
UFMC	2	130	tailings/meadow	79	65	82	46.44213	-112.19423	15	7/18/01	
UFMC	3	0	tailings/meadow	147	122	83	46.44083	-112.19592	17	7/18/01	
UFMC	3	100	tailings/meadow	145	93	64	46.44088	-112.1955	8	7/18/01	diff
UFMC	3	200	tailings/meadow	169	105	62	46.44093	-112.19509	8	7/18/01	diff
UFMC	3	250	tailings/meadow	193	135	70	46.44095	-112.19495	8	7/18/01	diff
UFMC	3	300	tailings/meadow	200	122	61	46.44098	-112.19479	8	7/18/01	diff
UFMC	3	390	tailings/meadow	106.5	82	77	46.44102	-112.19445	20	7/18/01	
UFMC	250	75	tailings/meadow	103	75	73	46.4412	-112.1949		7/18/01	digitized
UFMC	250	200	tailings/meadow	148	89	60	46.4415	-112.1948		7/18/01	digitized
UFMC	4	0	meadow	112.5	72	64	46.44003	-112.19511	8	7/19/01	diff
UFMC	4	100	meadow	129	106	82	46.44003	-112.19475	8	7/19/01	
ULGFR		1	meadow	170	132	78	46.43616	-112.18516	9	7/14/01	diff
ULGFR		2	meadow	173	86	50	46.43599	-112.18469	12	1/15/01	diff
ULGFR		3	meadow	162.5	114	70	46.43565	-112.18484	13	1/15/01	

1b. Shallow core descriptions.

[Starting and ending depths and thickness are corrected for compaction during coring by dividing the length of recovered material by the total depth of penetration. The measured lengths of the recovered core for each subinterval were then multiplied by the inverse of the calculated value to provided corrected beginning and ending values for the interval used in the table and to provide an estimated true thickness.]

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
PMC		*1*		0.52						58
			a		0	10	10		brown soil, abundant roots, grass stems	
			b		10	29	19		gray-brown plastic clay, abundant fresh mica	
			c		29	34	5		two 2 cm layers of tan, moderately well sorted, subangular, medium quartz sand; some iron oxide grain coating bottom first layer. 1.5 cm clay layer similar to "b" separating the two layers.	
			d		34	58	24	complete interval	brown clay and tan-gray, well sorted, fine sand interlayered; sand lenses grade to coarse at bottom. Much of the sequence a mixture of clay and sand and clay-only layers.	
PMC		*2*		0.7						65
			a		0	7	7		dark brown, heavily-rooted soil; lower contact gradational	
			b		7	15	8		gray, plastic clay with abundant root impressions	
			c		15	32.5	17.5		mixture of gray clay, fine sand, and some rounded rock fragments. Coarsens downward. Cyclic sand and grus units.	
			d		32.5	52	19.5		medium gray clay, interbedded with thin fine sand stringers near top. Several 0.5-0.25 diameter charcoal fragments	
			e		52	65	13		light gray silt with fine iron oxide coated quartz sand lenses near bottom	
PMC		*3*		0.71						80
			a		0	4	4		brown, heavily rooted clay-rich, soil	
			b		4	33.5	29.5	14-39 cm	brown, clay grading to darker gray brown downward; 2 cm well sorted sand layer near middle of unit; abundant wood fragments, branches, roots	
			c		33.5	80	46.5	compete interval	3 interlayered tan quartz sand layers with some rounded weathered granite fragments (a few pebbles of well sorted, rounded, quartz sandstone). Top and bottom very poorly sorted and tan, subangular and subrounded, coarse and v. coarse sand, and coarsen downward. Middle unit (9 cm) is moderately well sorted, subangular, medium grained. Units separated by thin brown clay.	
LFMC		*1*		0.67						84
			a		0.0	3.0	3.0		dark brown soil, abundant reedy stems and roots	
			b		3.0	13.5	10.5	complete interval	tailings, moderately oxidized, mottled gray and light orange-brown, fine sand size, thinly bedded, abundant fine pyrite, alternating sulfide-rich and quartz-rich layers transition from overlying soil 0.5 cm., numerous roots,	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			c		13.5	30.0	16.5	complete interval	tailings as above with few roots, some thin oxidation bands	
			d		30.0	49.0	19.0	complete interval	dark gray-brown clay and fine tailings, numerous roots, reeds. Upper 10 cm contains sparse pyrite grains. Transitional to unit below over several centimeters. Pond deposits.	
			e		49.0	98.5	49.5	composite of 5-4 cm samples	dark gray, thinly bedded organic-rich clay, numerous fine root fibers. Pond deposits.	
			f		98.5	118.5	20.0	complete sand layers only	interbedded dark clay and fine and medium quartz sand. Five sand beds 2 cm thick, overall coarsening downward separated by 1-4 cm thick clay beds. One 1.5 cm long iron oxide on bedding plane consisting of quartz grain coatings.	
			g		118.5	125.5	7.0		gray-brown, unbedded clay	
LFMC	*5*	*0*		0.75						92
			a		0.0	19.0	19.0		dark brown grass roots and silty soil in upper part, lower contact at black organic-rich layer,	
			b		19.0	46.0	27.0		medium brown-gray clay with abundant root grass root casts in upper 13 cm.	
			c		46.0	59.0	13.0		gray, moderately sorted quartz sand; some dark gray clay.	
			d		59.0	79.0	20.0		brown clay upper half; green-gray clay lower half.	
			e		79.0	88.0	9.0		tan, sub-rounded, well-sorted quartz sand.	
			f		88.0	94.0	6.0		green-gray clay.	
			g		94.0	100.0	6.0		gray and tan, subrounded, medium, poorly-sorted quartz sand.	
			h		100.0	120.0	20.0		green-gray clay.	
			i		120.0	123.0	3.0		very poorly-sorted, medium to coarse, quartz sand and weathered rock fragments.	
LFMC	*5*	*100*		0.71						97
			a		0.0	20.0	20.0		dark brown grass roots and silty soil upper, lower contact at black organic-rich layer,	
			b		20.0	67.0	47.0		medium brown-gray clay with abundant root grass root casts in upper 28 cm.	
			c		67.0	113.0	46.0		upper contact is 0.2 cm layer of rusty poorly sorted, sub-angular coarse, quartz sand; green-gray clay, thinly bedded in lower 14 cm; mottled appearance from numerous iron oxide layers and spots.	
			d		113.0	137.0	24.0	complete interval	tan, poorly sorted fine to medium quartz sand with abundant weathered granitic pebbles in bottom 11 cm. Abundant iron oxide grain coatings. Several 0.5 cm green-gray clay beds interbedded. H_2S odor when core was first opened.	
LFMC	*5*	*200*		0.7						96
			a		0.0	21.0	21.0		dark brown grass roots and silty soil upper, lower contact at black organic-rich layer.	
			b		21.0	35.0	14.0	complete interval	medium brown gray clay with moderately abundant root grass root casts.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			c		35.0	58.0	23.0	complete interval	interbedded fine, medium and coarse quartz sand layers (2-4 cm) and brown-gray clay. Downward coarsening, at bottom coarse sand is well sorted and sub-angular.	
			d		58.0	88.5	30.5		brown silt and fine sand; upward coarsening. muscovite flakes. Some grass stalks.	
			e		88.5	137.0	48.5		tan, subrounded, interbedded fine and medium quartz sand and gray-green clay. Periglacial sediments.	
LFMC	*5*	*300*		0.58						71
			a		0.0	27.0	27.0	complete interval	meadow soil, woody debris, small volume of inorganic component; bottom at black organic-rich layer.	
			b		27.0	96.5	69.5	46-74 cm	dark gray clay, upper 14 cm very abundant roots, a few large roots and moderately abundant roots 10 cm above lower contact. Bottom 7 cm very dark organic clay.	
			c		96.5	122.0	25.5	lower 12 cm	light tan, massive, tuff (Mazama ash), gritty, very fine-grained silt size particles	
LFMC	*5*	*400*		0.88						64
			a		0.0	19.0	19.0		dark brown, silty soil with abundant grass roots upper 10 cm, grading downward to medium brown-gray clay with abundant roots, lower contact at black organic-rich layer.	
			b		19.0	39.0	20.0		dark gray-brown clay with few root casts, one dark organic-rich layer at 26	
					39.0	60.0	21.0		dark gray-brown clay; top is grass stem and root zone (0.5 cm thick); medium, well-sorted sand layer at 45 cm; bottom is poorly bedded clay with no roots.	
			c		60.0	73.0	13.0		Mazama ash; tan, fresh biotite.	
LFMC	*6*	*0*		0.65						75
			a		0.0	31.0	31.0	complete interval	brown mixture of wood fragments and silt, grading to dark gray clay with abundant roots near base.	
			b		31.0	63.0	32.0	complete interval	dark gray clay, few fine well-sorted quartz sand lenses.	
			c		63.0	77.0	14.0	complete interval	dark gray fine quartz sand with some moderately rounded granite pebbles to 1.5 x 2.5 cm.	
			d		77.0	115.0	38.0	complete interval	green-gray mixture of clay, silt, and fine-grained poorly-sorted, angular quartz sand, one large fresh granite cobble (2 x 5 cm). Periglacial sediment.	
LFMC	*6*	*50*		0.7						70
			a		0.0	11.0	11.0		brown roots, plant stalks.	
			b		11.0	30.0	19.0		dark gray clay, roots and some woody branch fragments.	
			c		30.0	61.5	31.5	complete interval	dark gray-brown clay with some roots.	
			d		61.5	83.0	21.5	middle of unit, sand with two small clay intervals	interbedded dark gray-brown clay and tan, subangular, poorly sorted, coarse quartz sand; sand in narrow cut and fill channels.	
			e		83.0	98.5	15.5		dark gray-brown clay, one 0.2 cm gray, medium sand layer.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
LFMC	*6*	*100*		0.79						44
			a		0.0	9.0	9.0		dark brown, abundant roots and grass stems	
			b		9.0	19.0	10.0		very coarse willow fragments.	
			c		19.0	31.5	12.5	complete interval	interbedded tan, fine, well-sorted quartz sand and gray clay beds, average thickness 1 cm.	
			d		31.5	55.5	24.0		tan, subangular, moderately well-sorted, medium quartz sand.	
UFMC		*1*		0.63						52
			a		0.0	7.0	7.0		tan, clay soil, indeterminate thickness (poor recovery)	
			b		7.0	41.0	34.0	complete interval	orange-brown poorly sorted, medium to coarse grained, quartz-rich tailings, no quartz chips. Coarse, 3 cm layer of iron oxide in middle of interval. Abundant woody stalks.	
			c		41.0	52.5	11.5	complete interval	upper 3 cm, mottled, red gray, clay slimes overlying clay-rich root and stem-rich lower part.	
			d		52.5	62.0	9.5		root and stem-rich layer, little non-organic material.	
			e		62.0	82.5	20.5	complete interval	upper 3 cm is gray clay with abundant roots; lower part moderately well sorted, subangular to subrounded, gray, quartz sand.	
UFMC	*1*	*0*		0.58						59
			a		0.0	15.5	15.5		orange-brown silty soil mixed with coarse subrounded rock fragments.	
			b		15.5	33.0	17.5	complete interval	yellow-brown silt-size tailings mixed with dark clay layers and some wood fragments; overbank deposit.	
			c		33.0	84.5	51.5		interbedded dark brown silt and fine sand with fresh mica. Abundant wood fragments (tree branches) mixed with clay.	
			d		84.5	102.0	17.5	complete interval	dark gray, fine sand and clay mixture, one very thin tan sand bed, abundant wood fragments.	
UFMC	*1*	*40*		0.88						46
			a		0.0	7.5	7.5	complete interval (-transition zones)	medium brown, transported soil, some clay.	
			b		7.5	21.5	14.0	complete interval (-transition zones)	tailings, dark red-brown silt size bands (1 cm thick) alternating with fine to medium, medium red-brown sand layers with some 0.2 cm quartz chips, bottom of interval is the dark red-brown silt size tailings.	
			c		21.5	37.0	15.5	complete interval (-transition zones)	medium brown sandy tailings with 0.3 milled quartz chips; some alluvial pebbles.	
			d		37.0	44.0	7.0	complete interval (-transition zones)	abundant light yellow-tan quartz chips (0.2-1.0 cm) in medium sandy tailings.	
			e		44.0	49.0	5.0	clay only	yellow-tan clay tailings slimes.	
			f		49.0	52.0	3.0	complete interval (-transition zones)	tan, poorly sorted alluvial tailings deposits, rounded granite pebbles some to 2 cm in medium sand.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
UFMC	*1*	*100*		0.85						74
			a		0.0	8.0	8.0		brown, forest soil.	
			b		8.0	15.0	7.0		brown, peat, numerous roots.	
			c		15.0	22.0	7.0		brown clay and silt with fresh mica with abundant wood fragments.	
			d		22.0	34.0	12.0		brown clay and fine sand.	
			e		34.0	46.0	12.0		fine and medium, moderately well sorted tan quartz sand.	
			f		46.0	87.0	41.0		medium to coarse unsorted sand, silt, gravel, abundant gravel-sized subangular rock fragments.	
UFMC	*1*	*150*		0.83						92
			a		0.0	11.0	11.0	complete interval (-transition zones)	light brown, poorly sorted, slightly to moderately rounded quartz chips (average 0.2 cm) mixed with fine to medium sand-size tailings. Base is transitional and iron-rich over 1 cm thick.	
			b		11.0	26.5	15.5	complete interval (-transition zones)	dark red brown, fine sand to clay, tailings. Some woody debris.	
			c		26.5	40.0	13.5	complete interval (-transition zones)	iron stained transported granite fragments, poorly sorted mod to well rounded, 1.5 cm thick and beds of well sorted, light tan, fine sand.	
			d		40.0	59.0	19.0	complete interval (-transition zones)	highly organic dark gray clay, some roots, one very dark layer 0.5 cm..	
			e		59.0	94.5	35.5	complete interval (-transition zones)	medium brown, fine-medium sand mixed with decomposed granite rock fragments (0.2-1 cm diameter), bottom 0.5 cm is dark brown cut-fill base.	
			f		94.5	111.0	16.5	complete interval (-transition zones)	moderately well sorted, medium light tan sand with well rounded rock fragments, some iron oxide patches, a few decomposed granite pebbles (0.1 cm), one charcoal fragment.	
UFMC	*1*	*200*		0.8						95
			a		0.0	5.0	5.0		light brown, very poorly sorted, silt to pebbles (to 2 cm).	
			b		5.0	30.0	25.0		light brown quartz sand tailings and rock fragments, poorly sorted, fine to medium sand at top, coarse sand at bottom, decomposed granite fragments to 0.5 cm in lower half; several dark gray clay lenses.	
			c		30.0	38.0	8.0		gray-brown, well sorted, subangular-subrounded, medium sand tailings in clay matrix	
			d		38.0	89.0	51.0		tan, subangular, poorly sorted, mottled, medium and coarse sand with abundant iron oxides in several zones and near bottom; occasional decomposed pebbles to 1 cm thick and 3.5 cm long in lower 3/4 of interval.	
			e		89.0	102.5	13.5		light brown, subangular, well sorted, fine sand; black organic-rich zone (0.25 cm thick) at bottom.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			f		102.5	118.0	15.5		tan to yellow, fine sand at top grading to medium sand at bottom with a few 0.2 cm pebbles in bottom 4 cm of interval.	
UFMC	*1*	*250*		0.8						115
			a		0.0	8.0	8.0		light red-brown, silty soil(?) layer with few rock fragment pebbles.	
			b		8.0	18.0	10.0	complete interval	yellow-tan, unsorted, silt size to 0.3 cm quartz and rock fragments, slight sulfur odor. Mixture of fine tailing slime and slope wash debris. Yellow silt layer (0.2 cm thick) at bottom.	
			c		18.0	26.0	8.0	complete interval	tan, well sorted, very fine, quartz sand tailings.	
			d		26.0	59.0	33.0	complete interval	top is very dark brown, highly organic clay layer 0.5 cm thick; fine sand and clay mixture tailings with one 1.5 cm organic layer at 44 cm. Some coarse sand size decomposed rock fragments lower 25%. Bottom of unit is 0.5 cm brown gray clay layer.	
			e		59.0	144.0	85.0	complete interval	poorly sorted, tan quartz sand with sparse decomposed rock fragments (0.2 cm). Middle of unit is iron oxide rich (4 cm zone). Poorly developed bedding (9-12 cm thick), medium sand alternating with coarse sand. Several very thin charcoal layers in bottom 25%.	
UFMC	*1*	*300*		0.89						121
			a		0	11.0	11.0		light red-brown, silty soil (?) layer with a few rock fragment pebbles	
			b		11	40.0	29.0		dark gray fine sand-clay tailings at top with very dark gray clay at bottom; separated by highly organic layer at 28 cm.	
			c		40	66.0	26.0		tan, medium-coarse, poorly sorted, quartz sand; (to 50 cm) then 2 cm layer dark brown clay, bottom is moderately well sorted fine-medium quartz sand; fresh micas throughout.	
			d		66	110.0	44.0		poorly sorted, tan quartz coarse sand and gravel with sparse sub-rounded decomposed pebbles (average 1 cm). Bottom of unit is iron oxide rich (4 cm zone). Poorly developed bedding (8-11 cm thick) with medium sand alternating with coarse sand.	
			e		110	136.0	26.0		mixed, coarse, poorly-sorted tan sand and fine gravel, medium gray-tan quartz sand, dark gray clay. Several 2.5 cm subrounded pebbles. Beds are 3-7 cm thick.	
UFMC	*1*	*350*		0.75						36
			a		0.0	23.0	23.0	complete interval	dark red brown, poorly sorted, medium to coarse quartz sand tailings with a high iron oxide content. A few angular quartz chips present.	
			b		23.0	42.0	19.0	complete interval	dark brown-gray meadow soil, abundant grass roots and stalks	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			c		42.0	48.0	6.0	complete interval	medium, subrounded to subangular, brown quartz sand	
UFMC	*1*	*400*		0.63						106
			a		0.0	3.0	3.0	complete interval	red-brown, fine sand tailings, abundant iron oxide.	
			b		3.0	20.0	17.0	composited with d	dark brown clay tailings with abundant reeds, roots.	
			c		20.0	26.0	6.0		very poorly sorted sand and pebble layer with subrounded granite pebbles up to 1.5 cm diameter mixed with tan, medium sand.	
			d		26.0	47.5	21.5		dark brown clay with abundant reeds, roots and woody material.	
			e		47.5	75.5	28.0	complete interval	light brown, medium to coarse sand with a few very thin interbedded 1 mm-thick organic-rich layers.	
			f		75.5	83.0	7.5		very dark gray to black organic-rich clay.	
			g		83.0	97.0	14.0	composite sandy layers of g, h, i	gray tan, well sorted, medium sand, few roots.	
			h		97.0	124.5	27.5		interbedded organic clay and organic-rich well sorted, medium sand, clay layers 2-4 cm thick	
			i		124.5	133.0	8.5		tan, well-sorted, medium quartz sand	
			j		133.0	154.0	21.0		interbedded organic clay and moderately well-sorted medium quartz sand, clay layers 2-42 cm thick, base is 4 cm thick reedy or grassy layer (dark gray, highly organic).	
			k		154.0	168.0	14.0		beginning of interbedded highly organic clay and medium sand.	
UFMC	*1*	*500*		0.79						122
			a		0.0	4.0	4.0		brown meadow soil.	
			b		4.0	23.0	19.0	complete interval	very poorly sorted, silt and brown, medium quartz sand tailings, some small pebbles, abundant roots.	
			c		23.0	44.0	21.0	complete interval	very poorly sorted, medium to coarse, tan quartz sand tailings; rock and quartz pebbles.	
			d		44.0	108.0	64.0	complete interval	gray clay with moderately abundant roots throughout, several thin well-sorted, subrounded, fine quartz sand lenses.	
			e		108.0	154.0	46.0	complete interval	gray, angular and subangular, very poorly sorted medium to coarse, quartz sand and granite pebbles. Three thin organic-rich soils in upper 18 cm.	
UFMC	*1*	*600*		0.78						115
			a		0.0	5.0	5.0		brown meadow soil.	
			b		5.0	40.0	35.0	complete interval	gray-brown clay with some root casts in upper 1/3.	
			c		40.0	54.0	14.0	complete interval	tan, subangular, moderately well-sorted, quartz sand with a few quartz pebbles	
			d		54.0	108.0	54.0		tan, subangular, very poorly sorted, medium to coarse quartz sand and rock and quartz pebbles. Three 0.5 cm clay layers.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			e		108.0	135.0	27.0		3 cm thick dark gray pond sediment, overlying gray, angular, medium-grained, moderately well sorted, quartz sand; 5 cm thick pond sediment layer at 126 cm. Bottom 2 cm very poorly sorted conglomerate with granite clasts to 3 cm.	
			f		135.0	148.0	13.0		black clay with 0.5 cm diameter roots trunks. t.	
UFMC	*1*	*700*		0.51						44
			a		0.0	8.0	8.0		brown root zone, some reeds	
			b		8.0	53.0	45.0		dark gray organic-rich clay, numerous roots and reed fragments.	
			c		53.0	86.0	33.0		light gray clay with light gray fine sand, top layer 1 cm, bottom sand layer 21 cm thick. Bottom 4 cm is more organic than clay above.	
UFMC	*2*	*0*		0.51			0.0			54
			a		0.0	10.0	10.0		grass stems and roots transitional to dark red brown peaty soil.	
			b		10.0	17.0	7.0	complete interval	red brown, peaty root zone with some silty transported tailings.	
			c		17.0	65.0	48.0	complete interval	very sticky dark gray clay with abundant roots 3 cm into top of unit.	
			d		65.0	106.0	41.0	complete interval	poorly sorted, angular, quartz sand and abundant decomposed granite pebbles. Grus deposit with two thin gray clay layers interbedded. Slope wash deposit.	
UFMC	*2*	*60*		0.61						77.5
			a		0.0	8.0	8.0		brown soil zone, with abundant roots.	
			b		8.0	20.5	12.5	complete interval	mixture of red-brown, angular, quartz sand tailings and silt with abundant roots.	
			c		20.5	34.5	14.0	complete interval	dark brown-gray clay, abundant roots.	
			d		34.5	70.0	35.5	complete interval	moderately well sorted, tan, subangular, quartz sand; grading from medium at top to coarse at bottom.	
			e		70.0	86.0	16.0	complete interval	dark gray brown clay. Pond deposit.	
			f		86.0	127.0	41.0		dark gray clay with abundant roots.	
UFMC	*2*	*130*		0.82						76.5
			a		0.0	17.0	17.0		dark brown silty soil with abundant grass roots with upper, lower contact at black organic-rich layer.	
			b		17.0	26.0	9.0	complete interval	tan, subangular, poorly sorted, medium to coarse, quartz sand with a few granitic pebbles.	
			c		26.0	72.5	46.5	complete interval	dark gray clay with several very thin, silt and medium quartz sand lenses. Pond deposit	
			d		72.5	79.0	6.5		very poorly sorted, medium to very coarse quartz sand and granite fragments.	
					79.0	93.0	14.0		dark gray clay. Pond deposit.	
UFMC	*3*	*0*		0.83						122

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			a		0.0	40.0	40.0	complete interval	orange-tan, subangular, fine to coarse, moderately well-sorted, quartz sand tailings; moderately thick iron oxide coatings.	
			b		40.0	88.0	48.0	40-59 cm, gray upper part	gray clay with abundant grass roots and stems several thin, fine quartz sand layers; below 59 cm black abundant grass roots and stems.	
			c		88.0	111.0	23.0	complete interval	very poorly sorted mixture of medium to coarse quartz sand and 0.5 to 1 cm decomposed granite pebbles.	
			d		111.0	134.0	23.0	complete interval	dark gray fine sand and silt, mica present, abundant root casts lower half.	
			e		134.0	147.0	13.0		very poorly sorted mixture of medium to coarse quartz sand and 0.5 to 1 cm decomposed granite pebbles.	
UFMC	*3*	*100*		0.64						93
			a		0.0	49.0	49.0	5-27 cm	medium brown gray clay tailings, no roots at top; grading to abundant roots at bottom, some 0.5 cm in diameter.	
			b		49.0	83.0	34.0	72-81 cm	black, organic-rich clay tailings with numerous roots, several 0.1 cm gray, medium quartz sand layers.	
			c		83.0	107.0	24.0		dark brown clay, few roots.	
			d		107.0	130.5	23.5	complete interval	gradational upper contact; clay with medium grained, brown gray, well sorted, subrounded sand increasing in volume downward.	
			e		103.5	145.0	41.5		brown clay, abundant roots, top is 0.5 cm thick black organic layer.	
UFMC	*3*	*200*		0.62						105
			a		0.0	5.5	5.5	complete a and b, excluding upper 2 cm of b	brown, poorly sorted, mixture of poorly developed soil and silt, and medium and coarse quartz sand tailings; some 0.4 cm quartz chips.	
			b		5.5	13.0	7.5		brown-orange silty tailings, sparse coarser sand-sized component, abundant fractured quartz.	
			c		13.0	33.0	20.0	complete interval	dark gray clay, upper 1 cm is mottled with iron oxide from tailings above; bottom 1 cm is very organic-rich with H_2S odor. Pond deposits.	
			d		33.0	55.5	22.5	complete interval	medium brown clay, abundant roots zone upper 13 cm; some large roots. Few medium 0.5 cm thick, sand lenses near bottom.	
			e		55.5	122.5	67.0		interbedded, tan, quartz sand and gray silt layers. Sand is subangular well-sorted, medium at top of sequence and medium to coarse, moderately well-sorted, subrounded at bottom; very coarse quartz sand base. Several silt-sand beds (6-8 cm) near middle of unit.	
			f		122.5	130.5	8.0	upper 29 cm	dark gray brown clay, pond deposit	
			g		130.5	169.0	38.5	upper 19 cm (excluding Mazama	interbedded silt and sand as from 55-122 cm; Mazama ash 135-138 cm, tan, biotitic.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
								ash)		
UFMC	*3*	*250*		0.7						135
			a		0.0	11.5	11.5	complete interval	bedded tailings, dark red brown, moderately well sorted, medium sand, no crushed quartz chips, some root material	
			b		11.5	23.5	12.0	complete interval	mottled red and gray silty tailings with some iron oxide-coated roots.	
			c		23.5	31.5	8.0	complete interval	red-brown, unsorted coarse tailings sand and angular quartz chips (0.1-0.5 cm).	
			d		31.5	49.0	17.5	complete interval	thin bedded, dark gray, organic-rich clay-size tailings, several very organic-rich layers. Moderate amount of reeds and roots.	
			e		49.0	56.5	7.5		reed-root layer with dark gray clay matrix.	
			f		56.5	84.0	27.5		medium gray clay with abundant fine roots.	
			g		84.0	137.0	53.0	complete interval	gray-tan, well-sorted, medium sand overlying 4 cm thick organic clay-rich layer; below clay sand is gray, well sorted, fine grained to bottom of unit.	
			h		137.0	158.5	21.5		very dark highly organic gray clay unit with 0.5 cm sandy layer in middle of interval.	
			i		158.5	193.0	34.5	complete interval	medium gray, well-sorted medium sand. A 6 cm clay-rich layer is 7 cm from bottom..	
UFMC	*3*	*300*		0.61						122
			a		0.0	29.5	29.5	complete interval	red-brown, fine sand tailings with 4 cm thick gray clay at at 13 cm. Well sorted, light brown oxidation at surface.	
			b		29.5	46.0	16.5	complete interval	medium to coarse, poorly sorted, subangular, some sub-rounded, quartz sand tailings; very iron oxide-rich.	
			c		46.0	103.0	57.0	upper 10 cm (to organic-rich layer	dark gray brown clay with at highly rooted zone at 59-66, very plastic clay. Bottom 8 cm fine sand mixed with clay.	
			d		103.0	115.5	12.5	complete interval	dark gray clay with moderately abundant root casts.	
			e		115.5	124.5	9.0	complete interval	Mazama ash, tan, fine grained, biotitic.	
			f		124.5	142.5	18.0	complete interval	dark gray clay. Pond fill deposits	
			g		142.5	200.0	57.5		interbedded gray clay and fine, well-sorted quartz sand, beds commonly 1 cm, uppermost clay is 11 cm thick. Coarse wood fragments in brown-gray clay in the bottom 19 cm. (Periglacial sediments)	
UFMC	*3*	*390*		0.77						82
			a		0.0	15.5	15.5		dark gray brown clay with abundant grass roots and stems.	
			b		15.5	36.0	20.5		dark gray clay, some organic debris.	
			c		36.0	61.5	25.5		gray, poorly sorted, medium to coarse quartz sand.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			d		61.5	106.0	44.5		dark gray clay grading to light gray green between 91-96 cm.	
			e		106.0	106.5	0.5		gray, poorly-sorted ,subangular, medium quartz sand.	
UFMC	*250*	*75*		0.73						75
			a		0.0	9.0	9.0	complete interval	very poorly-sorted subangular gravel with abundant rock fragments and quartz sand tailings, some silt size material.	
			b		9.0	22.0	13.0	complete interval	red-brown, fine gravel to medium, angular, quartz tailings sand; several 0.1 cm dark silt-rich intervals, abundant wood fragments, numerous quartz chips (0.3 cm).	
			c		22.0	33.0	11.0	complete interval	abundant wood fragments, red-brown silty tailings.	
			d		33.0	55.5	22.5	complete interval	dark gray clay with numerous thin, medium sub-rounded and sub-angular, sand lenses, stained with red iron oxide. Tailings. Numerous roots.	
			e		55.5	83.0	27.5	complete interval	gray clay with 10 cm fine gray sand-silt layer from 68-79 cm; some roots.	
			f		83.0	88.0	5.0	complete interval	dark gray clay with numerous roots.	
			g		88.0	103.0	15.0	complete interval	tan, sub-angular, well sorted, medium-coarse quartz sand.	
UFMC	*250*	*200*		0.6						89
			a		0.0	27.0	27.0	complete interval except clay	red brown, iron oxide-rich coarse to fine sand tailings, numerous quartz chips. Clay intrudes along lower contact, clay intrudes 3 cm into tailings in bottom 50% the interval.	
			b		27.0	38.0	11.0	complete interval	upper 13 cm contains very abundant roots in dark gray silty tailings, some bedding in lower organic-rich clay part of unit. Iron oxide along roots in upper 8 cm.	
			c		38.0	73.0	35.0	complete interval	medium gray quartz sand at upper and lower contacts (1 cm top, 2 cm bottom) with gray, well sorted, fine sand in middle.	
			d		73.0	88.0	15.0	complete interval	gray and black bedded clay (1 cm average bed thickness).	
			e		88.0	106.0	18.0		light tan, massive, Mazama ash.	
			f		106.0	126.5	20.5	lower 12 cm	interbedded, medium gray clay and fine-medium, moderately-sorted, gray sand lenses.	
			g		126.5	148.0	21.5		tan, subangular, poorly sorted, medium to coarse, quartz sand.	
UFMC	*4*	*0*		0.64						
			a		0.0	11.0	11.0		upper 3 cm is tan clay mixed with roots and wood fragments, grading downward to brown matted roots and willow stems.	
			b		11.0	25.0	14.0	complete interval	dark gray clay and silt, fine tailings.	
			c		25.0	67.0	42.0	complete interval	top 3 cm is root-rich zone in a somewhat mottled black and dark gray, clay.	
			d		67.0	73.0	6.0	complete interval	gray, subangular, poorly sorted, fine quartz sand, with moderate silt content.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			e		73.0	82.0	9.0		mottled gray-tan clay.	
			f		82.0	103.0	21.0		Mazama ash.	
			g		103.0	112.5	9.5		mottled gray-tan clay.	
UFMC	*4*	*100*		0.82						106
			a		0.0	26.0	26.0		brown grass stems, roots with gray clay content increasing toward bottom.	
			b		26.0	58.0	32.0		gray clay with abundant grass and willow (?) roots upper 3 cm.	
			c		58.0	107.0	49.0	sand intervals only; 18 cm total; 60-65; 76-87; 94-98	tan, subangular, moderately-sorted fine quartz sand interlayered with dark gray clay pond sediments.	
			d		107.0	129.0	22.0		dark brown peat upper 7 cm, increasing brown clay downward; bottom 1.5 cm is light gray finely bedded clay.	
ULGFR		*1*		0.78						132
			a		0.0	20.5	20.5	clay and wood mixture	reeds, grass, dark red brown fine silt with one 2 cm dark gray clay layer.	
			b		20.5	52.5	32.0	medium sand intervals only	yellow-tan, poorly sorted, medium-coarse sand with a few decomposed granite pebbles; top 5 cm interbedded with light brown clay containing abundant roots. One grain of rounded pyrite observed.	
			c		52.5	59.5	7.0	complete layer and upper part of d	2 cm transition to a dark gray, clay-rich layer, much fresh mica, some thin roots.	
			d		59.5	77.0	17.5		black peat with abundant reeds and willow fragments. Transition to next layer below is marked by the decrease in woody material.	
			e		77.0	91.0	14.0		dark gray, highly organic silt, fresh mica, some woody material.	
			f		91.0	106.0	15.0	complete interval	tan-gray, well-sorted ,medium quartz sand, with 1 cm dark gray clay layer in the middle of the unit.	
			g		106.0	128.0	22.0		woody, reedy interval mixed with dark gray clay.	
			h		128.0	152.5	24.5	complete interval	very poorly-sorted, coarse sand mixed with moderately rounded pebbles up to 2 cm in diameter, most 0.5 cm; interbedded with thin clay layers. Heavy manganese oxide coatings of quartz grains.	
			i		152.5	164.0	11.5		medium tan-gray clay.	
			j						extremely poorly sorted medium to coarse sand and pebbles.	
ULGFR		*2*		0.5						86
			a		0.0	9.0	9.0	complete interval	tan, poorly sorted, subangular and angular, medium and coarse sand.	
			b		9.0	25.5	16.5	complete interval	abundant woody debris and medium tan, medium sand.	

area	line no.	core no.	sub-inter-val	comp-action	start (cm)	end (cm)	thickness (cm)	sampled	Description	total recovered length (cm)
			c		25.5	67.5	42.0	complete interval	black, bedded silt, some tan, fine quartz sand lenses. Abundant woody debris and fresh muscovite.	
			d		67.5	132.0	64.5	81-111 cm	interbedded medium gray clay, silt, and fine sand. Sand is well-sorted, subangular and subrounded. Lower 13 cm is very plastic light gray clay, bottom 1 cm is gray, poorly sorted, medium to coarse sand with some small gravel-size quartz.	
ULGFR		*3*		0.7						114
			a		0.0	37.0	37.0	0-28.5 cm	alternating dark orange-brown, grass stems and roots and tan, poorly-sorted, subangular, coarse to very coarse quartz sand. Silty intervals immediately below stem-rich layers are tan to dark gray, some with abundant organics.	
			b		37.0	53.0	16.0		tan, well-sorted fine quartz sand at top with very coarse woody debris near bottom of unit. Bottom is very dark gray clay.	
			c		53.0	157.0	104.0	54-79 cm	gray-brown clay alternating with 1-4 cm thick tan , well-sorted, subrounded fine sand. A few poorly sorted tan, subangular, fine quartz sand lenses (3 cm thick). Near top, is a 5 cm of gray, a mixture of clay and fine sand with occasional subrounded granite pebbles; 13 cm from bottom is a 3 cm layer of medium moderately well sorted quartz sand with a 3 cm long subrounded quartz monzonite cobble.	
			d		157.0	174.0	17.0	complete interval	very poorly sorted quartz sand and silt with abundant coarse gravel- and pebble- sized rounded rock fragments. H_2S smell very apparent. Manganese oxide pebble coatings abundant.	
			e		174.0	190.0	16.0	complete interval	mottled gray and orange-tan clay, silt, and coarse quartz sand, rounded granite pebbles and one 2.5 x 5 cm angular, fresh quartz monzonite cobble. Unit is extremely poorly sorted.	

Appendix 2. QA/QC data for solid samples.

Appendix 2a. Means, standard deviations, certified values and percent recovery for SRMS's, NIST 2704, NIST 2709, and NIST 2711 for samples analyzed by mixed-acid digestion ICP-AES technique.

Standard		Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm
NIST 2704	MEAN (n=10)	6.13	2.62	4.03	1.98	1.21	0.60	0.10	0.30	< 2	24	437	2.0	5.5	59.7	16.1	136	99.4
	STD DEV	0.17	0.06	0.08	0.08	0.03	0.03	0.00	0.03	-	6.7	17.7	0.0	0.7	4.1	1.2	8.4	4.6
	% RSD	2.8	2.4	2.0	4.0	2.6	4.2	4.1	9.9	-	27.9	4.0	0.0	12.9	6.9	7.4	6.2	4.7
	CERTIFIED	6.11	2.60	4.11	2.00	1.20	0.55	0.10	0.46	-	23.4	414	-	3.45	72	14	135	98.6
	% RECOVERY	100	101	98	99	101	108	102	65	-	103	106	-	159	83	115	101	101
NIST 2709	MEAN (n=10)	7.39	1.91	3.51	1.98	1.51	1.18	0.06	0.34	< 2	21.3	899	3.6	2.9	42.2	13.5	121	35.8
	STD DEV	0.20	0.03	0.10	0.10	0.03	0.05	0.01	0.0	-	8.0	33.1	0.5	0.6	2.6	2.4	3.2	5.4
	% RSD	2.7	1.7	2.1	3.2	2.1	4.1	8.1	4.8	-	37.4	3.7	14.3	19.6	6.1	17.5	2.6	15.0
	CERTIFIED	7.50	1.89	3.50	2.03	1.51	1.16	0.06	0.34	-	17.7	968	-	-	42	13	130	35
	% RECOVERY	99	101	100	98	100	102	17	99	-	120	93	-	-	100	104	93	102
NIST 2711	MEAN (n=10)	6.49	2.83	2.86	2.41	1.06	1.18	0.09	0.28	4.4	102	696	2.0	36.3	68.2	8.7	43.4	118
	STD DEV	0.22	0.07	0.08	0.12	0.10	0.04	0.01	0.02	0.50	7.8	32.0	0.0	3.0	4.2	0.80	1.8	7.9
	% RSD	3.5	2.4	2.9	5.0	9.1	3.3	6.2	5.7	11.2	7.7	4.6	0.0	8.2	6.2	9.5	4.1	6.7
	CERTIFIED	6.53	2.88	2.89	2.45	1.05	1.14	0.086	0.31	4.6	105	726	-	42	69	10	47	114
	% RECOVERY	99	98	99	98	101	103	99	89	97	97	96	-	86	99	87	92	104
Standard		**Ga ppm**	**La ppm**	**Li ppm**	**Mn ppm**	**Mo ppm**	**Nb ppm**	**Nd ppm**	**Ni ppm**	**Pb ppm**	**Sc ppm**	**Sn ppm**	**Sr ppm**	**Th ppm**	**V ppm**	**Y ppm**	**Yb ppm**	**Zn ppm**
NIST 2704	MEAN (n=10)	14.6	31.1	47.0	570	4.2	23.1	29.9	44.1	148	11.5	9.5	135	9.5	93.7	22.0	2.2	420
	STD DEV	0.50	1.7	2.3	20.5	1.1	6.5	2.0	1.0	15.5	0.50	2.3	5.3	0.50	2.8	0.9	0.40	26.2
	% RSD	3.5	5.6	4.8	3.1	27.0	28.2	6.6	2.3	10.5	4.6	23.9	3.9	5.5	3.0	4.3	19.2	6.2
	CERTIFIED	15	29	50.0	555	-	-	-	44.1	161	12	12	130	9.2	95	-	-	438
	% RECOVERY	97	107	94	103	-	-	-	100	92	96	79	104	103	99	-	-	96
NIST 2709	MEAN (n=10)	14.9	23.4	54.2	541	2.3	28.9	18.1	80.8	20.6	11.8	5.5	231	12.6	113	15.7	2.0	108
	STD DEV	0.7	1.2	5.0	12.0	0.50	9.7	1.0	2.3	3.7	0.40	0.70	7.4	0.70	4.8	0.5	0.0	6.6
	% RSD	5.0	5.0	9.2	2.2	20.6	33.6	5.5	2.8	18.2	3.6	12.9	3.2	5.5	4.3	3.1	0.0	6.2
	CERTIFIED	14	23	55	538	2	-	-	88	18	12	-	231	11	112	18	1.6	106
	% RECOVERY	106	102	99	101	113	-	-	92	114	98	-	100	117	101	87	125	102
SRM 2711	MEAN (n=10)	15.7	38.4	26.8	630	2.0	38.1	29.7	21.7	1100	9.1	6.0	243	14.6	81.2	25.8	2.6	346
	STD DEV	0.7	1.6	1.7	14.9	0.0	11.4	1.1	1.1	116.0	0.3	0.8	8.2	1.1	1.6	0.8	0.5	11.7
	% RSD	4.3	4.1	6.3	2.4	0.0	30.0	3.6	4.9	10.5	3.5	13.6	3.4	7.4	2.0	3.1	19.9	3.4
	CERTIFIED	15	40	-	638	1.6	-	31	21	1162	9.0	-	245	13.6	82	25	2.7	350
	% RECOVERY	105	96	-	99	125	-	96	103	95	101	-	99	107	99	103	96	99

Appendix 2b. Field duplicate pairs analyses for streambed sediments samples using the total digestion, mixed-acid ICP-AES technique.

Field No.	Sample Description	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm
C-100	medium sand	7.4	0.76	4.3	3.2	0.50	1.6	0.09	0.24	7	730	1,000	2	4	56	7	30	88
C-100d	field duplicate of C-100	6.6	0.64	3.1	2.6	0.42	1.5	0.09	0.21	4	210	850	2	3	43	3	37	87
C-102	sand and gravel	8.2	2.1	5.6	2.1	0.50	2.8	0.14	0.26	2	<10	790	2	4	110	12	40	13
C-102r	field duplicate of C-102	7.7	1.8	11	2.0	0.55	2.4	0.14	0.29	<2	16	700	2	6	110	30	83	15
C-103	sand and gravel	8.1	2.4	5.8	2.7	0.82	1.8	0.16	0.40	<2	49	950	2	12	100	18	33	43
C-103r	field duplicate of C-103	7.7	2.1	5.6	2.4	0.72	1.7	0.14	0.36	<2	42	860	2	13	97	12	28	51
C-3	coarse and medium sand	7.6	1.4	5.1	3.1	0.78	0.9	0.12	0.38	<2	51	820	2	12	90	14	43	50
C-3r	field duplicate of C-3	7.6	1.4	5.8	3.0	0.70	1.0	0.12	0.42	<2	44	770	2	9	88	13	49	32
C-4	sand and gravel	6.9	1.4	5.8	2.5	0.73	1.0	0.16	0.26	11	1,300	790	3	51	87	22	60	700
C-4r	field duplicate of C 4	7.4	1.4	7.4	2.6	0.70	1.2	0.15	0.29	11	1,400	790	3	36	91	24	77	590
D-1	medium sand	7.4	2.6	8.9	2.0	0.83	2.3	0.17	0.43	<2	<10	640	2	6	180	21	58	26
D-1r	field duplicate of D 1	7.3	2.6	11	1.9	0.71	2.4	0.16	0.52	<2	<10	610	2	6	200	26	74	29
L-100	coarse gravel and sand	7.6	0.99	5.8	1.9	0.27	1.6	0.06	0.09	45	3,900	1,000	3	110	49	140	9	400
L-100r	field duplicate of L-100	7.6	0.98	4.8	1.9	0.25	1.8	0.05	0.09	25	3,200	400	2	57	42	84	6	300
L-3b	fine and medium sand	6.7	1.1	8.4	1.6	0.26	1.5	0.13	0.09	4	1,600	1,600	3	170	61	130	9	290
L-3br	field duplicate of L-3b	8.6	1.4	4.9	1.9	0.25	2.8	0.09	0.11	<2	640	1,000	3	90	55	77	4	140
L-4	silt, fine sand, muck	7.8	2.2	4.6	2.4	0.84	2.2	0.13	0.38	<2	30	660	3	18	120	14	29	55
L-4r	field duplicate of L-4	7.4	1.7	3.4	1.9	0.45	2.2	0.12	0.18	<2	72	870	2	37	71	4	14	52
L-4a	sandy sediment	9.3	1.9	3.8	2.3	0.45	3.1	0.09	0.20	<2	83	970	2	21	84	7	11	28
L-4ar	field duplicate of L-4a	8.8	1.7	2.3	2.2	0.29	2.9	0.06	0.16	<2	37	880	2	14	64	<1	10	22
PP-3	medium sand	5.9	1.5	4.6	2.1	0.62	1.2	0.11	0.28	15	390	620	2	19	74	9	39	420
PP-3r	field duplicate of PP-3	6.5	1.7	5.6	2.2	0.77	1.4	0.14	0.32	13	360	570	2	15	83	12	46	440
PP-5	medium sand	6.6	2.8	14	1.8	0.98	1.8	0.26	0.61	2	59	680	2	12	230	42	140	71
PP-5r	field duplicate of PP-5	7.2	2.7	12	2.0	0.86	2.2	0.21	0.48	2	45	600	2	9	160	41	120	54
S-3	sand	7.7	2.0	5.7	2.5	0.80	1.8	0.13	0.38	<2	34	710	2	12	100	15	42	51
S-3r	field duplicate of S-3	7.6	1.6	4.6	2.7	0.46	2.0	0.10	0.27	6	300	870	2	11	69	6	35	260
S-4	sand and gravel	5.00	1.2	5.3	1.9	0.48	0.75	0.09	0.17	36	780	620	2	52	65	5	32	960
S-4r	field duplicate ofOF S-4	5.6	1.3	6.2	2.0	0.51	0.95	0.12	0.22	38	720	620	2	41	82	8	43	940

2b. (continued)

Field No.	Sample Description	Ga ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th pm	V ppm	Y ppm	Yb ppm	Zn ppm
C-100	medium sand	18	31	23	660	<2	23	24	11	450	8	13	380	13	66	14	2	400
C-100d	field duplicate of C-100	15	25	18	440	2	38	20	10	330	6	15	320	10	70	12	1	310
C-102	sand and gravel	19	68	16	880	<2	27	42	11	32	8	<5	570	17	160	25	3	90
C-102r	field duplicate of C-102	21	63	18	620	<2	44	47	15	29	9	<5	460	32	340	25	3	89
C-103	sand and gravel	21	56	22	8,700	2	<4	37	18	150	13	<5	440	33	150	31	4	1,800
C-103r	field duplicate of C-103	21	59	20	8,200	3	<4	36	19	160	12	<5	390	22	120	27	3	2,200
C-3	coarse and medium sand	20	50	22	7,100	4	5	30	21	230	12	<5	290	23	140	24	3	1,400
C-3r	field duplicate of C-3	20	52	17	4,600	4	24	32	19	200	11	<5	290	26	170	21	2	1,100
C-4	sand and gravel	21	50	23	12,000	3	<4	30	35	1,400	12	<5	280	15	150	34	3	7,400
C-4r	field duplicate of C 4	22	54	21	7,900	4	<4	37	30	1,300	12	6	290	17	220	30	3	5,800
D-1	medium sand	17	100	18	700	7	36	66	14	20	14	<5	480	140	280	42	5	54
D-1r	field duplicate of D 1	20	120	13	730	5	82	80	14	19	14	7	460	170	340	49	6	54
L-100	coarse gravel and sand	28	28	55	29,000	9	<4	<4	33	4,900	5	7	390	24	44	25	3	7,700
L-100r	field duplicate of L-100	27	23	49	18,000	7	<4	6	19	3,800	4	5	420	5	40	17	2	4,400
L-3b	fine and medium sand	24	41	27	30,000	8	<4	7	40	660	6	7	380	38	47	34	4	12,000
L-3br	field duplicate of L-3b	24	37	25	10,000	5	<4	20	17	320	5	<5	620	10	42	20	2	5,600
L-4	silt, fine sand, muck	20	68	34	2,600	3	29	45	16	52	12	<5	420	29	120	37	4	1,300
L-4r	field duplicate of L-4	18	44	28	4,300	5	15	31	14	58	8	<5	470	15	58	27	3	2,800
L-4a	sand	23	50	26	2,400	2	21	30	10	63	6	<5	690	35	57	17	2	2,100
L-4ar	field duplicate of L-4a	22	40	18	890	2	44	25	7	56	4	<5	650	17	50	12	2	1,100
PP-3	medium sand	17	44	21	10,000	6	<4	21	16	2,400	8	8	270	30	120	22	2	3,300
PP-3r	field duplicate of PP-5	19	48	25	6,900	7	4	31	17	1,800	11	9	310	34	150	26	3	2,600
PP-5	medium sand	18	140	17	2,200	3	26	90	22	230	17	9	380	150	470	54	7	910
PP-5r	field duplicate of PP-5	21	92	18	1,700	4	64	65	19	220	15	<5	420	82	380	44	5	680
S-3	sand	19	57	20	2,400	3	26	38	16	180	12	<5	420	23	180	28	3	1,200
S-3r	field duplicate of S-3	20	40	18	1,300	4	42	28	13	890	8	<5	480	13	110	14	2	1,700
S-4	sand and gravel	24	34	30	22,000	4	<4	9	16	5,400	8	10	230	25	110	22	2	7,300
S-4r	field duplicate ofOF S-4	24	47	26	19,000	5	<4	21	17	4,900	8	7	250	16	140	24	3	6,900

Appendix 2c. Laboratory duplicate pairs analyzed by the total digestion, mixed-acid ICP-AES technique.

Field No.	Sample Description	Al %	Ca %	Fe %	K %	Mg %	Na %	P %	Ti %	Ag ppm	As ppm	Ba ppm	Be ppm	Cd ppm	Ce ppm	Co ppm	Cr ppm	Cu ppm
300066	NURE re-analysis	7.2	2.3	4.8	2.0	0.88	2.1	0.15	0.34	< 2	13	660	2	4	120	13	34	67
300066r	NURE re-analysis	7.4	2.4	4.9	2.0	0.87	2.1	0.15	0.35	< 2	10	670	2	4	110	8	33	66
UFMC 2-0-c	shallow core	10	1.3	1.9	1.7	0.50	1.7	0.04	0.24	2	64	900	2	3	77	<1	21	72
UFMC 2-0-cr	shallow core	9.4	1.2	1.9	1.6	0.47	1.5	0.04	0.26	<2	59	880	2	3	70	<1	20	65
UFMC 3-250-i	shallow core	10	1.8	1.6	3.2	0.35	4.2	0.04	0.27	<2	140	1,300	3	3	28	<1	10	23
UFMC 3-250-ir	shallow core	9.3	1.4	1.2	2.4	0.33	3.0	0.03	0.18	<2	87	1,000	2	2	47	<1	7	15
B-100	sandy sediment	7.5	2.4	3.6	2.7	1.1	1.8	0.15	0.42	<2	15	590	2	3	94	14	19	110
B-100r	sandy sediment	7.8	2.5	3.6	2.8	1.1	1.8	0.15	0.42	<2	<10	630	2	3	98	12	19	110
C-204	sandy sediment	7.3	1.9	8.9	2.4	1.0	1.2	0.13	0.65	<2	31	710	2	39	110	21	86	220
C-204r	sandy sediment	7.5	2.0	8.6	2.5	1.0	1.2	0.14	0.64	<2	32	700	2	40	120	22	83	220
C-5	coarse and medium sand	8.1	2.2	3.8	2.9	0.72	2.2	0.14	0.32	<2	120	760	2	8	86	10	28	63
C-5r	coarse and medium sand	7.7	2.1	3.5	2.7	0.73	2.0	0.12	0.28	<2	120	750	2	8	86	9	22	67
PMC-1d	shallow core	8.4	1.2	1.5	1.7	0.31	2.3	0.03	0.19	<2	48	820	2	3	60	<1	11	34
PMC-1dr	shallow core	8.8	1.2	1.5	1.8	0.32	2.2	0.04	0.19	<2	28	850	2	3	60	<1	13	33
RES-2e	lake bottom core	6.3	1.1	4.5	1.3	0.52	1.0	0.08	0.21	2	290	470	2	40	72	33	18	150
RES-2er	lake bottom core	6.2	1.1	4.5	1.3	0.53	1.0	0.08	0.21	2	290	600	2	40	74	32	18	160
S-202	sandy sediment	8.2	1.6	1.6	2.6	0.46	2.3	0.08	0.17	<2	42	960	2	4	33	<1	21	66
S-202r	sandy sediment	8.2	1.6	1.6	2.6	0.46	2.3	0.08	0.17	<2	36	940	2	4	38	<1	22	69

2c. (continued)

Field No.	Sample Description	Ga ppm	La ppm	Li ppm	Mn ppm	Mo ppm	Nb ppm	Nd ppm	Ni ppm	Pb ppm	Sc ppm	Sn ppm	Sr ppm	Th ppm	V ppm	Y ppm	Yb ppm	Zn ppm
300066	NURE re-analysis	18	76	28	710	4	37	50	14	24	11	6	520	88	130	28	3	69
300066r	NURE re-analysis	18	69	28	700	4	39	48	13	19	11	< 5	540	69	130	29	3	65
UFMC 2-0-c	shallow core	27	51	72	220	2	47	40	13	140	10	<5	420	19	62	38	4	740
UFMC 2-0-cr	shallow core	24	45	62	210	2	47	35	12	140	9	<5	390	16	60	35	3	720
UFMC 3-250-i	shallow core	32	16	44	190	4	34	12	12	210	4	<5	730	9	48	8	1	340
UFMC 3-250-ir	shallow core	23	29	32	140	2	30	18	9	140	4	<5	620	11	35	9	<1	250
B-100	sandy sediment	16	53	16	1,500	8	32	39	15	36	14	7	390	32	86	33	4	140
B-100r	sandy sediment	16	56	16	1,400	7	37	40	14	35	14	<5	400	27	86	33	4	140
C-204	sandy sediment	24	61	21	8,000	4	8	43	34	230	16	<5	270	37	320	41	4	4,000
C-204r	sandy sediment	22	71	22	8,100	13	<4	46	34	220	17	<5	280	26	300	42	4	4,000
C-5	coarse and medium sand	19	47	19	1,700	<2	28	34	13	170	11	<5	480	29	110	25	3	760
C-5r	coarse and medium sand	18	46	19	1,900	<2	22	32	13	180	10	<5	470	17	93	22	2	840
PMC-1d	shallow core	22	40	34	170	<2	26	32	7	85	6	<5	460	13	39	25	2	130
PMC-1dr	shallow core	23	41	36	180	<2	27	32	7	72	6	<5	470	12	40	26	2	140
RES-2e	lake bottom core	16	43	42	2,400	4	12	35	17	180	10	<5	240	18	72	34	3	3,400
RES-2er	lake bottom core	16	45	42	2,500	4	11	37	16	180	10	<5	240	19	73	35	3	3,400
S-202	sandy sediment	21	20	30	570	<2	43	15	9	260	5	<5	620	6	31	10	1	240
S-202r	sandy sediment	22	22	30	560	<2	42	16	10	260	5	<5	620	7	31	10	1	250

Appendix 2d. Comparisons of SRM's NIST 2709 and NIST 2711 analyzed from 2M HCl-1% hydrogen peroxide partial extractions from this study with the partial extraction analyses of the same SRM's from a previous study (Fey and others, 1999).

NIST 2709		**Ag ppm**	**Al ppm**	**As ppm**	**Ba ppm**	**Ca ppm**	**Cd ppm**	**Co ppm**	**Cr ppm**	**Cu ppm**	**Fe ppm**	**K ppm**	**Li ppm**
other studies	**MEAN (n=26)**	< 2	9,770	< 10	373	15,100	< 2	10.2	38.6	21.5	15,300	2,000	18.9
	STD DEV	--	817	--	27.0	1,075	--	1.7	3.2	2.0	1,659	186	1.5
	REL STD DEV	--	8.4	--	7.2	7.1	--	17	8.3	9.2	11	9.3	7.7
this study	**MEAN (n=3)**	< 2	8,533	<10	310	12,300	< 2	9.6	35.0	19.0	12,670	1,700	16.0
	STD DEV	--	1,290	--	61.0	2,140	--	0.7	6.1	3.0	1,530	265	2.6
	REL STD DEV	--	15	--	20	17	--	7.0	18	16	12	16	17
		Mg ppm	**Mn ppm**	**Mo ppm**	**Na ppm**	**Ni ppm**	**P ppm**	**Pb ppm**	**Si ppm**	**Sr ppm**	**Ti ppm**	**V ppm**	**Zn ppm**
other studies	**MEAN (n=26)**	8,520	424	< 2	577	58.2	502	12.0	1,790	92.3	228	34.4	57.5
	STD DEV	628	27.0	--	79	4.4	34	7.0	328	5.7	84	2.9	6.6
	REL STD DEV	7.4	6.3	--	14	7.5	6.7	58	18	6.2	37	8.5	12.0
this study	**MEAN (n=3)**	7,900	397	< 2	510	54.0	473	8.5	2,067	80.0	106	30.0	66.0
	STD DEV	917	25.0	--	98	7.8	83.0	1.3	586	13.0	32	3.0	7.2
	REL STD DEV	12	6.0	--	19	14	18	15	28	16	30	10	11
NIST 2711		**Ag ppm**	**Al ppm**	**As ppm**	**Ba ppm**	**Ca ppm**	**Cd ppm**	**Co ppm**	**Cr ppm**	**Cu ppm**	**Fe ppm**	**K ppm**	**Li ppm**
other studies	**MEAN (n=25)**	3.9	6,690	82	183	23,000	40.0	7.2	8.1	89.6	8,160	2,200	6.4
	STD DEV	0.5	681	9.6	19	2,440	4.0	1.0	1.0	7.8	956	273	0.8
	REL STD DEV	12.0	10	12	10	11	10	14	13	8.7	12	12	12
this study	**MEAN (n=4)**	3.1	5,550	68	150	17,800	34.0	5.7	6.2	77.0	6,925	1,825	5.4
	STD DEV	0.2	614	8.0	29	3,202	7.0	0.5	0.9	13	499	263	0.5
	REL STD DEV	5.0	11	12	20	18	20	9.0	14	16	7.0	14	9.0
		Mg ppm	**Mn ppm**	**Mo ppm**	**Na ppm**	**Ni ppm**	**P ppm**	**Pb ppm**	**Si ppm**	**Sr ppm**	**Ti ppm**	**V ppm**	**Zn ppm**
other studies	**MEAN (n=25)**	4,940	487	< 2	165	11.6	718	1,180	2,200	42.9	350	16.4	252
	STD DEV	508	46	--	26	1.2	66	105	376	4.1	53	2.3	21.0
	REL STD DEV	10	9.5	--	15	10	9.2	8.9	17	9.5	15	14	8.2
this study	**MEAN (n=4)**	4,275	448	< 2	140	10.8	620	970	2,180	34.0	215	13.0	242
	STD DEV	499	19	--	23	1.0	104	154	670	5.2	30	1.2	15
	REL STD DEV	12	4.0	--	16	13	17	16	31	15	14	9.0	6.0

Appendix 2e. Certified and analyzed values for water-quality standards run with EPA-1312 leach solutions analyzed by ICP-AES.

Certified values	Al mg/L	As µg/L	B µg/L	Ba µg/L	Be µg/L	Ca mg/L	Cd µg/L	Co µg/L	Cu µg/L	Fe mg/L	K mg/L	Mn µg/L	Ni µg/L	Pb µg/L	Si mg/L	Sr µg/L	Zn µg/L	SO_4^{2-} mg/L
USGS WRD AMW-3	21	72	153	4.5	12	320	121	133	4,670	143	3.5	82,800	206	15	22.4	1,474	41,450	
USGS-WRD M-100			425			180					4.5				4.77	3,450		1,180
USGS-WRD M-130			8.9			21					3.0				4.3	180		58
NIST 1643d	0.128	56	145	506	12	31	6.5	25	21	0.090		18	58	18		295	72	
USGS-WRD T-153	0.035	0.50	99	184		28	16		24	0.075	1.6	75	32	43	2.7	311	73	
USGS-WRD T-159	0.032	28	26	38	11	26	24	13	33	0.049	1.5	22	22	17	5.4	190	19	
USGS-WRD T-161	0.032	26	37	70	13	7.2	17	13	22	0.062	1.3	37	29	16	6.9	54	41	
Analyzed values	**Al mg/L**	**As µg/L**	**B µg/L**	**Ba µg/L**	**Be µg/L**	**Ca mg/L**	**Cd µg/L**	**Co µg/L**	**Cu µg/L**	**Fe mg/L**	**K mg/L**	**Mn µg/L**	**Ni µg/L**	**Pb µg/L**	**Si mg/L**	**Sr µg/L**	**Zn µg/L**	**SO_4^{2-} mg/L**
USGS WRD AMW-3	21.1	73	23	4	13	334	127	173	5,120	153	4.2	95,300	275	< 10	24	1,630	42,600	
USGS-WRD M-100			428			146					4.8				5.1	3,470		1,170
USGS-WRD M-130			7			23					3.3				4.6	194		58
NIST 1643d	0.067	< 100	135	502	13	33	5.3	24	18	0.05		33	66	17		306	73	
USGS-WRD T-153	< 0.01	< 100	94	187		29	15		21	<0.05	1.7	73	39	43	2.7	319	79	
USGS-WRD T-159	< 0.01	< 100	23	38	11	27	24	13	31	< 0.05	1.6	16	30	7.5	5.4	195	30	
USGS-WRD T-161	< 0.01	< 100	34	72	14	8	19	15	20	< 0.05	1.3	33	34	9.6	6.8	54	47	