APPENDIX F

Mass-Balance Calculations

Mass-Balance Calculations for Metals Contribution from Eroded Mine Waste

Statement of Problem

Mine-waste deposits are present within the Upper Arkansas River floodplain (500-year floodplain) and some lie along the banks of the river's main channel. The deposits located along the main-channel banks are potentially susceptible to erosion and transport by river flow, especially during bank-full flow conditions. Mine waste eroded from the banks then contributes to either the total metals load carried downstream as suspended and bed-load sediment or the dissolved metals load when metals are released from mine waste to solution. The purpose of the mass-loading calculations described below is to specifically evaluate the dissolved metals load that could be contributed to the Upper Arkansas River by erosion of mine waste from the channel banks during bank-full flow conditions.

Explanation of Approach and Assumptions

In order to evaluate the contribution of mine-waste erosion to the dissolved metals content of river water, river flow and mine-waste characteristics along the river reach between California Gulch and the bottom of Reach 3, approximately 9.5 miles downstream of California Gulch, (Site Characterization Report's Reaches 1, 2 and 3; InterFluve's [1999] subreaches 2 through 6) were described from existing sources of data. Some of the mine-waste deposits present along these river reaches are susceptible to erosion and entrainment due to channel migration (InterFluve 1999). These are also the river reaches where the locations and extent of mine-waste deposits have been delineated and mapped to date.

<u>Mine-Waste Erosion from Channel Banks</u>

Mine-waste deposits within the 500-year floodplain were originally mapped by USEPA (URS, 1997), and we used those maps to identify the mine-waste deposits that lie along the main-channel banks. Mine-waste deposits in contact with the main channel are on average less than 2-feet thick. We assume an average mine-waste thickness at the main-channel banks of 1 foot and also assume that the entire thickness at the banks has the potential for erosion by river flow during bank-full conditions. We also conservatively assume that mine-waste deposits from any location along the main-channel bank have equal potential to be eroded and entrained in river flow.

Metals Release from Mine Waste to Solution

The average metals content of each mine-waste deposit mapped along the Arkansas River, estimated from all available sample data including data for surficial samples, was used to describe the mass of metals associated with a unit mass of those mine wastes.

Metals are present in various forms within the mine-waste deposits. Previous studies of soil and mine waste in the river's floodplain have shown that cadmium, lead and zinc are primarily associated with iron and manganese oxide phases (Levy et al., 1992) and that metals are readily leached from mine waste (Smith et al., 1998). Given these observations, we assumed that the observed metals leaching from mine waste (by water) was controlled primarily by desorption from secondary mineral phases (e.g. hydrous oxides), and possibly organic matter, rather than by dissolution of the primary mineral phases (carbonates and sulfides). Secondary salts, such as soluble sulfate salts, commonly form on the upper surfaces of mine-waste deposits and have been observed on some mine wastes and other floodplain deposits along the upper Arkansas River (Levy et al., 1992; Smith et al., 1998). These salts are generally soluble in water and may also release metals when mine wastes are entrained by river water.

Work performed by Smith et al. (1998) demonstrates that lead is readily leached from the upper portions of the mine-waste deposits present along the Arkansas River. In a series of batch leaching experiments on depth-specific, mine-waste core samples, lead partitioning to water was greatest in samples from the surface layer and lowest in deeper layers. The resultant empirical partition coefficients (Kd = concentration in solid/concentration in solution) for lead, from all of the mine-waste samples evaluated including those from the surface layer, range from approximately 765 to 30,000 L/Kg. Because the mass of metals associated with the surface salts and their occurrence within the floodplain are not known, the release of metals from soluble surface salts was considered by adopting the conservative assumptions described below.

Once mine wastes are eroded and entrained by river water, we assume that distribution of metals to the dissolved phase is controlled by equilibrium partitioning rather than by precipitation and dissolution reactions. The presence of readily water-soluble forms of metals at the mine-waste surface was considered when partition coefficients were selected to describe metals release from mine waste; very conservative (low Kd values; i.e., relatively greater partitioning from solid to water) estimates of metals release were used in the mass-balance calculations. The Kd values selected are likely to be too low to accurately describe metals release from mine waste at depth within the deposits and result in over-estimation of dissolved concentrations. We also conservatively assume that once metals are released to solution they remain in solution without sorption or other removal processes retarding their transport.

Based on descriptions of bed sediments from the Arkansas River (Kimball et al., 1995) that contain metals transported downstream from the mine-waste deposits this is appears to be an overly conservative assumption as well.

Dissolved Metals Mass-Load Calculation

Calculation of the net metals mass load and resultant dissolved metals concentrations was performed for defined subreaches of the Arkansas River using a simple spreadsheet (table attached).

For the purposes of these calculations, we assumed that metals are distributed between solid mine waste and the dissolved phase in accordance with equilibrium partitioning behavior once those mine wastes are eroded and entrained by river water. Dissolved-phase metals are transported conservatively, and the dissolved-metals load increases downstream in proportion to the mass of mine waste eroded by the river. The result is an estimate of the net dissolved-metals load at a location downstream of mine-waste deposits that may be contributed from the eroded mine waste.

Mine-waste erosion to river water was estimated from the total length of tailing in contact with the main channel and an estimated bank erosion rate for mine waste in contact with the main channel. The weighted average metals concentration of mine waste eroded along a specified subreach of the river was estimated by summing the average metal concentration for each tailing deposit times the proportion of total mine waste length represented by each deposit along the subreach. The mass of metals released to the dissolved phase from the mass of mine waste eroded was computed using estimates of an equilibrium partition coefficient for each metal at chemical conditions representative of Upper Arkansas River water at bank-full flow conditions. The net mass of dissolved metals contributed to the river flow and resulting net change in dissolved concentrations along the defined subreach was then computed and summed to obtain an estimate of the dissolved metal concentration increase resulting from mine-waste erosion along Reaches 1, 2 and 3.

Sources of Information/Data

1. Linear feet of mine waste in contact with main channel for each mine-waste deposit:

   Maps from URS (1997) were used to delineate areas of mine-waste deposits within the river floodplain. GIS methods were used to identify and define the length of each distinct mine-waste deposit in contact with the main channel. The channel-length estimates obtained using GIS mapping methods are included on the attached table and were used in computations.

2. Average metals concentrations for each mine-waste deposit:

The average metals concentrations for each mine-waste deposit are the same as those used in the mine waste ranking analysis. All metals concentration data, regardless of depth, for each deposit was used to calculate an average for that deposit. It is not known whether the data available are representative of the actual average conditions.

3. Mine-waste erosion rate:

The mine-waste erosion rate at bank-full conditions was estimated using a conservative approach. A moderately high bank-erosion rate of 5.0 ft/yr, for a small area of active channel migration, was reported by InterFluve (1999). This value of 5.0 feet per year was applied for the full length of the channel, creating a much exaggerated average erosion rate for the length of the 11-mile reach. This erosion rate was used along with an estimated average thickness for mine-waste deposits of 1 foot to compute the volume of mine wastes eroded per year per foot of channel length along Reaches 1, 2 and 3 (InterFluve's subreaches 2 through 6). This estimate was then used along with an estimated bulk density for mine wastes of 1.5 Kg/L to describe the mass of mine waste eroded per unit time per linear foot of mine-waste length along the main-channel bank (6.8×10^{-6} Kg/second). This value was used with the length-of-mine-waste estimates to compute the mass of mine waste eroded (per unit time) in each of the reaches evaluated on the attached table.

4. Discharge at various points along river at bank-full conditions:

Bank-full discharge was estimated by InterFluve (1999) at various points along the river. They report average bank-flow discharges for their subreaches 2, 3 and 4 of 300, 550 and 1057 cfs, respectively.

Subreach (InterFluve, 1999)	Bank Full Discharge (cfs)
2	330
3	550
4	1057
5	515
6	n/a (792*)

n/a = not available

*Bank-full discharge for subreach 7 substituted for subreach 6.

5. Solid/water distribution coefficients (K_d):

K_d values for the metals of interest under chemical conditions similar to those expected for Upper Arkansas River (high-flow conditions) were compiled from the following sources:

Davis, A., R.L. Olsen, D.R. Walker, 1991. Distribution of metals between water and entrained sediment in streams impacted by acid mine discharge, Clear Creek, Colorado, USA, Applied Geochemistry, v. 6, p. 333-348.

Dempsey, B.A. and P.C. Singer, 1980. The effects of calcium on the adsorption of zinc by MnOx(s) and Fe(OH)3(am), In Contaminants and Sediments, Vol. 2, ed., R.A. Baker, Ann Arbor, MI: Ann Arbor Science, Ann Arbor, MI, p. 333-352.

Duddridge, J.I. and M. Wainright, 1981. Heavy metals in river sediments – Calculation of metal adsorption using Langmuir and Freundlich isotherms, Environmental Pollution, v.B2, p. 387-397.

Gadde, R.R. and H.A. Laitinen, 1974. Studies of heavy metal adsorption by hydrous iron and manganese oxides, Analytical Chemistry, v. 46, p. 2022-2026.

Gardiner, J., 1974. The chemistry of cadmium in natural waters – II. The adsorption of cadmium on river muds and naturally occurring solids, Water Resources, v. 8, p. 157-164.

Levy, D.B., K.A. Barbarick, E.G. Siemer and L.E. Sommers, 1992. Distribution and partitioning of trace metals in contaminated soils near Leadville, Colorado, J. Environ. Quality, v. 21, p. 185-195.

Oakley, S.M., P.O. Nelson, and K.J. Williamson, 1981. Model of trace-metal partitioning in marine sediments, Environmental Science and Technology, v. 15, p. 474-480.

O'Connor, J.T. and C.E. Renn, 1981. Soluble adsorbed zinc equilibrium in natural waters, J. American Water Works Association, v. 56, p. 1055-1061.

Ramamoorthy, S. and B.R. Rust, 1978. Heavy metal exchange processes in sediment water systems, Environmental Geology, v. 2, p. 165-172.

Smith, K.S., S.J. Sutley, P.H. Briggs, A.L., Meier, K.Walton-Day, 1998. Trends in water-leachable lead from a fluvial tailings deposit along the upper Arkansas River, Colorado. Proceedings Tailings and Mine Waste Conference '98, Ft. Collins, CO, Balkema Press. p. 763-768.

U.S. EPA, 1999. Understanding Variation in Partition Coefficient, Kd, Values, Prepared by U.S. EPA Office of Radiation and Indoor Air and Office of Environmental Restoration, August 1999, EPA 402-R-99-004B.

The resultant compilation is presented on the attached table titled "K_d Calculations."

Two of these sources, Levy et al. (1992) and Smith et al. (1998), provide site-specific partitioning data for mine wastes from the Upper Arkansas River floodplain and one, Davis et al. (1991), provides empirical partitioning data for suspended stream sediment in Clear Creek, central Colorado. The remaining references describe metals partitioning to sediments and soils from a range of settings. The attached table presents the Kd values found. The Kd values used for the mass-balance calculations were selected to represent the conservative (low) end of the range determined from site-specific studies. These are generally more conservative than Kd values from other sources/settings.

Results and Discussion of Uncertainties

Results are shown on the attached tables as the increase in metals concentration (micrograms/L) resulting from metals partitioning to water from eroded mine wastes occurring along the reach from California Gulch downstream to the Highway 24 bridge. The estimated increase in concentrations, or the concentrations attributable to metals release from eroded mine wastes at bank-full conditions, are extremely low (< 1 µg/L for cadmium, copper, lead and zinc) in comparison to the high-flow dissolved metals concentrations observed in the river at the downstream end of Reach 2 (InterFluve's subreach 4) at the Highway 24 bridge, as shown below.

Estimated Mass Loading from Tailings

Location	**Discharge (cfs) (Date)**	**Current Dissolved Concentration (µg/l)**				**Estimated Increase in Concentration (µg/l) due to Mine-Waste Erosion from River Banks**			
		Cd	**Cu**	**Pb**	**Zn**	**Cd**	**Cu**	**Pb**	**Zn**
AR-5*	200 (8/95)	1	5	1	240	0.002	0.002	0.006	0.092
AR-5	500 (5/96)	6	11	114	1030				
AR-5	500 (7/96)	0.4	2	0.3	95				
AR-5	347 (5/98)	1	5	1	160				
AR-5	300 (7/98)	0.4	2	0.6	70				
AR-70**	na (7/96)	<5	<50	27	78	0.004	0.007	0.014	0.206
AR-70	na (5/96)	<5	<50	<5	267				
AR-70	na (6/96)	<5	<50	<5	85				
AR-70	na (7/96)	<5	<50	<5	69				

*AR-5 is a Resurrection sampling location at the top of Reach 3, approximately 0.25 miles downstream of Highway 24 Bridge above confluence with Empire Gulch.
**AR-70 is a USGS sampling location within Reach 3.

Based on these comparisons, it appears that the dissolved metals contributed to river water as a result of mine-waste erosion from the channel banks is not a significant source of metals loading in comparison to other sources.

These results are consistent with those of Walton-Day et al. (1999) who found that the dissolved metals load was not significantly changed at Arkansas River stations upstream and downstream of mine-waste deposits in Reach 3. The most significant increases in metals loads were observed during local snowmelt conditions, rather than during later high-flow conditions, suggesting that surface runoff over mine waste is more significant contributor to metals concentrations in river water than mine-waste erosion. The Walton-Day et al. (1999) study concluded that mine-waste deposits do not contribute measurable trace-element loads to the river.

References cited

InterFluve, Inc. and FLO Engineering, 1999. Fluvial Geomorphic Assessment of Upper Arkansas River, Final Report, prepared for URS Operating Services, Inc., Denver, Colorado, May 7, 1999.

Kimball, B.A., E.Callender, E.V. Axtmann, 1995. Effects of colloids on metal transport in a river receiving acid mine drainage, upper Arkansas River, Colorado, USA, Applied Geochemistry, v. 10, p. 285-306.

Levy, D.B., K.A. Barbarick, E.G. Siemer and L.E. Sommers, 1992. Distribution and partitioning of trace metals in contaminated soils near Leadville, Colorado, J. Environ. Quality, v. 21, p. 185-195.

Smith, K.S., S.J. Sutley, P.H. Briggs, A.L., Meier, K.Walton-Day, 1998. Trends in water-leachable lead from a fluvial tailings deposit along the upper Arkansas River, Colorado. Proceedings Tailings and Mine Waste Conference '98, Ft. Collins, CO, Balkema Press. p. 763-768.

URS Operating Services, Inc., 1997. Sampling Activities Report, Upper Arkansas Fluvial Tailings, Leadville, Colorado: Report to U.S. Environmental Protection Agency, Contract No. 68-W5-0031.

Walton-Day, K., F.J. Rossi, L.J. Gerner, J.B. Evans, T.J. Yager, J.F. Ranville, and K.S. Smith, 1999. Effects of fluvial tailings deposits on soils and surface- and ground-water quality, and implications for remediation – Upper Arkansas River, Colorado, 1992-1996, U.S.Geological Survey Water Resources Investigation Report 99-4273.

K_d Calculations

Metal	Reference	KL		Am	Diss. Metal Conc.		Mol. Wt.	Solid Metal Conc.		Langmuir Kd	Kd	Comments
		log(L/mol)	L/umol	umol/g	umol/L	ug/L	g/mol	umol/g	mg/Kg	L/kg	L/Kg	
Cadmium							112					
	Gardiner, 1974	5.2	0.158489	2	0.09	10		0.03	3.17	317		pH = 7.3 to 8, river sediment
	Ramamoorthy and Rust, 1978	5.4	0.251189	31	0.09	10		0.70	77.87	7787		pH = 7.5, 36% organic matter
	Ramamoorthy and Rust, 1978	5.4	0.251189	17	0.09	10		0.38	42.70	4270		pH = 7.5, 1% organic matter
	Ramamoorthy and Rust, 1978	5.4	0.251189	10	0.09	10		0.22	25.12	2512		pH = 7.5, 2.5% organic matter.
	Duddridge and Wainright, 1981	4.4	0.025119	30	0.09	10		0.07	7.54	754		pH = 7.4, 3.7% organic matter
	Duddridge and Wainright, 1981	4	0.01	26	0.09	10		0.02	2.60	260		pH = 7.1, 1% organic matter
	USGS, 1999										50	pH = 8 to 10
	USGS, 1999										12600	pH = 8 to 10
	Levy et al., 1992										115 to1050	Arkansas River tailings study/water soluble
Copper							63.5					
	Ramamoorthy and Rust, 1978	5.2	0.158489	173	0.31	20		8.64	548.37	27419		36% organic matter
	Ramamoorthy and Rust, 1978	5.1	0.125893	34	0.31	20		1.35	85.61	4280		1% organic matter
	Oakley et al., 1981										205	Iron oxide only, seawater
	Oakley et al., 1981										7300	Manganese oxide only, seawater
	Davis et al., 1991										200	Empirical for Clear Creek
	McKenzie, 1980	3.1	0.001259	133	0.31	20		0.05	3.35	167		Goethite only, fresh water
	Levy et al., 1992										130 to 5400	Arkansas River tailings/water soluble
Lead							207.2					
	Ramamoorthy and Rust, 1978	5.4	0.251189	13.9	0.10	20		0.34	69.83	3492		36% organic matter
	Duddridge and Wainwright, 198	4.9	0.079433	20	0.10	20		0.15	31.77	1589		1% organic carbon
	USGS, 1999										1950	pH = 6.4 to 8.7, 1 to 10 ug/L Pb
	USGS, 1999										10760	pH = 6.4 to 8.7, 1 to 10 ug/L Pb
	McKenzie, 1980	2.9	0.000794	85	0.10	20		0.01	1.35	68		Goethite only, fresh water
	McKenzie, 1980	4	0.01	2600	0.10	20		2.51	520.00	26000		Manganese oxide only, fresh water
	Gadde and Laltinen, 1974	4.1	0.012589	2400	0.10	20		2.92	604.28	30214		amorphous iron oxide, pH = 6
	Smith et al., 1998										765 to 30,000	Arkansas River tailings/water leachable
Zinc							65.4					
	O'Connor and Wainwright, 1981	3.8	0.00631	180	30.58	2000		34.73	2271.45	1136		pH = 7.3, river sediment
	Duddridge and Wainwright, 198	4.2	0.015849	47	30.58	2000		22.78	1489.80	745		pH = 7.1 (river sediment), 1% organic carbon
	Duddridge and Wainwright, 198	4.7	0.050119	59	30.58	2000		90.43	5914.01	2957		pH = 7.3 (river sediment), 4% organic carbon
	Davis et al., 1991										26	Empirical for Clear Creek
	Dempsey and Singer, 1980	5.9	0.794328	170	30.58	2000		4129.54	270071.60	135036		amorphous iron oxide only, pH = 7
	Levy et al., 1992										75 to 1200	Arkansas River tailings/water soluble

Metals Loading Calculations Worksheet

Mapped Deposits	Total Distance Along River Bank	Total Length of Tailing Exposed to Bank	Fraction of Tailings Exposed at Bank	Average Metals Content (mg/Kg)				Weighted Average Metals Concentration (mg/Kg) in Erodable Tailing along Reach				Mass Bank Eroded/Second/Bank-Linear-Foot	Mass of Tailing Eroded/Second along Reach	Average Bank-Full Discharge	Discharge	Eroded Tailing Suspended in River Water	Metals Kd Values (at ambient pH)				Mass of Metal Released (mg) to Water per Kg of Tailing in River				Dissolved Concentration (ug/L) Increase Along Reach				Mass Load (mg/sec) Increase Along Reach			
	Feet	Feet		Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc	Kg/Sec/Ft	Kg/Sec	cfs	L/sec	Kg/L	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc
7081200	0	0	0.000											200																		
Cal. Gulch at Ark River	15218	0	0.000											200																		
Cal. Gulch to AA	2733	0	0.000											200																		
AA		36.39	0.050	115	160	3900	1700	6	8	196	86																					
AB		0	0.000	220	535	3900	1650	0	0	0	0																					
AC		235.52	0.326	250	453	4883	17750	82	148	1592	5788																					
AD		0	0.000	115	120	520	1900	0	0	0	0																					
AE		0	0.000	414	698	8402	26433	0	0	0	0																					
AG		153.01	0.212	105	857	5400	16600	22	182	1144	3517																					
AH		0	0.000	95	290	3400	2000	0	0	0	0																					
AI		297.35	0.412	208	88	2095	3900	86	36	862	1606																					
AJ		0	0.000	95	1200	6500	2500	0	0	0	0																					
AA-AI	2394	722.27	1.000					195	374	3795	10996	6.80E-06	4.91E-03	330	9345.6	5.26E-07	115	130	765	75	1.68	2.85	4.95	144.68	0.001	0.001	0.003	0.076	8.26E-03	1.40E-02	2.43E-02	7.11E-01
BB	3330	286.34	1.000	85	228	5350	1135	85	228	5350	1135	6.80E-06	1.95E-03	330	9345.6	2.08E-07	115	130	765	75	0.73	1.74	6.98	14.93	0.000	0.000	0.001	0.003	1.43E-03	3.39E-03	1.36E-02	2.91E-02
CA		254.4	0.207	115	55	5800	3100	24	11	1201	642																					
CC		0	0.000	85	1100	4800	4400	0	0	0	0																					
CD		255.88	0.208	517	867	9080	41000	108	181	1891	8538																					
CE		128.45	0.105	232	282	3251	2621	24	29	340	274																					
CF		0	0.000	120	300	8500	980	0	0	0	0																					
CG		0	0.000	115	55	2700	440	0	0	0	0																					
CJ		0	0.000	338	178	8015	6615	0	0	0	0																					
CK		85.87	0.070	100	60	1075	200	7	4	75	14																					
CL02		174.75	0.142	175	917	3108	16105	25	130	442	2291																					
CN		0	0.000	85	185	1776	1670	0	0	0	0																					
CO		0	0.000	244	956	1936	6227	0	0	0	0																					
CP		0	0.000	100	293	2533	1210	0	0	0	0																					
CR		0	0.000	111	391	1622	4383	0	0	0	0																					
CS		329.34	0.268	208	431	2926	9990	56	116	784	2678																					
CA-CS	3786	1228.69	1.000					88	250	1301	4982	6.80E-06	8.36E-03	330	9345.6	8.94E-07	115	130	765	75	0.76	1.91	1.70	65.56	0.001	0.002	0.002	0.059	6.31E-03	1.60E-02	1.42E-02	5.48E-01
FA		0	0.000	133	676	3245	6413	0	0	0	0																					
FB		302.5	0.088	88	848	4062	6020	8	75	357	529																					
FC		351.9	0.102				6020	0	0	0	615																					
FD		49.77	0.014				460	0	0	0	7																					
FE		49.69	0.014	95	55	85	460	1	1	1	7																					
FF		114.32	0.033	305	165	2725	955	10	5	91	32																					
FH		0	0.000				955	0	0	0	0																					
FG		280.62	0.082	95	55	2300	1000	8	4	188	82																					
FI		211.33	0.061	95	55	680	1100	6	3	42	68																					
FJ		469.58	0.136	230	220	9700	3200	31	30	1323	437																					
FL		69.81	0.020	350	190	2700	1500	7	4	55	30																					
FM		565.6	0.164	270	231	5640	9350	44	38	927	1536																					
FN		164.43	0.048	95	140	1400	900	5	7	67	43																					
FO		0	0.000				900	0	0	0	0																					
GA		0	0.000	95	285	3133	6767	0	0	0	0																					
GB		0	0.000				6767	0	0	0	0																					
GC		0	0.000				6767	0	0	0	0																					
GE		51.11	0.015	95	210	2700	1000	1	3	40	15																					
GH		33.68	0.010	95	55	350	310	1	1	3	3																					
GI		33.54	0.010	95	55	1600	840	1	1	16	8																					
GJ		59.83	0.017				840	0	0	0	15																					
GK		121.97	0.035				840	0	0	0	30																					
GL		0	0.000	203	153	6300	9600	0	0	0	0																					
GM		211.46	0.061	260	370	9200	9800	16	23	565	602																					
GN		0	0.000				9800	0	0	0	0																					
HA		0	0.000	95	55	3400	2900	0	0	0	0																					
HB		0	0.000	78	120	1350	800	0	0	0	0																					
HD		31.33	0.009	95	120	2500	1300	1	1	23	12																					
HE		37.67	0.011	95	130	1100	510	1	1	12	6																					
HI		125.46	0.036	240	130	7200	13000	9	5	262	474																					
HK		106.35	0.031	95	300	1600	2200	3	9	49	68																					
FA-HK	10081	3441.95	1.000					153	211	4021	4617	6.80E-06	2.34E-02	550	15576	1.50E-06	115	130	765	75	1.32	1.61	5.25	60.75	0.002	0.002	0.008	0.091	3.09E-02	3.76E-02	1.23E-01	1.42E+00
IA		105.32	0.345	210	55	3800	750	72	19	1311	259																					
IC		0	0.000	95	130	1000	680	0	0	0	0																					
KK		200	0.655	148	185	2350	1250	97	121	1539	819																					
KL		0	0.000	228	218	4783	4360	0	0	0	0																					
IA-KW	9975	305.32	1.000					169	140	2850	1078	6.80E-06	2.08E-03	1057	29934.24	6.94E-08	115	130	765	75	1.46	1.07	3.72	14.18	0.000	0.000	0.000	0.001	3.03E-03	2.22E-03	7.73E-03	2.94E-02
																												mg/sec increase in load for Reaches 1 and 2 combined	0.050	0.073	0.183	2.739
Cal Gulch to 07083710	32299	5984.57																										ug/L increase at end of Reach 2	1.67E-03	2.45E-03	6.10E-03	9.15E-02
SUBREACH 4/REACH 2																																
LA		0	0.000	260	260	5600	12000	0	0	0	0																					
LB		159.24	0.039	275	210	3300	10450	10.73006	8.193867	128.7608	407.7424																					
LC		0	0.000	374	434	4680	48320	0	0	0	0																					
LD		0	0.000	74	226	1856	2792	0	0	0	0																					
LG		118.95	0.029	190	200	5300	7700	5.537777	5.829239	154.4748	224.4257																					
LH		507.92	0.124	48	480	3500	7800	5.973846	59.73846	435.5929	970.7499																					
LI		7.01	0.002	269	345	2500	11400	0.462049	0.59259	4.294133	19.58125																					
LK		0	0.000					0	0	0	0																					
LL		0	0.000					0	0	0	0																					
LM		290.18	0.071	152	425	7300	5273	10.80758	30.21857	519.0483	374.9235																					
LN		0	0.000					0	0	0	0																					
LO		0	0.000					0	0	0	0																					
LP		0	0.000					0	0	0	0																					
LQ		0	0.000					0	0	0	0																					
LR		0	0.000					0	0	0	0																					
LS		0	0.000					0	0	0	0																					
LT		0	0.000					0	0	0	0																					
LU		0	0.000					0	0	0	0																					
LV		0	0.000					0	0	0	0																					
MA		45.19	0.011	85	140	1000	3000	0.941193	1.5502	11.07286	33.21858																					
MB		493.15	0.121	123	242	2075	6518	14.86283	29.24232	250.7348	787.6093																					
ME		0	0.000					0	0	0	0																					

Mapped Deposits	Total Distance Along River Bank	Total Length of Tailing Exposed to Bank	Fraction of Tailings Exposed at Bank	Average Metals Content (mg/Kg)				Weighted Average Metals Concentration (mg/Kg) in Erodable Tailing along Reach			
	Feet	Feet		Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc
MF		53.89	0.013	228	140	1203	11800	3.010651	1.848646	15.88515	155.8144
MG		0	0.000					0	0	0	0
MH		0	0.000					0	0	0	0
MI		0	0.000					0	0	0	0
MJ		0	0.000					0	0	0	0
MK		0	0.000					0	0	0	0
ML		74.41	0.018				2350	0	0	0	42.84662
MM		61.45	0.015				2350	0	0	0	35.38402
MN		0	0.000					0	0	0	0
MP		104.21	0.026	89	170	1160	1677	2.272568	4.34086	29.61998	42.82131
MQ		144.02	0.035	101	313	1458	5798	3.564196	11.04548	51.45147	204.606
NA		95.34	0.023	169	225	950	3765	3.94802	5.256239	22.19301	87.9544
NB		307.18	0.075	95	280	2500	1900	7.15046	21.07504	188.17	143.0092
NC		0	0.000					0	0	0	0
ND		183.23	0.045	120	170	1270	640	5.387599	7.632432	57.01876	28.73386
NG		0	0.000					0	0	0	0
NH		0	0.000					0	0	0	0
NH1		0	0.000					0	0	0	0
NI		0	0.000					0	0	0	0
NJ		75.08	0.018	115	55	760	410	2.115629	1.011823	13.98155	7.542678
NL		0	0.000					0	0	0	0
NN		63.66	0.016	80	108	4300	2200	1.247884	1.684643	67.07374	34.3168
NO		176.19	0.043	85	330	3000	1500	3.669591	14.24665	129.515	64.75748
NP		89.86	0.022	128	180	1950	1250	2.818343	3.963295	42.93569	27.52288
NR		0	0.000					0	0	0	0
NT1		74.27	0.018	94	235	1950	2900	1.71064	4.276601	35.48669	52.77508
NT2		0	0.000					0	0	0	0
NT3		0	0.000					0	0	0	0
NU		0	0.000					0	0	0	0
OA		180.19	0.044	57	455	3150	2700	2.516651	20.08906	139.0781	119.2098
OB		375.86	0.092	85	65	813	868	7.82821	5.986278	74.87453	79.93984
OC		0	0.000					0	0	0	0
OD		0	0.000					0	0	0	0
OE		37.6	0.009	221	268	3513	6912	2.036093	2.469108	32.36558	63.68087
OF		199.63	0.049	85	65	340	660	4.157786	3.179484	16.63115	32.28399
OG		72.82	0.018	97	70	100	970	1.730772	1.249011	1.784301	17.30772
OH		90.62	0.022	48	160	2150	1675	1.065817	3.552724	47.73973	37.19258
OI		0	0.000					0	0	0	0
LA-OH	12507.5	4081.15	1.000					105.55	248.27	2469.78	4095.95
END OF SUBREACH 5											
OJ		0	0.000					0	0	0	0
OJ3		0	0.000					0	0	0	0
OK		0	0.000					0	0	0	0
PA		79.89	0.044	95	330	4050	1900	4.133472	14.35838	176.2164	82.66943
PC		0	0.000					0	0	0	0
PD		69.42	0.038	85	103	5500	455	3.213679	3.894223	207.9439	17.20263
PE		0	0.000					0	0	0	0
PF		0	0.000					0	0	0	0
PG		50.93	0.028	94	170	2395	4800	2.607357	4.715433	66.43212	133.1416
PJ		0	0.000					0	0	0	0
PM		0	0.000					0	0	0	0
PN		0	0.000					0	0	0	0
PP		0	0.000					0	0	0	0
PX		0	0.000					0	0	0	0
QA		0	0.000					0	0	0	0
QD		0	0.000					0	0	0	0
QF		335.56	0.183	160	114	2431	698	29.24079	20.83406	444.2773	127.5629
QG		0	0.000					0	0	0	0
QH		0	0.000					0	0	0	0
QI		317.97	0.173	115	370	3100	2400	19.91512	64.07473	536.8424	415.6199
QJ		87.58	0.048	115	190	1600	2700	5.485317	9.062697	76.31745	128.7857
QK		0	0.000					0	0	0	0
QM		0	0.000					0	0	0	0
QN		0	0.000					0	0	0	0
QO		0	0.000					0	0	0	0
QP		81.61	0.044	80	535	1900	3450	3.555759	23.77914	84.44927	153.3421
QQ		0	0.000					0	0	0	0
QR		0	0.000					0	0	0	0
QT		129.58	0.071	75	300	1300	1200	5.292955	21.17182	91.74455	84.68728
QV		0	0.000					0	0	0	0
QW		0	0.000					0	0	0	0
QX		133.66	0.073	65	670	6400	2300	4.731662	48.77252	465.8868	167.4281
QY		0	0.000					0	0	0	0
QZ		0	0.000					0	0	0	0
RA		0	0.000					0	0	0	0
RB		262.94	0.143	65	240	3000	1000	9.30827	34.369	429.6124	143.2041
RC		171.61	0.093	65	300	1700	1100	6.07512	28.03902	158.8878	102.8097
RF		115.37	0.063	320	520	3100	12000	20.10675	32.67346	194.7841	754.003
OJ-RF	6813.75	1836.12	1.000					113.67	305.74	2933.39	2310.46
SUBREACH 6/REACH 3											
GRAND TOTAL	81186.25	11901.84									

Mapped Deposits	Mass Bank Eroded/Second/ Bank-Linear-Foot	Mass of Tailing Eroded/Second along Reach	Average Bank-Full Discharge	Discharge	Eroded Tailing Suspended in River Water	Metals Kd Values (at ambient pH)				Mass of Metal Released (mg) to Water per Kg of Tailing in River				Dissolved Concentration (ug/L) Increase Along Reach				Mass Load (mg/sec) Increase Along Reach			
	Kg/Sec/Ft	Kg/Sec	cfs	L/sec	Kg/L	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc	Cadmium	Copper	Lead	Zinc
LA-OH	6.80E-06	2.78E-02	515	14584.8	1.90E-06	115	130	765	75	0.91	1.90	3.22	53.89	0.002	0.004	0.006	0.103	2.53E-02	5.26E-02	8.95E-02	1.50E+00
OJ-RF	6.80E-06	1.25E-02	792	22429.44	5.57E-07	115	130	765	75	0.98	2.33	3.83	30.40	0.001	0.001	0.002	0.017	1.22E-02	2.91E-02	4.78E-02	3.80E-01
SUBREACH 6/REACH 3																	mg/sec increase in load for Reaches 1, 2 and 3 combined	8.74E-02	1.55E-01	3.20E-01	4.61E+00
GRAND TOTAL																	ug/L increase at end of Reach 3	3.90E-03	6.91E-03	1.43E-02	2.06E-01