2012

TRACKING RELEASE OF RESERVOIR SEDIMENT CONTAMINATED BY HEAVY METAL MINING WASTE: A STUDY OF LARGE-SCALE DAM REMOVAL AT MILLTOWN, MONTANA

Katrina Louise Garcia
The University of Montana

Recommended Citation

Garcia, Katrina Louise, "TRACKING RELEASE OF RESERVOIR SEDIMENT CONTAMINATED BY HEAVY METAL MINING WASTE: A STUDY OF LARGE-SCALE DAM REMOVAL AT MILLTOWN, MONTANA" (2012). *Graduate Student Theses, Dissertations, & Professional Papers*. 1131.
https://scholarworks.umt.edu/etd/1131

TRACKING RELEASE OF RESERVOIR SEDIMENT CONTAMINATED BY HEAVY METAL MINING WASTE: A STUDY OF LARGE-SCALE DAM REMOVAL AT MILLTOWN, MONTANA

By

KATRINA LOUISE GARCIA

B.S., Pacific University, Forest Grove, OR, 2007

Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Environmental/Analytical Chemistry

The University of Montana
Missoula, MT

May 2012

Approved by:

Sandy Ross, Associate Dean of The Graduate School
Graduate School

Michael DeGrandpre, Co-Chair
Chemistry

Johnnie Moore, Co-Chair
Geosciences

Edward Rosenberg
Chemistry

Heiko Langner
Geosciences

Garcia, Katrina L., M.S., May 2012 Chemistry

Tracking Release of Reservoir Sediment Contaminated by Heavy Metal Mining Waste: A Study of Large-scale Dam Removal at Milltown, Montana

Co-Chairperson: Michael D. DeGrandpre

Co-Chairperson: Johnnie N. Moore

The removal of Milltown Dam at the confluence of the Clark Fork and Blackfoot rivers, near Missoula, Montana, caused an elevation in heavy metals concentration in downstream sediment. The primary source of contamination came from base metal extraction mining waste which had collected in reservoir sediments for more than a century. Health and environmental concerns associated with high concentrations of arsenic and copper in the sediment and nearby groundwater prompted the removal of the dam and its toxic sediments. Milltown Dam was breached on March 28, 2008.

Fine-grain (<63 μm) bed sediment was collected between May 3 and August 21, 2008, over a 254-km stretch in the Clark Fork River downstream of the dam and analyzed for concentrations of heavy metals (As, Cd, Cr, Cu, Pb, Zn and Hg). The highest metals concentration occurred in early May, before the peak in stream discharge began transporting massive amounts of sediment. Metals concentration peaked at 290 ppm As, 8 ppm Cd, 2200 ppm Cu, 180 ppm Pb, 2400 ppm Zn, and 2 ppm Hg. Dam removal did not affect Cr, but the other metals were enriched well above background conditions: As was 42x higher and Cu was 103x higher in the lower CFR than its tributaries. Elevated metals concentration extended over the entire study area, decreasing exponentially with distance downstream and returning to near pre-breach conditions by the end of the study period.

Supplemental data from the USGS for suspended-sediment was combined with bed sediment results to track the source and sequence of sediment release. Contaminants in the sediment acted as tracers, showing that heavily contaminated, fine-grain sediment was released from the lower reservoir during low flows immediately after dam removal. Nearly two months later, a much larger volume of less contaminated, mixed-grain sediment from the upper reservoir was released during maximum stream discharge, resulting in overall decrease in metals concentration.

Acknowledgments

I would like to thank the members of my thesis committee, Mike DeGrandpre, Johnnie Moore, Heiko Langner, and Ed Rosenberg, for their ideas and assistance in the completion of this project. Special thanks to Heiko and Johnnie for helping me at every step of the way, including sample collection, lab instruction, data analysis, and thesis revision. Thanks to Johnnie for his ideas in how to interpret the data, and to Mike for his patience and understanding.

I am also extremely grateful to Matt Young for teaching me the lab procedures and analytical techniques, as well as accompanying me in the field to collect samples. His assistance and knowledge was greatly appreciated. I am also grateful to the others who helped me collect field samples: Johnnie Moore and his wife Lynn, Heiko Langner, Cleo Woelfle-Erskine and Ivan Orsic.

My thanks goes out to the folks in the DeGrandpre group: Sarah Cullison, Katherine Harris, Cory Beatty, Tommy Moore, and Reggie Spaulding, with a very special thanks to Sarah for her generous assistance with thesis editing, helping me learn the new graphing program, and her support and encouragement.

Extra special thanks to Patricia Moore for help with revisions and organization of this thesis, and to Sara Connors, Karyn Aho, and my family for the support and drive to get it done.

Table of Contents

List of Tables

List of Equations

List of Figures

Introduction

1.1 Implications of Dam Removal

Dam removal has become a serious environmental concern in recent years due to the prevalence of outdated and ineffective dams. One of the primary environmental concerns of dam removal is the fate of sediments impounded in reservoirs behind the dam (Pejchar and Warner, 2001; Pizzuto, 2002; Graf, 2005; Syvitski *et. al.*, 2005). Globally, over 100 billion metric tons of sediment has been impounded behind dams constructed since the mid-1950s (Syvitski et. al, 2005). The removal of Marmot Dam on Sandy River, Oregon, showed that large-scale dam removal and subsequent erosion in high energy rivers can sometimes be the best ecological and economical solution for dispersing these impounded sediments (Grant *et. al.,* 2008). However, when reservoir sediments have been contaminated, rapid release following dam removal could present a serious environmental hazard downstream.

In river systems that have experienced mining operations upstream of the dam the sediments that have accumulated in the reservoir can be highly enriched with toxic mining wastes, including trace metals such as copper (Cu), arsenic (As), zinc (Zn), lead (Pb), cadmium (Cd), mercury (Hg), and other heavy metals which adsorb to the surface of the sediments (Andrews, 1987; Moore and Luoma, 1990; Axtmann and Luoma, 1991). The accumulation of contaminants in the sediment can increase the environmental stress and toxic effects on the vegetation, fish, and other aquatic organisms, as well as birds, terrestrial animals and humans through the food chain (Rader *et. al.*1997; American Rivers, 2002; EPA, 2005; EPA, 2011).

Dam removal initiatives need to include a plan to deal with the scouring of potentially toxic material that has accumulated within the reservoir (Pizzuto, 2002; Pejchar and Warner, 2001; Graf, 2005; EPA, 2005). Otherwise, similar to dam failure, massive quantities of highly contaminated reservoir sediments could be released downstream, which can cause immediate and long-lasting ecological effects on biota and further contaminate far reaches of the ecosystem, making it very difficult to implement remediation efforts. The intentional breach of Fort Edwards Dam in 1973 resulted in the release of large amounts of PCBs that had accumulated in the reservoir sediments, which spread through the Hudson River and created a contaminant plume that became one of the largest "Superfund" sites in the United States (EPA, 2002).

One solution to minimize ecological impacts downstream of the dam, for both the short and long-term, is to physically remove the contaminated sediments from the reservoir before they have an opportunity to erode into the river (Doyle *et. al.*, 2002; Pizzuto, 2002; EPA, 2005). This has been recommended by numerous experts when the sediments present an "extreme hazard" (Pizzuto, 2002) or can potentially further degrade the ecosystem (Pejchar and Warner, 2001).

Milltown Reservoir, located in western Montana at the confluence of the Clark Fork River (CFR) and the Blackfoot River (BFR), presents a unique opportunity and an ideal case study to monitor and characterize the effects of reservoir sediment removal in a large-scale dam removal and restoration project. Since its construction in 1907, Milltown Reservoir has trapped more than 6.6 million cubic yards (over 9 million tons) of sediment, including metals-contaminated mining waste from large-scale metal extraction operations at the headwaters of the CFR in Butte and Anaconda (ROD, 2004; EPA, 2008). Milltown Reservoir was added to the Clark Fork River Basin "Superfund" Complex when high levels of As were discovered in the local drinking water in 1981 and the source of the contamination was backtracked to the reservoir sediments (See Appendix A for History of Milltown Reservoir).

The removal of Milltown Dam was the first large-scale dam removal in which the reservoir sediments were isolated and removed to limit downstream contamination (EPA, 2008).

Contaminated reservoir sediments were mechanically excavated and transported by train 90 miles upstream to Opportunity Ponds, to be used for site reclamation at the Anaconda Smelter “Superfund” site (EPA, 2008). A series of permanent drawdowns of the reservoir, beginning in 2006 two years prior to dam removal, was used to help dewater and consolidate the sediments to increase sediment stability, minimize erosion, and allow construction teams access (Lambing and Sando, 2008). Another effort to minimize the release of contaminated sediments downstream was the construction of a bypass channel around the most contaminated sediments in the reservoir (ROD, 2004). The flow of the CFR was diverted into the bypass channel prior to and throughout dam removal so that excavation teams could access the contaminated sediments in the reservoir, particularly in the area of the original river channel which was filled with the most contaminated sediments soon after the dam was constructed in the early 20th century. The bypass channel would also minimize erosion from the reservoir by constraining flows within the riprapped banks of its channel (ROD, 2004). Excavation of reservoir sediments and the construction of the bypass channel began in October, 2007. One-third of the reservoir sediments, about 2.2 million cubic yards (over 3 million tons) were slated for removal. The bypass channel was activated just days before Milltown Dam was breached on March 28, 2008 (EPA, 2008).

Following dam removal, erosion of reservoir sediments increased significantly during the high flows of late spring and early summer, on the scale of tens of thousands of tons of sediment per day (USGS, 2008). Between October 2007 and September 2008, throughout the major stages of sediment and dam removal, more than 391,000 tons of contaminated sediment were mobilized out of Milltown Reservoir and transported downstream (Lambing and Sando, 2009). The dam removal project estimated and planned for the natural scour of 300,000 tons from the reservoir in 2008 (Nielsen, 2009). This indicates that the remediation effort of isolating and removing reservoir sediment was not entirely effective at controlling the release of sediments downstream during the dam removal process.

Previous studies have shown that metals in sediment tend to behave conservatively in active rivers, remaining bound to the sediment during transport, which allows them to be used as tracers in the sediment (Essig and Moore, 1992; Helgen and Moore, 1996; Hornberger *et.al.*, 1997). Therefore, analysis of the metal content in the sediment should allow us to track the movement of sediments downstream after they are released from the reservoir. The ability to monitor the remobilization and transport of reservoir sediments is key to developing strategies for future large-scale dam removals that can minimize the negative impacts on downstream geomorphology and contamination. The amount of metal contamination can also give us information about the health of the ecosystem in the CFR, since aquatic organisms are susceptible to heavy metals which can bioaccumulate through the food chain to land animals and even humans (Axtmann *et. al.*, 1997; Burton, 2002; McGeer *et. al.*, 2003).

1.2 Study Objectives

The objective of this study is to track the transport of contaminated sediments through trace metal analysis of fine-grained bed sediment downstream of the former Milltown Dam. Determination of metal concentrations in the bed sediment downstream of the dam allows for identification of the source and the fate of sediment transported by the river (Essig and Moore, 1992). Analysis of the bed sediment can help us answer the following questions concerning the downstream effects of dam removal:

1. Were metal concentrations elevated downstream, and how long did it take metal concentrations to return to pre-breach conditions?
2. How far were contaminated sediments transported and how long did it take?
3. What was the primary source of sediments deposited in the channel?

2. Methods

2.1 Bed Sediment

Samples were collected in five separate events over the course of the spring runoff following removal of the dam on March 28, between May 3 and August 21, 2008. Fine-grain bed sediment samples were collected from the channel margins and filtered onsite with a 63 µm nylon mesh screen using collection techniques described by Nagorski *et. al.* (2002) and Essig and Moore (1992). The top layer (1-2 cm) of bed sediment was collected, representing the most recent deposits of suspended-sediment that was being transported by the river at that time (Essig and Moore, 1992; Helgen and Davis, 2000).

Fine-grain sediments were collected in order to eliminate bias of grain size variability (Essig and Moore, 1992). Due to the larger surface area to volume ratio in fine-grain sediment (clay, silt) compared to larger grain sizes (sand, pebbles), there is a strong negative correlation between grain size and metal concentrations. The fine-grain fraction tends to have higher metal concentrations than the bulk sediment because of the greater number of adsorption sites (Brook, 1988; Drake, 1997). Limiting grain size allows for comparison between sites where sediment composition varies and yields metal concentrations that are more likely to be above the detection limits in analytical techniques. More importantly, the fine-grain size fraction is the most biologically available, creating the greatest impacts on biota (Luoma and Bryan, 1979; Axtmann *et al*., 1989; Axtmann *et. al*., 1997; Essig and Moore, 1992).

Table 1: Bed sediment sampling sites, including site name, distance from Milltown Dam in river kilometers (negative values indicate sites are upstream of the dam), site location with river and access point, and coordinates for latitude and longitude. *denotes sites removed from the sampling method after the first sampling event; CFCA was sampled every other event. **denotes downstream sites added after first sampling event; CFTS removed after third event. Note: CFSR and CFDC are at the same location on opposite sides of the river. Sites were combined for mean and standard deviation.

Site Name	River Km	Site Location	Latitude	Longitude
BFWS	-3.49	Blackfoot River at old weigh station, near Bonner	46°52'49.16"N	113°51'9.98"W
CFTB	-9.41	CFR at Turah Bridge, near Bonner	46°49'19.37"N	113°48'26.29"W
*CFIB	1.47	CFR at I-90 Bridge, Tamarack Lane	46°52'42.54"N	113°54'34.66"W
CFBF	2.28	CFR at Bandman Flats, golf course	46°53'2.45"N	113°54'58.05"W
CFSR	4.06	CFR at Sha-Ron Fishing Access	46°52'52.84"N	113°56'3.49"W
CFDC	4.20	CFR at Deer Creek Bridge	46°52'49.50"N	113°55'58.34"W
CFHC	8.09	CFR at Hellgate Park	46°51'43.76"N	113°57'47.62"W
*CFEG	9.81	CFR at Eastgate-UM foot bridge	46°52'1.07"N	113°59'0.62"W
CFMP	11.73	CFR at McCormick Park	46°52'26.04"N	114° 0'12.53"W
*CFCA	12.52	CFR at California St. foot bridge	46°52'33.73"N	114° 0'48.11"W
BRMF	22.17	Bitterroot River at Maclay Flats Interpretive Trail	46°50'14.45"N	114° 6'13.60"W
CFKI	21.38	CFR at Kelly Island, Spurgin Road Access	46°51'45.09"N	114° 6'2.47"W
CFKB	28.94	CFR at Kona Ranch Rd. Bridge	46°53'58.43"N	114° 9'3.20"W
CFHB	35.69	CFR at Harper's Bridge	46°55'53.04"N	114°12'29.55"W
CFPC	69.87	CFR at Petty Creek Fishing Access	46°59'29.72"N	114°26'44.20"W
**CFTA	97.83	CFR at Tarkio Fishing Access	47° 0'52.33"N	114°44'22.85"W
**CFDY	133.11	CFR at Dry Creek Fishing Access	47°13'32.48"N	114°57'51.16"W
**CFKC	173.25	CFR at Ferry Landing Fishing Access	47°19'21.61"N	114°53'27.50"W
**FHKN	190.31	Flathead River at Knowles (River Km at confluence)	47°20'39.38"N	114°42'34.13"W
**CFPN	204.13	CFR at Plains Bridge	47°27'12.01"N	114°53'46.47"W
**CFTS	254.45	CFR at Thompson Falls State Park	47°36'57.34"N	115°23'23.53"W

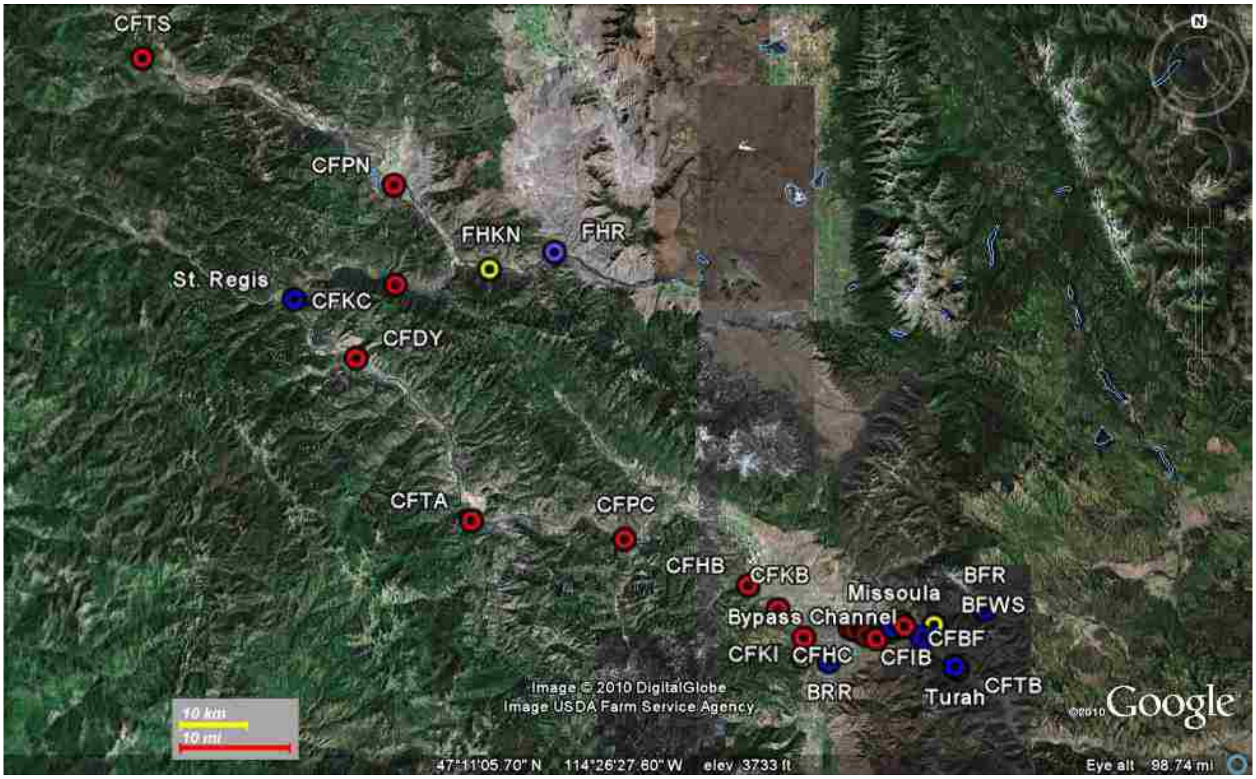


Figure 1a: Map of all bed sediment sampling sites collected from the CFR (red) and tributaries (yellow), and USGS gauge sites for suspended-sediment (blue). Image provided by GoogleEarth.

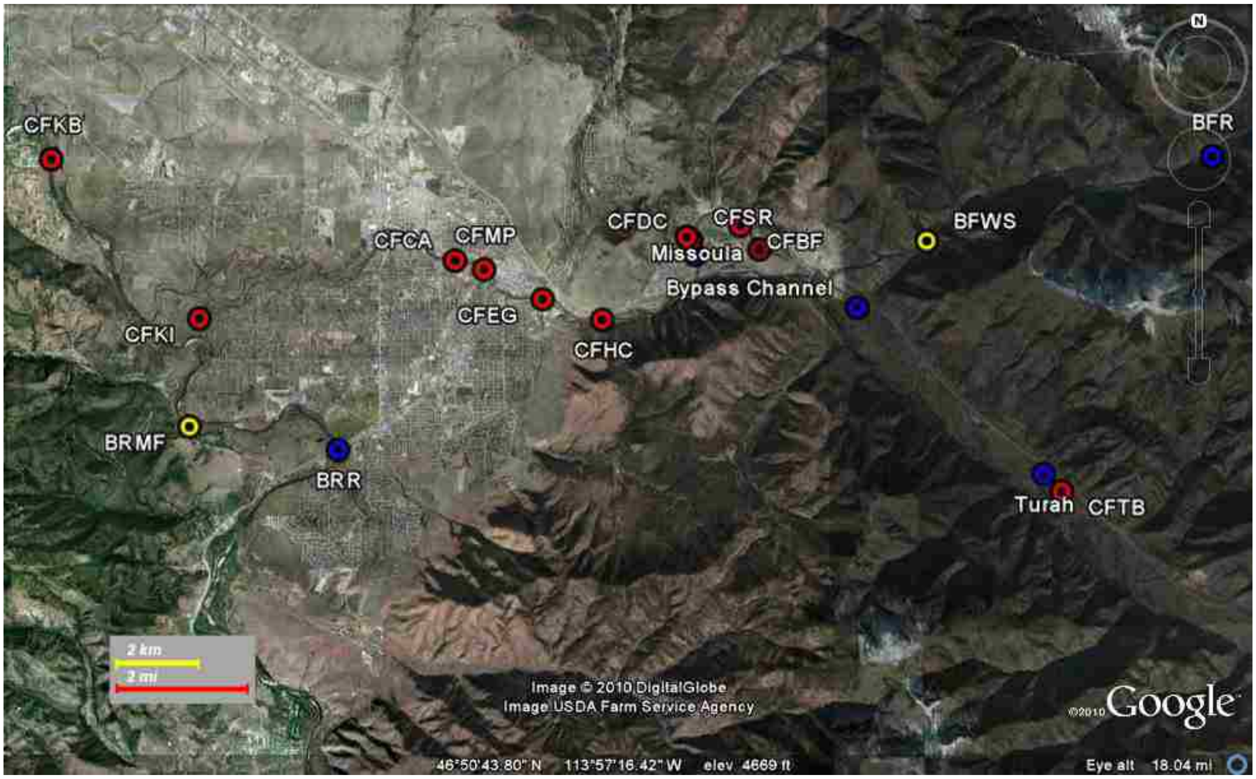


Figure 1b: Zoom-in view of Figure 1a; upstream sampling sites near Missoula, Montana. Image provided by GoogleEarth.

A maximum of 15 sites on the CFR downstream of Milltown Reservoir were sampled over a 2-3 day period for each event (Table 1, Figure 1). One site upstream of the reservoir on the CFR at Turah Bridge (CFTB) and one site on the BFR near Bonner (BFWS) provided background data on the sediment concentrations potentially flowing into the reservoir. The Bitterroot (BRR) and Flathead (FHR) rivers were also sampled above their confluence with CFR downstream of the dam. All three tributaries and the upstream site at CFTB were sampled during each event, except for the FHR which was not included in the first two sets of data collected in May.

The initial sample set collected May 3-5 only extended 70 river km from Milltown Dam to Petty Creek (CFPC), but preliminary analysis showed that metals concentration were still extremely high in the deposited sediments at this distance downstream and were not significantly different from concentrations found closest to the dam. Therefore, the sampling method was revised and six more sites were added to expand the study area downstream (Figure 1a). Because of time constraints, inaccessibility during high flows and proximity to neighboring sites, two sites in and above Missoula (CFEG and CFIB) were omitted during subsequent sampling, while CFCA was only sampled every other event.

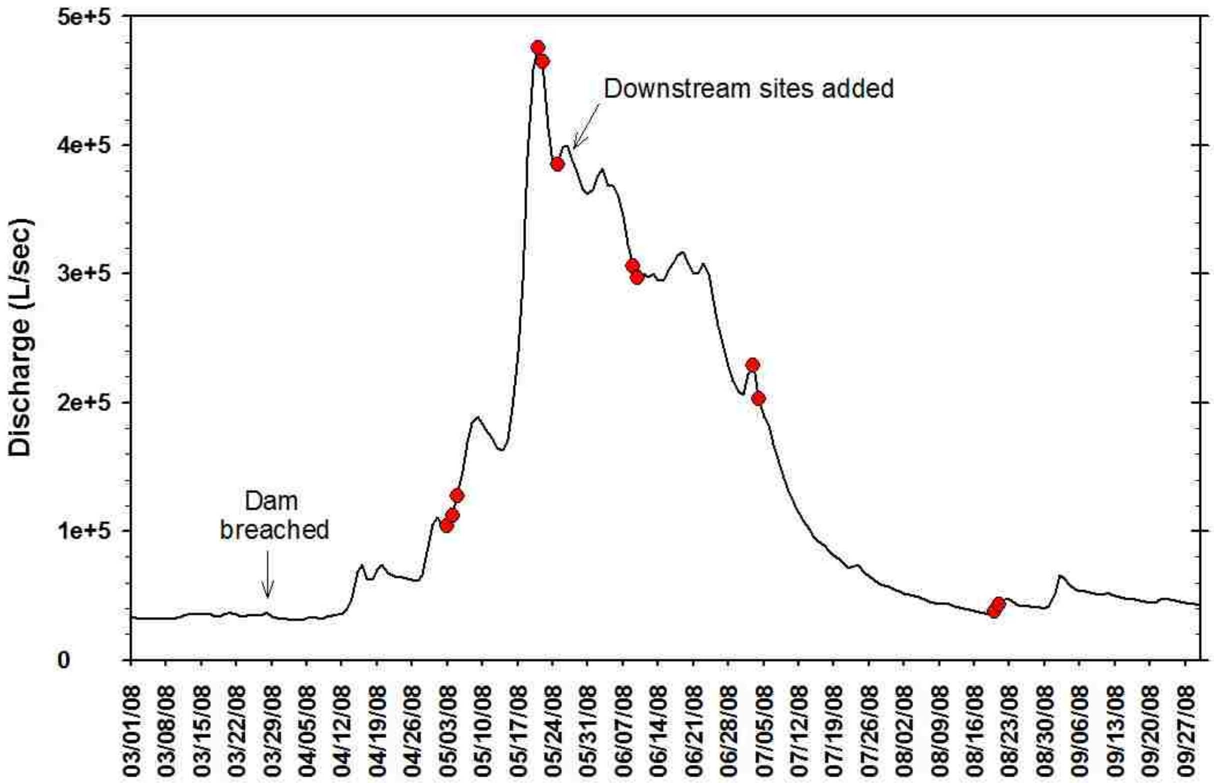


Figure 2: Hydrograph for CFR stream discharge (L/sec) at USGS Missoula gauging station (12340500) from March through September, 2008. Red circles indicate which days bed sediment samples were collected. Data from the USGS.

Samples were collected at key days in the hydrograph 2-5 weeks apart (Figure 2). Stream discharge measured on the CFR at Missoula was below normal until mid-April when sustained runoff due to snowmelt began, and increased to near normal levels until the sharp increase in mid-May. Stream discharge peaked above normal levels on May 22 (Lambing and Sando, 2009).

2.2 Bank Sediment

As water levels receded in the late summer of 2008, visual observation revealed that there was significant sediment build-up on the banks, islands, side channels and eddies of the CFR beyond even CFPC, 70 kilometers downstream of the dam. In some places sediment was more than one meter thick and covered tens of meters wide. Extensive sediment accumulation was present at CFSR, CFMP and CFCA. These three sites near and in Missoula were selected for preliminary analysis of metal concentrations in the dry banks to see if further study on the geochemistry of the exposed bank sediments might be warranted.

Fine-grain and bulk sediment samples were collected from the exposed banks on August 29, 2008 at the three selected sites. Three dry bulk samples (unsieved grab samples) were collected in a plastic Ziploc bag at each site from various locations on the exposed bars and banks. For better comparison with the channel bed sediment samples, fine-grain samples were collected from these same exposed bar locations by using the filtering method used in the bed samples with ambient stream water at the site. Bulk sediments were later thoroughly mixed and crushed using a ball mill.

Each pair of bulk and fine-grain samples was from a different morphological unit of sediment aggradation, if possible, because grain size effects and elevation as the water recedes, promoting deposition, can influence where the sediment is deposited (Ladd, *et. al.,* 1998). At CFSR, one sample, X, was collected from a huge eddy return sandbar that formed on the outside bank of a river bend. Sample Y was collected from a small side channel which cut into the sandbar along the major bank, and was still damp with river water. Sample Z was collected from a sand bar that formed the edge of the channel at the river bend during low flow, and was upstream of the eddy. At CFMP and CFCA, however, the river ran straight so the samples were all collected in a straight line from just above the water's edge at 15-30 meter intervals, though CFCA was from a large side channel rather than the main channel.

2.3 Laboratory Analysis

Sediment samples deposited in the channel bed and on the banks were collected and analyzed in the Environmental Biogeochemistry Laboratory (EBL) in the Geosciences Department at The University of Montana. Bed and bank sediment samples were drained, dried

(<70°C), crushed, and digested using an acid digest with nitric and hydrochloric acid reflux (90°C), then oxidized with hydrogen peroxide (EPA Method 3050B).

All digested samples were analyzed by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) using EPA Method 200.7, with a focus on heavy metals of concern most often associated with mining waste: As, Cd, Cr, Cu, Pb, and Zn. Mercury concentrations were determined separately with cold vapor atomic fluorescence spectrometry (CVAFS) using a Leeman Hydra AF Mercury Analyzer and EPA Method 245.7. The complete quantitative results for all elements analyzed for the five bed sediment and the one bank sediment sampling events are presented in Appendix B.

2.4 Quality Assurance/Quality Control

Laboratory analysis was conducted under a strict quality control protocol to determine the precision and accuracy of the lab method and analytical techniques. The QA/QC program consisted of blanks, spikes, duplicates, and standard reference material. The quality control compliance was focused on the elements of interest for our study, primarily As, Cd, Cr, Cu, Pb, Zn, and Hg, and the QA/QC results for these elements are presented in Appendix C.

2.5 External Data Sources for Reservoir and Suspended-Sediment

Several outside sources were used to provide supporting data for our analysis. Pre-breach conditions in the lower CFR were provided by USGS Open-File Reports by Dodge *et.al.,* (2005, 2006, 2007) who provided bed sediment concentrations from 2004 to 2006 at three sites on the CFR above and below the dam (Appendix D). The Record of Decision (ROD, 2004) for Milltown Reservoir Sediment Operable Unit (MRSOU) provided detailed As and Cu concentrations and sediment depths for five sediment accumulation areas (SAA) within the reservoir that can be used for comparison to identify the source of sediments from the reservoir (Appendix D).

Data from the United States Geological Survey (USGS) for suspended-sediment and total recoverable metals was also used to identify the source and fate of sediments, and to help characterize the spatial and temporal transport of sediments in the river from 2006-2008 to support our conclusions (Appendix D). Supplemental sampling was approved by the EPA to monitor the Milltown Dam removal project, and was conducted by the USGS in addition to a long-term monitoring program of the Clark Fork River Basin. The supplemental data was collected at various sites on the CFR and its tributaries from 2006-08 during the spring runoff from March to June in order to more accurately monitor water quality and erosion processes within the reservoir (Table 2, Figure 3). Several water quality parameters were reported from the supplemental sampling, but we only utilized instantaneous discharge (L/day), suspended-sediment discharge (tons/day) and concentration (mg/L), percent of suspended-sediment smaller than 63 μm, and unfiltered (total recoverable metal) and filtered metal concentrations for As, Cu, Pb, and Zn (μg/L). These six parameters are used in various equations to calculate source contributions of sediment coming out of the reservoir, sediment and metal loads, and approximate metal concentrations in the suspended-sediment at each gauged site. These USGS parameters and results of calculations are included in Appendix D. Data reported by the USGS followed a strict quality assurance program, with field clean-sampling techniques described by Horowitz et al. (1994) and ultra-clean analytical techniques described by Dodge and Lambing (2006) (Lambing and Sando, 2009).

Table 2: USGS gauging sites which reported water quality parameters used in this report. Table includes the site name as it is referred to in this report, river and site location, the gauging station number assigned by the USGS, and latitude and longitude.

Site Name	**USGS Site Location**	**Gauging Station**	**Latitude**	**Longitude**
Turah	CFR at Turah Bridge near Bonner	12334550	46°49'34"N	113°48'48"W
BFR	Black Foot River near Bonner	12340000	46°53'59"N	113°45'20"W
Bypass Channel	Clark Fork Bypass near Bonner	12334570	46°51'53.50"N	113°52'35.20"W
Missoula	CFR above Missoula, at Deer Creek Bridge	12340500	46°52'38"N	113°55'53"W
BRR	Bitterroot River near Missoula	12352500	46°49'55"N	114° 03'11"W
St. Regis	CFR at St. Regis	12354500	47°18'07"N	115°05'11"W
FHR	Flathead River at Perma	12388700	47°22'03"N	114°35'03"W

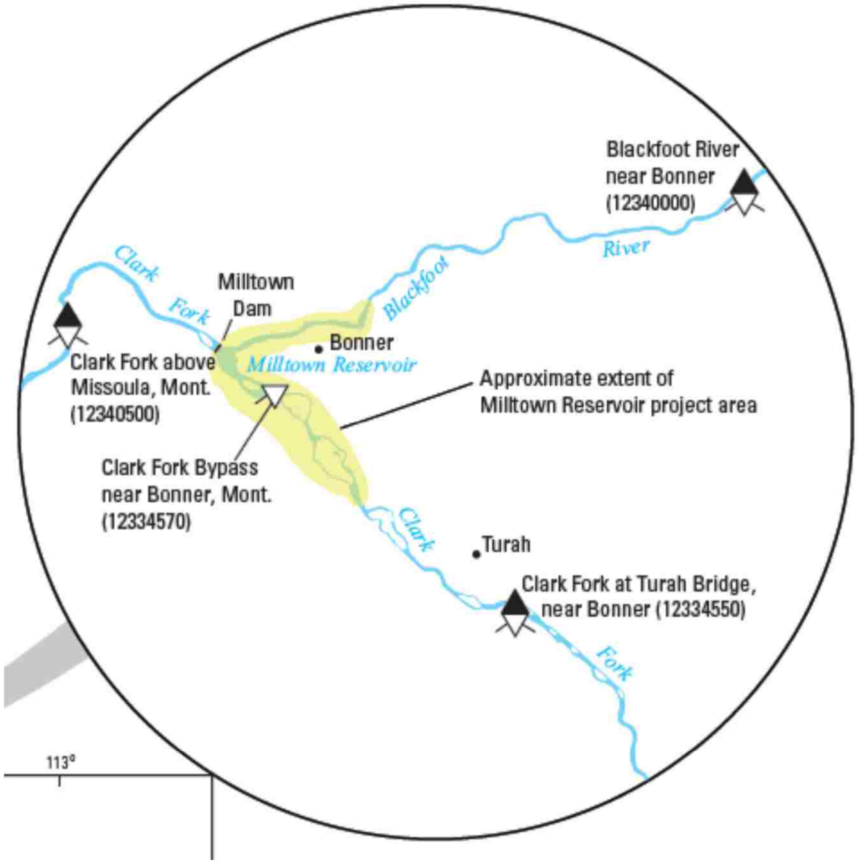


Figure 3: Map of the USGS gauge sites (white triangles) around Milltown Reservoir. Image does not include USGS gauges for St. Regis and the two downstream tributaries, BRR and FHR. Map copied from Lambing and Sando (2009).

2.6 ***Suspended-Sediment Calculations***

2.6.1 Sediment and Metal Loads

Sediment loads at each USGS gauging site were calculated from total suspended-sediment (TSS) concentration and stream discharge.

$$[TSS]\ (mg/L) \times Q\ (L/day) / (10^9\ mg/kg) = \text{Sediment Load}\ (kg/day) \qquad \text{(Eqn 1)}$$

where [TSS] is suspended-sediment concentration and Q is stream discharge.

Metal loads bound to suspended-sediment were also calculated for As, Cu, Pb and Zn using unfiltered and filtered metal concentrations to differentiate between total metal load and sediment metal load;

$$[M]_T\ (\mu g/L) - [M]_{aq}\ (\mu g/L\ ) = [M]^*\ (\mu g/L) \qquad \text{(Eqn 2)}$$

where $[M]_T$ is total recoverable metal concentration (unfiltered), $[M]_{aq}$ is metal concentration in filtered (<62 µm) water, and $[M]^*$ is the concentration of metal in a given volume of stream water that is bound to sediment. The result of this equation was then used in Equation 3 to calculate the load of sediment-bound metals, M_{ss} load:

$$[M]^*\ (\mu g/L\ ) \times Q\ (L/day) / (10^9\ \mu g/kg) = M_{ss}\ \text{Load}\ (kg/day) \qquad \text{(Eqn 3)}$$

This yields the metal load associated with TSS that is transported through each gauging site. The sediment and metal loads can help us to identify the source and magnitude of metals contamination at each USGS site.

The fine-grained sediment load was calculated at each site in addition to the total sediment load:

$$\text{Sed. Load}\ (10^3\ kg/day) \times (\% < 63\ \mu m) = \text{Fine-Grain Load}\ (10^3\ kg/day) \qquad \text{(Eqn 4)}$$

Comparison of the fine-grain and total sediment loads provides insight into the composition of the sediment being transported by the river and the effects of streamflow on grain size mobility.

2.6.2 Erosion and Deposition from Sediment Load Differences

Erosion and deposition in the reservoir and the lower CFR channel was calculated by monitoring inflow and outflow of sediment load. Differences in sediment load between two or more sites can indicate either erosion or deposition of the sediment along the given stretch of river. Calculations of the differences in sediment load were performed over two major areas: the reservoir, divided into the upper and lower reservoirs by the bypass channel gauge, and the lower CFR downstream of the reservoir (Figure 3). The following equations were used to calculate sediment load differences:

$$\text{Bypass Channel} - \text{Turah} = \text{Upper Reservoir} \qquad \text{(Eqn 5)}$$

$$\text{Missoula} - (\text{Turah} + \text{BFR}) = \text{Total Reservoir} \qquad \text{(Eqn 6)}$$

$$\text{Missoula} - (\text{Bypass Channel} + \text{BFR}) = \text{Lower Reservoir} \qquad \text{(Eqn 7)}$$

$$\text{St. Regis} - (\text{Missoula} + \text{BRR}) = \text{Lower CFR} \qquad \text{(Eqn 8)}$$

Positive values indicate erosion from the given area while negative values indicate deposition. If the value is close to zero, this means that there was neither erosion nor deposition, or the amount of erosion and deposition is equal. Differences in metal loads were also calculated using the same equations.

2.6.3 Metals Concentration

In order to estimate the concentrations of metals in the suspended-sediment, we utilized previous equations from calculating metal load to determine the metal content in the sediment in a given volume of water, [M]* (Eqn 2). In order to convert this directly to the concentration in the sediment, we must account for the concentration of suspended-sediment in the water sample, rather than the volume of water.

$$[M]^{*}\ (\mu g/L)\ /\ [TSS]\ (mg/L)\ /\ (1000\ mg/g) = [M]_{ss}\ (\mu g/g) \text{ or } (mg/kg) \qquad \text{(Eqn 9)}$$

Although these calculations account for total sediment rather than only fine-grain sediment the result is a good estimate of the concentration of metal bound to the suspended-sediment which can be compared to our values in fine-grained bed sediment.

3. Results

3.1. Metals in Bed Sediment

Throughout the study period from May 3 through August 21 at all downstream sites on the CFR, bed sediment concentrations of all metals except for Cr were significantly elevated above background concentrations, and for the first two sampling events in May were significantly higher than pre-breach and upstream conditions. The highest metals concentration was found in samples collected May 3-5 (Figure 4A-10A), before the rising limb of the hydrograph (Figure 2) and one month after the dam was breached. At this time, the metal concentrations did not appear to decrease significantly with distance downstream, which is why our experimental method was revised, extending the size of our study area in the downstream direction. By May 21-25 longitudinal distribution of metals concentration showed an exponential decrease with distance downstream, a trend which remained throughout the rest of the study period, with overall decreasing concentrations over time.

Metals enrichment factors over both background and pre-breach conditions can help to quantify the impact of the metals from reservoir sediment release on the downstream environment (Table 3, Figure 11). The greatest enrichment in the CFR occurred in early May, when As concentration was more than 40 times greater than background conditions, and more than 100 for Cu. Compared to pre-breach data, As was 9 times higher and Cu was 5 times higher. All metals except for Cr were enriched by more than a factor of 20 over background conditions in early May. Chromium, not a known contaminant in the reservoir, was the only metal which showed no enrichment over the course of our study over both background and pre-breach conditions, and did not significantly change over time or distance from the dam (Figure 9). Mercury was the only metal which was highest at the upstream site at CFTB, and remained so throughout the study period, but followed similar downstream trends of the other metals over distance and time (Figure 10). The one site upstream of the dam (CFTB) yielded metals concentration that were similar to pre-breach data at the same site, suggesting that the dam removal did not significantly affect the channel contamination upstream of the reservoir.

By May 21-25 during the maximum annual streamflow event (Figure 2), As, Cd, Cu, Pb and Zn concentrations in the CFR had decreased by about half (Table 3). From June 9 through August 21, metals concentration at the most upstream sites had already returned to near pre-breach conditions at Missoula (Figure 11). However, concentrations at the most downstream sites were generally greater than or equal to the pre-breach conditions found in 2004 below the confluence of the CFR and BRR, about 22 km downstream of the dam (Figures 4-10). This is evidence of the long-distance impact of the dam removal, extending metals enrichment from 20 to 200 km downstream of the dam.

Minimum metals enrichment in the bed sediment occurred in the July 3-4 data, and then increased again by August 20-21 to levels found prior to June 9-10. Between June and August, the sites closest to the dam are similar to the pre-breach concentrations, with a pre-breach enrichment factor of about 1 for all trace metals except As, and Cu in August. Metals concentration went up slightly in August at the sites closest to the dam, but continued to decrease at sites furthest downstream.

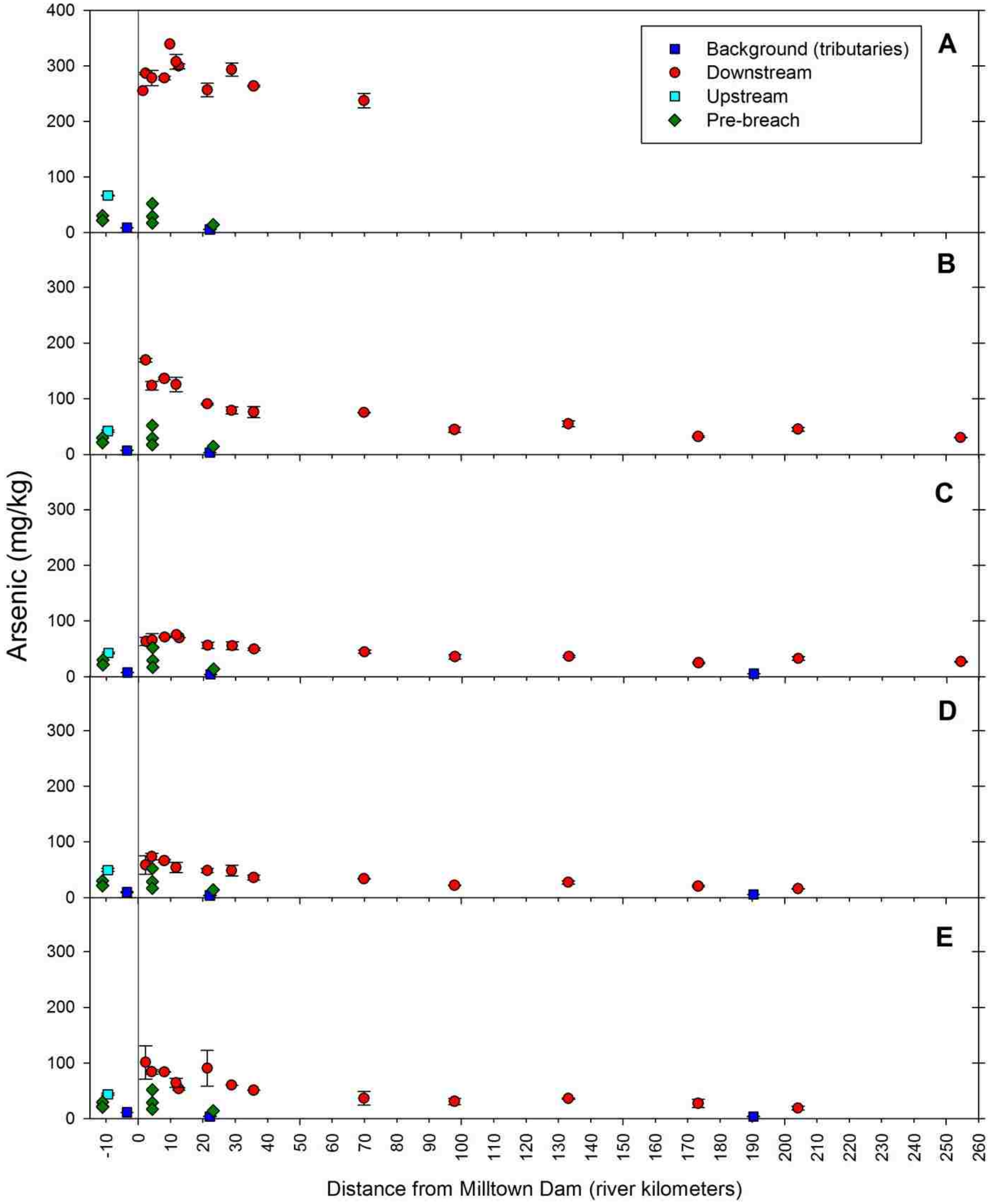


Figure 4: Arsenic bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

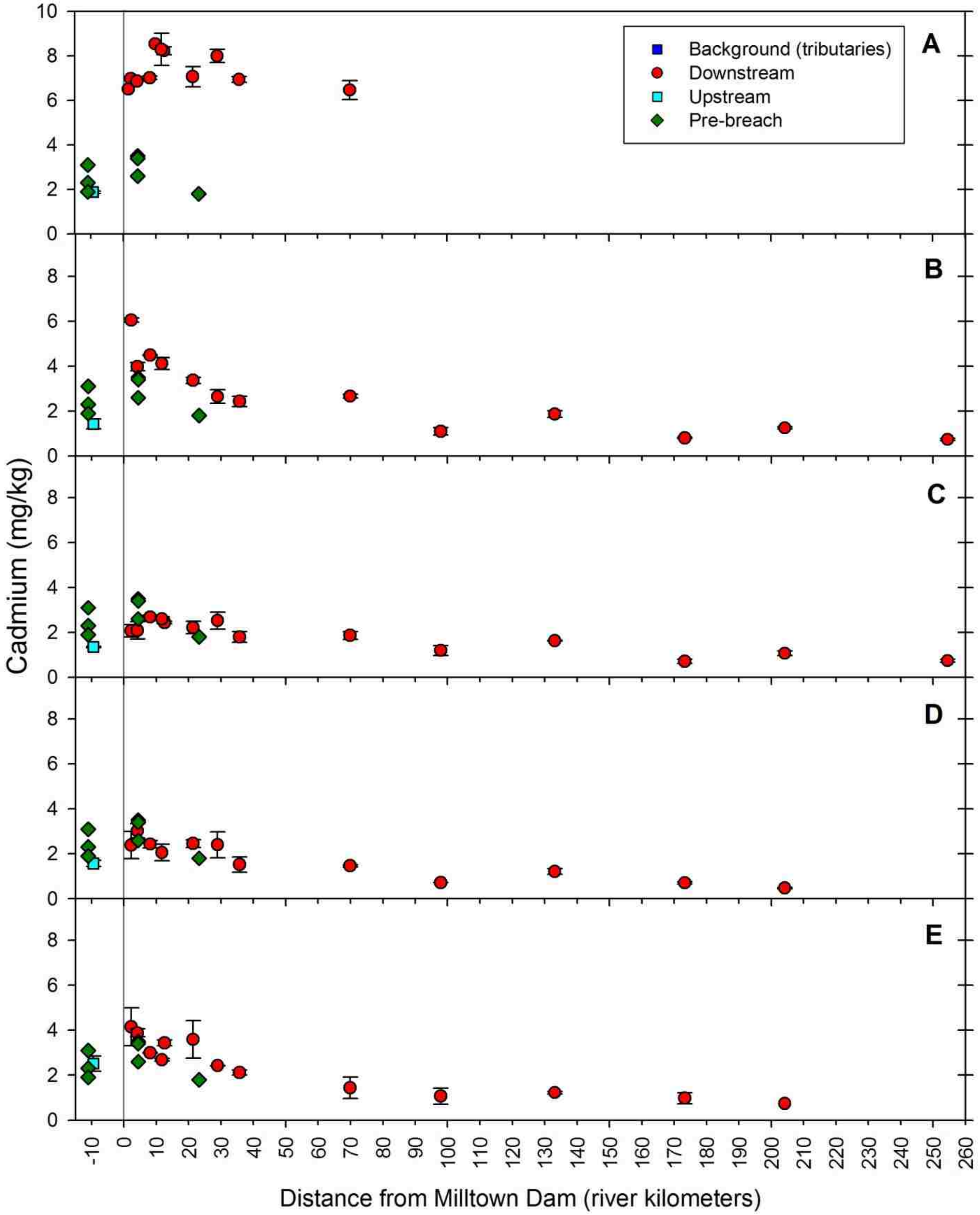


Figure 5: Cadmium bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

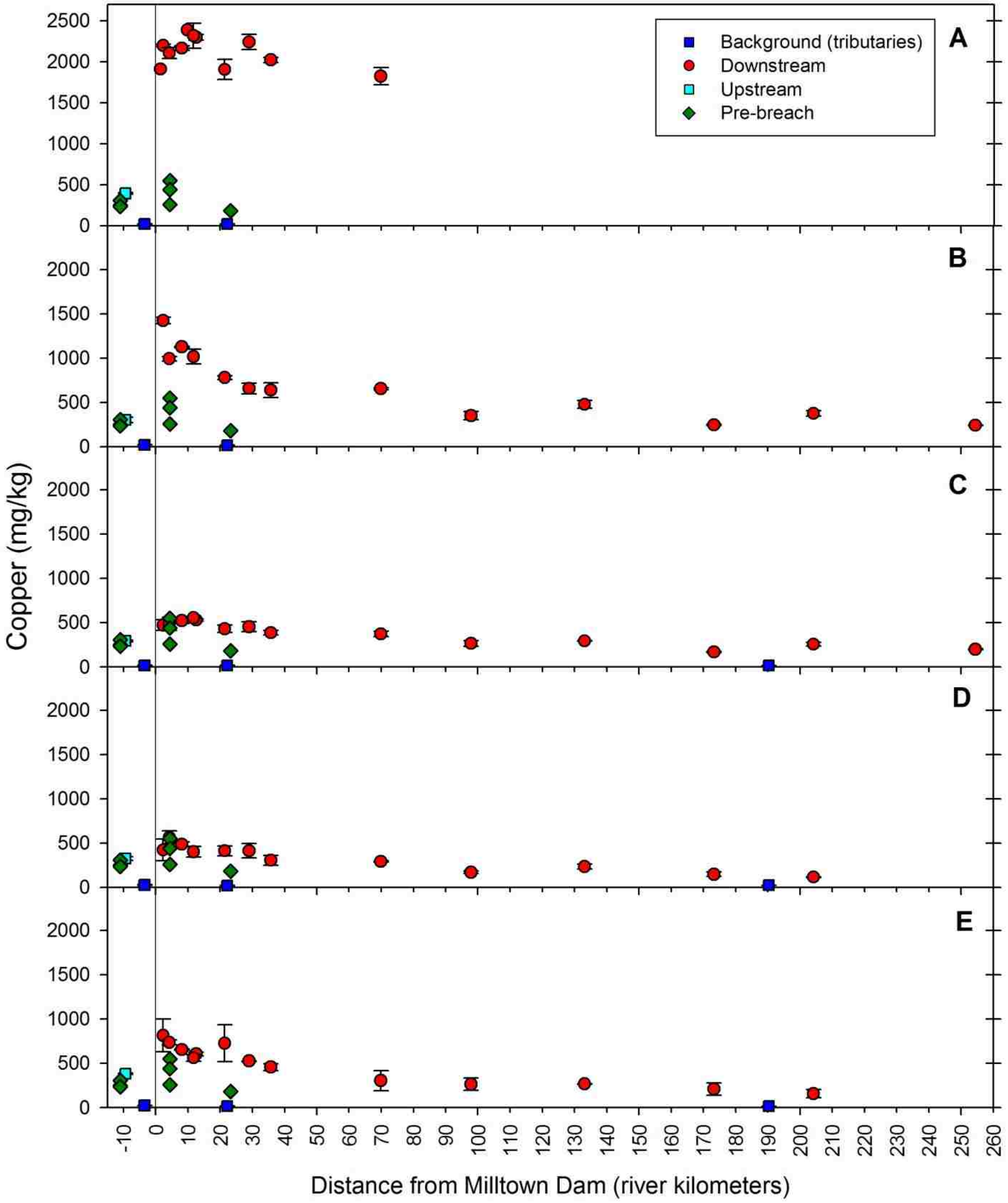


Figure 6: Copper bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

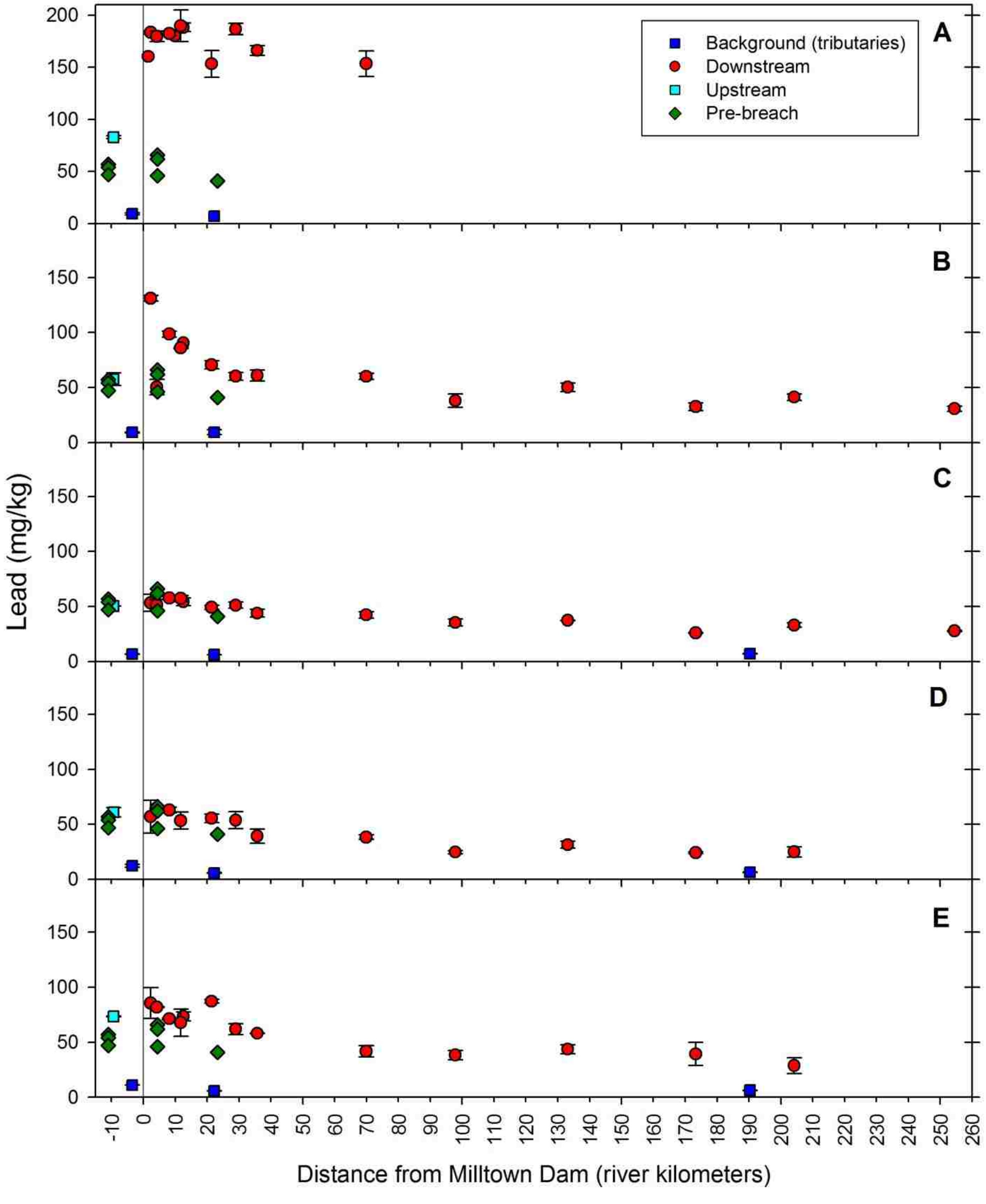


Figure 7: Lead bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

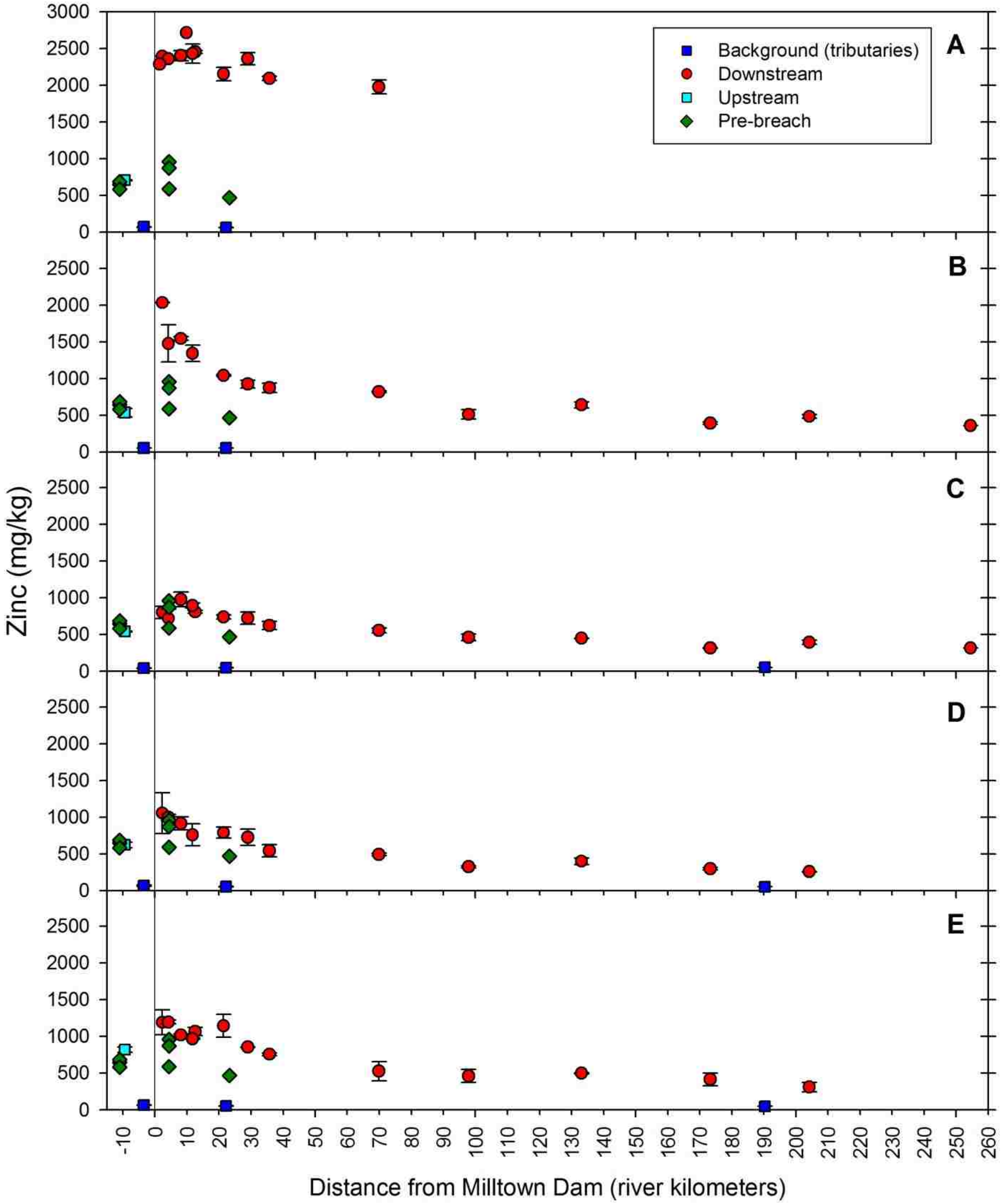


Figure 8: Zinc bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

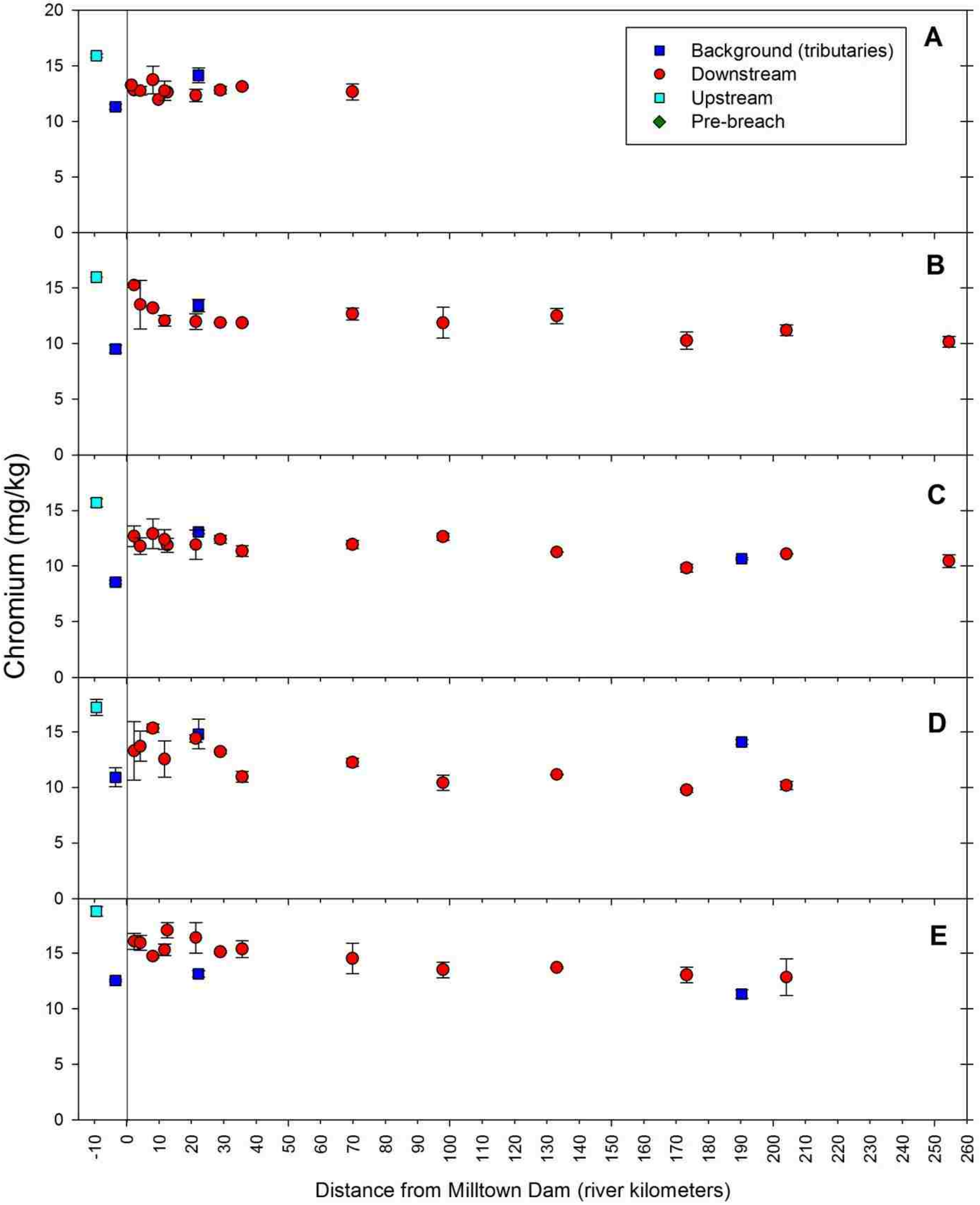


Figure 9: Chromium bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

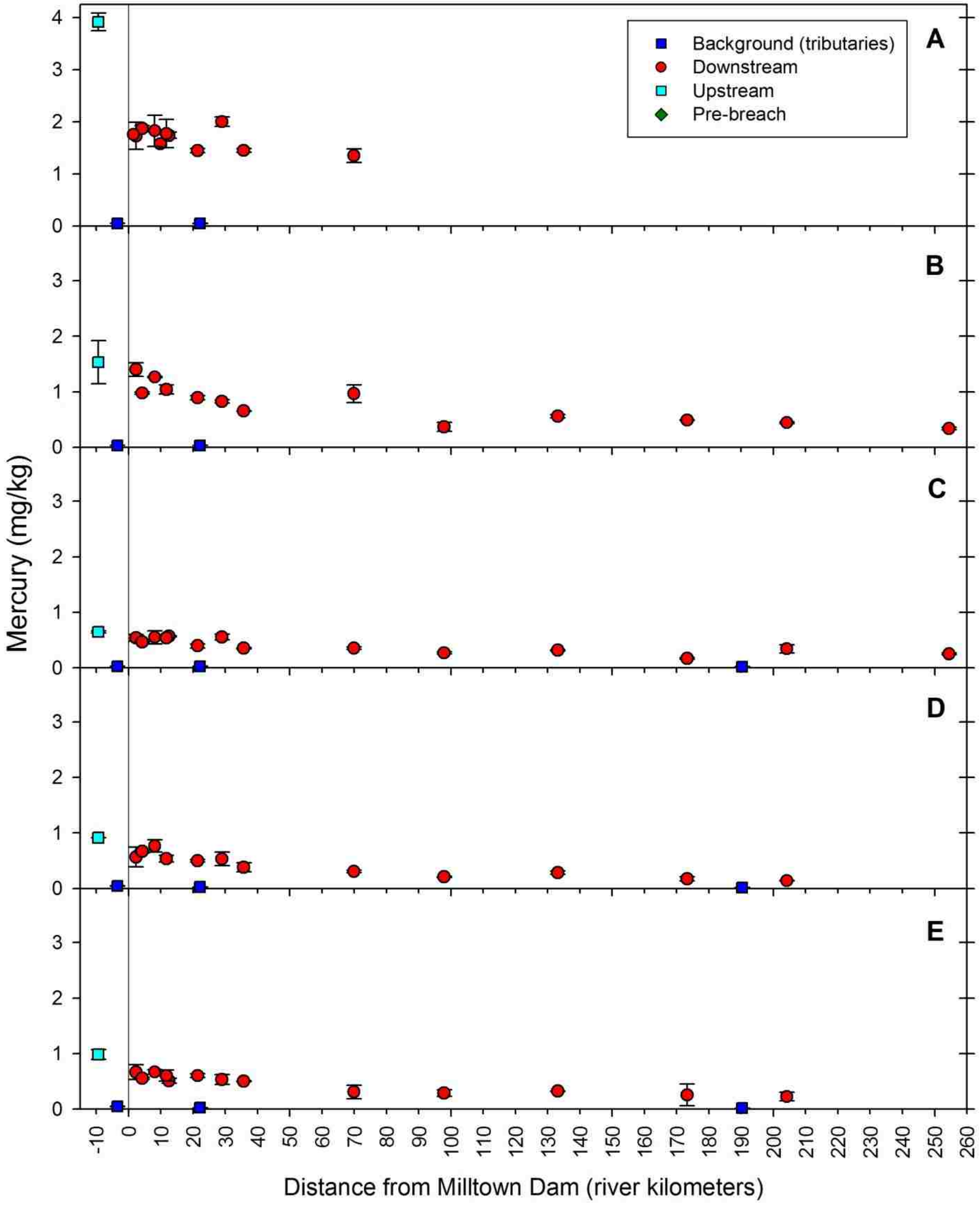


Figure 10: Mercury bed sediment concentrations (mg/kg) versus distance downstream of the dam for each sampling event A) May 3-5: B) May 21-25; C) June 9-10; D) July 3-4; E) August 20-21.

Table 3: Mean bed sediment metals concentration (mg/kg) in the upstream CFR sites (0-13km) for each sampling event; mean metals concentrations in background tributaries (BFR, BRR, FHR); enrichment values in the CFR over background conditions (CFR/Background); average pre-breach conditions at Missoula (Appendix D); and enrichment in CFR over pre-breach conditions (CFR/Pre-breach).

May 3-5

	As	**Cd**	**Cu**	**Pb**	**Zn**	**Cr**	**Hg**
CFR (0-13)	291	7.5	2207	182	2424	12.9	1.8
Background	6.9	< 0.005	21	8.2	67	12.7	0.05
CFR/Background	**42**	**-**	**103**	**22**	**36**	**1**	**35**
Pre-breach	32.7	3.2	417	58.0	807	22.2	-
CFR/Pre-breach	**8.9**	**2.4**	**5.3**	**3.1**	**3.0**	**0.6**	**-**

May 21-25

	As	**Cd**	**Cu**	**Pb**	**Zn**	**Cr**	**Hg**
CFR (0-13)	139	4.7	1141	101	1602	13.5	1.2
Background	5.2	< 0.005	21	9.2	56	11.5	0.04
CFR/Background	**27**	**-**	**55**	**11**	**29**	**1**	**32**
Pre-breach	32.7	3.2	417	58.0	807	22.2	-
CFR/Pre-breach	**4.2**	**1.5**	**2.7**	**1.7**	**2.0**	**0.6**	**-**

June 9-10

	As	**Cd**	**Cu**	**Pb**	**Zn**	**Cr**	**Hg**
CFR (0-13)	68.9	2.4	514	54.7	842	12.3	0.5
Background	5.5	< 0.005	18	6.6	49	10.8	0.03
CFR/Background	**13**	**-**	**29**	**8**	**17**	**1**	**20**
Pre-breach	32.7	3.2	417	58.0	807	22.2	-
CFR/Pre-breach	**2.1**	**0.8**	**1.2**	**0.9**	**1.0**	**0.6**	**-**

July 3-4

	As	**Cd**	**Cu**	**Pb**	**Zn**	**Cr**	**Hg**
CFR (0-13)	63.1	2.5	468	59.4	932	13.7	0.6
Background	6.6	< 0.005	23	8.1	58	13.3	0.03
CFR/Background	**10**	**-**	**20**	**7**	**16**	**1**	**21**
Pre-breach	32.7	3.2	417	58.0	807	22.2	-
CFR/Pre-breach	**1.9**	**0.8**	**1.1**	**1.0**	**1.2**	**0.6**	**-**

August 20-21

	As	**Cd**	**Cu**	**Pb**	**Zn**	**Cr**	**Hg**
CFR (0-13)	77.4	3.4	676	76.0	1089	15.8	0.6
Background	6.6	< 0.005	19	7.7	57	12.3	0.03
CFR/Background	**12**	**-**	**35**	**10**	**19**	**1**	**20**
Pre-breach	32.7	3.2	417	58.0	807	22.2	-
CFR/Pre-breach	**2.4**	**1.1**	**1.6**	**1.3**	**1.3**	**0.7**	**-**

Overall metals concentration level off over time and distance around 20 ppm As, 150 ppm Cu, 0.7 ppm Cd, 25 ppm Pb and 300 ppm Zn (Figures 4-8). These values in the bed sediment about 200 km from Milltown Dam are well above natural background concentrations found in all three tributaries and are only slightly lower than pre-breach conditions found below the confluence with the BRR (~23 km) in 2004 (Appendix D).

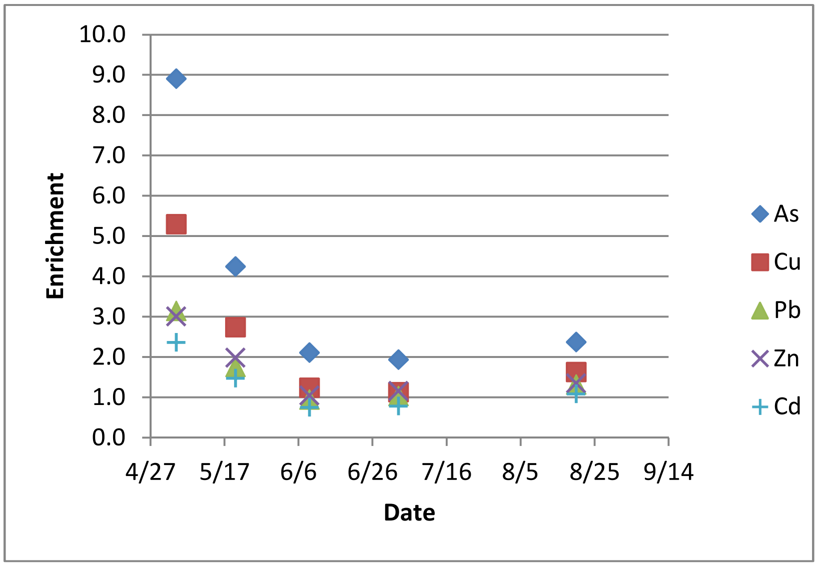


Figure 11: Plot of enrichment factors over pre-breach conditions for metals concentration in the CFR near Missoula (0-13km) versus time for As (blue diamond), Cu (brown square), Pb (green triangle), Zn (purple X), and Cd (blue +).

The first dataset only extended 70 km downstream (to CFPC), where the lowest [M] were found at that time, but there was not much variability between the sites to immediately recognize an overall trend with distance from the dam (Figures 4A-10A). A downstream trend became more apparent in the second sample set with the added sites extending the study area to 254 km from the dam, displaying an exponentially decreasing curve over distance downstream, with no offset peak (Figures 4B-10B). This trend continued from June through August. Figure 12 shows the semi-logarithmic linear relationship for As and Cu with distance downstream for the final four sampling events, representing the decreasing exponential trend in metal concentrations in bed sediment with distance downstream. The exponential decrease in the last four sampling events also occurs for Cd, Pb, Zn, and Hg. The exponential curve remains over time but with an overall decrease in metals concentration to pre-breach conditions at every site in the June 9-10 and July 3-4 sample sets (Table 3), followed by a very slight overall increase above pre-breach conditions by August 20-21.

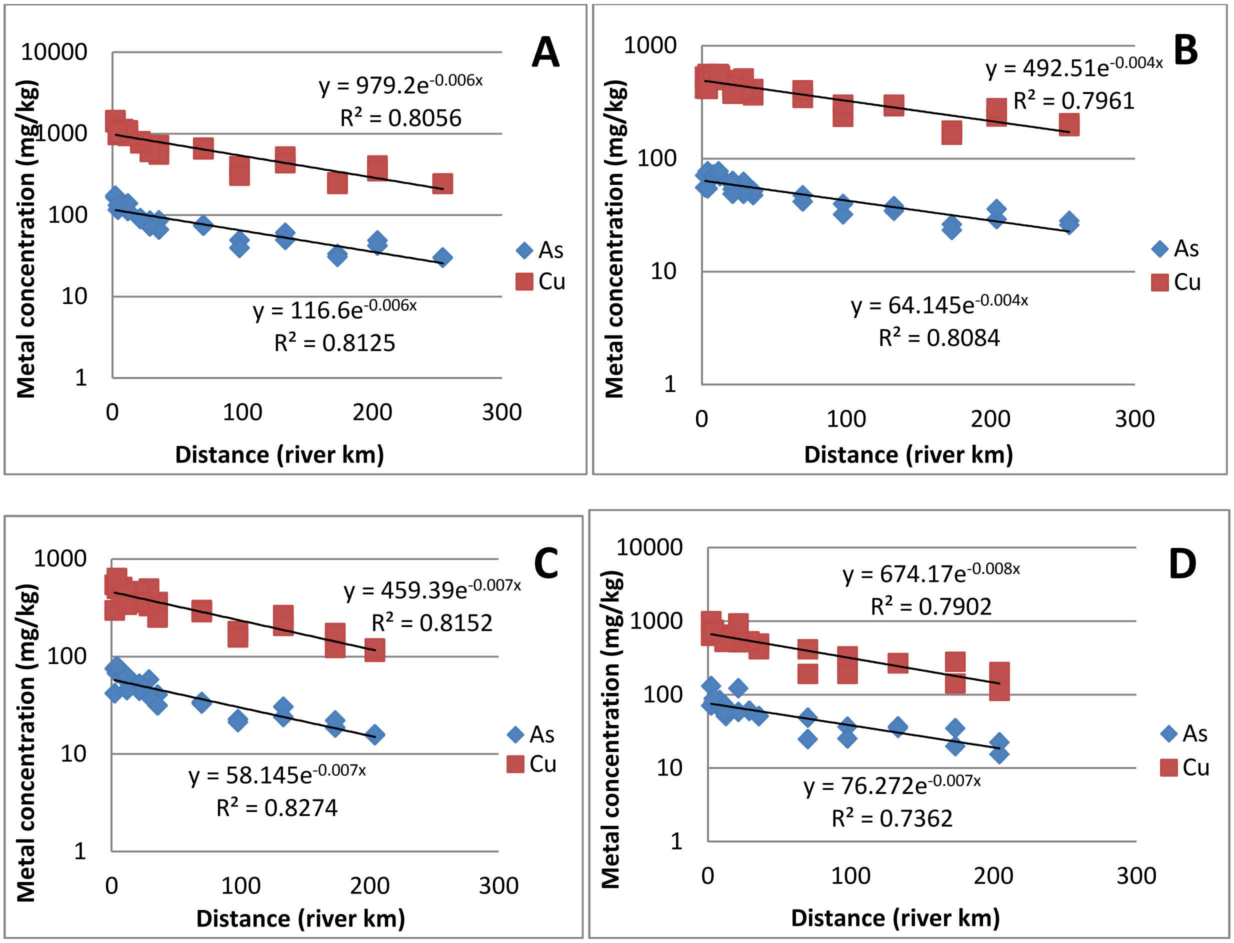


Figure 12: Graphs showing the semi-log relationship for As (blue diamond) and Cu (brown square) versus distance downstream (river km) of the dam for A) May 21-25; B) June 9-10; C) July 3-4; and D) August 20-21. Each graph includes the best-fit linear regression equations and R-squared value for each metal. Similar trends exist for Cd, Pb, Zn and Hg.

Table 4: Regression equations and R^2 values for As, Cd, Cu, Pb, Zn, and Hg in bed sediment samples sets for May 21-25, June 9-10, July 3-4, and August 20-21.

	As	Cd	Cu	Pb	Zn	Hg
May 21-25	$116.6e^{-0.006x}$	$4.1046^{-0.008x}$	$979.2e^{-0.006x}$	$85.783^{-0.005x}$	$1332.8e^{-0.006x}$	$1.0694e^{-0.005x}$
R^2	0.8125	0.7977	0.8056	0.7415	0.8056	0.6681
June 9-10	$64.145e^{-0.004x}$	$2.4258e^{-0.005x}$	$492.51e^{-0.004x}$	$53.33e^{-0.003x}$	$807.34e^{-0.004x}$	$0.4868e^{-0.003x}$
R^2	0.8084	0.7753	0.7961	0.8120	0.8428	0.5684
July 3-4	$58.145e^{-0.007x}$	$2.509e^{-0.008x}$	$459.39e^{-0.007x}$	$56.919e^{-0.005x}$	$864.86e^{-0.007x}$	$0.5981e^{-0.007x}$
R^2	0.8274	0.8137	0.8152	0.7465	0.8236	0.8187
Aug. 20-21	$76.272e^{-0.007x}$	$3.3443e^{-0.008x}$	$674.17e^{-0.008x}$	$75.68e^{-0.005x}$	$1082.5e^{-0.006x}$	$0.6037e^{-0.006x}$
R^2	0.7362	0.7769	0.7902	0.7331	0.8288	0.6412

The BFR, BRR and FHR, the only major tributaries to the CFR in our study area, had very low bed sediment metals concentration that did not significantly vary over the course of our study. The CFR had concentrations that were 1.5 to 3 orders of magnitude larger than the background conditions established by the tributaries (Figures 4-8, 10). The BFR had the highest concentrations of the three but Cu concentrations did not exceed 30 ppm, while concentrations in the CFR were never less than 100 ppm, even 250 km downstream of the dam and months after the dam was breached. For every metal analyzed, the highest concentrations found in all three tributaries never exceeded the lowest concentrations anywhere in the CFR. It was much more difficult to locate substantial amounts of fine-grain sediment in the three tributary rivers compared to the CFR, which suggests that there was much less sediment being transported in these tributaries.

3.2 Metals in Bank Sediment

3.2.1 Bank vs. Bed Metal Concentrations

Significantly elevated concentrations of metals were found in the bank sediment along the channel margins. Metals concentration was higher in the bank than in the bed sediment in late August (Figure 13). The differences between fine-grain bed and bank sediment metals concentration become more distinct further downstream. Although at CFSR, the most upstream site where bank sediment was collected, bed and bank samples yield very similar results, nine kilometers downstream at CFCA concentrations are consistently higher on the banks than in the channel for all heavy metals. The bank values correspond to the channel bed sediment that was deposited during the higher flows between May 21 and June 9. The sediment in that particular area of the bank was most likely deposited within this time frame and remained on the bank as the waters receded.

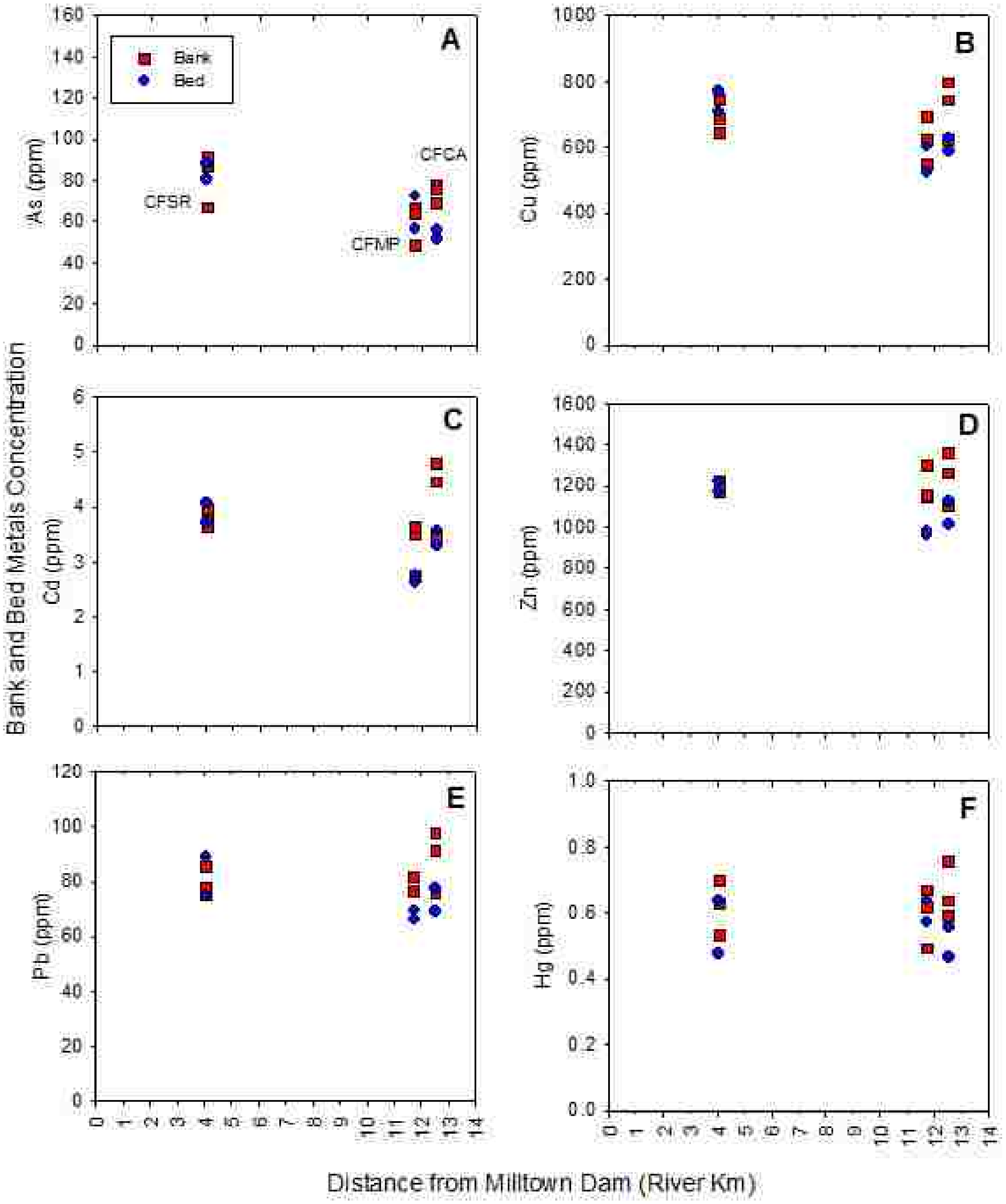


Figure 13: A comparison of fine-grain bank (red squares) and bed (blue circles) sediment metals concentration versus distance downstream for A) As; B) Cu; C) Cd; D) Pb; E) Zn; and F) Hg. Bank sediment was collected August 29, 2008, bed sediment was collected August 21, 2008.

3.2.2 Bank Sediment Composition

Bulk sediment samples were also collected from the banks to compare with the fine-grain sediment collected at the same time and location. In Figure 14, the results for fine-grain concentrations are compared with the bulk concentrations for all three sites to illustrate the relationship between the two sample types, as well as the differences between the sites. Depending on the metal and the site, fine-grain concentrations were a factor of 1.5-10 times higher than bulk concentrations. There does not appear to be a strong linear correlation between bulk and fine-grained sediment (Figure 15), but to a certain extent it does show that fine-grain sediment tends to have higher concentrations of trace metals than coarse-grain, or bulk sediment. Although the fine-grain metals concentrations are similar at all three sites, the bulk sediment show more variability. For example, the larger particles in the bulk sediment (sand) were more contaminated at CFCA than CFSR (Figure 15). This indicates that the coarse sediment deposited at CFCA might have come from a more contaminated region of the reservoir.

The bulk and fine sediments were collected from the same location on the banks at the same time, so the results should not be significantly different from localized variability. However, there was a lot of variability between the three samples at each site, which may have been an effect of the type of morphological unit (riffles, pools, eddies, bars) and location on the bank from which the samples were collected. Previous studies have shown significant variations in metal concentrations between different morphological units (Ladd *et. al.,* 1998).

The CFR bank sediments are being studied more in-depth by other groups from The University of Montana to characterize the stratification of the sediments and their impact on downstream channel geomorphology following the removal of Milltown Dam. Some of their results will be used later to help establish the fate of the former reservoir sediments.

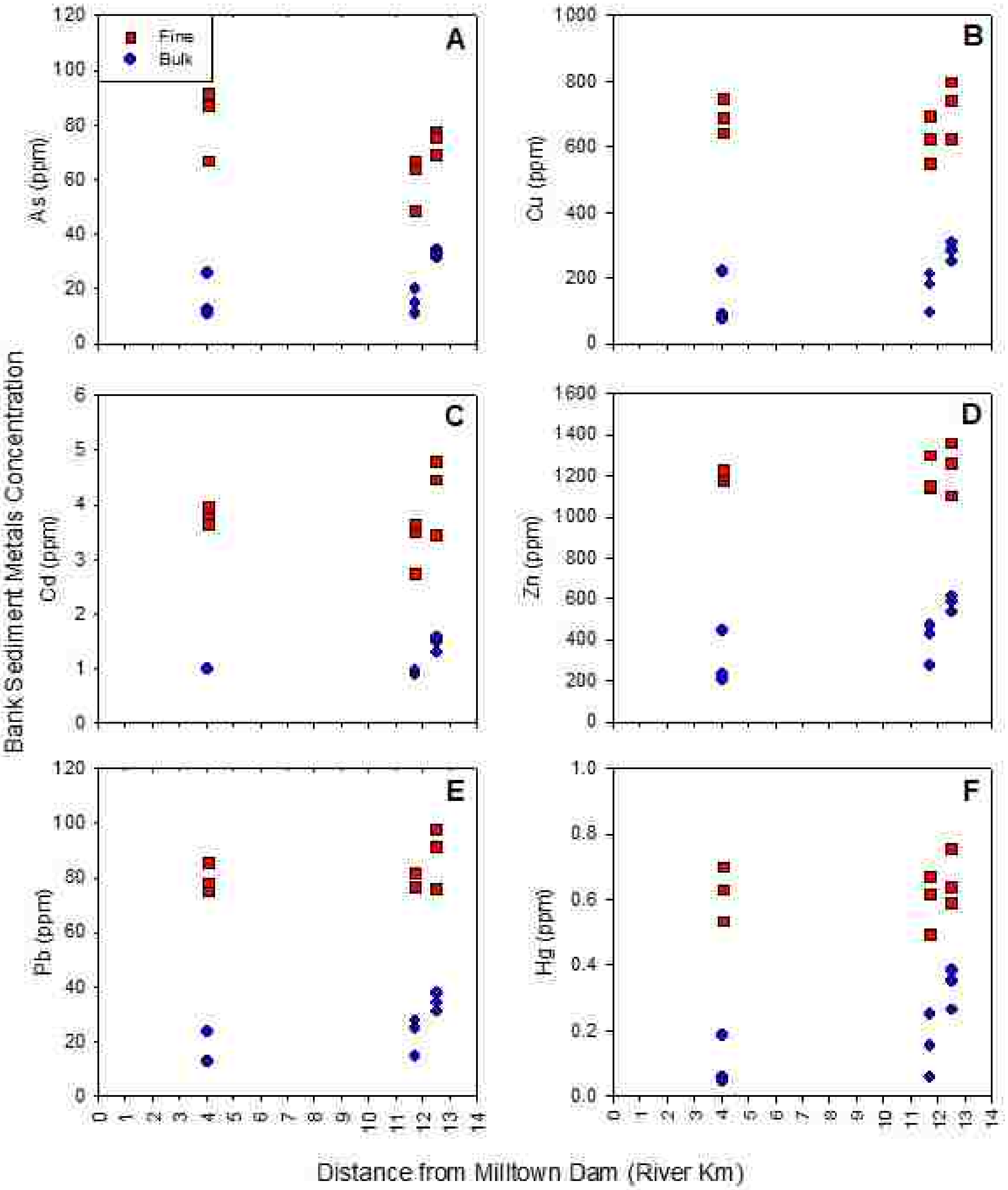


Figure 14: A comparison of fine-grain (red squares) and bulk (blue circles) bank sediment metals concentration on August 29, 2008 for A) As; B) Cu; C) Cd; D) Pb; E) Zn; and F) Hg versus distance downstream.

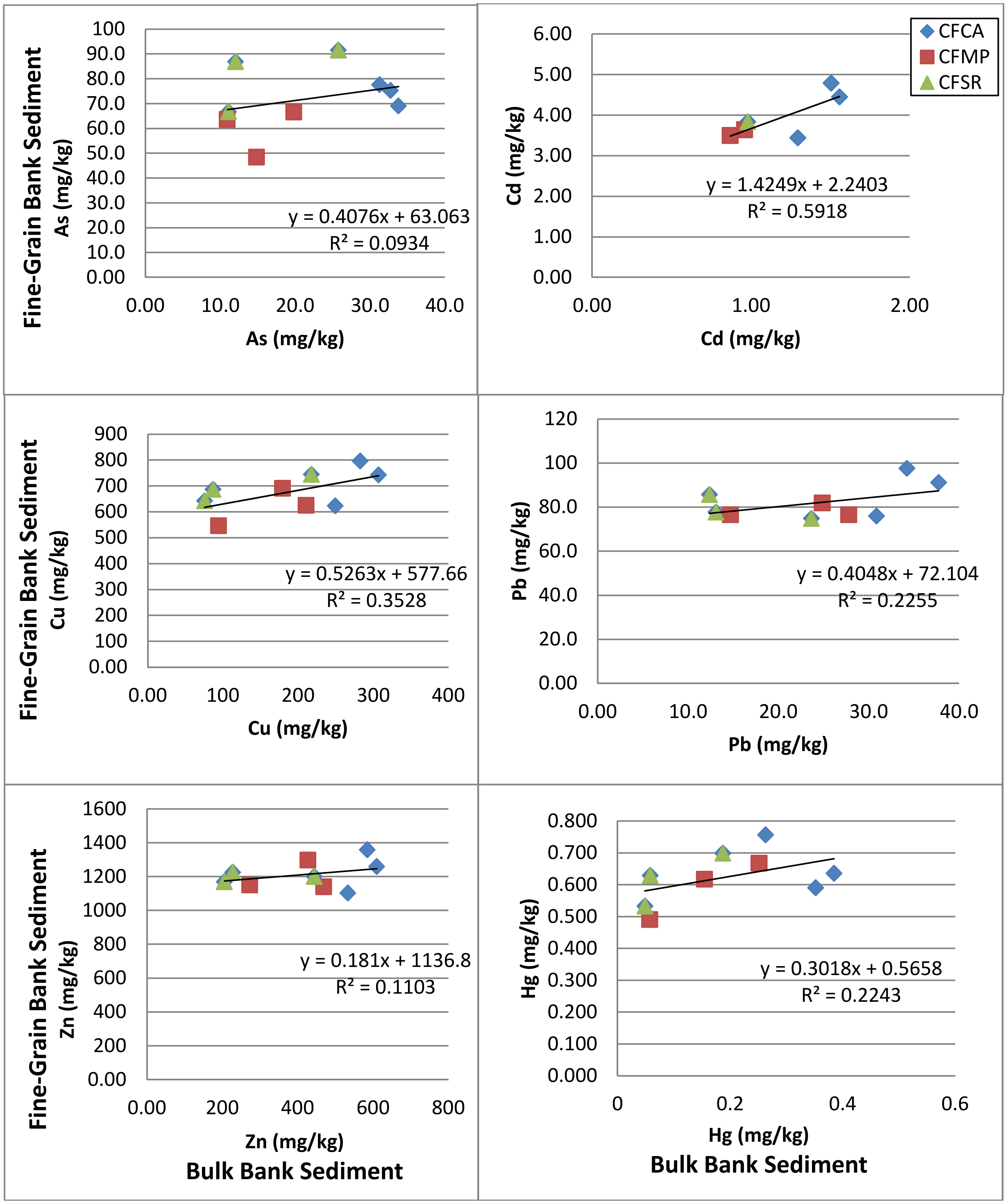


Figure 15: Linear regression lines and R^2 correlation values for As, Cd, Cu, Pb, Zn, and Hg in fine-grain (y-axis) versus bulk (x-axis) bank sediment collected on August 29, 2008. Each site is represented by a different symbol: CFSR (blue triangle), CFCA (red circle), and CFMP (green square).

4. Discussion

4.1 Sediment Transport Effects on Bed Sediment Metals Concentration

4.1.1 Elevated Metals Concentration

Our analysis of the river bed deposits downstream of the reservoir showed significantly elevated concentrations of As, Cd, Cu, Pb, and Zn, indicating that dam removal caused enrichment of metals contaminants in the downstream bed sediment. Enrichment in the CFR was generally more than ten times greater than the tributaries throughout the study (Table 3). Only one month after Milltown Dam was breached, As had peaked at more than 300 ppm at several locations, and Cu was between 2000 and 2500 ppm at all but three downstream sites on the CFR. To put these values in context, the bed sediment concentrations found below Milltown Dam after the ice jam floods of 1996, which encouraged the timely removal of the contaminated reservoir sediments, were 115 ppm As and 775 ppm Cu, less than half of what we found in early May, 2008 (Landrigan,1997; see Appendix A: History of Milltown Reservoir).

Metal enrichment was found over the entire study area, extending more than 254 kilometers downstream of the dam to Thompson Falls Reservoir. By the end of the study period there was similar enrichment of metals in the bed sediment more than 200 km downstream that had been found in 2004 just 22 km downstream (Figures 4-10). This indicates the long-range impacts in the bed sediment. With the removal of Milltown Dam, Thompson Falls Reservoir became the first major impoundment of sediments being transported downstream in the CFR, including the contaminated sediment from Milltown Reservoir. It is reasonable to assume that most of the sediment that was carried through the study area continued to be transported to Thompson Falls where it accumulated in the reservoir. Since the dam will act as a barrier, preventing most of the sediment from passing through and being carried downstream, the final fate of the Milltown sediments will most likely be Thompson Falls Reservoir, unless Thompson Falls Dam is removed. The elevated concentrations found at CFTS (Thompson Falls State Park, 254 km downstream) indicate that some of the Milltown sediments have already completed their journey.

4.1.2 Geochemistry of Transported Sediment

Chromium was not affected by the removal of the dam, with concentrations similar to upstream conditions and natural background levels in all three tributaries (Figure 9). Chromium enrichment over background conditions was 1 for all sampling events, indicating that there was no Cr contamination in the CFR (Table 3). This confirms that Cr was not a contaminant in the reservoir. Chromium was not a major component of the mineral ores mined in the Upper CFR, therefore it is not a byproduct in the mining wastes of this region but is only present as a naturally occurring background contaminant (Axtmann and Luoma, 1991). Chromium is therefore our control in this study, and provides a baseline for what we would see if the reservoir sediment was not contaminated.

Although Hg was a contaminant in the reservoir sediment, it did not show the same behavior as the other metals. Mercury followed similar downstream trends as the other metals, the exception being that the greatest decrease in Hg concentration occurred between May 21 and June 9, while all other metals had the greatest decrease with the increase in stream discharge. This could be related to the fact that the upstream site at CFTB had the highest Hg concentrations, implying that the reservoir was less contaminated than the channel upstream (Figure 10). Historically, Hg was used in gold placer mining throughout the CFR Basin and so it had a different spatial distribution than the other metals that came predominantly from mining wastes from Cu and Ag mines and smelters at the headwaters of the CFR in Butte and Anaconda.

The fact that Hg followed the same downstream trends as the other metals shows that the reservoir was contaminated with Hg to a certain extent, and that some of these Hg enriched sediments were released downstream. However, the reservoir was not the primary source of the contamination. For Hg, the reservoir sediments behaved as a dilutant to the sediment coming from upstream, rather than as the source. These higher concentrations coming from upstream of the reservoir could explain why concentrations did not decrease during maximum stream discharge, since high concentrations of Hg were still being carried through the former reservoir.

The chemical behavior of As generally differs from other metals, dissolving more readily into the liquid fraction under anoxic conditions in aquatic systems (ROD, 2004). This is evidenced by the mobilization of As into the groundwater at Milltown Reservoir when iron oxyhydroxides to which the As are bound are reductively dissolved. In aquatic systems, As exists in the anionic form of arsenate, rather than the cationic form like most metals, which can affect its adsorption to the sediment (Nimick *et. al.*, 2003). Although the chemistry of As did not seem to affect the downstream trend significantly compared to the other contaminants, it is relevant in the partitioning of As between the dissolved ($[As]_{aq}$) and adsorbed particulate state ($[As]^*$), which was nearly equal throughout the study, in contrast to the other metals for which the particulate state was clearly dominant at all CFR sites (Figures 16-19). Any As dissolved in the water was not reflected in our bed sediment samples, so the concentrations that we found would have been even higher if As was completely retained on the sediment. However, the similar trends between all metals concentration in bed sediment, including As, versus distance downstream signifies that the mobilization of metals downstream from the reservoir was not selective with respect to the individual chemistry. The main mode of metal transport was through adsorption to sediments which were carried as suspended-sediment by the river. Other studies confirm that chemical mobilization is not as important as the physical processes of sediment transport in near-neutral pH rivers (Andrews, 1987; Axtmann and Luoma, 1991). This enhances our ability to track the sediments released from the reservoir and to determine their ultimate fate based on metal content.

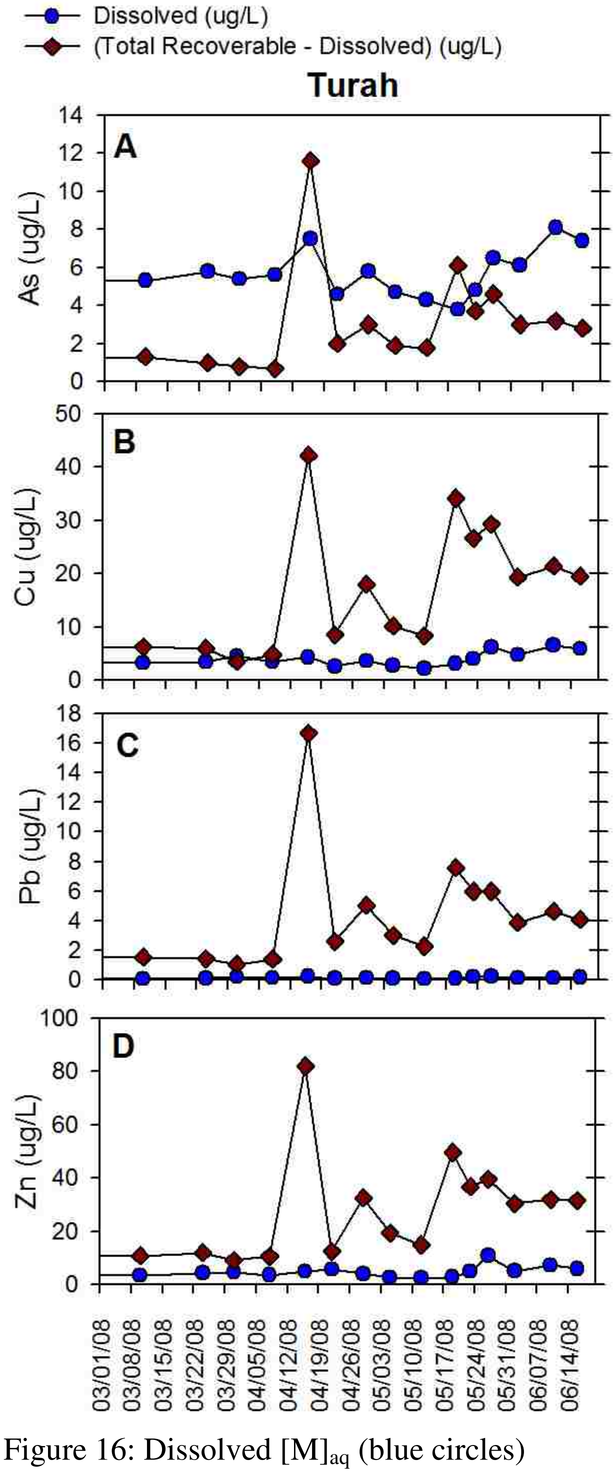


Figure 16: Dissolved $[M]_{aq}$ (blue circles) and particulate (Total Recoverable – Dissolved) [M]* (brown diamond) concentrations for A) As; B) Cu; C) Pb; and D) Zn at Turah. Data provided by the USGS (Appendix D).

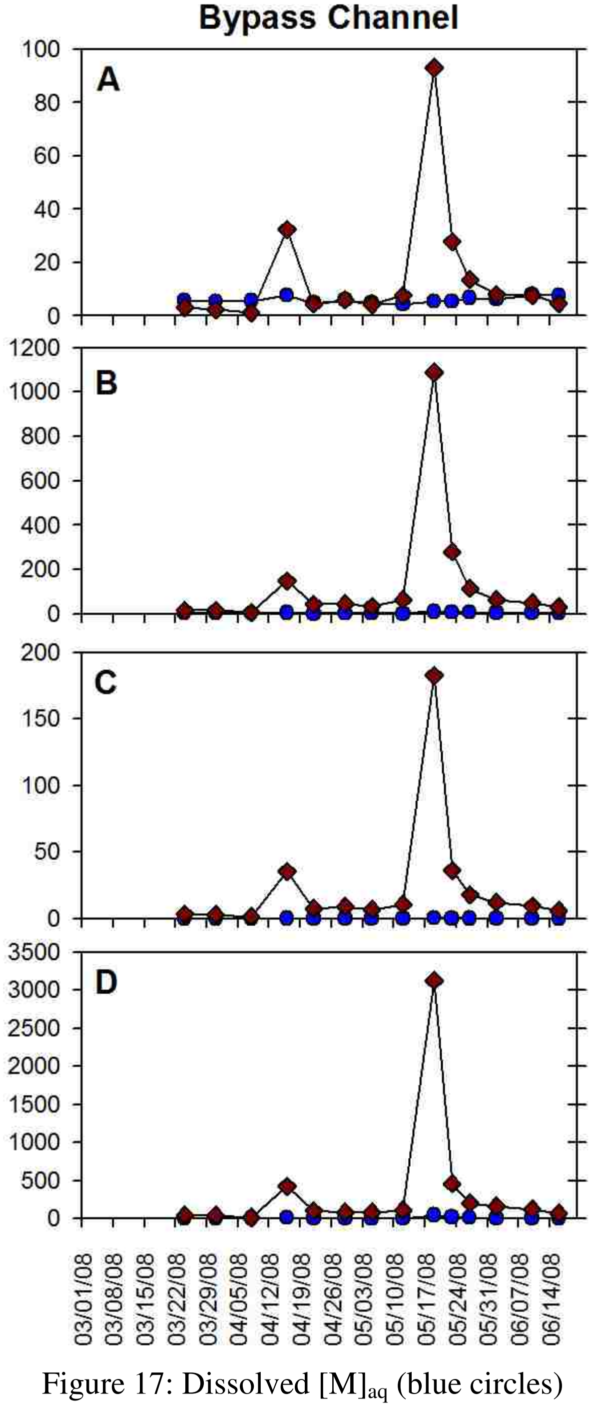


Figure 17: Dissolved $[M]_{aq}$ (blue circles) and particulate (Total Recoverable – Dissolved) [M]* (brown diamond) concentrations for A) As; B) Cu; C) Pb; and D) Zn at Bypass Channel. Data provided by the USGS (Appendix D).

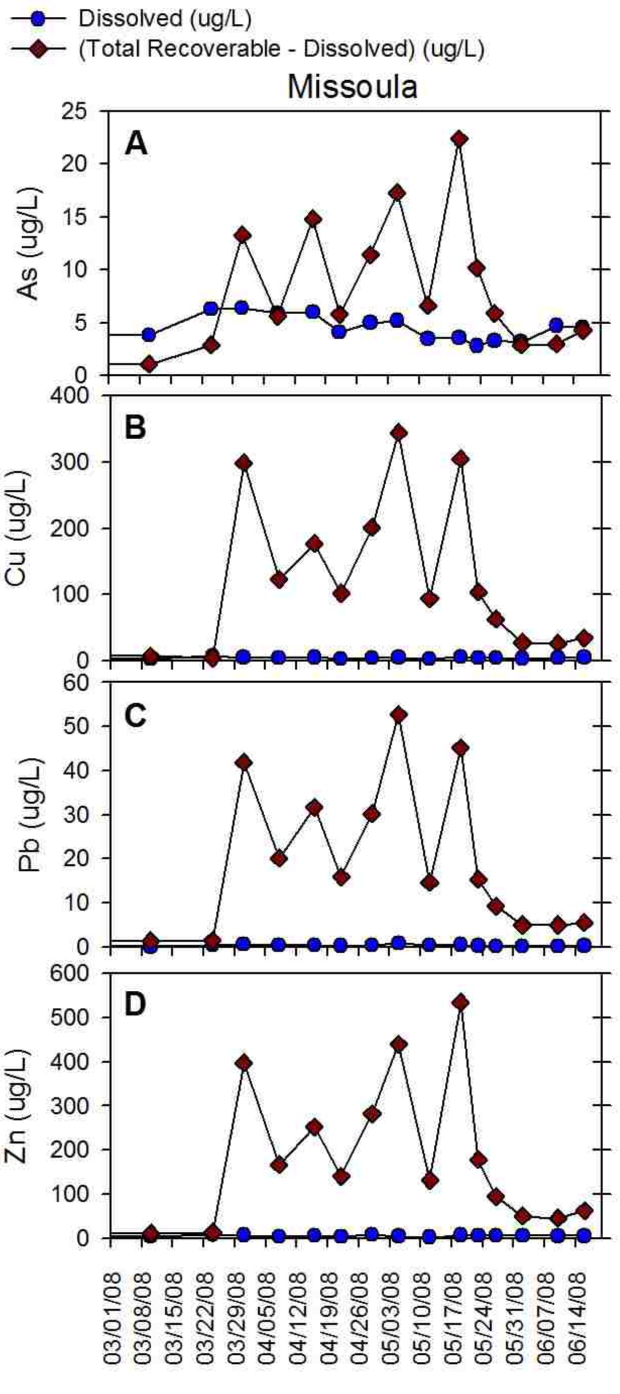


Figure 18: Dissolved $[M]_{aq}$ (blue circles) and particulate (Total Recoverable – Dissolved) [M]* (brown diamond) concentrations for A) As; B) Cu; C) Pb; and D) Zn at Missoula. Data provided by the USGS (Appendix D).

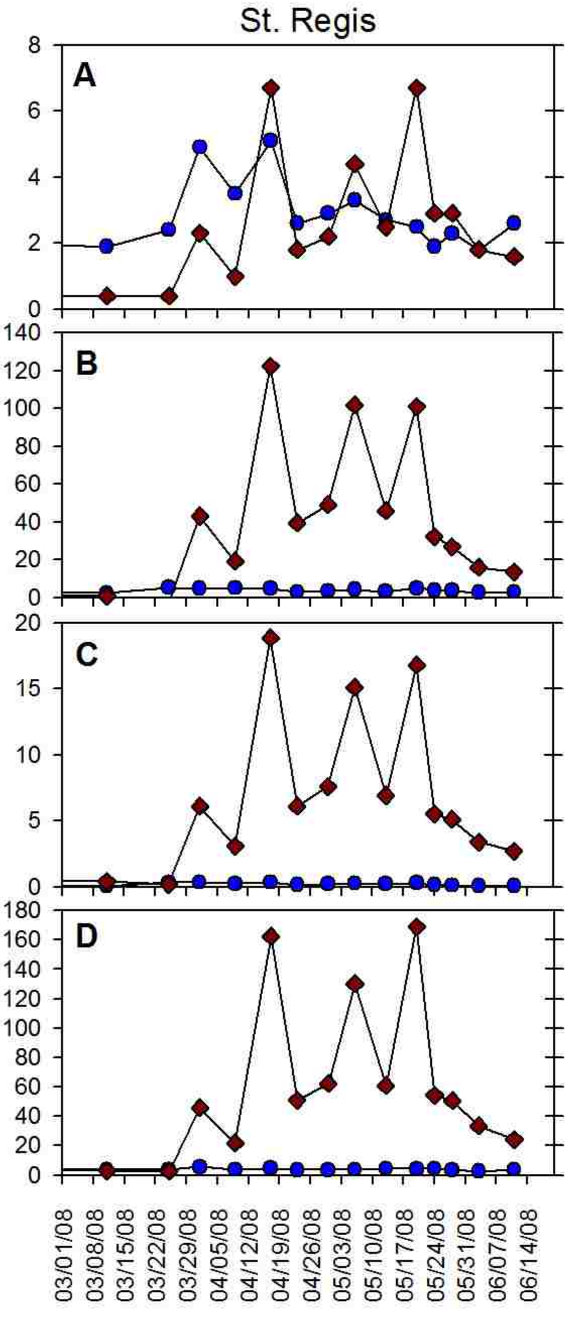


Figure 19: Dissolved $[M]_{aq}$ (blue circles) and particulate (Total Recoverable – Dissolved) [M]* (brown diamond) concentrations for A) As; B) Cu; C) Pb; and D) Zn at St. Regis. Data provided by the USGS (Appendix D).

4.1.3 Environmental Concerns of Metal Pollution

Most of the focus of the EPA's "Superfund" project was on the CFR and its floodplain upstream of the reservoir, between the dam and the headwaters of the CFR where mining operations occurred, but our results provided clear evidence that we cannot ignore the downstream effects of dam removal on the environment. Massive amounts of suspended-sediment were transported through St. Regis, covering a distance of more than 200 river kilometers in a relatively short amount of time. Ultimately, the fate of all sediments in the CFR will be the Pacific Ocean, but there are numerous anthropogenic barriers that can interfere with this natural transport process, the first of which is Thompson Falls Reservoir; the Columbia River Basin has more than 400 dams and is the most hydroelectrically developed river system in the world.

Previous studies have shown that there is a strong correlation between metal concentrations in bed sediment and metals found in certain aquatic organisms, particularly fish and benthic insects which are directly exposed to the metals in the sediment. Benthic insects are directly exposed to metals adsorbed to the surface of the bed sediment, while metals in the fine-grain suspended-sediment are taken in through the gills of fish (Essig and Moore, 1992; EPA, 2011). Axtmann *et.al.* (1997) reported a strong correlation between Cd, Cu and Pb concentrations in benthic insect taxa and bed sediment in the upper CFR, showing similar spatial variability and localized effects of metal concentrations in the bed sediment and aquatic biota. Similar studies on the upper CFR have shown that metals in the floodplain soil can adversely affect the vegetation, resulting in slickens, or denuded areas of phytotoxic soil where most native plant species are unable to grow (Rader et.al., 1997). There is also a negative correlation between species richness on the upper CFR and metal concentrations in the sediment (Luoma *et. al.,* 1997, see references). In general, these and other studies show that metal concentrations in the sediment can be used as bioindicators of metal contamination in upper trophic level organisms (Luoma *et. al.,* 1997). This provides a tool for monitoring the health of an ecosystem.

Sediments can also directly impact the bioavailability of metals: under anoxic conditions sulfide reducing bacteria convert mercury in the sediment to its highly toxic organic form, methyl mercury (EPA, 2011). Additionally, geochemistry of the sediment can affect a metals oxidation state, which can alter its toxicity; As (III) is more toxic than As (V). Some heavy metals bioaccumulate and are biomagnified through the food chain (McGeer *et.al*, 2002; EPA, 2011). Over time, a significant portion of the metals released downstream can enter the food chain, accumulating in many types of plants and animals including macroinvertebrates, fish, osprey, humans and other wildlife that eat the fish or vegetation that grows near the river. Observations made in the field at CFSR revealed that people, including very young children, had been playing in the exposed sand, digging small holes and building sand castles, directly exposing themselves to the heavy metals adsorbed to the surface of the sediment.

4.2 Analysis of Sediment Release from Milltown Reservoir

4.2.1 Sources of Sediment Release

Since the primary transport of metals downstream is via adsorption to the surface of suspended-sediment (Figures 16-19), we can utilize data provided by the USGS for suspended-sediment for a more in-depth analysis of the source and sequence of sediment release from the reservoir. The contaminated suspended-sediment that is released from the reservoir was either deposited as bed sediment or transported out of the study area. The frequency of the suspended-sediment sampling by the USGS can help us to fill in the gaps between our sampling dates, including the month between the removal of the dam and our first samples collected May 3-5.

Determining the various source contributions to sediment discharge from Milltown Reservoir allows us to determine how much of the sediment was due to scouring of the reservoir bottom and banks, and how much was from suspended-sediment in the two inflowing rivers. Based on the sediment discharge (tons/day) at each USGS site we can calculate rough estimates of the percent contributions of each source to the overall sediment discharge from the reservoir for the spring runoff of 2006, 2007, 2008, and 2006-2008 combined (Figure 20). We can immediately identify the shift in the primary source of sediment released from the reservoir between 2006 and 2008. In 2006, before any major activities in the reservoir to prepare for the dam removal, the major source of sediment coming out of the reservoir was the CFR, with only a minor contribution from the reservoir sediments. By 2007, however, we can already see a major shift in source contribution with almost a complete reversal from 2006, with 67% from reservoir sediments and the two rivers combined accounting for the remaining 33%. In 2008, more than 75% of the sediment released downstream was scoured from the reservoir. The abrupt enrichment from pre-breach conditions strongly suggests the metals contamination came from the reservoir.

Pre-dam removal activities, particularly the permanent drawdown of the reservoir standing water which occurred in June, 2006 and subsequent drawdowns, increased the amount of sediment eroding from the reservoir and passing over the dam a year before the dam was actually breached. Overall, analysis of the percent contributions to output from the reservoir reveals that by 2007 the primary source of sediment coming out of the reservoir was the former reservoir sediments, rather than the upstream inputs from the CFR and BFR as in 2006. Lambing and Sando (2008) reported that there was an increase in sediment leaving the reservoir after the initial permanent reservoir drawdown which occurred on June 6, 2006, as well as subsequent drawdowns in 2007, resulting in a large net loss of 130,000 tons of sediment from October 2006-September 2007.

Figure 20: Source contributions to annual average sediment discharge from Milltown Reservoir (Missoula) for A) 2008; B) 2007; C) 2006; and D) 2006-2008. Percent values were determined from sediment discharge (tons/day) at the BFR, Turah, and Missoula USGS gauge sites. Sediment discharge data provided by the USGS (Appendix D).

These results are critical to our understanding of the metal concentrations in the bed deposits downstream because they indicate that the lowering of the reservoir in preparation for dam removal caused significant loss of contaminated sediment before the dam was even breached. This was an amount equal to about one-third of the total estimated load that was released from the reservoir in water year 2008, following the removal of Milltown Dam (Lambing and Sando, 2008; Lambing and Sando, 2009). It is highly possible that some of the high metal concentrations that were discovered in the first bed sediment samples in the lower CFR channel had actually been released by 2007, before the dam was breached.

The release of contaminated sediments from the reservoir prior to dam removal is confirmed by metals concentrations in the suspended-sediment (Figure 21). In 2006, two years before Milltown Dam was removed, metals concentration in suspended-sediment peaked at Missoula in mid-June after the first permanent drawdown of the reservoir. As expected, the biggest change in suspended-sediment metals concentration was in 2008, when maximum concentrations shot up 4.5-6 times higher at Missoula and St. Regis than the upstream conditions at Turah and the newly activated Bypass Channel. These peak concentrations are similar to what we found in the bed sediment in early May, however, the maximum suspended-sediment metals concentration occurred immediately after the dam was breached in late March. The metals that we found in the bed sediment 0-70 km downstream of the dam in early May were likely deposited there within days of the dam removal, and remained there for more than a month and a half before new sediment deposits had any significant effect on the bed sediment metals concentration.

The effects of dam removal are immediately evident as the suspended-sediment metals concentration reveals the long-range transport of these heavily contaminated sediments within a matter of days of the dam breaching (Figure 21). Concentrations decreased rapidly at Missoula and Regis over the next two weeks to levels slightly higher than the upstream site at Turah. However, during the rising limb of the hydrograph as streamflow increased, the suspended-sediment metals concentrations downstream of the dam decreased. By the time of maximum streamflow in mid-May, concentrations at all four CFR sites had leveled off to around Turah levels, so that the concentrations entering the reservoir were the same being transported out of the reservoir and downstream. The rapid decrease in concentration in bed sediment might indicate a source of less contaminated sediment which could dilute the high concentrations released and deposited immediately after removal of the dam.

The origin of this less contaminated sediment source is more difficult to pinpoint by only looking at metals concentration in suspended-sediment because of the similarity between all the sites in late May when bed sediment metals concentration decreased. To locate the source of this less contaminated sediment, we will need to look at the sediment loads being transported through the study area (Figures 22-28). Sediment and metal loads were significantly higher at the two downstream sites in 2008 than the two previous years, peaking during maximum stream discharge on May 21-22. As the sediment load in the river increased, the metals concentration in the bed and suspended-sediment both decreased. Turah and the BFR sediment load inputs could not account for the increased sediment loads downstream, so this less contaminated sediment must also be coming from the reservoir.

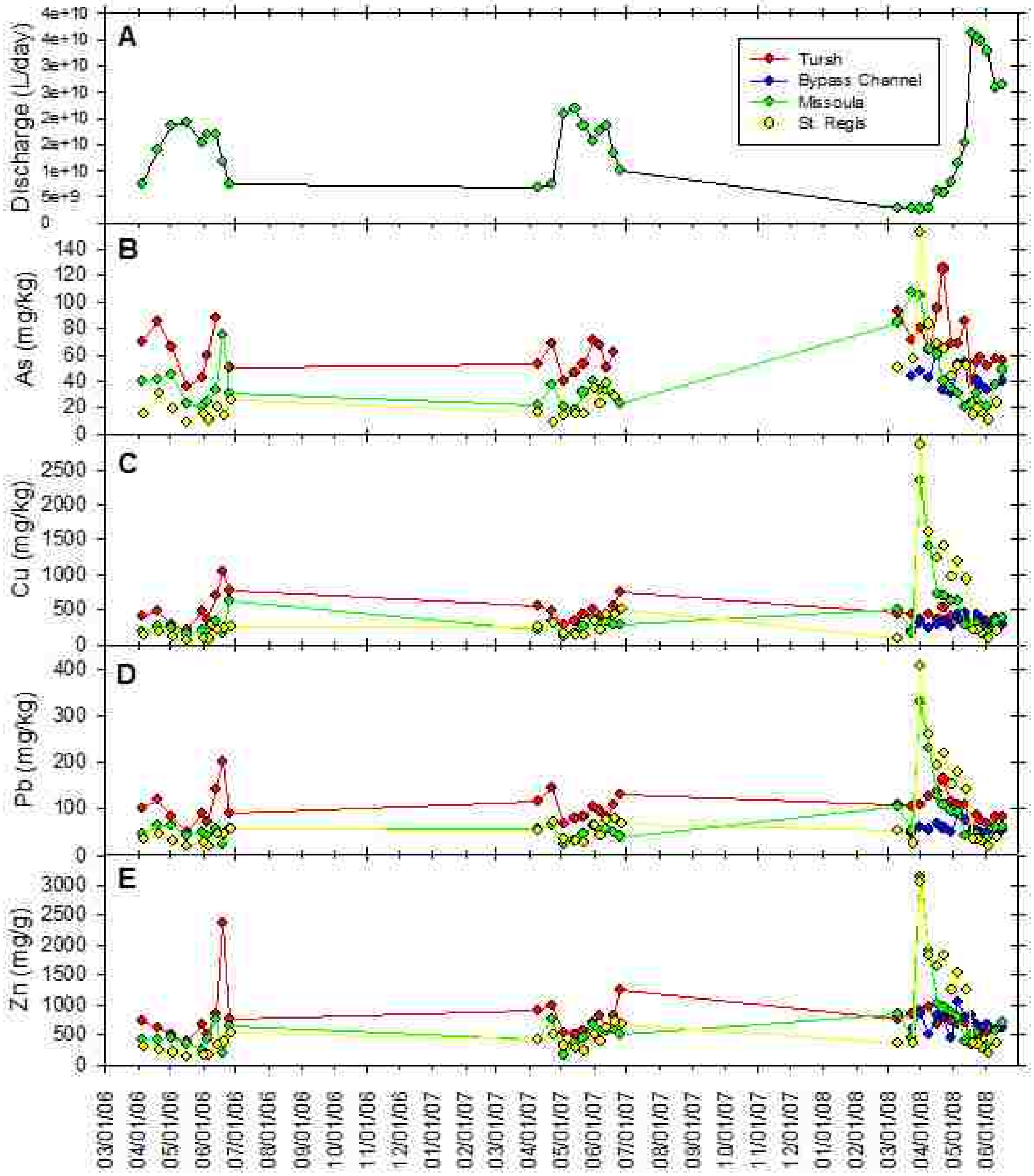


Figure 21: A) Stream discharge at Missoula (L/day); and metals concentration (mg/kg) in suspended-sediment for B) As; C) Cu; D) Pb; and E) Zn, for each USGS site on the CFR from 2006-2008. Results calculated from data supplied by the USGS (Eqn 9; Appendix D).

Within months of dam removal bed sediment metals enrichment had returned to near pre-breach conditions, following high flows in late May which caused metals concentration to rapidly decrease downstream, with enrichment of about 2 or less for all metals by mid-June (Table 3). However, the sites closest to the dam did not decrease to upstream levels (CFTB) except when the upstream concentrations were similar to pre-breach conditions, such as As and Pb (Figures 4 and 7). This indicates that not all of the contaminated sediment available for scouring had been depleted from the reservoir, and was still contributing a supply of metals-enriched sediment to the river downstream at the end of our study period.

Considering that the last sample set was collected less than five months after the dam was breached, it is not surprising that the reservoir was not completely depleted. There have been few studies of scour and release of reservoir sediment to predict any reliable time frame in which the river reestablishes the channel and natural conditions within the former reservoir (Pizzuto, 2002). However, several studies have shown sediments stored in the floodplain can take thousands of years to flush out of a river system (Axtmann *et. al.,* 1990; Helgen and Moore, 1996; Marcus *et.al.*, 2001; Lauer and Parker, 2008). Floodplain storage is not limited to the CFR, nor to heavy metals (i.e. PCBs in the Hudson River), and these ‘legacy sediments’ are a problem for river systems all around the world (EPA, 2002; Lauer and Parker, 2008). Floodplain sediments in the upper CFR are still enriched with heavy metals despite mining operations having ceased more than three decades ago, and are a continuous source of metal contamination to the CFR (Andrews, 1987; Axtmann and Luoma, 1991).

In the bed sediment collected August 20-21, the metals enrichment factor increased slightly from the June and July data at the most upstream sites, which suggests that a new source of contaminated sediment was released from the reservoir after the streamflow receded (Figure

11). Some of this new sediment supply could have come from slumping and erosion of newly exposed and unstable banks immediately below the dam and within the reservoir, but it could also be due to increased activity within the restoration project area which resulted in localized sediment input (Lambing and Sando, 2009) or due to natural variability.

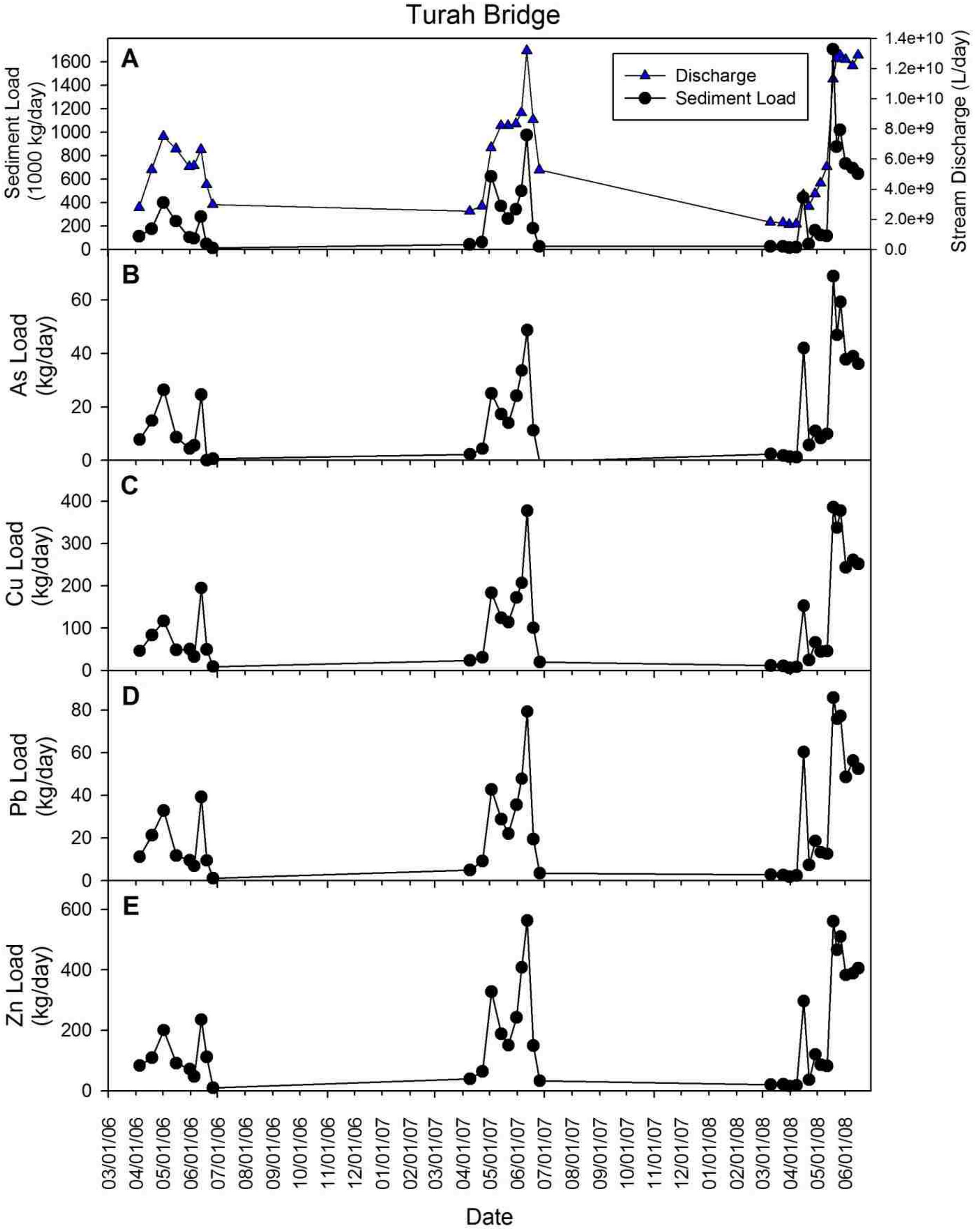


Figure 22: Turah A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

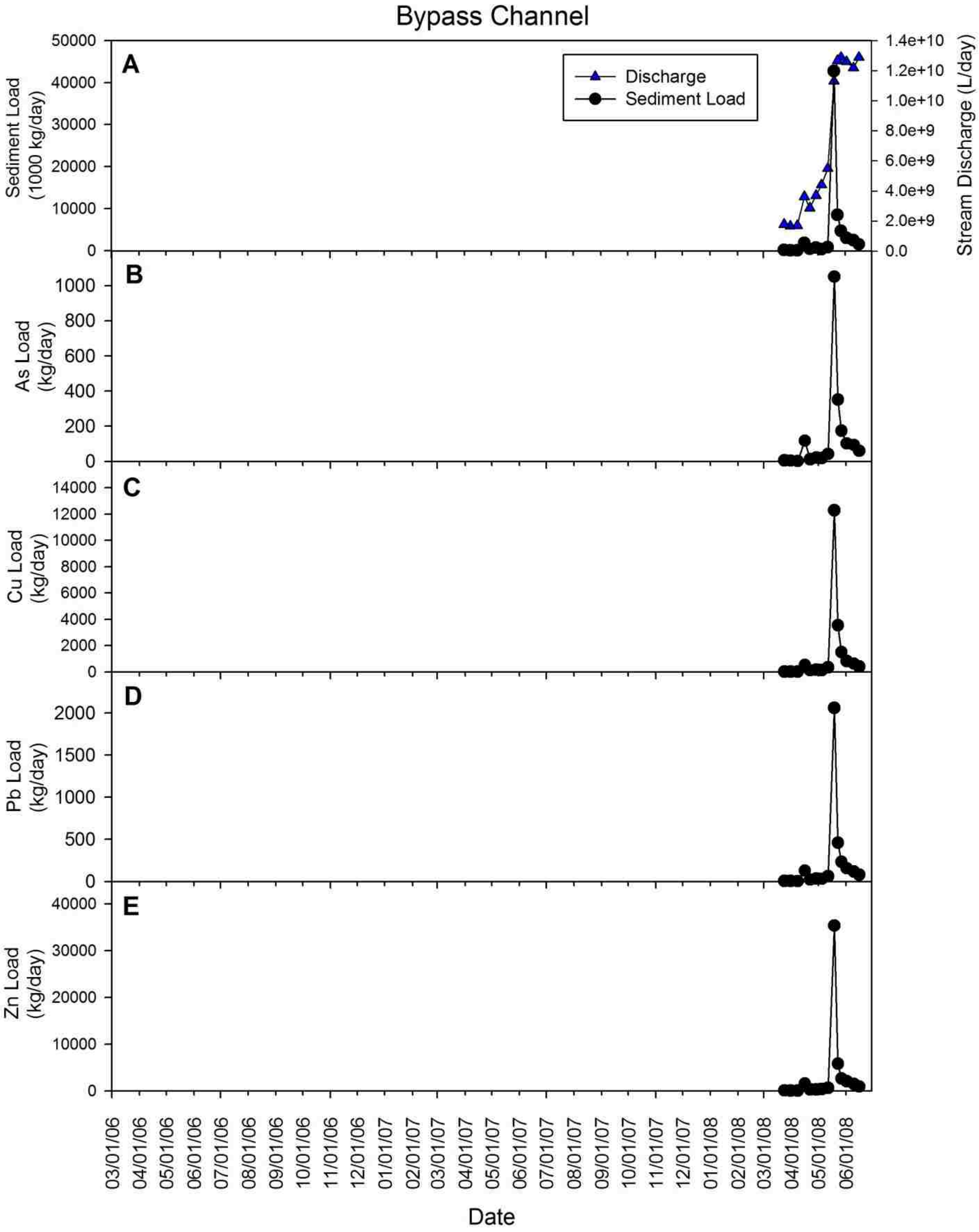


Figure 23: Bypass Channel A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

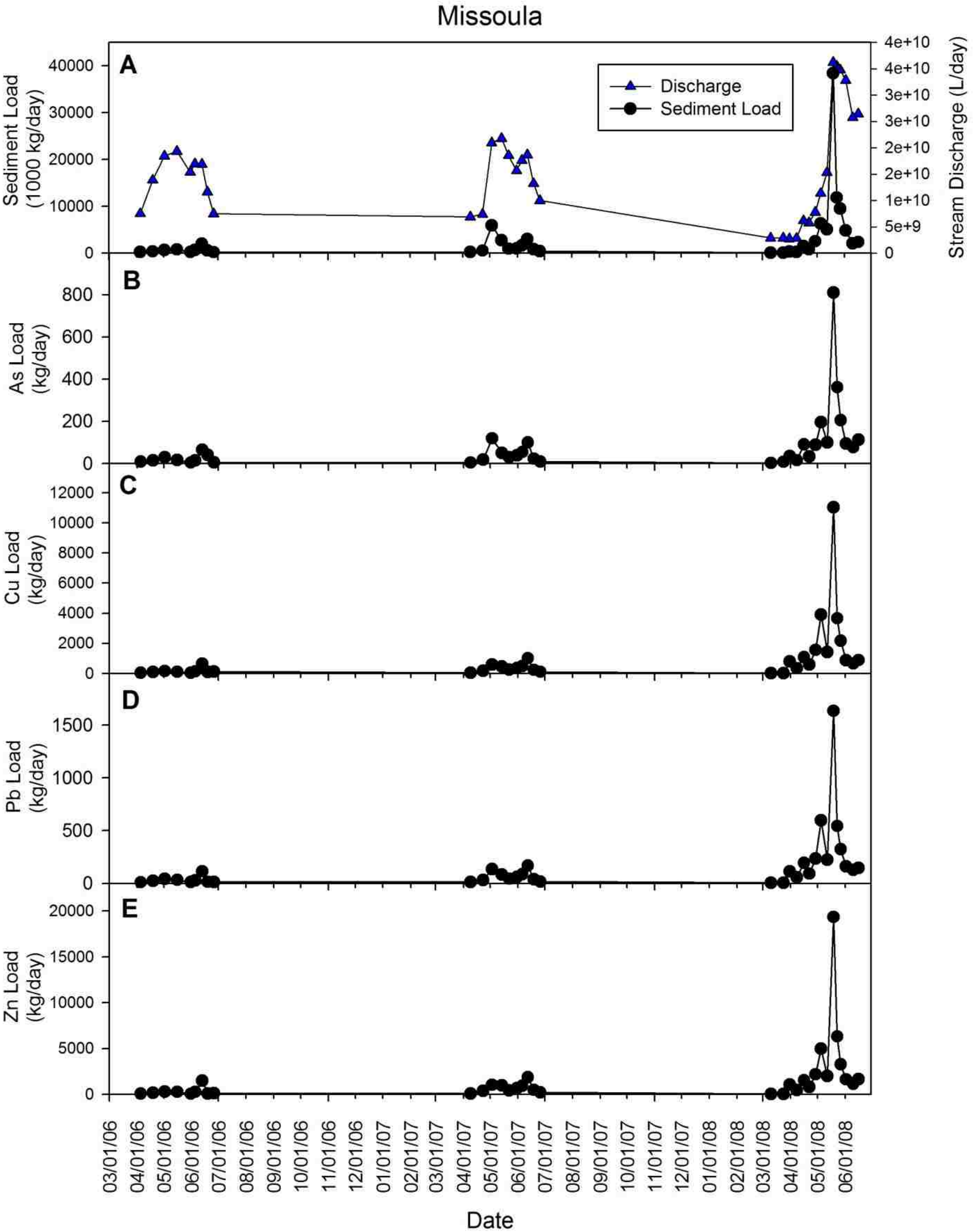


Figure 24: Missoula A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

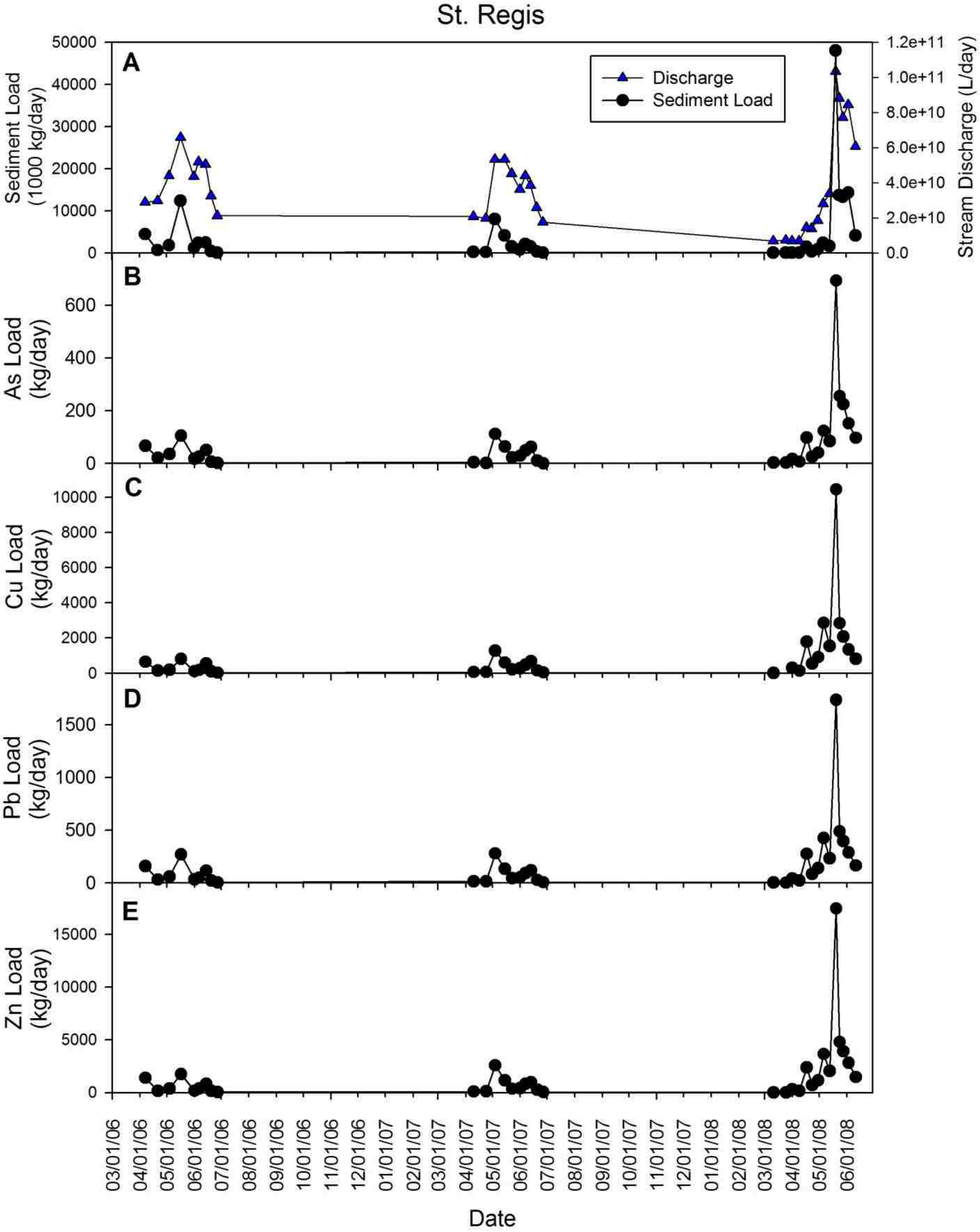


Figure 25: St. Regis A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

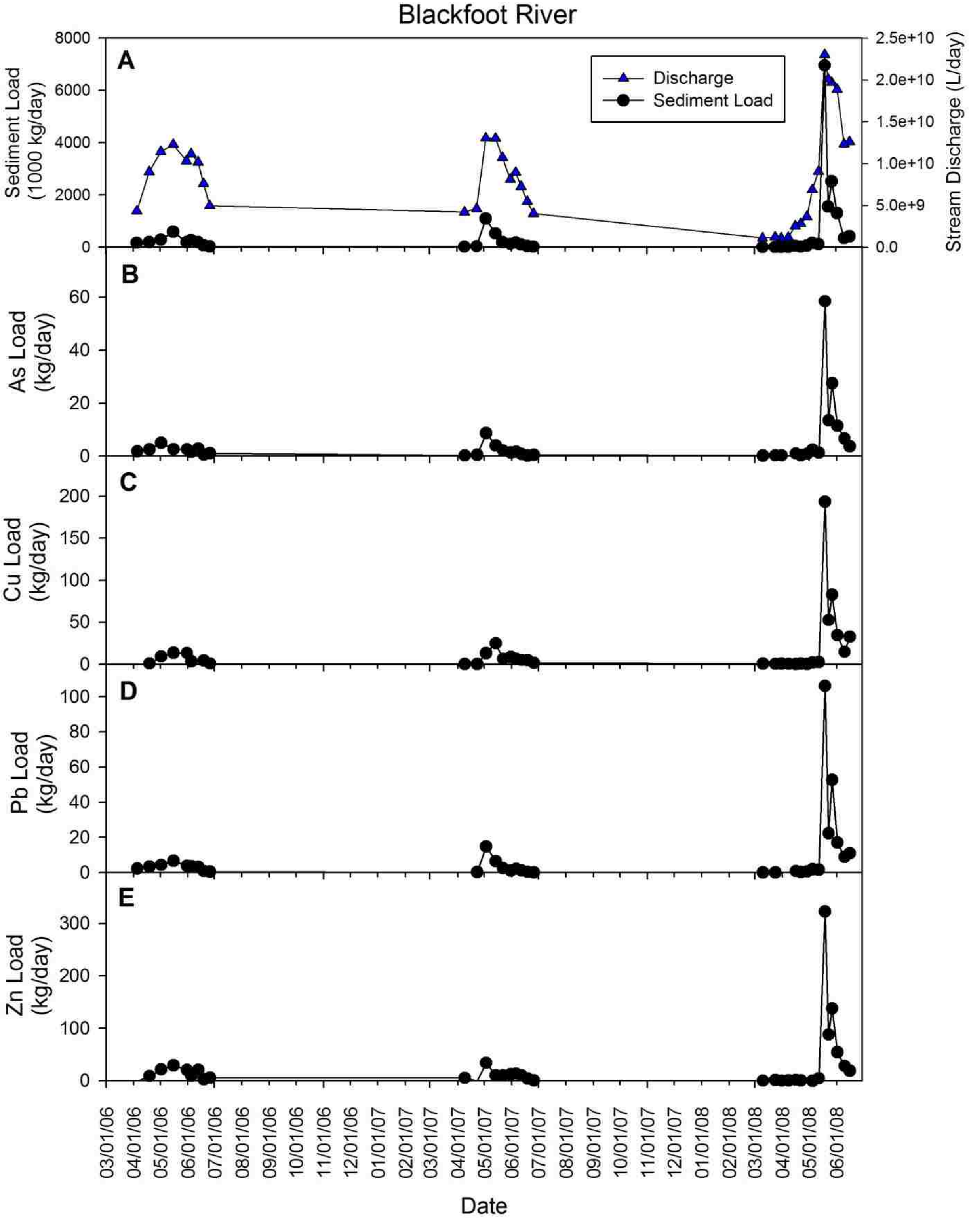


Figure 26: Blackfoot River A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

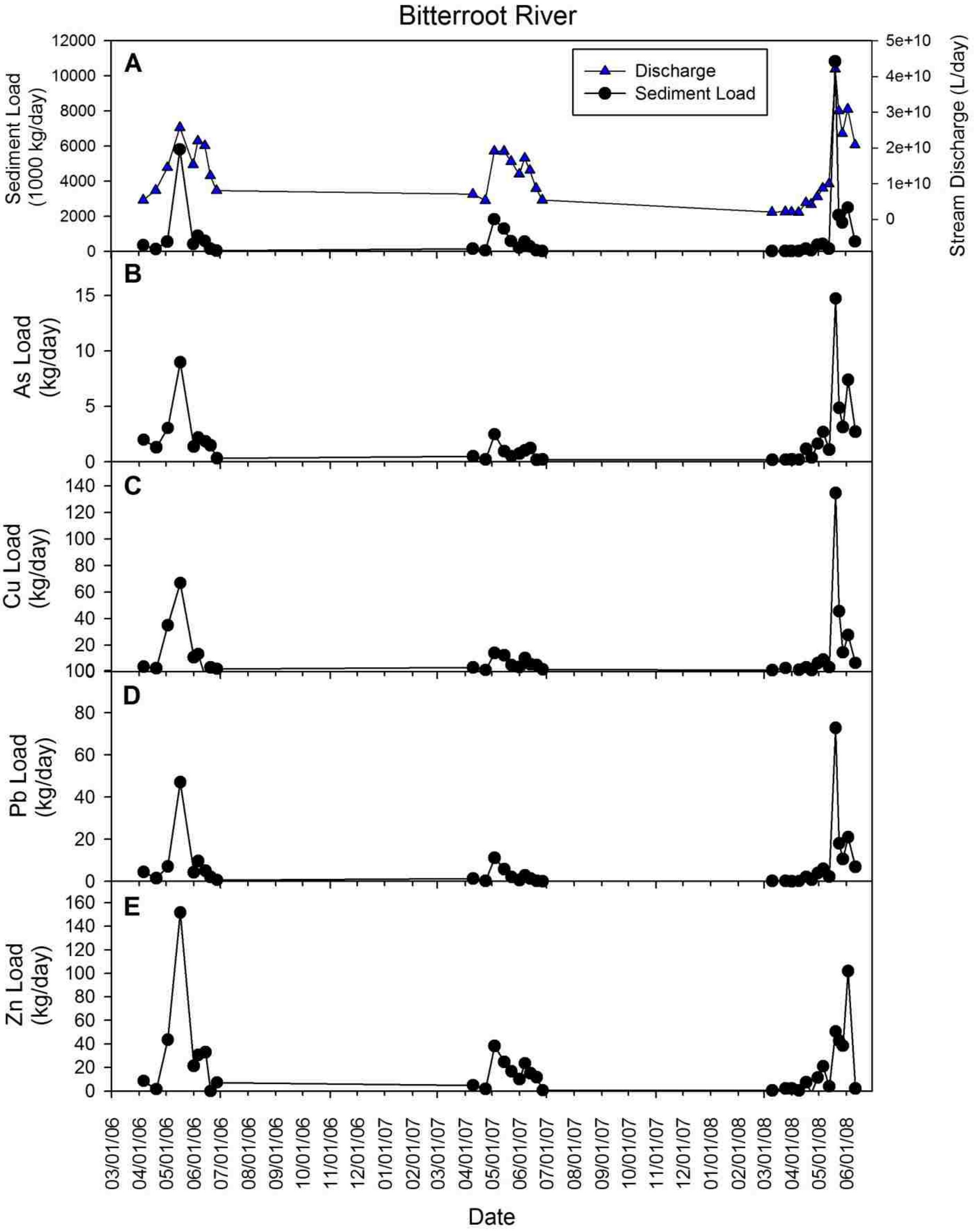


Figure 27: Bitterroot River A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

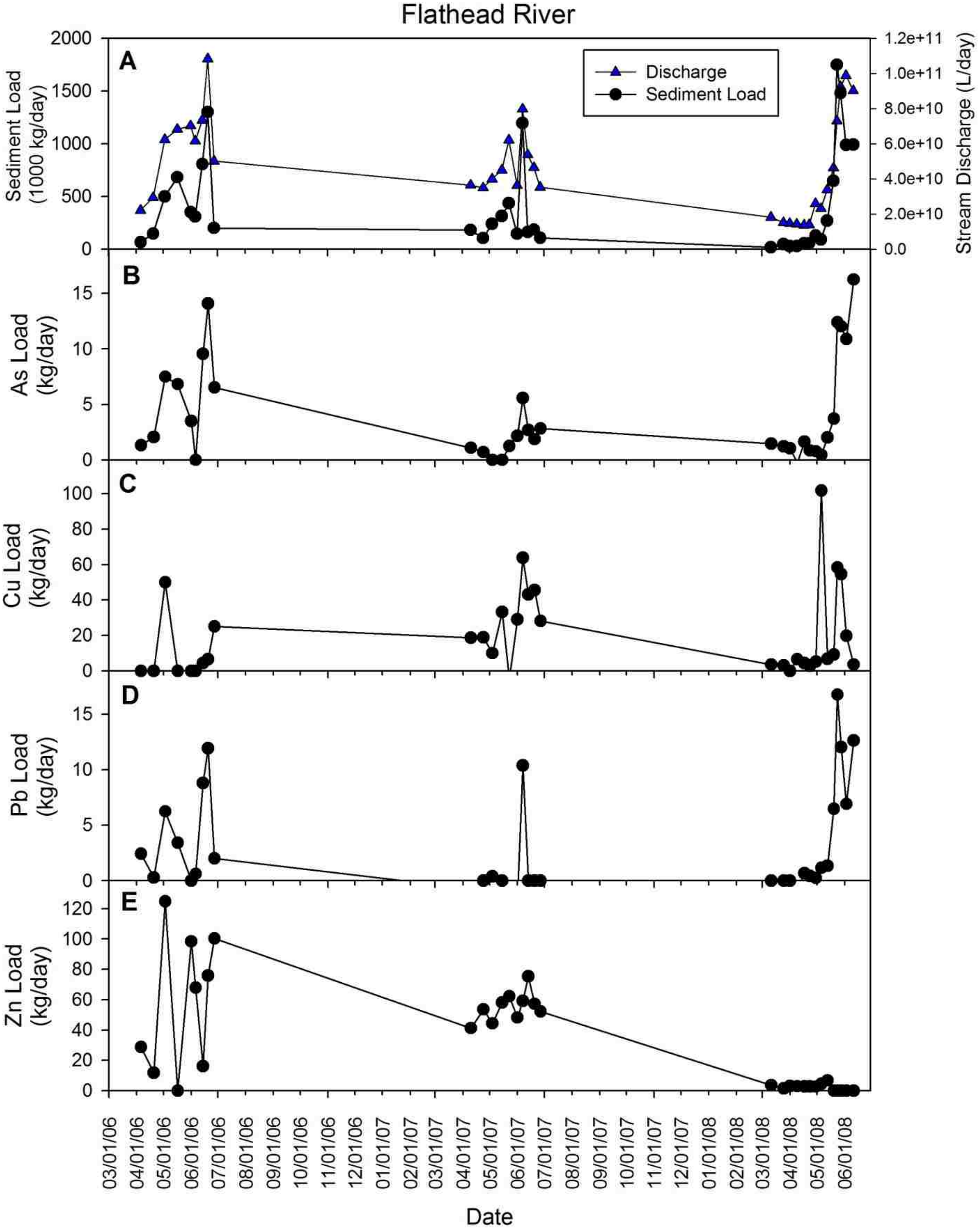


Figure 28: Flathead River A) sediment load (1000 kg/day) and stream discharge (L/day); B) As load; C) Cu load; D) Pb load; E) Zn load. Loads were calculated with Eqn 3 using USGS data.

4.2.2 Sequence of Sediment Release: Erosion and Deposition

By June, 2008, less than three months after Milltown Dam was breached, an estimated 200,000 cubic yards of impounded sediment from the reservoir was released downstream (EPA, 2009). By monitoring the inflow and outflow of suspended-sediment to Milltown Reservoir, Lambing and Sando (2009) estimated that 391,000 tons of sediment eroded from the reservoir and was transported downstream in water year 2008 (October 1, 2007-September 30, 2008). Including low flow years in which there was deposition of sediment in the reservoir, the historical record shows an average annual sediment load release from the reservoir of 6,000 tons, with 142,000 tons entering and 148,000 tons leaving the reservoir. The high flow years of 1996-97, which included the ice jam flood of 1996, combined for a total scour of 107,000 tons, less than one-third of what was released within six months of the removal of Milltown Dam (ROD, 2004; see Appendix A: History of Milltown Reservoir).

With the addition of the Bypass Channel USGS gauge in 2008, the reservoir could be divided into the upper and lower regions, with about an 8 kilometer stretch of the upper reservoir between Turah and the Bypass Channel (Figure 3). Most of the restoration efforts were focused in the lower reservoir, where the most contaminated sediments were impounded. The reservoir was divided into five separate sediment accumulation areas (SAA) for the dam removal project (ROD, 2004), based on location, sediment thickness and metals concentration (Figure 29, Appendix D). Equations 5-8 divide the study area into three main regions of erosion and deposition: the upper reservoir, the lower reservoir, and the lower CFR channel. The lower reservoir includes SAA-I and SAA-II in the CFR arm of the reservoir, and SAA-III in the BFR arm of the reservoir. The upper reservoir includes SAA-IV and SAA-V. However, the USGS gauges used for our calculations cannot provide enough spatial resolution to determine specifically where sediments are being eroded from between the gauges. For example, in addition to the major SAAs in the CFR arm of the reservoir, estimates for the lower reservoir may be coming from the stretch of the BFR between the gauge near Bonner and its confluence with the CFR at the reservoir. It would also include the 4.4 km stretch of the CFR channel below the dam to the gauge near Missoula (Figure 3).

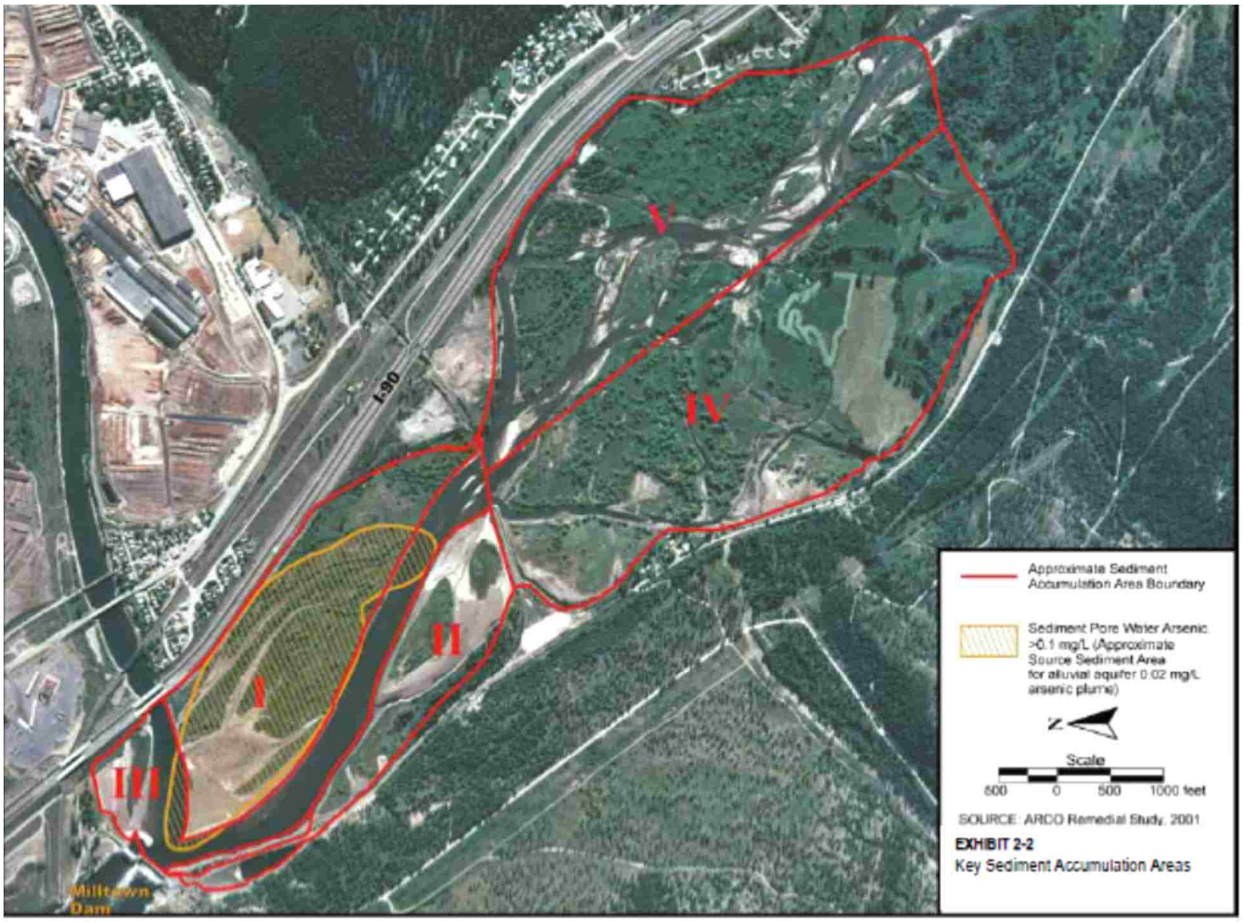
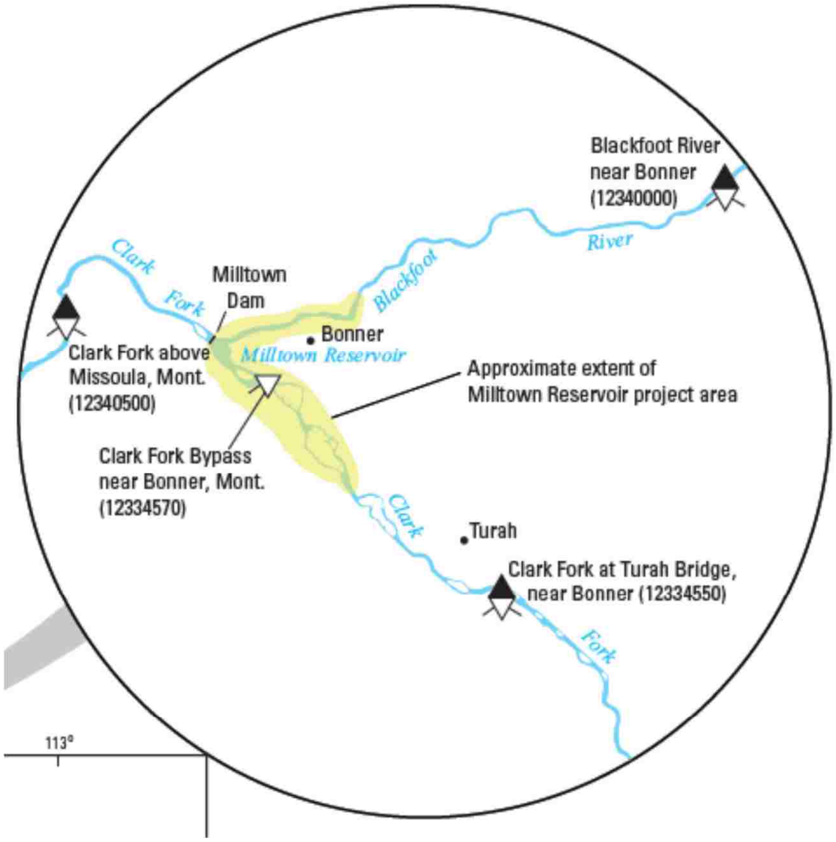


Figure 29: Aerial view of Milltown Reservoir prior to the Restoration Project showing the five areas of sediment accumulation, outlined by a solid red line, as described by the Record of Decision. The yellow-highlighted segment in Area I shows where sediment pore water As concentration is > 0.1 mg/L. This area is the primary source for the arsenic plume in the alluvial aquifer. Milltown Dam is located in the bottom left corner. The river coming down from the left is the BFR, the river going through the reservoir parallel to I-90 is the CFR. This figure was copied from the Record of Decision for Milltown Reservoir Sediments Operable Unit (ROD, 2004).



Copy of Figure 3

On May 19-20, 2008 there was maximum erosion from the total reservoir (Eqn 6), but there was also maximum deposition into the lower reservoir (Eqn 7), indicating that a lot of the sediment that passed through the bypass channel from the upper reservoir either did not leave the reservoir or was deposited in the CFR channel before the first gauging site at Missoula (Figure 30). Prior to this, there was a brief peak in erosion from mainly the lower reservoir in early May, 2008, around the time we collected our first bed sediment samples. The combination of these two results signifies that sediment was eroded from the reservoir in two or more separate events, from the lower reservoir first in early May, and then from the upper reservoir two weeks later during peak streamflow (Figure 31). Maximum erosion from the upper reservoir in mid-May corroborates this conclusion (Eqn 5, Figure 32).

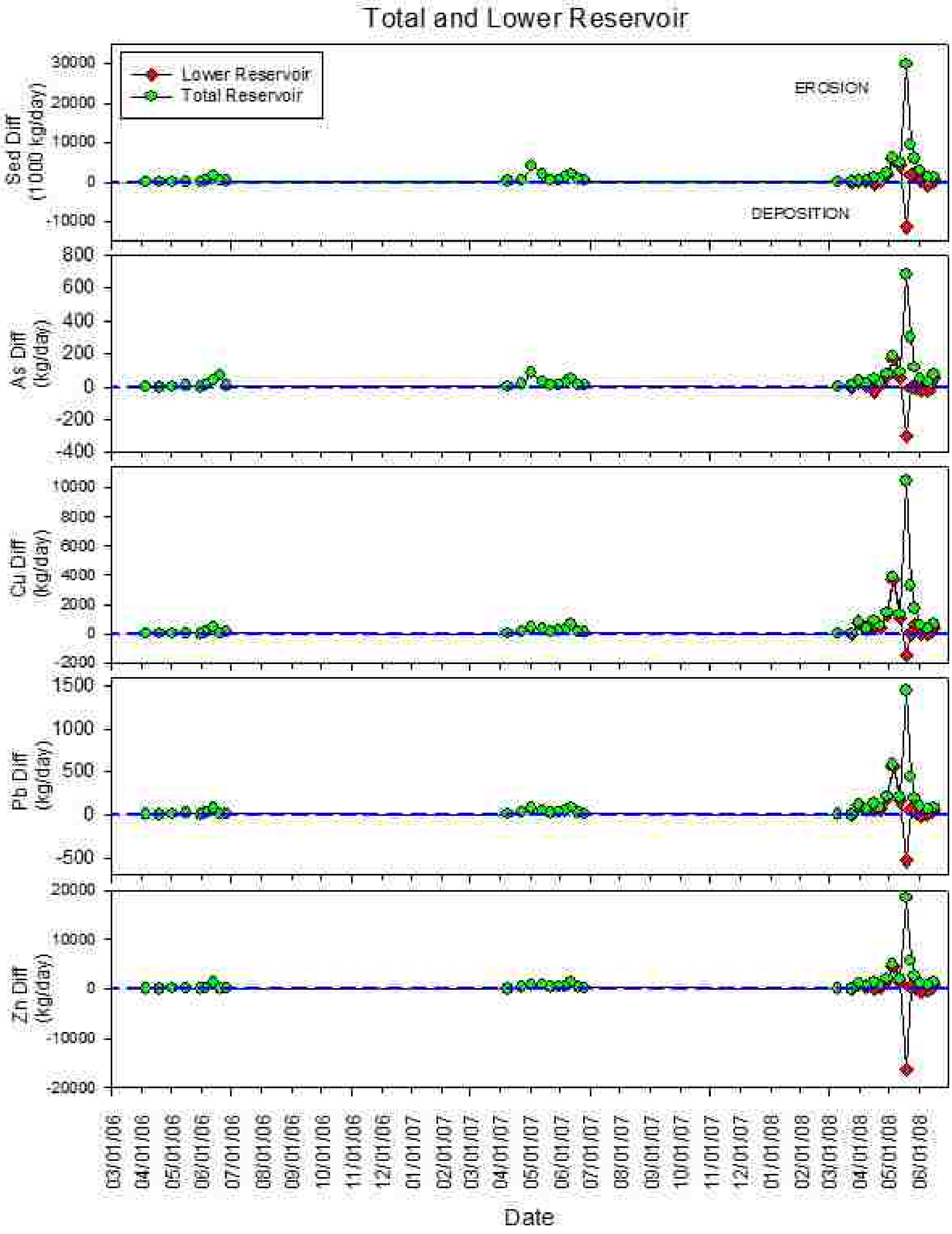


Figure 30: Total (green) and Lower Reservoir (red) sediment and metal load differences for 2006-2008 between Turah and Missoula and Bypass Channel and Missoula, respectively. Positive values indicate erosion from the reservoir, negative values indicate deposition.

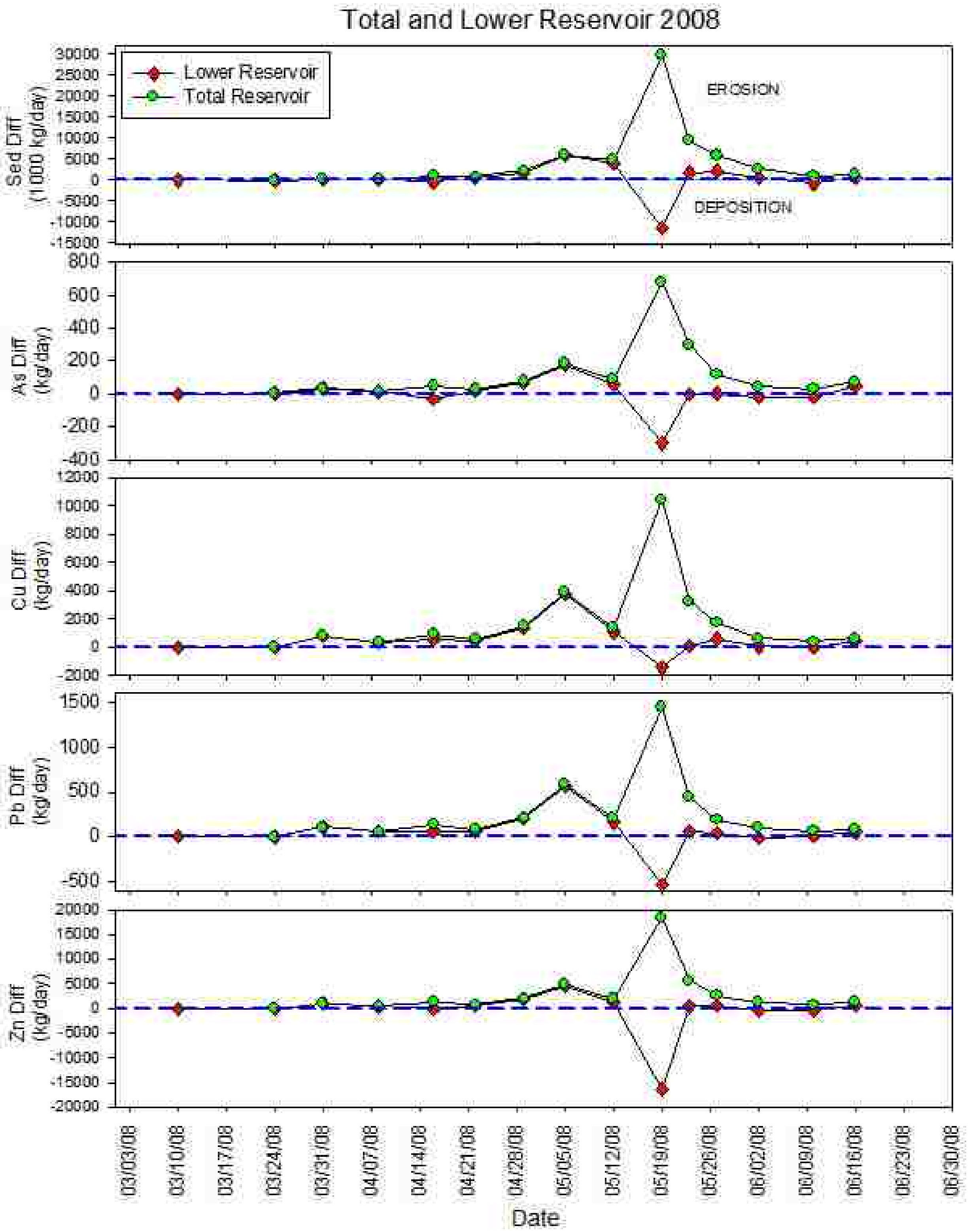


Figure 31: Total (green) and Lower Reservoir (red) sediment and metal load differences for 2008 between Turah and Missoula and Bypass Channel and Missoula, respectively. Positive values indicate erosion from the reservoir, negative values indicate deposition.

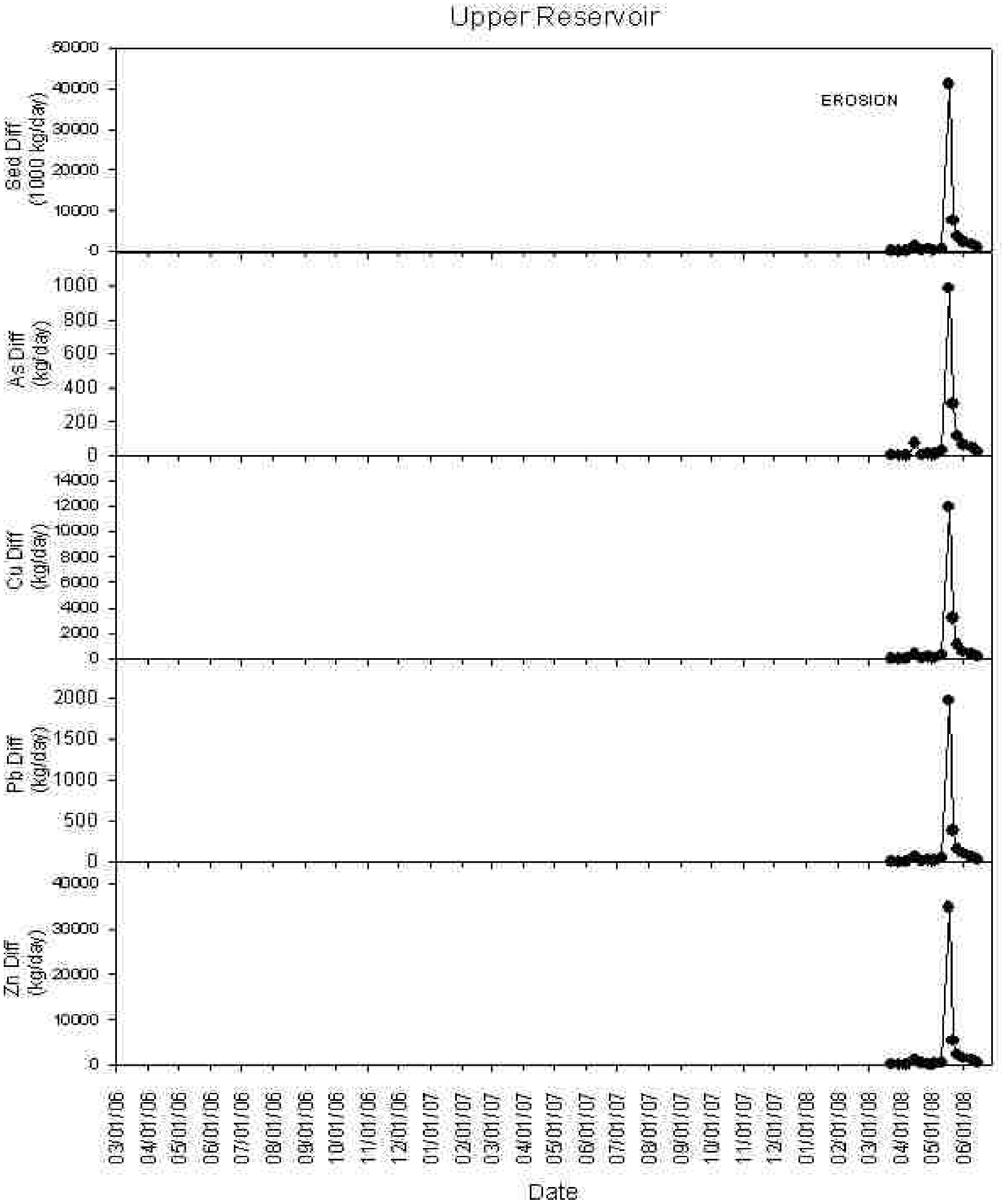


Figure 32: Upper Reservoir sediment and metal load differences for 2006-2008 between Turah and the Bypass Channel. Positive values indicate erosion from the reservoir, negative values indicate deposition.

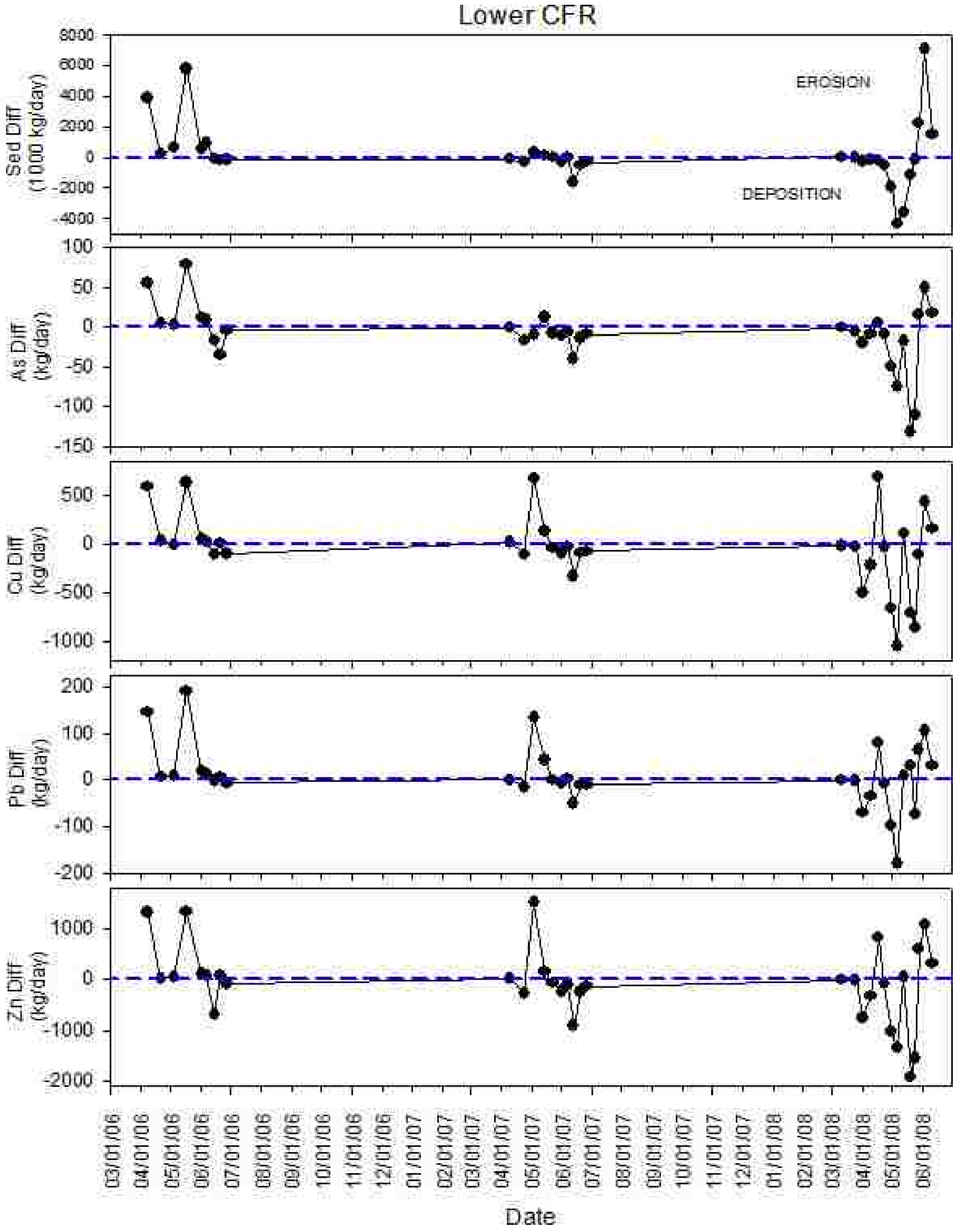


Figure 33: Lower CFR sediment and metal load differences for 2006-2008 between Missoula and St. Regis. Positive values indicate erosion from the reservoir, negative values indicate deposition.

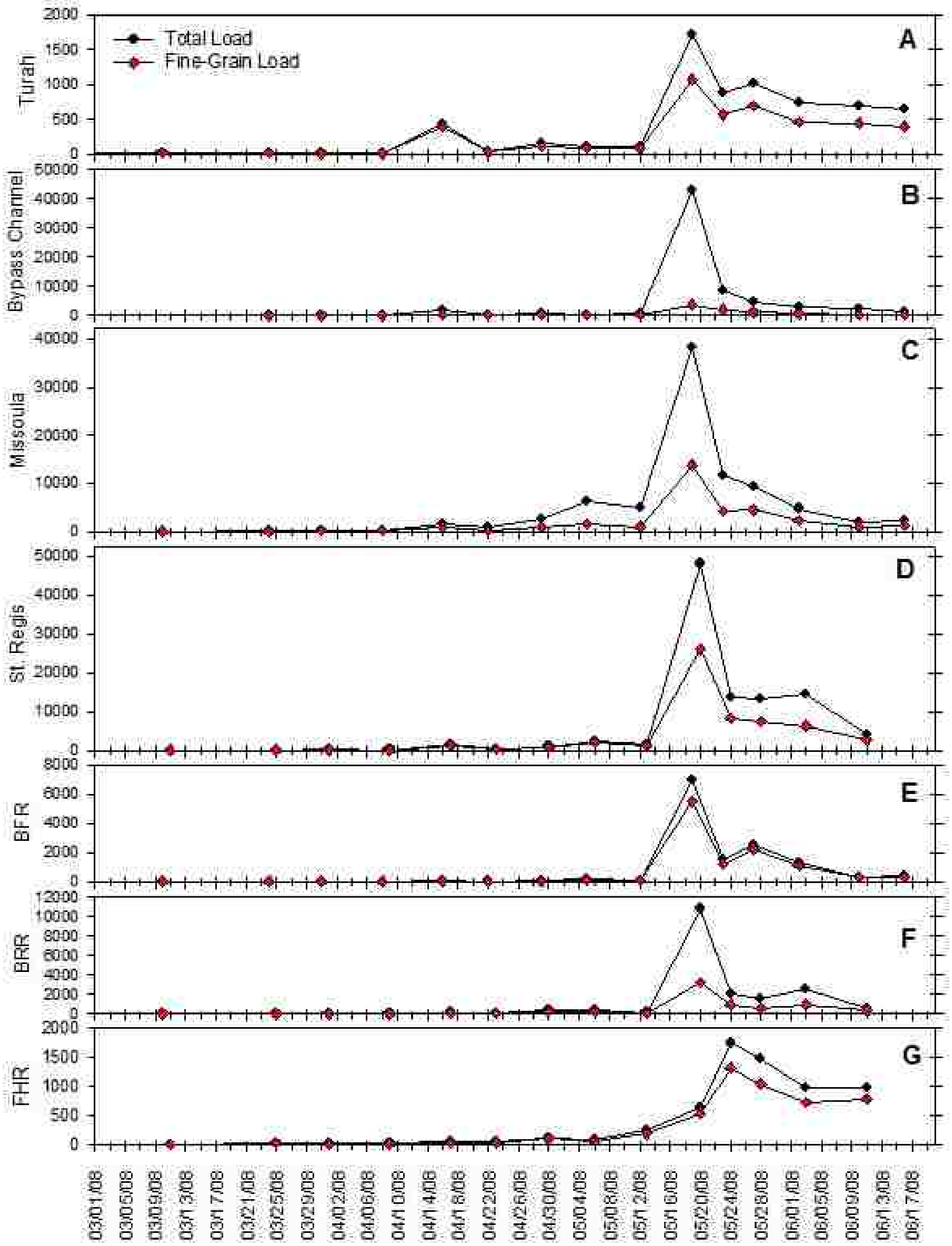


Figure 34: Total (black circle) and fine-grain (red diamond) sediment loads (1000 kg/day) in 2008 for A) Turah; B) Bypass Channel; C) Missoula; D) St. Regis; E) BFR; F) BRR; and G) FHR.

From March 24-April 8, 84% of the sediment at Missoula was fine-grained, and for most of April over 90% was fine-grained at St. Regis (Appendix D, Figure 34). Most of this sediment had to be coming from below the Bypass Channel, because the sediment load at Missoula was much larger than the load at Bypass Channel (Figures 22 and 24). Previous studies have shown that fine-grain sediment is more easily transported by low flows, which explains the predominantly fine-grained load at the most distant gauge at St. Regis (Figure 34D) (Pizzuto, 2002). This trend also supports the established order of erosion from the reservoir. Since heavier particles settle out in the upper reservoir as the water is slowed, most of the lower reservoir was filled with predominantly fine-grain sediment (ROD, 2004). These fine-grained sediments could be mobilized during the low flows prior to mid-May snowmelt, so although the bed sediment metals concentration in early May were very high, the amount of sediment was relatively low. The low flows did not have sufficient energy to mobilize the larger particles in the upper reservoir. As streamflow and hydraulic energy increased, the water rose above the CFR channel and was able to scour and mobilize massive amounts of the upper reservoir sediments.

Most of the sediment was not coming from the lower reservoir, where the restoration efforts were focused on minimizing erosion, but from the upper reservoir which had been largely ignored because of less metal contamination in the upper reservoir sediment. The bulk of the sediment released through the dam came from the upper reservoir during high flows and deposited in the lower CFR. The erosion of upper reservoir sediments could dilute the more contaminated sediments from the lower reservoir deposited downstream both before and after the dam was removed.

There were similar sediment loads at both downstream sites on the CFR, nearly 200 river kilometers apart (Figures 34-35). This is indicative of long-range transport of the contaminated sediment over a relatively short period of time, supporting the bed sediment and suspended-sediment metals concentration analysis. The lower CFR accounts for the sediment differences between Missoula and St. Regis (Eqn 7, Figure 33). The large, negative values in 2008 indicate deposition along this 200 km stretch on the CFR, occurring between dam removal and maximum stream discharge. The previous two years had not experienced much deposition, although there were periods of significant erosion. However, by early June, 2008, there was more sediment leaving the lower CFR than entering it. One possibility is that sediments from the reservoir previously deposited in the CFR were re-eroded from the banks and mobilized further downstream through St. Regis. The sediment differences in the lower CFR were much smaller than the differences in the reservoir, but the region covers a much greater distance, with more unknown variables. The USGS data used only goes through early June, while stream discharge was still high, so it is highly probable that as the water receded deposition into the lower CFR increased. We know from visual observations in the field from June 9 through August 21 that massive amounts of sediment were deposited throughout the entire lower CFR study area.

Overall, the results for sediment differences indicate reservoir sediments were first scoured from the lower reservoir during low, rising streamflow and then from the upper reservoir during high flows. Erosion analysis was not able to identify the release of heavily contaminated sediment which occurred in late March immediately after the dam was breached, either because the amount of sediment was relatively small compared to the massive loads in high streamflow, or because the amount of sediment between the gauges was the same, showing neither erosion nor deposition. Additionally, while significant volumes of sediment were transported over 200 kilometers downstream through St. Regis, massive amounts were also deposited along the CFR channel, potentially impacting the geomorphology and environmental quality. Sediment accumulation occurred downstream in channel margins, side channels, pools, riffles, and islands, and was often greater than one meter thick and several meters wide even 25 kilometers downstream of the dam.

4.2.3 Relating Metal Concentrations in Bed and Suspended-Sediment

The comparison of metals concentration in the bed sediment versus suspended-sediment is the key to understanding the source and fate of sediments from Milltown Reservoir. The maximum reported concentrations in the suspended-sediment that was mobilized downstream through St. Regis immediately after removal of the dam on March 28 (Figure 21 or 35) were similar to the concentrations found in the bed sediment at all downstream sites May 3-5 (Figures 4-8A). For example, the maximum suspended-sediment Cu concentration transported through Missoula was 2350 ppm (Figure 35), while average concentration in the bed sediment collected one month later around Missoula (0-13 km) was 2,210 ppm (Table 3). Although we saw no evidence of erosion or deposition at this time, the similarity of these concentrations suggests that the sediments that were mobilized in late March after the dam was breached were deposited in the CFR channel by low flows, and these same sediments were collected one month later in the bed sediment May 3-5. Therefore, we can use metals concentration to track the bed sediment from when it was released as suspended-sediment to understand the source and sequence of release. The following sections discuss the potential sources of sediment transported by the CFR, as determined by metal concentrations in the sediment. Although we know the general sources based on the previous analysis of sediment loads and differences, the metals concentration help us pinpoint more specific locations within the reservoir and rivers.

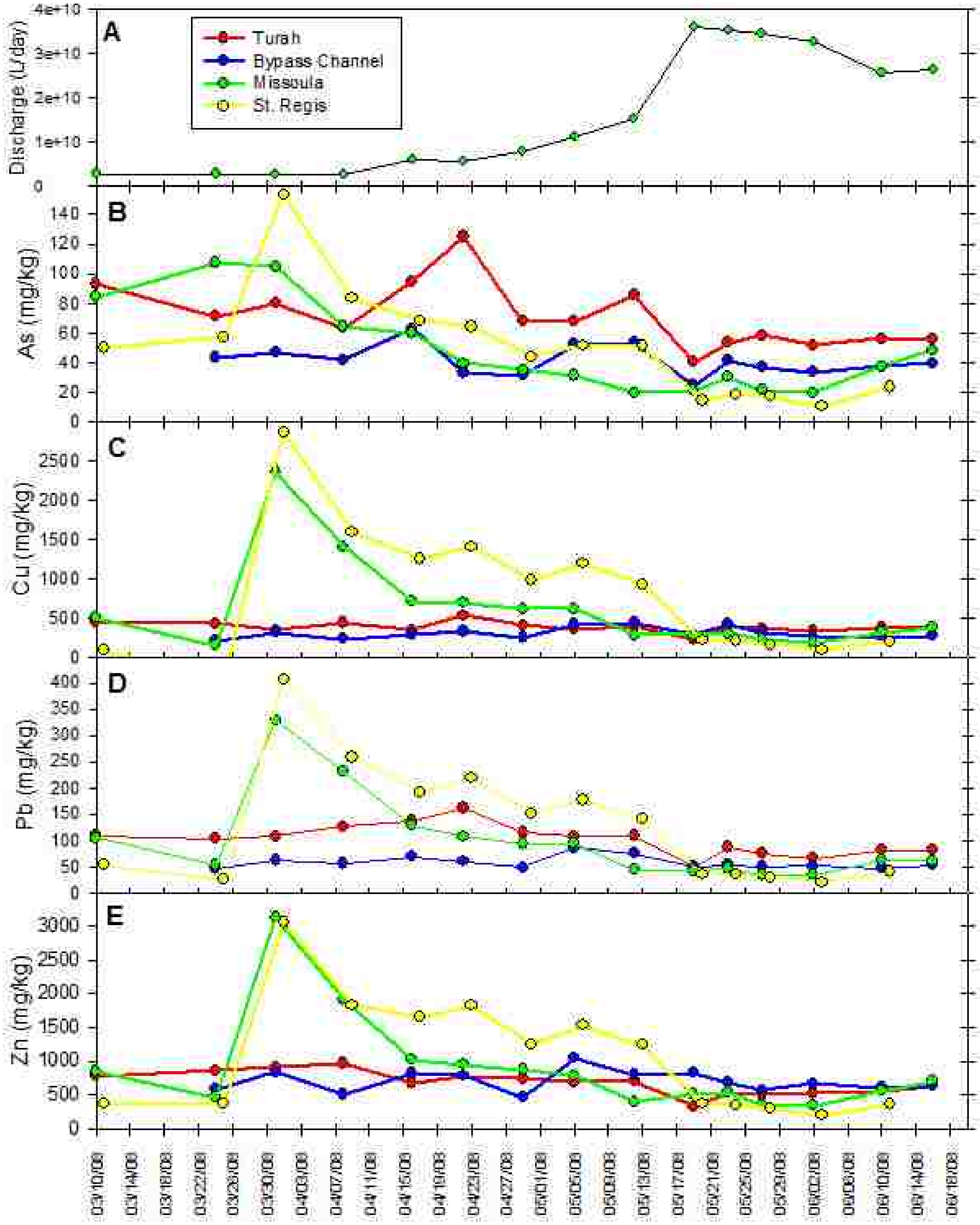


Figure 35: Same as Fig. 21 for only 2008; A) stream discharge at Missoula; metals concentration (mg/kg) in suspended-sediment, $[M]_{ss}$ for B) As; C) Cu; D) Pb; and E) Zn, for each site on the CFR. Results calculated from data supplied by the USGS (Eqn 9; Appendix D).

4.2.3.1 Lower Reservoir

Since we know the fate of contaminated sediments, at least temporarily, based on metals concentration in the bed and suspended-sediment, the question is where did they come from? To determine the source we have to take a closer look at pre-breach conditions provided by the USGS and other supplementary data, particularly for the lower reservoir. For bed sediment collected in early May, the parameters we are looking for are heavily contaminated fine-grain sediment that could be mobilized in low streamflow, which excludes Turah, the BFR, and the upper reservoir. The suspended-sediment metals concentration at Turah and the Bypass Channel were never high enough to explain the concentrations in our initial dataset or the suspended-sediment that was coming out of the reservoir at Missoula. Likewise, contributions from the BFR and the BFR arm of the reservoir (SAA-III) would not account for the extreme contamination in the channel downstream. The contaminated material deposited downstream prior to May 5 had to be from below the gauge at Bypass Channel, primarily the lower reservoir.

Until maximum stream discharge in mid-May, the lower reservoir was the primary source of sediment discharge at Missoula (Figure 31). As the reservoir was lowered in 2006 and 2007 to initiate the process of sediment and dam removal, the water in the reservoir began to incise into the reservoir sediments. Shallow water created more potential for bottom scouring (Graf, 2005), pushing these sediments out of the reservoir and depositing them downstream. This type of scour has been recognized in other dam removals, and is one of six major stages in channel adjustment within the reservoir that occurs as a reservoir is converted to a river system (Doyle et. al., 2002; Pizzuto, 2002).

Arsenic in bed sediment ranged from about 250-350 ppm at all of the upstream sites on the CFR (0-70 km), while Cu ranged from about 1800-2400 ppm. Prior to dam removal, SAA-I in the lower reservoir had average As concentrations of 320 ppm and Cu of 2300 ppm (Appendix D). Therefore, we can deduce that the initial source of sediments deposited in the channel bed during our first sample set in early May was SAA-I. Most of this sediment was dispersed downstream in low flows after the dam was breached, although some was released prior to the breaching of the dam (Lambing and Sando, 2009). There was also a pulse of fine-grain sediment released from the lower reservoir in early May, during the rising limb of the hydrograph (Figure 31), before the upper reservoir took over during peak streamflow (Figure 32). These sediments could have impacted our bed sediment results.

Metals concentration in suspended-sediment help to illustrate the impacts of early sediment release (prior to dam removal on March 28, 2008). The highest concentrations that could account for the elevated concentrations in the May 3-5 bed sediment occurred March 31-April 1, and had to be coming from the CFR below the Bypass Channel but above Missoula, since the high concentrations in suspended-sediment were only detected at Missoula and not Bypass Channel (Figure 35). This area accounts for the lower reservoir (SAA-I and SAA-II), directly behind the dam wall in the main channel, the BFR arm of the reservoir (SAA-III), the banks of the BFR between the gauge near Bonner and the dam, and the banks and channel of the CFR between the dam and the downstream gauge at Missoula (Figure 3 and 29). SAA-III is the least contaminated of all five areas (Appendix D) and we have already excluded the BFR because of its low concentrations. The purpose of the bypass channel was to divert the stream around the most heavily contaminated sediments in the lower reservoir, particularly SAA-1. Sediment scour from SAA-I would have occurred after reservoir drawdowns and during construction of the bypass channel and railroad system, but would have been minimized at the time of dam removal, when suspended-sediment metals concentration peaked. Although the sediment likely originated from SAA-I, it must have been stored elsewhere until the dam removal adjusted the stream conditions to mobilize it downstream.

One possibility is that the heavily contaminated sediment had been trapped behind the dam wall, and was released when the dam was finally breached, but the amount of sediment that was released in that time frame make this single source improbable. The only other major available source of sediment within the designated area (between the BFR, Turah and Missoula gauges) would be in the 4.4 km stretch of the CFR channel bed downstream of the dam between Milltown Dam and the Missoula gauge (Figure 3). A wedge of heavily contaminated sediment, released and deposited prior to dam removal, could exist here and not be noticed by the USGS sampling methods.

Breaching the dam and allowing the CFR and BFR to run free immediately caused the water level to rise by about one foot at the Missoula gauge, which increased the amount of scour and the carrying capacity of the river downstream of the dam (EPA weekly update, 04/02/08). This explains the timing of the highest suspended-sediment metals concentration occurring immediately after removal of the dam, even though sediments were released from the reservoir months and even years before the dam was removed. The rising waters in early May also could have initiated erosion of these sediments one month after the dam was removed.

4.2.3.2 Upper Reservoir

The above normal flows which occurred in mid-May and were sustained throughout June had the potential to transport extremely high concentrations and daily loads of suspended-sediment over long distances downstream (Figure 2; Lambing and Sando, 2009). The high flows are capable of carrying vast amounts of particulate matter in their large volumes of high-velocity water, which can also increase erosion rates and scouring of reservoir, channel bed and bank sediments (Pizzuto, 2002; Lambing and Sando, 2009). Differences in the sediment load showed that the greatest amount of sediment being transported during maximum streamflow was coming from the upper reservoir, from SAA-IV and SAA-V, between the Bypass Channel and Turah (Figure 32).

SAAs-IV and -V had significant metals concentration, but they were about half of the average concentrations found in SAA-I in the lower reservoir (Appendix D). The upper reservoir contained larger coarse-grain sediments which deposited in the slow moving waters of the reservoir while the fine-grain sediments were transported as far as the dam, where they became trapped behind the wall, depositing in SAA-I (ROD, 2004). It would require larger flows to erode and transport the coarse-grain sediments in SAA-IV and SAA-V. Bed sediment data was consistent with this prediction. Bed sediment metals concentration collected May 21-25, during maximum streamflow conditions, decreased to less than half of what they had been two weeks prior before the rising limb of the hydrograph (Figures 4-10B). The bed sediment As and Cu concentrations were consistent with average concentrations found in the upper reservoir (Appendix D), indicating that the upper reservoir was most likely the main source of the bed sediment at that time.

By May 19, as streamflow peaked, suspended-sediment metals concentration at Missoula and St. Regis began to level out to the same concentrations that were found entering the reservoir at Turah (Figure 35). These support conclusions from the bed sediment concentrations for the last three sample sets from June-August. As the suspended-sediment concentrations stabilize to Turah and upper reservoir levels there is a slight temporal offset in the bed sediment downstream, but eventually they also appear to be in the process of equalizing to Turah levels. The similarity of bed and suspended-sediment metals concentration at the upstream and downstream sites near the dam suggests that most of the contaminated reservoir sediment available for erosion has already been scoured out of the reservoir and transported downstream, where it was either deposited on the banks and channel of the CFR or carried through St. Regis to Thompson Falls Reservoir. By August, streamflow was at a minimum and the river was within the narrow confines of the channel. As the water receded, erosion and slumping of the drying banks may have exposed more contaminated sediments which were deposited earlier on the upper banks, and re-eroded them into the stream resulting in the overall increase in bed metals concentration which occurred at most of the sites in August. However, because the bed sediment concentrations are highest at the sites closest to the dam and are greater than upstream, we can see that there is still a source of contaminated sediment within the reservoir being supplied to the river at the end of our study period.

5. Conclusions

The purpose of this study was to use the geochemistry of stream and reservoir sediment to fingerprint, or track, the transport and deposition of sediments that were released from Milltown Reservoir. The combination of our bed sediment samples with the weekly USGS suspended-sediment water quality data provided sufficient information to characterize the spatial and temporal distribution of the sediments. One significant result was that activities leading up to the dam removal resulted in the release of some of the most contaminated sediments from the lower reservoir, which were stored in the channel of the first few kilometers of the CFR downstream of the dam, where they were not detected by the USGS sampling methods. These contaminated sediments, as well as fine-grained sediment from the lower reservoir released after the dam was breached during low streamflow, were responsible for the extremely high concentrations discovered in our initial bed sediment samples. Over the course of the spring runoff the more heavily contaminated sediments which were deposited first during low flows were covered up by less contaminated sediment from the upper reservoir, resulting in a decrease in the metals concentration from the top layer of bed sediment, and then further diluted with distance downstream from the uncontaminated banks of the CFR.

The sediment that was released downstream included some of the most contaminated deposits in the reservoir, which the restoration efforts were supposed to isolate and prevent from dispersing downstream. The low flows from late March to early May limited the amount and size of suspended-sediment the CFR was capable of transporting to predominantly fine-grained sediment. However, even low flows are capable of transporting significant amounts of fine-grain material over large distances, and due to the increased metals concentration found in fine-grain versus bulk or mixed sediment, large quantities of both metals and sediment could potentially be transported before the bulk of the sediment was eroded from the reservoir during high streamflow. This helps account for the extremely high metals concentration found in the bed sediment as far as CFPC (~70 km) in early May, and in the suspended-sediment at St. Regis through mid-May.

In combination with our bed sediment data, the USGS data for suspended-sediment, which includes our own calculations for sediment and metal loads, sediment load differences and metals concentration, helps to illustrate the timing of contaminant movement and the spatial distribution of the reservoir sediments throughout the lower CFR. The results of the metals concentration in the suspended-sediment were key to understanding the release of sediments from the reservoir over the course of the dam removal. Overall, the data suggests that the most contaminated fine-grain reservoir sediments were released immediately after breaching of the dam in two separate events. Another important result of this dam removal was the impact on the upper reservoir. Upper reservoir sediments were dispersed during maximum stream discharge, diluting the sediments already released from the lower reservoir during low flows. These less contaminated sediments were then further diluted by uncontaminated banks and tributary inputs downstream. The instability in the upper reservoir sediment was revealed by the massive amount of erosion between Turah and the bypass channel, much more than was expected. Remediation and stabilization efforts were focused primarily on the lower reservoir, including construction of the bypass channel and sediment removal. Restoration efforts such as seeding and planting trees after the reservoir was lowered could have helped to stabilize the soil, minimizing scouring effects as the river reestablished its natural channel.

Without the use of heavy metal analysis of these sediments, it would be much more difficult to determine, or ‘fingerprint,’ the source and fate of these sediments without a detailed analysis of the stream geomorphological changes. However, simply by knowing the concentrations of metals in the sediment we were able to determine that the bulk of the sediment entering Thompson Falls Reservoir was originally from the CFR, specifically Milltown Reservoir, and only minor contributions were made from the three tributaries. Additionally, after just our first sample set of bed sediment had been collected and analyzed, we could see that the short-term downstream impacts of the dam removal were a lot more severe and long-range than originally expected, and we could adjust our method accordingly to extend further downstream to capture the long-distance effects.

6. References

American Rivers, sum. by Higgs, Stephen; ed. Elizabeth Maclin and Margaret Bowman. (2002). The Ecology of Dam Removal: A Summary of Benefits and Impacts. American Rivers.

Andrews, E.D. (1987) Longitudinal dispersion of trace metals in the Clark Fork River, Montana. In *The Chemical Quality of Water and the Hydrologic Cycle,* Averett, R.C. and D.M. McKnight, eds., chapter 13, pp. 1-13 , Lewis Publishers.

Axtmann, E.V., Cain, D.J., and Luoma, S.N. (1997) Effect of Tributary Inflows on the Distribution of Trace Metals in Fine-Greained Bed Sediments and Benthic Insects of the Clark Fork River, Montana. *Environmental Science and Technology*, 31(3): 750-758.

Axtmann, E.V., Cain, D.J., and Luoma, S.N. (1990). Distribution of Trace Metals in Fine-grained Bed Sediments and Benthic Insects in the Clark Fork River, Montana. Clark Fork Symposium.

Axtmann, E.V., and Luoma, S.N. (1991). Large-scale Distribution of Metal Contamination in the fine-grained sediments of the Clark Fork River, Montana, U.S.A. *Applied Geochemistry*, (6): 75-88.

Brook, E.J., and Moore, J.N. (1989) Particle-size and chemical control of As, Cd, Cu, Fe, Mn, Ni, Pb and Zn in bed sediment from the Clark Fork River, Montana (USA). *Science and the Total Environment*, 76: 247-266.

CH2M Hill and The Clark Fork and Blackfoot, L.L.C. (2004). Biological Assessment of the Milltown Reservoir Sediments Operable Unit Revised Proposed Plan and of the Surrender Application for the Milltown Hydroelectric Project (FERC No. 2543). Prepared for U.S. Environmental Protection Agency, Helena, Montana. Biological Assessment Bull Trout.

Dodge, K.A., and Lambing, J.H. (2006). Quality-assurance plan for the analysis of suspended sediment by the U.S. Geological Survey in Montana: U.S. Geological Survey Open-File Report 2006-1242.

Dodge, K.A., Hornberger, M.L., and Dyke, J.L. (2005). Water-quality, bed sediment and biological data (October 2003 through September 2004) and statistical summaries of data for streams in the Clark Fork basin, Montana: U.S. Geological Survey Open-File Report 2005-1356.

Dodge, K.A., Hornberger, M.L., and Dyke, J.L. (2006). Water-quality, bed sediment and biological data (October 2004 through September 2005) and statistical summaries of data for streams in the Clark Fork basin, Montana: U.S. Geological Survey Open-File Report 2006-1266.

Dodge, K.A., Hornberger, M.L., and Dyke, J.L. (2007). Water-quality, bed sediment and biological data (October 2005 through September 2006) and statistical summaries of long-term data for streams in the Clark Fork basin, Montana: U.S. Geological Survey Open-File Report 2007-1301.

Dodge, K.A., Hornberger, M.L., and Dyke, J.L. (2008). Water-quality, bed sediment and biological data (October 2006 through September 2007) and statistical summaries of long-term data for streams in the Clark Fork basin, Montana: U.S. Geological Survey Open-File Report 2008-1318.

Doyle, M.W., Stanley, E.H. and Harbor, J.M. (2002). Geomorphic analogies for assessing probably channel response to dam removal. *Journal of the American Water Resources Association*, 38 (6): 1567-1579.

Drake, G.J. (1997). Long term variability of trace metal concentrations and carbon-metal relationships in fine-grained sediment of the upper Clark Fork River, Montana, M.S. thesis, 131 p., Univ. of Mont., Missoula.

Essig, D.A. and Moore, J.N. (1992). Clark Fork Damage Assessment: River bed sediment sampling and chemical analysis report: Natural Resource Damage Program, State of Montana, 110 p.

EPA (2002). Responsiveness Summary: Hudson River PCBs Site Record of Decision. Prepared by USEPA (United States Environmental Protection Agency) Region 2 and the USACE (United States Army Corp of Engineers), Kansas City District.

EPA (2005). Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. EPA-540-R-05-012Office of Superfund Remediation and Technology Innovation, 236 p.

EPA (2008). “Milltown Reservoir Sediments.” USEPA, Region 8. <http://epa.gov/region8/superfund/mt/milltown/>.

EPA (2009). Columbia River Basin: State of the River Report for Toxics. EPA 910-R-08-004. USEPA, Region 10.

EPA (2011). Contaminated Site Clean-up Information (CLU-IN): Sediments Risk Assessment. USEPA, Technology Innovation and Field Services Division. <http://www.clu-in.org/contaminantfocus/default.focus/sec/Sediments/cat/Overview/>

Forba, Russ. Personal Communication, 3-17-2009

Graf, W.L. (2005). Geormorphology and American dams: The scientific, social, and economic contect. *Geomorphology*, 71, 3-26.

Grant, G.E., Marr, J.D.G., Hill, C., Johnson, S., Campbell, K., Mohseni, O., Wallick, J.R., Lewis, S.L., O’Connor, J.E., Major, J.J., and Burkholder, B.K. (2008) Experimental and field observations of breach dynamics accompanying erosion of Marmot cofferdam, Sandy River, Oregon. World Environmental and Water Resources Congress 2008: Ahupua’a. ASCE.

Helgen, S.O. and Davis, A. (2000). Quantifying metal contributions from multiple sources to the Clark Fork River, Montana, U.S.A. *Journal of Environmental Forensics*, 1, 55-62.

Helgen, S.O. and Moore, J.N. (1996). Natural Background Determination and Impact Quantification in Trace Metal-Contaminated River Sediments. *Environmental Science and Technology*, 30 (1): 129-135.

Hochella M.F., Jr., Moore J.N., Putnis C.V., Kasama T., and Eberl D.D. (2005) Direct observation of heavy metal-mineral association from the Clark Fork River Superfund Complex: Implications for metal transport and bioavailability. *Geochim. Cosmochim. Acta* 69(7): 1651-1663.

Hornberger, M. I., Lambing, J.H., Luoma, S.N., and Axtmann, E.V. (1997). Spatial and Temporal Trends of Trace Metals in Surface Water, Bed Sediment, and Biota of the Upper Clark Fork Basin, Montana. U.S. Department of the Interior, U.S. Geological Survey. Open-File Report 97-669.

Horowitz, A.J., Demas, C.R., Fitzgerald, K.K., Miller, T.L., and Rickert, D.A. (1994). U.S. Geological Survey protocol for the collection and processing of surface-water samples for the subsequent determination of inorganic constituents in filtered water: U.S. Geological Survey Open-File Report 97-669. 84 p.

Johns, C.E., and Moore, J.N. (1995). Clark Fork Symposium. Copper, Zinc, and Arsenic in bottom sediments of Clark Fork River Reservoirs-Preliminary Findings. Clark Fork Symposium, 1985. http://www.umt.edu/clarkfork/Past_Proceedings/1985_proceedings/Johns/Johns.htm

Juracek, K.E. (2008). Channel-Bed Elevation Changes Downstream From Large Reservoirs in Kansas. USGS Water-Resources Investigations Report 01-4205.

Kondolf, G.M. (2006). River Restoration and Meanders. *Ecology and Society.* 11(2): 42.

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

Lambing, J.H., and Sando, S.K. (2008). Estimated loads of suspended sediment and selected trace elements transported through Milltown Reservoir in the upper Clark Fork Basin, Montana, water years 2004-07. U.S. Geological Survey Scientific Investigations Report 2008-5080, 24 p. accessible at http://pubs.usgs.gov/sir/2008/5080.

Lambing, J.H., and Sando, S.K. (2009) Estimated Loads of Suspended Sediment and Selected Trace Elements Transported through the Milltown Reservoir Project Area Before and After the Breaching of Milltown Dam in the Upper Clark Fork Basin, Montana, Water Year 2008. U.S. Geological Survey Scientific Investigations Report 2009-5095, 30 p.

Lauer, J.W., and Parker, G. (2008). Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meandering river: Application to the Clark Fork River, Montana. Water Resources Research, vol. 44.

Lisle, T.E., Yantao Cui, Parker, G., Pizzuto, J.E. and Dodd, A.M. (2001). The Dominance of Dispersion in the Evolution of Bed Material Waves in Gravel-Bed Rivers. *Earth Surface Processes and Landforms.* 26, pp. 1409-1420.

Luoma, S.N., Hornberger, M, and Cain, D.J. (1997) Fate, Bioavailability and Effects of Metals in Rivers and Estuaries: Role of Sediments. Proceedings of the U.S. Geological Survey Sediment Workshop, February 4-7, 1997.

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

McGeer, J.C., Brix, K.V., Skeaff, J.M., DeForest, D.K., Brigham, S.I., Adams, W.J., and Green, A. (2003). Inverse Relationship Between Bioconcentration Factor and Exposure Concentrations for Metals: Implications for Hazard Assessment of Metals in the Aquatic Environment. *Environmental Toxicology and Chemistry*: 22 (5), p. 1017-1037.

Mickey, J.W. (1998). The effects of the discharge variation on dissolved element concentrations through Milltown Reservoir, Montana, M.S. thesis, 158 p., Univ. of Mont., Missoula.

Moore, J.N., and Luoma, S.N. (1990). Hazardous wastes from large-scale metal extraction. *Environmental Science & Technology*: 24 (9), pp. 1278-1285.

Nagorski, S.A., McKinnon, T.E., Moore, J.N., and Smith, D.B. (2000). Geochemical characterization of surface water and streambed sediment of the Blackfoot River, Montana during low flow conditions, August 16-20, 1998, U.S. Geological Survey Open-File Report 00-0003, pp. 59.

Nagorski, S.A, Moore, J.N., and Smith, D.B. (2002). Distribution of Metals in the Water and Bed Sediment in a Mineral-Rich Watershed, Montana, USA. *Mine Water and the Environment:* 21, pp. 121-136.

Nielsen, Peter. 2-2-2009. Milltown Superfund Site- Clean-up status and summary of water monitoring. Chemistry Department Seminar. Environmental Health Division.

Nimick, D.A. and Moore, J.N. (1991). Prediction of water-soluble metal concentrations in fluvially deposited tailings sediments, Upper Clark Fork Valley, Montana, U.S.A., *Applied Geochemistry,* 6: 635-646.

Nimick, D.A., Gammons, C.H., Cleasby, T.E., Madison, J.P., Skaar, D., and Brick, C.M. (2003). Diel cycles in dissolved metal concentrations in streams: Occurrence and possible causes. Water Resources Research 39 (9): 1247.

Orsic, Ivan. Personal Communication. 5-28-2008

Orsic, Ivan. Unknown Title. Master's Thesis, in progress. University of Montana.

Pejchar, L., and Warner, K. (2001). "A River Might Run Through it Again: Criteria for Consideration of Dam Removal and Interim Lessons from California." *Environmental Management*. 28(5): 561-575.

Pizzuto, J. (2002). "Effects of Dam Removal on River Form and Process." *BioScience*. 52(8): 683-691.
Poff, N.L, Bledsoe, B., and Cuhaciyan, C.O. (2006). "Hydrologic variation with land use across the contiguous United States: Geomorphic and ecological consequences for stream ecosystems." *Geomorphology* 79, 264-285.

Rader, B.R., Nimmo, D.W.R., and Chapman, P.L. (1997). "Phytotoxicity of Floodplain Soils Contaminated with Trace Metals Along the Clark Fork River, Grant-Kohrs Ranch National Historic Site, Deer Lodge, Montana, USA." *Environmental Toxicology and Chemistry*, 16 (7): 1422-1432.

Record of Decision (ROD) (2004). Milltown Reservoir Sediments Operable Unit. US EPA Region 8. December, 2004.

Shifflett, Jan, (2002). The effect of discharge variation on suspended sediment and particulate contaminant transport through Milltown Reservoir, Montana. Geology M.S. thesis, University of Montana, 290 p.

Steiger, J, Tabacchi, E., Dufour, S., Corenblit, D., and Peiry J.L. (2005). "Hydrogeomorphic processes affecting riparian habitat within alluvial channel-floodplain river systems: a review for the temperate zone." *River Research and Applications*, 21: 719-737.

Stumm, V., and Morgan, J.J., (1996). Aquatic Chemistry, chemical equilibria and rates in natural waters, 3rd ed. JohnWiley and Sons, Inc., New York, 1022 p.

Sullivan, S. Mažeika P., Watzin, M.C., Hession W.C. (2004). "Understanding Stream Geomorphic State in Relation to Ecological Integrity: Evidence Using Habitat Assessments and Macroinvertebrates." *Environmental Management*, 34 (5), 669-683.

Syvitski, J.P.M., Vörösmarty, C. J., Kettner, A.J., and Green, P. (2005). "Impact of humans on the flux of terrestrial sediment to the global coastal ocean." *Science,* 308: 376-380.

USGS (2008). Clark Fork Water-Quality Monitoring Project. Montana Water Science Center, USGS. <http://mt.water.usgs.gov/projects/clarkfork/retrieve_wq_data.html>

APPENDIX A

History of Milltown Reservoir

The CFR, the largest tributary of the Columbia River in the Pacific Northwest has been heavily contaminated by mining wastes for more than 125 years from large-scale metal extraction operations near the headwaters in Butte and Anaconda, Montana (Axtmann and Luoma, 1991; ROD, 2004; EPA, 2008). Open pit copper and silver mining and smelting operations finally ceased in the early 1980s because of the negative environmental impacts of the mining wastes on the CFR and the surrounding area (Moore and Luoma, 1990; ROD, 2004). Although the primary sources of contamination were eliminated when mining operations were shut down, vast amounts of waste material has been deposited in the channel and on the floodplain downstream of the mining districts (Andrews, 1987; Axtmann and Luoma, 1991, Moore *et. al.*, 1989). The contaminated sediments are transitionally stored in the banks and floodplain and behave as a secondary source of contamination that continues to contribute heavy metals to the river system as they are reworked and eroded by the river and deposited further downstream (Moore and Luoma, 1990). Longitudinal dispersion allowed for the transport of contaminated sediments over great distances from their original contaminant sources, until they were stopped behind natural barriers or man-made dams, in this case, Milltown Dam. The accumulation of contaminated sediments in Milltown Reservoir, more than 200 kilometers downstream of the CFR headwaters, has elevated the concentrations of mining-associated metals (As, Cd, Cu, Hg, Pb, Zn) in the sediment well above natural background levels (Moore, 1994).

Milltown Reservoir is located near Missoula, Montana, at the confluence of the CFR and Blackfoot River (BFR), and has been trapping and storing substantial amounts of mining waste and contaminated sediments for over 100 years since Milltown Dam was completed in 1907 for flood control and hydroelectric power (Figures 1 and 3). Heavy metal contamination of the reservoir sediments was discovered in 1981 when extremely high concentrations of As were found in the groundwater system near Milltown. Backtracked groundwater flow patterns determined the reservoir as the source of the contamination (ROD, 2004). The reservoir was estimated to retain 1.6 million kg (1,760 tons) of As and 13 million kg (14,300 tons) of Cu (Moore and Luoma, 1990). Over several decades, arsenic at Milltown was predominantly released into the groundwater when the unstable minerals to which they were sorbed (iron oxyhydroxides) reductively dissolved (ROD, 2004). The chemically reducing conditions within the reservoir could also partially control the partitioning of arsenic and metals into the dissolved phase which allowed them to be released into the groundwater system (Stumm and Morgan, 1996; Mickey, 1998; others). Up to 7300 lbs/year of As was released to the groundwater system and accumulated in the aquifer at Milltown (Nielsen, 2009), creating an As plume with concentrations exceeding the federal drinking water standard of 0.01 mg/L (10 ppm) spanning an area of about 325 acres (ROD, 2004) (Figure 29).

Milltown Reservoir was placed on the United States Environmental Protection Agency's (EPA) National Priorities List (NPL) in 1983 as a high priority "Superfund" site due to high concentrations of arsenic and copper in the local groundwater and reservoir sediments. Over six million cubic yards of sediment highly enriched with As, Cd, Cu, Pb, Zn, and other hazardous substances had accumulated within Milltown Reservoir (EPA, 2008). In addition to acting as a tertiary source of As to the groundwater - contaminating the local drinking water in public and private wells – the reservoir was also a secondary source of metal-laden sediment to the river downstream (ROD, 2004).

The risk of allowing the metal-enriched sediments to remain trapped behind Milltown

Dam was emphasized in February of 1996 when an ice jam and its associated flood threatened the structural integrity of the dam. Fortunately the ice jam was discovered in time for the dam's spillways to be opened and the reservoir lowered in order to prevent damage to the dam by the ice, however, substantial amounts of contaminated fine-grain sediment were scoured from the reservoir and remobilized downstream. In this case, Milltown Dam was ineffective as a barrier to prevent the suspended-sediment from leaving the reservoir (Landrigan, 1997). The metals released from the reservoir had a major impact on the trout population downstream of the dam, resulting in a 62% decrease in the rainbow trout population, with an even larger decrease in the juvenile population (Landrigan, 1997, see references). If the dam had been damaged, the scouring and remobilization of the heavily contaminated reservoir sediments in one pulse, during low flows, would have been catastrophic. Ice jams are common on the CFR, occurring every ten years or so in the past century, and thus present an extreme hazard to the downstream ecosystem by potentially damaging the dam and remobilizing massive quantities of metal-enriched sediment over a very short time span. The immediacy of these concerns encouraged the EPA and interested parties to initiate the clean-up process sooner rather than later.

Due to the age of the dam, deterioration of the infrastructure, its low hydroelectric energy production, the public desire to restore natural systems and stream connectivity for fish migration, and the threat of dam failure and scouring by ice jams, the EPA and other interested parties decided that Milltown Dam would be removed and the reservoir area restored, in one of the largest and most expensive dam removal and river restoration projects to date, estimated at $120 million (EPA, 2008). The EPA site risk assessment for the Milltown Reservoir Sediments Operable Unit of the Milltown Reservoir/Clark Fork River Superfund Site was primarily concerned with arsenic and copper contamination of the groundwater and reservoir sediments

(ROD, 2004). The reservoir was conceptually divided into five separate sediment accumulation areas (SAA) by the Restoration Project, based upon sediment thickness and trace metal content (Figure 29). The primary area of concern was SAA-I, which was located on the northern side of the channel and contained the highest concentrations of metals. This SAA is where the original river channel used to be when the dam was first constructed in the early 1900s, and was responsible for most of the groundwater As plume. The historic channel was filled with a massive volume of the most contaminated sediments from flooding in the early mining days, eventually forcing the channel to migrate south and west around these sediments. The average copper concentrations in SAA-I before Milltown Dam was removed was 2300 ppm, ranging from 5000 ppm in fine-grain sediment and 83 ppm in sand, while average As was 320 ppm (Appendix D). (ROD, 2004)

The first goal of the EPA restoration project was to remove the source of groundwater and river contamination by relocating the contaminated sediments in the reservoir to an isolated site 90 miles upstream at the waste settling ponds in Opportunity Ponds in Anaconda (EPA, 2008). Removal of the contaminants would improve water quality and provide a healthier habitat for fish and wildlife. The sediments from the reservoir were used to cap tailings for revegetation in restoration efforts at the Anaconda smelter site. About 2.2 million cubic yards of the most contaminated sediments were slated for removal. Prior to dam removal, the reservoir was gradually lowered over a period of two years and a bypass channel was created to divert the river around the contaminated reservoir sediments so that a railroad could be constructed right up to the reservoir and the exposed sediments could be physically removed and hauled upstream. Excavation of the reservoir sediments began in October, 2007, and the bypass channel was activated on March 24, 2008, four days before the dam was breached (EPA, 2008).

The second goal of the restoration plan was to remove Milltown Dam in order to reestablish natural conditions and to restore stream connectivity to allow fish passage at the confluence of the BFR and CFR (EPA, 2009). In June, 2006, the standing water level of the reservoir was permanently lowered 10-12 feet to enable work crews access to prepare for the sediment and dam removal. Gradually, subsequent drawdowns followed, for a total drawdown of 29 feet, which returned the water elevation to the pre-dam river conditions (Lambing and Sando, 2009). The time between drawdowns allowed the EPA and environmental consultants to monitor the resultant lowering of the local water table, which affected the As plume in the groundwater system as well as the necessary depth for wells in the area. Milltown Dam was breached March 28, 2008, and for the first time since its completion in 1907 these two rivers were allowed to flow free.

Appendix B: Analytical Results

ICP Bed Sediment Analysis Results
Collection Date: 5/03/08 - 5/05/08
Analysis Date: 6/02/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
BFWS-X 80503		11530	8.32	b.d.	369	b.d.	23990	b.d.	6.00	11.2	20.8	15450	1941	22.4	9224	790
BFWS-Y 80503		11260	8.56	b.d.	353	b.d.	21100	b.d.	6.36	11.5	22.6	15820	2031	25.0	9815	688
BRMF-X 80503		16970	5.85	b.d.	175	0.53	5312	b.d.	6.32	14.6	22.1	17470	2760	26.7	4831	791
BRMF-Y 80503		16630	4.99	b.d.	168	0.53	5084	b.d.	5.93	13.7	20.4	16630	2696	23.8	4593	735
CFBF-X 80503		13800	284	b.d.	513	b.d.	16610	7.01	6.94	12.8	2184	21660	2235	18.8	7066	934
CFBF-Y 80503		13870	288	b.d.	504	b.d.	15130	6.95	7.01	12.8	2216	21900	2200	20.4	7091	885
CFCA-X 80504		14030	304	b.d.	562	b.d.	17650	8.40	7.38	12.7	2334	21750	2269	19.3	6745	1034
CFCA-Y 80504		13880	295	b.d.	617	b.d.	16980	8.05	7.07	12.6	2266	21850	2264	19.3	6855	976
CFDC 80504		13820	264	b.d.	599	b.d.	16170	6.88	7.54	13.0	2040	21950	2211	18.8	6945	968
CFEG 80504		13090	339	b.d.	998	b.d.	17400	8.54	6.89	12.0	2388	21980	2198	18.8	6958	879
CFHB-X 80503		14400	265	b.d.	543	b.d.	14630	7.07	7.17	13.0	2054	21320	2363	20.7	6610	993
CFHB-Y 80503		14740	262	b.d.	546	b.d.	15270	6.80	7.08	13.2	1991	21060	2396	20.2	6656	985
CFHC-X 80503		15820	275	b.d.	788	b.d.	16290	7.09	8.00	14.6	2137	23780	2424	21.5	7541	937
CFHC-Y 80503		13670	281	b.d.	597	b.d.	16490	6.94	7.15	12.8	2197	21510	2164	19.0	6881	953
CFIB 80504		13960	255	b.d.	770	b.d.	15700	6.50	7.68	13.2	1910	22040	2194	18.9	6964	904
CFKB-X 80503		14530	305	b.d.	578	b.d.	16840	8.30	7.41	13.0	2335	21780	2319	20.3	6674	1059
CFKB-Y 80503		13860	281	b.d.	569	b.d.	16300	7.69	7.31	12.6	2149	20690	2264	19.0	6397	1005
CFKI-X 80503		11930	244	b.d.	678	b.d.	15910	6.61	6.58	11.9	1784	19290	1950	17.3	6217	853
CFKI-Y 80503		13420	269	b.d.	555	b.d.	18010	7.52	7.16	12.7	2029	20630	2191	18.2	6588	897
CFMP-X 80503		12910	294	b.d.	627	b.d.	16200	7.56	6.71	12.1	2166	20740	2137	17.1	6432	931
CFMP-Y 80503		14970	321	b.d.	552	b.d.	18650	9.02	7.55	13.4	2472	23040	2385	21.4	7263	1068
CFPC-X 80505		12850	224	b.d.	458	b.d.	14420	6.04	6.59	12.1	1717	19050	2175	18.4	6153	964
CFPC-Y 80505		14530	250	b.d.	455	b.d.	15540	6.89	7.54	13.2	1928	20720	2440	19.7	6517	1125
CFSR 80504		13330	292	b.d.	595	b.d.	16100	6.86	7.39	12.5	2174	21100	2139	17.7	6483	975
CFTB-X 80503		16480	67.2	b.d.	306	b.d.	36570	1.81	7.28	15.8	383	19020	2395	16.7	6153	1375
CFTB-Y 80503		17030	66.0	b.d.	304	b.d.	37860	1.93	7.34	16.0	403	19480	2487	16.5	6218	1313

*b.d. – below detection, the detection limit is the Practical Quantitation Limit (PQL) listed at the top
Sample identification code:
The first four letters are the site name, listed in Table 1. Two samples were collected at most sites, labeled either X or Y. The five digit number at the end of the name indicate the day the sample was collected beginning with the year, the month, and then the day in the following manner: YMMDD.

Sample ID		Mo	Na	Ni	P	Pb	S	Sb	Se	Si	Sn	Sr	Ti	Tl	V	Zn
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
BFWS-X 80503		b.d.	104	9.36	941	8.58	802	b.d.	b.d.	2019	b.d.	31.9	223	b.d.	16.4	67.5
BFWS-Y 80503		b.d.	101	9.80	805	10.3	622	b.d.	b.d.	1928	b.d.	28.1	218	b.d.	17.2	73.0
BRMF-X 80503		b.d.	167	8.01	1213	7.05	1066	b.d.	b.d.	1907	1.37	32.2	585	b.d.	21.1	67.4
BRMF-Y 80503		b.d.	168	7.38	1189	b.d.	1073	b.d.	b.d.	2338	1.50	32.0	614	b.d.	20.4	61.1
CFBF-X 80503		b.d.	122	10.9	851	182	6310	b.d.	b.d.	1788	4.76	44.4	332	b.d.	25.1	2394
CFBF-Y 80503		b.d.	124	11.1	847	185	6436	b.d.	b.d.	2276	5.35	41.9	341	b.d.	25.2	2397
CFCA-X 80504		b.d.	133	10.8	895	192	6564	5.72	b.d.	1862	4.66	49.6	320	b.d.	22.9	2472
CFCA-Y 80504		b.d.	130	10.6	906	184	6493	5.60	b.d.	1827	4.71	48.4	315	b.d.	23.3	2433
CFDC 80504		b.d.	127	11.0	878	175	6250	b.d.	b.d.	1913	4.51	46.9	339	b.d.	25.1	2371
CFEG 80504		b.d.	128	10.3	827	180	6717	6.36	b.d.	2046	4.82	53.6	314	b.d.	22.8	2716
CFHB-X 80503		b.d.	138	10.5	948	171	5385	5.22	b.d.	1805	4.41	45.1	339	b.d.	22.8	2120
CFHB-Y 80503		b.d.	153	10.4	947	161	5311	5.40	b.d.	2313	4.54	46.8	396	b.d.	23.2	2064
CFHC-X 80503		b.d.	141	12.0	916	184	6325	b.d.	b.d.	2583	5.22	50.8	402	b.d.	27.8	2473
CFHC-Y 80503		b.d.	123	10.8	874	181	6091	b.d.	b.d.	1865	4.80	46.3	332	b.d.	24.7	2332
CFIB 80504		b.d.	133	11.0	904	160	6279	b.d.	b.d.	2591	4.45	47.7	393	b.d.	29.3	2288
CFKB-X 80503		b.d.	156	10.5	971	192	6060	5.60	b.d.	2174	4.80	47.8	366	b.d.	23.0	2445
CFKB-Y 80503		b.d.	144	10.2	910	181	5854	5.77	b.d.	1764	4.53	46.3	355	b.d.	22.4	2277
CFKI-X 80503		b.d.	131	9.37	917	140	5577	5.01	b.d.	2084	4.39	45.1	321	b.d.	22.4	2061
CFKI-Y 80503		b.d.	145	10.3	935	166	5627	5.32	b.d.	1863	4.22	48.6	333	b.d.	22.8	2243
CFMP-X 80503		b.d.	132	9.94	890	175	6042	5.55	b.d.	1760	4.49	47.5	322	b.d.	22.7	2301
CFMP-Y 80503		b.d.	136	11.4	950	205	6609	6.16	b.d.	2070	5.11	50.6	350	b.d.	24.2	2560
CFPC-X 80505		b.d.	146	9.45	884	141	4640	b.d.	b.d.	1895	4.54	42.8	339	b.d.	21.0	1883
CFPC-Y 80505		b.d.	143	10.6	948	166	4938	5.14	b.d.	1841	4.12	46.7	356	b.d.	21.7	2070
CFSR 80504		b.d.	130	10.6	877	185	6474	b.d.	b.d.	2178	4.56	48.0	341	b.d.	24.3	2351
CFTB-X 80503		b.d.	215	10.2	1108	81.5	1587	b.d.	b.d.	2280	1.34	95.1	507	b.d.	26.5	699
CFTB-Y 80503		b.d.	219	10.4	1133	84.1	1696	b.d.	b.d.	2147	1.24	97.9	505	b.d.	26.8	712

ICP Bed Sediment Analysis Results
Collection Date: 5/21/08 - 5/22/08, 5/25/08
Analysis Date: 6/3/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
BFWSX80521		9520	6.82	b.d.	310	b.d.	22700	b.d.	5.77	9.14	22.6	14110	1733	25.3	10350	466
BFWSY80521		10360	7.80	b.d.	334	b.d.	22040	b.d.	6.16	9.86	24.2	14950	1840	28.3	10570	505
BRMFX80522		14120	3.00	b.d.	122	0.42	3477	b.d.	6.08	14.0	18.9	15330	2921	24.7	5113	314
BRMFY80522		12930	2.99	b.d.	117	0.25	3939	b.d.	5.31	12.9	16.7	14190	2827	22.1	4820	237
CFBFX80521		14890	166	b.d.	338	b.d.	10570	6.14	8.79	15.0	1387	21730	2277	18.6	6826	919
CFBFY80521		15500	173	b.d.	352	b.d.	10960	5.95	8.77	15.5	1463	22550	2410	20.3	7027	927
CFDCX80521		15860	116	b.d.	391	b.d.	11540	4.16	9.59	15.7	969	23110	2420	23.7	8617	901
CFDYX80525		14540	60.3	b.d.	291	b.d.	9045	2.02	7.39	13.2	523	19530	2319	22.6	8276	690
CFDYY80525		12520	49.5	b.d.	262	b.d.	8448	1.72	6.64	11.8	434	17190	2051	19.5	7434	636
CFHBX80522		12090	86.4	b.d.	313	b.d.	9979	2.67	6.36	11.7	723	16710	1930	18.8	6896	618
CFHBY80522		11630	66.4	b.d.	331	b.d.	9602	2.20	6.66	12.0	557	16460	1900	18.0	6766	622
CFHCX80521		13130	134	b.d.	357	b.d.	11960	4.50	7.45	13.2	1118	19550	2018	18.9	7224	745
CFHCY80521		13310	139	b.d.	379	b.d.	12540	4.46	7.49	13.2	1137	19800	2077	20.4	7787	702
CFKBX80522		11730	85.3	b.d.	331	b.d.	11520	2.95	6.58	11.9	721	16840	1872	18.0	7019	597
CFKBY80522		11230	72.7	b.d.	333	b.d.	10980	2.34	6.54	11.9	597	16360	1789	16.8	6731	592
CFKCX80525		11230	33.3	b.d.	289	b.d.	6976	0.78	6.53	11.1	253	16680	1882	17.8	6999	559
CFKCY80525		9579	30.6	b.d.	210	b.d.	6314	0.83	5.50	9.48	242	13830	1636	14.9	6075	483
CFKIX80522		11370	89.2	b.d.	345	b.d.	13200	3.23	6.27	11.3	761	16430	1880	17.5	7012	585
CFKIY80522		12770	91.9	b.d.	353	b.d.	12800	3.50	6.82	12.7	803	17760	2043	18.8	7308	565
CFMPX80521		12660	112	b.d.	334	b.d.	14510	3.85	7.79	12.5	937	18350	2221	20.6	8088	900
CFMPY80521		11550	139	b.d.	366	b.d.	14360	4.38	6.77	11.6	1100	17640	1867	18.1	7300	734
CFPCX80522		12790	75.7	b.d.	265	b.d.	8749	2.64	6.76	12.4	653	16890	2070	20.0	7132	674
CFPCX80525		14670	75.1	b.d.	311	b.d.	9598	2.69	7.31	13.6	660	19190	2280	22.7	7848	683
CFPCY80522		12480	75.1	b.d.	270	b.d.	8808	2.55	6.81	12.2	641	16690	2034	19.6	7031	692
CFPCY80525		13530	74.1	b.d.	292	b.d.	9133	2.78	6.91	12.5	670	17510	2163	21.3	7338	678
CFPNX80525		12990	48.6	b.d.	253	b.d.	7522	1.29	7.10	11.7	406	17620	2209	21.2	8117	658
CFPNY80525		11480	42.1	b.d.	218	b.d.	6937	1.21	6.58	10.7	349	15780	2022	18.6	7373	594
CFSRX80521		11290	131	b.d.	330	b.d.	13940	3.79	6.61	11.3	1019	17160	1888	18.5	7923	696
CFTAX80525		13840	49.1	b.d.	339	b.d.	7817	1.26	7.52	13.3	399	19070	2206	20.7	7751	681
CFTAY80525		9920	39.7	b.d.	283	b.d.	7185	0.93	5.60	10.5	307	14310	1686	14.9	6190	495
CFTBX80521		15190	43.8	b.d.	276	b.d.	17920	1.64	8.00	16.0	334	18660	2294	18.2	6025	995
CFTBY80521		15550	40.0	b.d.	273	b.d.	14820	1.21	7.86	16.0	273	18350	2335	18.3	5991	948
CFTSX80525		11430	30.3	b.d.	242	b.d.	6231	0.69	6.77	10.6	241	16360	1870	18.7	7173	469
CFTSY80525		10200	29.8	b.d.	209	b.d.	6541	0.78	5.60	9.66	244	14250	1705	16.5	6532	443

Sample ID		**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Sr**	**Ti**	**Tl**	**V**	**Zn**
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
BFWSX80521		b.d.	79.5	8.80	752	8.75	393	b.d.	b.d.	813	b.d.	23.3	144	b.d.	15.8	55.3
BFWSY80521		b.d.	81.5	11.4	720	9.46	456	b.d.	b.d.	760	b.d.	23.9	158	b.d.	16.1	56.8
BRMFX80522		b.d.	131	7.94	563	7.06	292	b.d.	b.d.	859	b.d.	20.0	555	b.d.	19.0	56.0
BRMFY80522		b.d.	133	7.14	662	11.5	303	b.d.	b.d.	845	b.d.	21.9	525	b.d.	16.8	55.2
CFBFX80521		b.d.	136	12.6	837	128	3535	b.d.	b.d.	856	1.58	38.3	334	b.d.	26.4	2036
CFBFY80521		b.d.	142	12.7	851	134	3612	b.d.	b.d.	858	2.00	40.1	348	b.d.	27.7	2035
CFDCX80521		b.d.	133	14.1	807	97.3	2460	b.d.	b.d.	829	1.31	33.7	319	b.d.	28.1	1733
CFDYX80525		b.d.	139	10.9	726	54.0	1515	b.d.	b.d.	861	b.d.	26.5	329	b.d.	20.4	685
CFDYY80525		b.d.	125	9.79	689	46.2	1279	b.d.	b.d.	695	b.d.	24.5	305	b.d.	18.6	600
CFHBX80522		b.d.	123	9.51	703	65.9	2028	b.d.	b.d.	818	b.d.	30.0	287	b.d.	19.5	939
CFHBY80522		b.d.	120	9.75	717	55.8	1593	b.d.	b.d.	848	b.d.	29.1	294	b.d.	20.3	813
CFHCX80521		b.d.	122	11.0	783	95.7	3171	b.d.	b.d.	946	1.30	33.4	312	b.d.	23.5	1573
CFHCY80521		b.d.	119	11.2	789	101	3349	b.d.	b.d.	816	1.11	31.7	301	b.d.	22.4	1522
CFKBX80522		b.d.	117	9.89	740	63.6	2106	b.d.	b.d.	867	b.d.	31.3	290	b.d.	20.4	981
CFKBY80522		b.d.	112	9.65	748	56.6	1837	b.d.	b.d.	789	b.d.	30.2	291	b.d.	21.1	873
CFKCX80525		b.d.	115	9.22	771	36.0	923	b.d.	b.d.	799	b.d.	19.9	301	b.d.	18.2	411
CFKCY80525		b.d.	101	8.02	626	28.8	811	b.d.	b.d.	726	b.d.	18.2	280	b.d.	15.2	381
CFKIX80522		b.d.	118	9.53	760	66.8	2282	b.d.	b.d.	947	b.d.	33.0	273	b.d.	19.7	1033
CFKIY80522		b.d.	127	10.4	765	74.3	2414	b.d.	b.d.	895	b.d.	33.4	301	b.d.	21.5	1054
CFMPX80521		b.d.	122	11.1	793	86.3	2500	b.d.	b.d.	838	b.d.	36.0	277	b.d.	20.8	1233
CFMPY80521		b.d.	114	10.00	751	85.4	3331	b.d.	b.d.	854	b.d.	33.5	270	b.d.	20.4	1457
CFPCX80522		b.d.	132	10.1	685	58.3	1781	b.d.	b.d.	784	b.d.	27.7	301	b.d.	19.0	812
CFPCX80525		b.d.	139	11.0	758	63.3	1892	b.d.	b.d.	815	b.d.	30.7	321	b.d.	21.6	836
CFPCY80522		b.d.	128	10.0	672	56.8	1740	b.d.	b.d.	777	b.d.	28.0	305	b.d.	19.1	808
CFPCY80525		b.d.	130	10.2	726	61.6	1863	b.d.	b.d.	726	b.d.	29.0	304	b.d.	19.6	830
CFPNX80525		b.d.	138	10.5	670	44.1	1163	b.d.	b.d.	797	b.d.	20.0	296	b.d.	17.3	510
CFPNY80525		b.d.	117	9.64	630	38.2	986	b.d.	b.d.	760	b.d.	18.6	300	b.d.	15.9	461
CFSRX80521		b.d.	107	9.92	729	83.4	2966	b.d.	b.d.	784	b.d.	29.8	239	b.d.	19.8	1225
CFTAX80525		b.d.	132	10.5	733	44.0	1264	b.d.	b.d.	831	b.d.	25.6	318	b.d.	21.8	578
CFTAY80525		b.d.	116	8.00	695	31.6	1022	b.d.	b.d.	730	b.d.	22.2	289	b.d.	18.2	450
CFTBX80521		b.d.	158	11.4	999	63.3	904	b.d.	b.d.	878	b.d.	58.3	403	b.d.	24.9	598
CFTBY80521		b.d.	152	11.5	947	51.6	912	b.d.	b.d.	975	b.d.	49.8	438	b.d.	24.0	480
CFTSX80525		b.d.	111	9.30	721	33.0	839	b.d.	b.d.	787	b.d.	16.7	292	b.d.	16.4	359
CFTSY80525		b.d.	102	8.22	640	28.1	819	b.d.	b.d.	814	b.d.	16.7	279	b.d.	14.8	360

ICP Bed Sediment Analysis Results

Collection Date: 6/09/08 - 6/10/08
Analysis Date: 7/14/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
BFWSX80609		8080	7.81	2.17	278	0.58	20600	b.d.	5.32	8.71	19.9	12940	1582	25.6	9159	425
BFWSY80609		7537	7.18	1.99	327	0.53	18730	b.d.	5.01	8.39	17.3	12600	1467	24.3	8940	377
BRMFX80610		12580	3.86	b.d.	119	0.83	3677	b.d.	5.16	12.9	18.1	13700	2040	23.5	4354	365
BRMFY80610		13290	3.69	b.d.	124	0.87	3846	b.d.	5.26	13.2	19.4	14430	2130	24.6	4510	357
CFBFX80609		8212	55.5	b.d.	367	0.49	8016	1.79	4.94	11.8	414	13790	1333	12.0	4558	534
CFBFY80609		10500	70.9	b.d.	443	0.67	9412	2.35	6.39	13.6	533	17110	1638	16.9	5840	640
CFCAX80609		8977	69.7	b.d.	325	0.53	9616	2.38	5.30	11.3	520	14620	1467	14.7	5559	569
CFCAY80609		11410	69.9	1.36	325	0.71	12830	2.50	6.58	12.5	541	17180	1832	20.2	7144	746
CFDC80609		9269	77.2	b.d.	367	0.56	8551	2.47	5.46	12.6	561	15340	1517	14.8	5199	574
CFDYX80609		10460	34.4	b.d.	260	0.67	8332	1.61	6.32	11.3	291	15260	1700	20.0	6712	612
CFDYY80609		10360	38.0	b.d.	256	0.65	8148	1.65	6.18	11.2	300	15160	1718	20.1	6729	611
CFHBX80610		9230	47.3	b.d.	374	0.58	8699	1.56	5.60	10.9	362	14600	1501	16.8	5919	532
CFHBY80610		10520	51.5	b.d.	327	0.67	8598	2.03	6.32	11.8	412	15760	1660	18.6	6208	584
CFHCX80609		9663	72.5	b.d.	309	0.60	10670	2.60	5.92	11.6	550	15670	1579	16.6	6019	661
CFHCY80609		11850	69.7	b.d.	364	0.78	9792	2.77	8.00	14.2	494	19170	1836	19.7	6832	818
CFKBX80609		10350	48.6	b.d.	362	0.65	10830	2.15	6.29	12.0	398	15590	1629	18.9	6436	640
CFKBY80609		11620	62.1	1.29	347	0.75	11290	2.90	6.64	12.8	510	16860	1815	20.4	6824	733
CFKCX80609		8199	26.2	b.d.	224	0.47	6710	0.80	5.33	9.48	177	13290	1410	15.9	5746	568
CFKCY80609		8779	23.2	b.d.	267	0.50	6408	0.62	5.68	10.2	162	14680	1486	17.1	6030	453
CFKIX80609		8830	63.6	b.d.	439	0.55	11410	2.56	5.71	11.0	494	14930	1448	16.1	6002	697
CFKIX80610		10330	53.7	b.d.	379	0.66	11160	2.38	6.44	11.9	418	16250	1616	18.6	6568	669
CFKIY80609		8357	58.6	b.d.	500	0.53	10020	2.07	5.60	10.7	440	14480	1383	14.8	5732	610
CFKIY80610		11640	48.7	b.d.	525	0.73	10400	1.86	7.34	14.1	374	19080	1775	21.0	7186	652
CFMPX80609		9879	72.4	b.d.	339	0.60	11000	2.52	5.75	11.5	553	15670	1607	16.9	6174	629
CFMPY80609		10870	77.2	b.d.	409	0.68	10770	2.69	6.64	13.3	561	17260	1713	18.1	6394	693
CFPCX80609		10580	41.6	1.07	271	0.67	8627	1.69	5.91	11.6	343	14940	1737	19.2	6379	494
CFPCY80610		11660	47.5	1.14	267	0.74	8250	2.04	6.36	12.3	403	16220	1864	21.4	6641	534
CFPNX80609		11240	29.1	b.d.	226	0.65	7729	0.96	6.29	11.1	236	15630	1842	22.8	7395	517
CFPNY80609		11050	35.9	b.d.	240	0.63	7311	1.18	6.15	11.0	279	15510	1843	21.0	7019	519
CFSRX80609		9269	54.4	1.24	398	0.60	11320	1.71	5.56	11.0	412	14340	1582	18.4	6580	527
CFTAX80609		11020	31.9	b.d.	383	0.67	7361	0.97	6.43	12.3	234	16810	1749	20.6	6630	589
CFTAY80609		11970	39.7	b.d.	315	0.74	7009	1.42	7.31	13.0	299	17430	1920	22.1	6821	737
CFTBX80609		12970	40.8	1.04	249	0.78	10390	1.31	7.20	16.1	286	17700	2010	16.9	5599	888
CFTBY80609		12690	44.0	b.d.	225	0.78	11220	1.38	6.86	15.3	304	16960	1975	16.8	5519	787
CFTSX80609		9720	28.1	b.d.	215	0.54	6264	0.81	5.52	9.85	205	13800	1629	19.0	6101	465
CFTSY80609		10980	25.8	b.d.	216	0.62	7358	0.68	6.07	11.0	193	15190	1813	21.4	6871	505
FHKNX80609		13000	5.35	b.d.	130	0.44	5111	b.d.	6.13	10.8	15.9	16100	2445	34.2	9034	257
FHKNY80609		13210	5.15	b.d.	136	0.49	5090	b.d.	6.23	10.6	15.9	16100	1967	36.1	9748	259

Sample ID		**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Sr**	**Ti**	**Tl**	**V**	**Zn**
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
BFWSX80609		b.d.	60.6	8.97	606	7.01	184	b.d.	b.d.	851	b.d.	25.9	163	b.d.	14.6	46.4
BFWSY80609		b.d.	53.5	8.27	682	6.53	191	b.d.	b.d.	868	b.d.	23.5	161	b.d.	17.4	42.8
BRMFX80610		b.d.	112	7.53	577	6.02	124	b.d.	b.d.	844	b.d.	20.2	508	b.d.	16.2	48.2
BRMFY80610		b.d.	116	7.83	599	6.28	160	b.d.	b.d.	768	b.d.	20.9	500	b.d.	16.6	51.9
CFBFX80609		b.d.	91.1	7.69	915	45.6	1580	b.d.	b.d.	965	b.d.	28.8	315	b.d.	21.9	718
CFBFY80609		b.d.	94.4	9.86	916	60.9	1755	b.d.	b.d.	917	b.d.	31.4	334	b.d.	26.2	888
CFCAX80609		b.d.	94.5	8.58	807	50.8	1877	b.d.	b.d.	830	b.d.	27.6	296	b.d.	19.7	790
CFCAY80609		b.d.	104	10.5	728	57.8	1632	b.d.	b.d.	810	b.d.	33.0	303	b.d.	19.9	829
CFDC80609		b.d.	107	9.04	918	56.3	2108	b.d.	b.d.	884	b.d.	30.2	332	b.d.	23.9	846
CFDYX80609		b.d.	78.0	9.93	698	37.0	763	b.d.	b.d.	913	1.87	21.8	291	b.d.	16.6	452
CFDYY80609		b.d.	81.0	9.78	705	37.5	800	b.d.	b.d.	906	2.16	20.8	280	b.d.	16.0	447
CFHBX80610		b.d.	87.0	8.76	801	40.4	1180	b.d.	b.d.	960	b.d.	25.8	293	b.d.	19.4	569
CFHBY80610		b.d.	86.2	9.87	764	47.3	1129	b.d.	b.d.	978	b.d.	25.6	301	b.d.	19.7	679
CFHCX80609		b.d.	94.8	9.66	772	56.2	1766	b.d.	b.d.	944	b.d.	30.3	288	b.d.	19.3	879
CFHCY80609		b.d.	98.1	12.0	863	59.0	1374	b.d.	b.d.	886	b.d.	30.2	325	b.d.	24.6	1079
CFKBX80609		b.d.	93.9	9.93	767	48.4	1246	b.d.	b.d.	921	b.d.	29.0	289	b.d.	20.5	639
CFKBY80609		b.d.	102	10.6	762	53.9	1365	b.d.	b.d.	876	b.d.	31.9	316	b.d.	20.7	808
CFKCX80609		b.d.	72.9	8.12	674	26.4	508	b.d.	b.d.	772	b.d.	16.1	260	b.d.	14.5	326
CFKCY80609		b.d.	68.5	8.51	772	25.7	478	b.d.	b.d.	865	b.d.	16.5	273	b.d.	17.1	313
CFKIX80609		b.d.	86.8	8.99	833	52.2	1767	b.d.	b.d.	954	b.d.	28.7	270	b.d.	19.6	782
CFKIX80610		b.d.	82.6	10.1	800	48.7	1357	b.d.	b.d.	1036	2.29	27.9	293	b.d.	20.9	728
CFKIY80609		b.d.	81.9	8.72	846	48.1	1657	b.d.	b.d.	889	b.d.	28.8	275	b.d.	20.8	750
CFKIY80610		b.d.	81.7	11.5	947	47.4	1265	b.d.	b.d.	933	2.76	29.7	309	b.d.	28.4	701
CFMPX80609		b.d.	100	9.28	765	54.5	1833	b.d.	b.d.	915	b.d.	31.3	295	b.d.	19.9	860
CFMPY80609		b.d.	98.4	10.5	862	60.0	1879	b.d.	b.d.	889	b.d.	31.9	312	b.d.	23.2	930
CFPCX80609		b.d.	88.8	9.59	717	39.4	925	b.d.	b.d.	812	b.d.	24.5	307	b.d.	17.5	524
CFPCY80610		b.d.	95.9	10.6	724	45.3	1130	b.d.	b.d.	814	b.d.	24.9	317	b.d.	18.4	588
CFPNX80609		b.d.	87.6	10.1	638	31.0	649	b.d.	b.d.	957	b.d.	18.4	290	b.d.	15.3	367
CFPNY80609		b.d.	91.9	9.78	676	35.1	742	b.d.	b.d.	911	b.d.	18.9	292	b.d.	15.3	423
CFSRX80609		b.d.	90.1	8.96	768	46.3	1227	b.d.	b.d.	839	b.d.	29.5	263	b.d.	20.4	595
CFTAX80609		b.d.	87.8	9.72	790	32.1	685	b.d.	b.d.	859	b.d.	23.1	315	b.d.	21.8	419
CFTAY80609		b.d.	96.7	10.7	765	38.5	820	b.d.	b.d.	784	b.d.	23.6	327	b.d.	20.5	506
CFTBX80609		b.d.	147	11.3	928	50.4	441	b.d.	b.d.	909	b.d.	42.4	422	b.d.	25.2	538
CFTBY80609		b.d.	141	11.1	858	50.4	425	b.d.	b.d.	886	b.d.	43.2	412	b.d.	23.5	547
CFTSX80609		b.d.	74.5	8.66	688	27.3	604	b.d.	b.d.	844	b.d.	15.9	279	b.d.	14.3	319
CFTSY80609		b.d.	85.2	9.78	648	28.2	516	b.d.	b.d.	922	b.d.	18.2	296	b.d.	14.8	318
FHKNX80609		b.d.	b.d.	11.4	480	7.12	181	b.d.	b.d.	798	b.d.	8.81	282	b.d.	11.7	52.3
FHKNY80609		b.d.	b.d.	11.6	469	6.85	236	b.d.	b.d.	907	b.d.	8.21	209	b.d.	10.2	51.6

ICP Bed Sediment Analysis Results
Collection Date: 7/03/08 - 7/04/08
Analysis Date: 7/14/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
BFWSX80703		10260	9.05	2.79	373	0.72	17040	b.d.	6.92	10.1	23.6	15980	1834	33.6	10600	590
BFWSY80703		13370	10.7	3.73	497	0.87	13490	b.d.	7.63	11.8	29.6	18060	2236	41.9	10590	704
BRMFX80703		16330	4.31	b.d.	149	0.98	4273	b.d.	7.17	16.1	20.9	18870	2525	30.5	5800	454
BRMFY80703		14150	3.66	b.d.	126	0.85	3926	b.d.	5.66	13.5	18.6	15690	2182	26.3	4762	350
CFBFX80704		14730	75.0	b.d.	361	0.96	10950	3.00	10.3	15.9	545	22760	2197	24.7	8119	1006
CFBFY80704		9121	42.1	b.d.	228	0.58	7213	1.78	7.08	10.6	297	15120	1500	17.2	5839	610
CFDCX80704		13370	67.7	b.d.	335	0.85	10840	2.70	8.84	15.1	495	20630	2048	23.4	7596	990
CFDYX80703		10530	30.6	b.d.	232	0.64	7691	1.35	6.09	11.2	265	15070	1708	20.2	6424	461
CFDYY80703		10110	24.0	b.d.	255	0.62	7049	1.08	5.82	11.1	206	14850	1677	19.6	6317	550
CFHBX80703		11150	40.7	b.d.	311	0.71	8764	1.86	6.31	11.4	362	15020	1748	18.2	6539	567
CFHBY80703		9042	31.6	b.d.	313	0.56	7570	1.18	5.49	10.5	251	13870	1491	17.6	5800	607
CFHCX80704		14660	63.2	1.94	331	0.85	12960	2.26	8.10	15.0	459	21020	2249	30.1	8460	1023
CFHCY80704		15450	68.9	1.79	344	0.94	12550	2.60	8.65	15.7	514	22090	2331	29.0	8396	1014
CFKBX80703		11480	39.4	1.12	428	0.74	10890	1.82	6.58	13.0	331	17260	1770	21.8	6891	642
CFKBY80703		12140	58.0	1.18	353	0.77	10960	2.99	7.23	13.4	495	17950	1899	22.1	6918	802
CFKCX80703		8779	18.7	b.d.	327	0.51	6505	0.66	5.89	9.55	123	13340	1522	15.2	6301	578
CFKCY80703		8756	22.1	b.d.	258	0.53	6460	0.75	5.43	9.96	173	13860	1517	17.3	5901	476
CFKIX80703		12460	52.7	1.03	401	0.79	11180	2.63	7.79	14.1	467	19150	1886	23.2	7494	716
CFKIY80703		11650	44.8	b.d.	609	0.73	10440	2.28	7.67	14.7	358	19920	1761	22.3	7361	674
CFMPX80704		12810	63.1	1.27	355	0.81	11950	2.42	8.34	14.2	460	19570	1997	24.4	7767	1002
CFMPY80704		10500	45.2	1.39	256	0.64	9530	1.69	6.24	10.9	340	15450	1685	21.4	6232	772
CFPCX80703		11820	34.4	b.d.	294	0.76	7764	1.52	6.63	12.6	299	16720	1842	22.6	6631	631
CFPCY80703		11180	33.1	b.d.	298	0.70	7583	1.42	6.14	11.9	286	16160	1726	21.7	6478	560
CFPNX80703		9980	16.0	b.d.	236	0.55	5963	0.51	7.15	10.6	112	15940	1669	21.7	7069	508
CFPNY80703		9053	15.6	b.d.	228	0.52	6897	0.45	5.95	9.80	121	14350	1577	18.6	6385	455
CFSRX80704		11910	79.6	1.50	402	0.75	13260	3.34	7.18	12.3	637	18200	1853	24.5	7750	707
CFTAX80703		8627	22.8	b.d.	237	0.54	5902	0.72	4.88	9.72	182	12890	1461	16.9	5514	447
CFTAY80703		8991	21.3	b.d.	370	0.57	6372	0.71	5.94	11.1	157	14890	1459	17.5	5885	576
CFTBX80703		15950	52.3	1.16	276	0.93	11530	1.70	8.43	17.9	348	21140	2349	20.4	6676	1144
CFTBY80703		14610	46.8	1.11	279	0.83	11570	1.43	7.48	16.5	305	19740	2272	19.5	6217	1020
FHKNX80703		17170	5.94	b.d.	160	0.71	2827	b.d.	7.90	14.3	24.9	20780	2710	36.6	8048	178
FHKNY80703		16920	5.84	b.d.	153	0.66	2732	b.d.	8.28	13.9	22.3	20720	2516	35.0	8145	211

Sample ID		Mo	Na	Ni	P	Pb	S	Sb	Se	Si	Sn	Sr	Ti	Tl	V	Zn
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
BFWSX80703		b.d.	53.6	10.8	678	11.0	217	b.d.	b.d.	998	b.d.	22.0	174	b.d.	17.5	59.7
BFWSY80703		b.d.	60.5	12.2	695	13.6	222	b.d.	b.d.	931	b.d.	21.7	185	b.d.	16.0	74.9
BRMFX80703		b.d.	109	9.60	626	6.05	44.6	b.d.	b.d.	912	b.d.	21.8	606	b.d.	21.1	58.6
BRMFY80703		b.d.	109	8.04	583	5.44	47.4	b.d.	b.d.	903	b.d.	20.1	521	b.d.	17.3	50.9
CFBFX80704		b.d.	110	14.3	834	71.7	992	b.d.	b.d.	1008	b.d.	33.9	330	b.d.	25.9	1334
CFBFY80704		b.d.	71.5	10.0	559	42.1	473	b.d.	b.d.	828	b.d.	21.3	266	b.d.	19.1	775
CFDCX80704		b.d.	99.2	13.1	836	64.2	1061	b.d.	b.d.	965	b.d.	32.2	321	b.d.	23.7	1035
CFDYX80703		b.d.	79.3	9.55	682	34.5	751	b.d.	b.d.	964	b.d.	20.9	309	b.d.	15.8	444
CFDYY80703		b.d.	83.5	9.14	694	28.2	557	b.d.	b.d.	914	b.d.	19.5	302	b.d.	16.8	356
CFHBX80703		b.d.	81.8	9.96	752	45.7	958	b.d.	b.d.	1044	b.d.	24.8	268	b.d.	16.0	625
CFHBY80703		b.d.	79.5	8.24	768	32.9	766	b.d.	b.d.	843	b.d.	20.9	291	b.d.	17.9	457
CFHCX80704		b.d.	115	12.4	809	60.4	1137	b.d.	b.d.	1002	b.d.	34.3	339	b.d.	22.8	828
CFHCY80704		b.d.	114	13.2	823	65.5	1158	b.d.	b.d.	981	b.d.	35.2	349	b.d.	24.3	1002
CFKBX80703		b.d.	85.8	10.5	873	45.9	932	b.d.	b.d.	880	2.23	27.3	301	b.d.	22.2	614
CFKBY80703		b.d.	92.1	11.4	810	61.5	1402	b.d.	b.d.	891	2.18	28.9	306	b.d.	20.8	839
CFKCX80703		b.d.	60.6	8.96	838	23.6	328	b.d.	b.d.	1123	b.d.	16.7	238	b.d.	14.3	284
CFKCY80703		b.d.	74.4	8.25	759	24.9	521	b.d.	b.d.	929	b.d.	17.0	280	b.d.	15.2	316
CFKIX80703		b.d.	83.9	12.3	836	59.3	1286	b.d.	b.d.	986	2.44	30.0	300	b.d.	23.8	863
CFKIY80703		b.d.	83.9	11.8	1000	51.7	1221	b.d.	b.d.	1004	b.d.	30.1	328	b.d.	30.9	714
CFMPX80704		b.d.	102	12.3	844	61.0	1220	b.d.	b.d.	924	b.d.	32.2	315	b.d.	22.2	911
CFMPY80704		b.d.	68.4	9.35	606	45.7	828	b.d.	b.d.	1028	b.d.	25.1	249	b.d.	16.5	612
CFPCX80703		b.d.	80.1	10.4	760	40.4	787	b.d.	b.d.	1031	b.d.	23.7	323	b.d.	19.2	510
CFPCY80703		b.d.	80.8	9.77	760	36.3	768	b.d.	b.d.	931	b.d.	22.7	307	b.d.	18.5	474
CFPNX80703		b.d.	57.7	10.3	707	29.4	162	b.d.	b.d.	1000	b.d.	14.4	284	b.d.	15.0	260
CFPNY80703		b.d.	58.9	9.15	671	20.3	303	b.d.	b.d.	868	b.d.	15.5	266	b.d.	14.8	255
CFSRX80704		b.d.	80.0	11.1	816	65.0	2150	b.d.	b.d.	949	b.d.	30.6	264	b.d.	20.0	962
CFTAX80703		b.d.	80.1	7.77	683	23.2	496	b.d.	b.d.	836	1.01	17.8	278	b.d.	15.0	313
CFTAY80703		b.d.	68.2	8.69	825	26.2	434	b.d.	b.d.	759	b.d.	19.4	281	b.d.	21.2	337
CFTBX80703		b.d.	153	13.0	1007	65.0	528	b.d.	b.d.	1039	b.d.	47.4	437	b.d.	27.3	662
CFTBY80703		b.d.	143	11.5	1050	56.7	495	b.d.	b.d.	975	b.d.	44.4	412	b.d.	25.9	583
FHKNX80703		b.d.	54.1	16.6	344	6.58	b.d.	b.d.	b.d.	861	b.d.	8.42	521	b.d.	17.5	53.4
FHKNY80703		b.d.	b.d.	15.9	340	6.09	b.d.	b.d.	b.d.	887	b.d.	8.05	484	b.d.	17.2	52.4

ICP Bed Sediment Analysis Results
Collection Date: 8/20/08 - 8/21/08
Analysis Date: 9/25/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
BFWSX80820		12770	11.7	7.65	424	0.87	16430	b.d.	7.58	12.4	23.3	17230	2302	33.4	10600	954
BFWSY80820		13160	11.4	7.06	401	0.86	15440	b.d.	7.47	12.6	24.0	17830	2556	37.0	11180	864
BRMFX80820		14170	4.27	1.01	213	0.88	2691	b.d.	5.85	12.9	16.9	14540	2511	23.4	4453	335
BRMFY80820		14950	3.73	1.03	219	0.96	2808	b.d.	6.32	13.4	18.6	14690	2527	24.8	4615	256
CFBFX80821		15640	131	3.96	464	0.93	11000	5.00	8.61	15.3	1001	20080	2412	23.9	7637	831
CFBFY80821		15610	71.3	4.48	438	0.97	9985	3.31	9.93	16.8	630	20710	2438	24.9	8256	969
CFCAX80821		14740	51.3	2.96	369	0.87	8781	3.30	8.93	16.4	586	19400	2255	21.8	7376	771
CFCAY80821		16430	55.7	3.36	414	0.99	9002	3.56	10.3	17.8	628	21560	2485	24.3	7967	961
CFDYX80820		13630	37.1	3.47	327	0.85	5863	1.28	7.46	13.6	271	17710	2320	21.8	7256	866
CFDYY80820		13390	35.1	3.74	314	0.83	5568	1.17	7.94	13.8	267	17450	2307	21.8	7443	1039
CFHBX80820		16510	51.3	3.28	351	0.99	8172	2.23	8.45	16.1	498	20060	2534	26.4	8117	682
CFHBY80820		14650	51.0	5.54	362	0.93	8501	2.00	8.43	14.6	416	18330	2380	23.1	7552	698
CFHCX80821		13940	83.6	5.86	459	0.86	10920	2.98	7.85	14.6	650	18380	2260	21.8	7457	951
CFHCY80821		14230	84.1	5.43	442	0.87	11270	3.02	7.90	14.9	661	18850	2289	22.5	7560	981
CFKBX80820		15030	60.4	5.32	467	0.92	12090	2.43	8.34	15.0	522	19010	2433	23.2	7420	1053
CFKBY80820		14750	59.8	4.88	462	0.91	10720	2.42	8.28	15.2	532	19140	2347	23.3	7415	953
CFKCX80820		13940	34.9	3.40	292	0.83	4959	1.23	7.63	13.7	281	17870	2337	23.1	7232	933
CFKCY80820		10440	19.9	1.95	370	0.59	4577	0.72	6.86	12.3	142	16600	1876	18.0	6392	625
CFKIX80820		14420	123	3.86	541	0.88	11340	4.43	8.28	15.0	938	19810	2254	21.9	7327	804
CFKIY80820		16260	58.4	3.31	555	0.94	9593	2.75	9.09	17.8	520	22770	2537	28.6	9290	790
CFMPX80821		13330	72.4	4.32	444	0.81	9997	2.75	7.91	14.8	601	18250	2136	21.3	7302	1031
CFMPY80821		14660	56.7	4.87	439	0.88	10900	2.62	8.92	15.8	525	19470	2348	22.6	7779	1142
CFPCX80820		16580	48.7	4.10	335	0.97	6399	1.92	8.22	15.9	418	19910	2559	25.2	7650	848
CFPCY80820		11590	24.8	3.16	320	0.68	5484	0.95	7.37	13.1	191	16270	1993	20.0	6592	1333
CFPNX80820		16130	22.6	2.62	253	0.86	5301	0.73	7.80	14.5	204	18920	2459	27.9	8289	563
CFPNY80820		11120	15.5	2.24	245	0.56	4912	b.d.	6.95	11.2	113	15830	1980	21.9	7408	698
CFSRX80821		16790	80.1	4.29	477	1.05	12240	4.06	9.51	16.6	768	21820	2563	28.0	8963	836
CFSRY80821		13800	88.4	4.21	1245	0.82	13310	3.71	8.52	15.3	707	19790	2227	23.3	8071	936
CFTAX80820		14550	36.6	4.37	308	0.90	6254	1.42	7.56	14.2	332	17820	2372	22.4	7500	827
CFTAY80820		12460	25.5	4.13	322	0.74	7338	0.71	7.34	12.8	193	16860	2304	20.4	7084	1188
CFTBX80820		17330	42.1	9.07	311	1.08	12670	2.86	10.5	18.3	389	20010	2614	20.1	6511	1754
CFTBY80820		18850	45.9	6.26	319	1.08	11660	2.17	9.88	19.2	376	21270	2703	21.7	6944	1397
FHKNX80820		14910	4.24	2.22	149	0.55	2859	b.d.	6.58	11.7	16.9	16350	2363	33.4	9900	197
FHKNY80820		13500	4.14	1.67	140	0.49	3139	b.d.	6.50	10.9	14.6	15740	2092	29.7	8959	177

Sample ID		**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Sr**	**Ti**	**Tl**	**V**	**Zn**
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
BFWSX80820		b.d.	101	11.5	844	11.0	503	b.d.	b.d.	1508	b.d.	32.8	221	b.d.	17.7	64.2
BFWSY80820		b.d.	110	11.7	748	11.2	333	b.d.	b.d.	1567	b.d.	31.9	238	b.d.	17.3	67.4
BRMFX80820		b.d.	167	7.72	1018	5.47	571	b.d.	b.d.	1507	b.d.	19.0	566	b.d.	17.2	51.6
BRMFY80820		b.d.	162	8.67	916	6.09	613	b.d.	b.d.	1510	b.d.	21.9	583	b.d.	18.2	55.2
CFBFX80821		b.d.	157	12.5	860	99.7	3016	b.d.	b.d.	2035	b.d.	46.4	447	b.d.	22.5	1360
CFBFY80821		b.d.	147	13.9	917	71.7	1463	b.d.	b.d.	1687	b.d.	43.9	428	b.d.	25.8	1025
CFCAX80821		b.d.	146	12.6	906	69.2	1366	b.d.	b.d.	1586	b.d.	40.6	443	b.d.	24.7	1013
CFCAY80821		b.d.	145	14.0	925	77.6	1341	b.d.	b.d.	1653	b.d.	42.5	468	b.d.	27.8	1123
CFDYX80820		b.d.	136	10.6	995	43.4	972	b.d.	b.d.	1515	b.d.	24.0	415	b.d.	19.3	508
CFDYY80820		b.d.	143	10.9	902	44.0	1071	b.d.	b.d.	1503	b.d.	24.5	412	b.d.	18.8	490
CFHBX80820		b.d.	150	12.6	912	62.2	1433	b.d.	b.d.	1647	b.d.	37.8	471	b.d.	21.7	776
CFHBY80820		b.d.	143	11.5	997	54.1	1838	b.d.	b.d.	1590	b.d.	34.9	425	b.d.	20.8	742
CFHCX80821		b.d.	137	11.3	966	71.2	2418	b.d.	b.d.	1602	b.d.	43.6	392	b.d.	21.5	1008
CFHCY80821		b.d.	143	11.5	955	71.5	2250	b.d.	b.d.	1576	b.d.	44.9	400	b.d.	21.7	1033
CFKBX80820		b.d.	169	11.2	1051	61.0	1629	b.d.	b.d.	2070	b.d.	43.3	441	b.d.	21.7	851
CFKBY80820		b.d.	152	11.4	1007	62.7	1608	b.d.	b.d.	1461	b.d.	40.5	412	b.d.	22.2	859
CFKCX80820		b.d.	151	11.0	884	44.1	1043	b.d.	b.d.	1648	b.d.	24.1	400	b.d.	17.4	504
CFKCY80820		b.d.	121	9.57	967	34.4	517	b.d.	b.d.	1425	b.d.	21.7	367	b.d.	21.1	328
CFKIX80820		b.d.	138	12.1	978	97.9	2817	b.d.	b.d.	1588	b.d.	47.2	402	b.d.	23.3	1301
CFKIY80820		b.d.	139	14.3	980	76.6	1444	b.d.	b.d.	1578	b.d.	40.1	411	b.d.	29.5	993
CFMPX80821		b.d.	138	11.2	959	66.2	1758	b.d.	b.d.	1583	b.d.	42.2	396	b.d.	22.3	977
CFMPY80821		b.d.	150	12.2	1001	69.4	1497	b.d.	b.d.	1541	b.d.	46.3	422	b.d.	24.0	961
CFPCX80820		b.d.	176	12.1	957	54.1	1364	b.d.	b.d.	2232	b.d.	32.6	546	b.d.	22.6	659
CFPCY80820		b.d.	144	10.1	893	29.4	558	b.d.	b.d.	1449	b.d.	27.4	396	b.d.	20.0	397
CFPNX80820		b.d.	116	12.0	851	33.9	755	b.d.	b.d.	1563	b.d.	21.3	419	b.d.	16.4	374
CFPNY80820		b.d.	89.5	10.3	779	23.4	451	b.d.	b.d.	1460	b.d.	15.6	305	b.d.	13.8	246
CFSRX80821		b.d.	135	14.4	893	89.1	2100	b.d.	b.d.	1666	b.d.	47.7	411	b.d.	24.3	1223
CFSRY80821		b.d.	135	12.4	981	74.7	2451	b.d.	b.d.	1584	b.d.	61.0	387	b.d.	26.7	1172
CFTAX80820		b.d.	153	11.0	911	42.7	1121	b.d.	b.d.	1608	b.d.	30.3	419	b.d.	18.5	551
CFTAY80820		b.d.	135	10.3	890	34.2	631	b.d.	b.d.	1516	b.d.	27.7	358	b.d.	16.9	375
CFTBX80820		b.d.	206	14.8	1164	73.1	1603	b.d.	b.d.	1700	b.d.	69.4	521	b.d.	25.2	858
CFTBY80820		b.d.	224	14.0	1179	73.9	1598	b.d.	b.d.	2086	b.d.	67.5	608	b.d.	27.1	786
FHKNX80820		b.d.	56.7	11.9	597	6.18	315	b.d.	b.d.	1472	b.d.	8.98	239	b.d.	9.64	53.1
FHKNY80820		b.d.	53.4	11.0	563	6.44	159	b.d.	b.d.	1488	b.d.	8.79	271	b.d.	9.29	49.4

ICP Bank Sediment Analysis Results
Collection Date: 8/29/08
Analysis Date: 10/06/08
Units: mg/kg

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
Fine-grain bank sediment																
CFCAX80829		16600	77.6	2.61	369	1.12	12240	4.79	10.7	17.6	796	22520	2627	26.9	8241	1253
CFCAY80829		15110	69.0	2.07	345	0.98	10830	4.45	10.00	16.5	743	20650	2362	23.5	7452	1107
CFCAZ80829		13440	75.3	2.06	364	0.89	12150	3.44	8.70	14.8	623	19460	2134	22.5	7457	937
CFMPX80829		15890	66.6	1.80	404	1.09	12650	3.50	10.1	17.4	691	23000	2448	26.6	8278	987
CFMPY80829		15870	48.5	2.05	384	1.06	15510	3.64	9.12	16.8	625	21160	2384	25.9	8117	650
CFMPZ80829		15590	63.7	1.80	522	0.98	11880	2.73	10.7	17.9	546	23720	2445	27.3	8977	954
CFSRX80829		14230	86.9	2.27	439	1.00	14920	3.64	9.85	15.6	687	21710	2322	28.4	9294	818
CFSRY80829		12950	91.5	2.13	411	0.85	14070	3.84	8.21	14.1	744	19100	2076	23.5	7947	710
CFSRZ80829		15670	66.8	2.03	411	1.03	14810	3.96	10.4	17.2	642	22760	2425	30.3	9799	1054
Sample ID		**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Sr**	**Ti**	**Tl**	**V**	**Zn**
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
Fine-grain bank sediment																
CFCAX80829		b.d.	154	15.3	804	97.6	1256	b.d.	b.d.	832	5.95	42.4	399	b.d.	25.7	1360
CFCAY80829		b.d.	127	14.1	781	91.1	820	b.d.	b.d.	723	3.72	38.6	387	b.d.	23.7	1261
CFCAZ80829		b.d.	114	12.5	778	75.9	635	b.d.	b.d.	807	5.28	38.9	354	b.d.	21.8	1103
CFMPX80829		b.d.	101	14.3	801	81.8	81.6	b.d.	b.d.	821	3.83	40.8	382	b.d.	25.7	1299
CFMPY80829		b.d.	105	13.5	802	76.6	b.d.	b.d.	b.d.	794	3.44	45.7	388	b.d.	23.8	1141
CFMPZ80829		b.d.	80.6	14.3	842	76.5	b.d.	b.d.	b.d.	806	5.94	39.5	373	b.d.	28.4	1152
CFSRX80829		b.d.	70.7	14.3	721	77.7	475	b.d.	b.d.	761	6.11	38.4	339	b.d.	24.4	1171
CFSRY80829		b.d.	68.6	12.4	768	74.9	1220	b.d.	b.d.	703	5.51	37.9	326	b.d.	21.0	1202
CFSRZ80829		b.d.	82.5	15.6	748	85.6	127	b.d.	b.d.	783	5.79	41.1	348	b.d.	25.8	1226

Sample ID		Al	As	B	Ba	Be	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
	PQL	5	1.5	1	1	0.05	10	0.4	0.5	0.5	0.5	10	50	5	10	0.1
Bulk Bank Sediment																
CFCABX80829		8519	31.3	1.57	214	0.52	7877	1.51	6.27	9.83	283	12840	1820	14.2	5272	630
CFCABY80829		8908	33.8	1.63	235	0.55	7941	1.56	6.37	10.3	307	13190	1875	14.5	5334	620
CFCABZ80829		8255	32.8	1.69	237	0.48	7958	1.30	5.79	9.49	250	12510	1879	14.6	5391	503
CFSRBX80829		6523	12.1	1.87	187	0.34	5248	b.d.	4.58	7.00	86.9	10250	1727	16.3	5649	210
CFSRBY80829		7090	25.8	1.46	223	0.41	7608	0.98	4.98	8.47	218	11160	1603	13.6	5264	326
CFSRBZ80829		6059	11.1	1.47	180	0.31	4772	b.d.	4.31	6.89	75.8	9705	1547	12.9	4941	244
CFMPBX80829		7844	19.8	1.85	291	0.44	6089	0.87	5.27	9.09	179	12000	2078	13.5	4915	393
CFMPBY80829		7518	14.8	1.04	261	0.45	7702	0.96	5.33	9.30	211	12070	1525	12.9	4913	312
CFMPBZ80829		5835	10.9	b.d.	297	0.30	4333	b.d.	4.24	7.69	94.2	10240	1435	11.4	4366	238
Sample ID		**Mo**	**Na**	**Ni**	**P**	**Pb**	**S**	**Sb**	**Se**	**Si**	**Sn**	**Sr**	**Ti**	**Tl**	**V**	**Zn**
	PQL	0.5	50	1	6	5	10	5	5	10	1	0.5	1	10	1	0.1
Bulk Bank Sediment																
CFCABX80829		b.d.	82.2	8.56	462	34.2	b.d.	b.d.	b.d.	854	5.20	27.4	331	b.d.	16.1	585
CFCABY80829		b.d.	93.9	8.88	488	37.7	b.d.	b.d.	b.d.	818	5.37	28.9	347	b.d.	16.4	610
CFCABZ80829		b.d.	113	8.15	468	30.9	b.d.	b.d.	b.d.	785	6.19	27.4	306	b.d.	16.3	533
CFSRBX80829		b.d.	81.2	6.61	299	13.1	b.d.	b.d.	b.d.	725	3.28	15.5	216	b.d.	15.9	206
CFSRBY80829		b.d.	50.3	7.26	414	23.7	b.d.	b.d.	b.d.	782	3.20	22.8	270	b.d.	14.9	444
CFSRBZ80829		b.d.	77.1	6.12	306	12.4	b.d.	b.d.	b.d.	685	3.20	16.2	216	b.d.	14.8	228
CFMPBX80829		b.d.	191	7.25	407	24.9	b.d.	b.d.	b.d.	749	3.43	24.2	337	b.d.	22.7	428
CFMPBY80829		b.d.	b.d.	7.61	453	27.8	b.d.	b.d.	b.d.	870	1.54	26.6	321	b.d.	19.4	470
CFMPBZ80829		b.d.	73.0	6.12	364	14.7	b.d.	b.d.	b.d.	683	2.12	17.5	268	b.d.	22.9	274

Hg Analyzer Bed Sediment Analysis Results
Collection Date: 5/3/08-5/5/08, 5/20/08-5/21/08
Analysis Date: 5/30/08
Units: mg/kg

Sample ID	Hg		Sample ID	Hg
PQL	**0.0005**		**PQL**	**0.0005**
BFWSX80503	0.050		BFWSX80521	0.036
BFWSY80503	0.050		BFWSY80521	0.038
BRMFX80503	0.053		BRMFX80522	0.035
BRMFY80503	0.049		BRMFY80522	0.036
CFBFX80503	1.99		CFBFX80521	1.28
CFBFY80503	1.47		CFBFY80521	1.52
CFCAX80504	1.80		CFDCX80521	0.960
CFCAY80504	1.68		CFDY80525	0.534
CFDC80504	1.44		CFDYX80525	0.591
CFDCX80504	1.81		CFHBX80522	0.660
CFEGX80504	1.58		CFHBY80522	0.650
CFHBX80503	1.48		CFHCX80521	1.26
CFHBX80503	1.32		CFHCY80521	1.28
CFHBY80503	1.41		CFKBX80522	0.856
CFHCX80503	1.53		CFKBY80522	0.799
CFHCY50803	2.12		CFKCX80525	0.486
CFIBX80504	1.75		CFKCY80525	0.494
CFKBX80503	2.09		CFKIX80522	0.855
CFKBY80503	1.91		CFKIY80522	0.931
CFKIX80503	1.40		CFMPX80521	1.13
CFKIY80503	1.49		CFMPY80521	0.958
CFMPX80503	1.50		CFPCX80522	0.963
CFMPY80503	2.04		CFPCX80525	1.22
CFPCX80505	1.22		CFPCY80522	0.889
CFPCY80505	1.48		CFPCY80525	0.790
CFSRX80504	1.93		CFPNX80525	0.463
CFTBX80503	4.09		CFPNY80525	0.428
CFTBY80503	3.74		CFSRX80521	0.998
			CFTAX80525	0.452
			CFTAY80525	0.291
			CFTBX80521	1.93
			CFTBY80521	1.15
			CFTSX80525	0.317
			CFTSY80525	0.362

Hg Analyzer Bed Sediment Analysis Results

Collection Date: 6/9/08-6/10/08, 7/3/08-7/4/08
Analysis Date: 7/11/08
Units: mg/kg

Sample ID	**Hg**		**Sample ID**	**Hg**
PQL	**0.0005**		**PQL**	**0.0005**
BFWSX80609	0.029		BFWSX80703	0.050
BFWSY80609	0.026		BFWSY80703	0.044
BRMFX80609	0.032		BRMFX80703	0.029
BRMFY80609	0.029		BRMFY80703	0.026
CFBFX80609	0.483		CFBFX80704	0.745
CFBFY80609	0.600		CFBFY80704	0.390
CFCAX80609	0.560		CFDCX80704	0.643
CFCAY80609	0.580		CFDYX80703	0.315
CFDCX80609	0.453		CFDYY80703	0.257
CFDYX80609	0.330		CFHBX80703	0.465
CFDYY80609	0.307		CFHBY80703	0.299
CFHBX80610	0.343		CFHCX80704	0.653
CFHBY80610	0.366		CFHCY80704	0.876
CFHCX80609	0.666		CFKBX80703	0.412
CFHCY80609	0.434		CFKBY80703	0.652
CFKBX80609	0.502		CFKCX80703	0.138
CFKBY80609	0.607		CFKCY80703	0.212
CFKCX80609	0.185		CFKIX80703	0.519
CFKCY80609	0.156		CFKIY80703	0.482
CFKIX80609	0.453		CFMPX80704	0.600
CFKIX80610	0.402		CFMPY80704	0.477
CFKIY80609	0.371		CFPCX80703	0.333
CFKIY80610	0.362		CFPCY80703	0.288
CFMPX80609	0.535		CFPNX80703	0.138
CFMPY80609	0.544		CFPNY80703	0.142
CFPCX80609	0.337		CFSRX80704	0.695
CFPCY80609	0.376		CFTAX80703	0.224
CFPNX80609	0.270		CFTAY80703	0.201
CFPNY80609	0.417		CFTBX80703	0.915
CFSRX80609	0.477		CFTBY80703	0.915
CFTAX80609	0.256		FHKNX80703	0.018
CFTAY80609	0.287		FHKNY80703	0.019
CFTBX80609	0.628			
CFTBY80609	0.665			
CFTSX80609	0.269			
CFTSY80609	0.237			
FHKNX80609	0.021			
FHKNY80609	0.023			

Hg Analyzer Bed Sediment Analysis Results
Collection Date: 8/20/08-8/21/08
Analysis Date: 9/4/08
Units: mg/kg

Sample ID	Hg
PQL	0.0005
BFWSX80820	0.053
BFWSY80820	0.042
BRMFX80820	0.024
BRMFY80820	0.025
CFBFX80821	0.798
CFBFY80821	0.532
CFCAX80821	0.466
CFCAY80821	0.557
CFDYX80820	0.307
CFDYY80820	0.344
CFHBX80820	0.507
CFHBY80820	0.503
CFHCX80821	0.678
CFHCY80820	0.662
CFKBX80820	0.495
CFKBY80820	0.576
CFKCX80820	0.344
CFKCY80820	0.169
CFKIX80820	0.800
CFKIY80820	0.408
CFMPX80821	0.572
CFMPY80821	0.638
CFPCX80820	0.411
CFPCY80820	0.210
CFPNX80820	0.349
CFPNY80820	0.107
CFSRX80821	0.635
CFSRY80821	0.477
CFTAX80820	0.347
CFTAY80820	0.231
CFTBX80820	0.898
CFTBY80820	1.072
FHKNX80820	0.019
FHKNY80820	0.017

Hg Analyzer Fine-grain and Bulk Bank Sediment Analysis Results

Collection Date: 8/29/08
Analysis Date: 10/5/08
Units: mg/kg

Fine-grain **Bulk**

Sample ID	Hg		**Sample ID**	Hg
PQL	0.0005		**PQL**	0.0005
CFCAX80829	0.757		CFCABX80829	0.263
CFCAY80829	0.636		CFCABY80829	0.385
CFCAZ80829	0.591		CFCABZ80829	0.352
CFMPX80829	0.618		CFMPBX80829	0.154
CFMPY80829	0.668		CFMPBY80829	0.252
CFMPZ80829	0.491		CFMPBZ80829	0.057
CFSRX80829	0.630		CFSRBX80829	0.058
CFSRY80829	0.700		CFSRBY80829	0.187
CFSRZ80829	0.533		CFSRBZ80829	0.049

Appendix C: Quality Assurance/Quality Control

ICP-OES Analysis

Laboratory/Analytical Blanks ("LBlank")

ID Units PQL	Analysis Date	As mg/L 0.015	Cd mg/L 0.004	Cr mg/L 0.005	Cu mg/L 0.005	Pb mg/L 0.05	Zn mg/L 0.001
LBLANK	6/2/08	0.0229	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	6/2/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.0126
LBLANK	6/2/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.0231
LBLANK	6/2/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.0276
LBLANK	6/2/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.0166
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.002
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.005
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.006
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	6/3/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.006
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.002
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.002
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.002
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.003
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.001
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.002
LBLANK	7/14/08	b.d.	b.d.	b.d.	b.d.	b.d.	0.007
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	9/25/08	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	10/6/2008	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	10/6/2008	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	10/6/2008	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	10/6/2008	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
LBLANK	10/6/2008	b.d.	b.d.	b.d.	b.d.	b.d.	b.d.

*QA/QC was focused on elements of interest to our study

ICP-OES Analysis
Method Blanks (Digestion Blanks, "MBLANK")

ID	**Analysis Date**		**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
		Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
		PQL	0.015	0.004	0.005	0.005	0.05	0.001
MBLANK	6/2/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.005
MBLANK	6/2/08		b.d.	b.d.	b.d.	0.012	b.d.	0.041
MBLANK	6/3/08		b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MBLANK	6/3/08		b.d.	b.d.	b.d.	0.005	b.d.	0.002
MBLANK	7/14/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.001
MBLANK	7/14/08		b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MBLANK	7/14/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.004
MBLANK	7/14/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.003
MBLANK	9/25/08		b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MBLANK	9/25/08		b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MBLANK	9/25/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.008
MBLANK	10/6/08		b.d.	b.d.	b.d.	b.d.	b.d.	b.d.
MBLANK	10/6/08		b.d.	b.d.	b.d.	b.d.	b.d.	0.002

ICP-OES Analysis
Internal Performance Checks

ID	**Analysis**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units	**Date**	**%**	**%**	**%**	**%**	**%**	**%**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
IPC6	6/2/08	106	100	103	103	97	101
IPC6	6/2/08	105	99	103	104	97	102
IPC6	6/2/08	105	99	104	106	97	106
IPC6	6/2/08	105	98	104	106	97	105
IPC6	6/2/08	104	97	102	104	96	104
IPC6	6/3/08	103	98	102	104	95	98
IPC6	6/3/08	102	96	99	102	93	100
IPC6	6/3/08	98	95	99	104	92	96
IPC6	6/3/08	97	94	99	104	91	97
IPC6	6/3/08	97	93	97	103	91	98
IPC6	6/3/08	96	92	97	103	90	99
IPC6	7/14/08	104	96	101	101	95	99
IPC6	7/14/08	105	96	101	101	95	103
IPC6	7/14/08	103	97	101	102	95	102
IPC6	7/14/08	104	97	101	102	95	103
IPC6	7/14/08	103	97	100	101	95	104
IPC6	7/14/08	103	96	99	100	94	103
IPC6	7/14/08	104	97	99	101	94	105
IPC6	7/14/08	103	98	101	102	95	105
IPC6	7/14/08	103	97	99	101	94	106
IPC6	7/14/08	102	96	98	100	93	105
IPC6	7/14/08	103	97	100	101	95	107
IPC6	9/25/08	110	103	103	107	101	104
IPC6	9/25/08	105	98	100	103	97	102
IPC6	9/25/08	105	99	100	104	97	102
IPC6	9/25/08	104	97	99	102	97	105
IPC6	9/25/08	104	96	97	101	97	103
IPC6	9/25/08	105	97	99	103	97	105
IPC6	9/25/08	107	99	101	105	99	106
IPC6	9/25/08	105	98	99	103	97	106
IPC6	9/25/08	105	97	98	102	97	105
IPC6	9/25/08	104	97	98	102	96	102
IPC6	10/6/08	105	98	101	102	95	102
IPC6	10/6/08	105	97	102	103	96	104
IPC6	10/6/08	103	98	101	103	95	103
IPC6	10/6/08	107	99	103	104	97	107
IPC6	10/6/08	105	99	103	104	96	106

ICP-OES Analysis
Continuous Calibration Verification

ID Units PQL	Analysis Date	As % 0.015	Cd % 0.004	Cr % 0.005	Cu % 0.005	Pb % 0.05	Zn % 0.001
CCV	6/2/08	101	100	97	99	97	98
CCV	6/2/08	103	102	100	103	101	103
CCV	6/2/08	103	102	100	104	99	104
CCV	6/2/08	101	99	99	104	98	102
CCV	6/2/08	101	99	99	104	98	101
CCV	6/3/08	102	100	97	103	99	100
CCV	6/3/08	102	100	97	103	98	101
CCV	6/3/08	96	96	94	101	93	98
CCV	6/3/08	95	96	94	102	93	100
CCV	6/3/08	94	95	93	101	93	99
CCV	6/3/08	93	94	93	102	92	100
CCV	7/14/08	103	100	96	103	96	97
CCV	7/14/08	103	96	91	102	92	95
CCV	7/14/08	106	99	93	104	95	96
CCV	7/14/08	104	98	92	104	93	97
CCV	7/14/08	104	99	92	102	93	95
CCV	7/14/08	105	99	92	104	93	98
CCV	7/14/08	104	99	92	103	94	97
CCV	7/14/08	104	99	93	104	94	99
CCV	7/14/08	103	98	92	103	92	98
CCV	7/14/08	104	100	92	104	94	100
CCV	7/14/08	104	99	92	103	94	99
CCV	9/25/08	106	99	92	105	95	96
CCV	9/25/08	105	99	91	104	94	96
CCV	9/25/08	106	99	91	104	95	98
CCV	9/25/08	105	98	90	104	94	98
CCV	9/25/08	104	97	91	105	94	98
CCV	9/25/08	106	98	92	106	95	100
CCV	9/25/08	106	99	90	104	95	98
CCV	9/25/08	106	99	90	103	94	99
CCV	9/25/08	105	99	90	103	94	98
CCV	10/6/08	101	102	96	101	98	99
CCV	10/6/08	101	102	96	100	98	99
CCV	10/6/08	105	100	95	107	96	99
CCV	10/6/08	105	99	94	106	95	97
CCV	10/6/08	105	99	94	106	95	100
CCV	10/6/08	105	100	95	107	96	101

ICP-OES Analysis
Standard Reference Materials (NIST 2710 "Montana Soil")

ID	Analysis	As	Cd	Cu	Pb	Zn
Units	Date	%	%	%	%	%
PQL		0.015	0.004	0.005	0.05	0.001
NIST2710	6/2/08	95	83	99	87	89
NIST2710	6/2/08	94	77	100	86	90
NIST2710	6/3/08	90	82	97	82	83
NIST2710	6/3/08	86	81	97	79	82
NIST2710	7/14/08	89	97	94	80	81
NIST2710	7/14/08	90	103	95	82	85
NIST2710	7/14/08	91	105	96	82	86
NIST2710	7/14/08	90	105	96	82	88
NIST2710	9/25/08	94	101	98	87	87
NIST2710	9/25/08	93	101	97	86	87
NIST2710	9/25/08	92	100	99	86	90
NIST2710	10/6/08	91	100	96	84	86
NIST2710	10/6/08	90	100	96	83	86

*Cr was not included in this standard reference material

ICP-OES Analysis
Analytical (Laboratory) Duplicates ("LDUP")

Sample ID	**Analysis Date**	**As**	**Cd**	**Cr**	**Cu**	**Pb**
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05
CFHB-X 80503	6/2/08	2.651	0.071	0.130	20.540	1.71
CFHB-X 80503 LDUP	6/2/08	2.646	0.070	0.130	20.600	1.71
% RPD		**0.2**	**0.3**	**0.4**	**0.3**	**0.2**
CFEG 80504	6/2/08	3.390	0.085	0.120	23.880	1.80
CFEG 80504 LDUP	6/2/08	3.373	0.085	0.119	23.750	1.79
% RPD		**0.5**	**0.5**	**0.6**	**0.5**	**0.7**
CFSR 80504	6/2/08	2.920	0.069	0.125	21.740	1.85
CFSR 80504 LDUP	6/2/08	2.886	0.070	0.124	21.770	1.83
% RPD		**1.2**	**2.6**	**0.4**	**0.1**	**0.9**
CFTB-Y 80503	6/2/08	0.660	0.019	0.160	4.031	0.84
CFTB-Y 80503 LDUP	6/2/08	0.653	0.019	0.159	4.032	0.84
% RPD		**1.1**	**0.6**	**0.6**	**0.0**	**0.7**
CFBFX80521	6/2/08	1.659	0.061	0.150	13.870	1.28
CFBFX80521 LDUP	6/3/08	1.669	0.062	0.152	13.950	1.29
% RPD		**0.6**	**1.3**	**0.9**	**0.6**	**0.5**
CFHCX80521	6/3/08	1.337	0.045	0.132	11.180	0.96
CFHCX80521 LDUP	6/3/08	1.342	0.046	0.133	11.150	0.96
% RPD		**0.4**	**1.7**	**0.3**	**0.3**	**0.5**
CFKBX 80522	6/3/08	0.853	0.029	0.119	7.205	0.64
CFKBX 80522 LDUP	6/3/08	0.856	0.029	0.119	7.192	0.64
% RPD		**0.3**	**2.3**	**0.1**	**0.2**	**0.5**
CFKCX 80525	6/3/08	0.333	0.008	0.111	2.530	0.36
CFKCX 80525 LDUP	6/3/08	0.332	0.008	0.111	2.535	0.36
% RPD		**0.5**	**4.1**	**0.2**	**0.2**	**0.0**
CFDYX 80525	6/3/08	0.603	0.020	0.132	5.234	0.54
CFDYX 80525 LDUP	6/3/08	0.607	0.020	0.133	5.236	0.55
% RPD		**0.5**	**1.4**	**1.1**	**0.0**	**1.3**
CFSRX 80609	7/14/08	0.544	0.017	0.110	4.122	0.46
CFSRX 80609 LDUP	7/14/08	0.545	0.017	0.114	4.155	0.46
% RPD		**0.2**	**0.6**	**2.8**	**0.8**	**0.2**

Sample ID	**Analysis Date**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
CFBFY 80609	7/14/08	0.709	0.023	0.136	5.334	0.61	8.880
CFBFY 80609 LDUP	7/14/08	0.707	0.024	0.135	5.321	0.61	8.984
% RPD		**0.2**	**2.7**	**0.6**	**0.2**	**0.1**	**1.2**
CFPCY 80610	7/14/08	0.475	0.020	0.123	4.027	0.45	5.883
CFPCY 80610 LDUP	7/14/08	0.481	0.021	0.124	4.015	0.46	5.913
% RPD		**1.4**	**0.9**	**0.9**	**0.3**	**0.9**	**0.5**
CFHCX 80609	7/14/08	0.725	0.026	0.116	5.503	0.56	8.789
CFHCX 80609 LDUP	7/14/08	0.720	0.025	0.114	5.537	0.56	8.772
% RPD		**0.8**	**3.0**	**1.1**	**0.6**	**0.8**	**0.2**
CFKBX 80703	7/14/08	0.394	0.018	0.130	3.306	0.46	6.141
CFKBX 80703 LDUP	7/14/08	0.387	0.018	0.129	3.296	0.45	5.967
% RPD		**1.6**	**2.8**	**1.1**	**0.3**	**2.1**	**2.9**
CFTAX 80703	7/14/08	0.228	0.007	0.097	1.820	0.23	3.125
CFTAX 80703 LDUP	7/14/08	0.229	0.007	0.097	1.801	0.23	3.129
% RPD		**0.5**	**3.3**	**0.1**	**1.0**	**0.2**	**0.1**
CFPCX 80703	7/14/08	0.344	0.015	0.126	2.988	0.40	5.100
CFPCX 80703 LDUP	7/14/08	0.339	0.015	0.125	3.006	0.40	5.044
% RPD		**1.3**	**1.1**	**1.0**	**0.6**	**0.3**	**1.1**
CFDYX 80703	7/14/08	0.306	0.014	0.112	2.648	0.35	4.442
CFDYX 80703 LDUP	7/14/08	0.296	0.013	0.112	2.676	0.34	4.383
% RPD		**3.2**	**1.3**	**0.2**	**1.1**	**1.1**	**1.3**
FHKNX 80703	7/14/08	0.059	-0.005	0.143	0.249	0.07	0.534
FHKNX 80703 LDUP	7/14/08	0.057	-0.005	0.142	0.249	0.06	0.537
% RPD		**4.2**	**b.d.**	**0.4**	**0.0**	**8.5**	**0.5**
BRMFX 80820	9/25/08	0.043	-0.004	0.129	0.169	0.05	0.516
BRMFX 80820 LDUP	9/25/08	0.045	-0.004	0.127	0.167	0.06	0.512
% RPD		**4.8**	**b.d.**	**1.1**	**1.1**	**4.6**	**0.9**
CFHCX 80821	9/25/08	0.836	0.030	0.146	6.504	0.71	10.080
CFHCX 80821 LDUP	9/25/08	0.825	0.030	0.146	6.544	0.71	10.080
% RPD		**1.3**	**1.5**	**0.4**	**0.6**	**0.7**	**0.0**
CFMPY 80821	9/25/08	0.567	0.026	0.158	5.245	0.69	9.609
CFMPY 80821 LDUP	9/25/08	0.563	0.026	0.159	5.254	0.70	9.610
% RPD		**0.6**	**0.3**	**0.4**	**0.2**	**0.3**	**0.0**

Sample ID	Analysis	As	Cd	Cr	Cu	Pb	Zn
Units	Date	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PQL		0.015	0.004	0.005	0.005	0.05	0.001
CFSRX 80821	9/25/08	0.801	0.041	0.166	7.676	0.89	12.230
CFSRX 80821 LDUP	9/25/08	0.805	0.041	0.166	7.623	0.89	12.170
% RPD		**0.5**	**0.9**	**0.2**	**0.7**	**0.1**	**0.5**
CFMPY 80829	10/6/08	0.485	0.036	0.168	6.245	0.77	11.410
CFMPY 80829 LDUP	10/6/08	0.469	0.035	0.166	6.253	0.75	11.330
% RPD		**3.4**	**2.8**	**1.2**	**0.1**	**1.8**	**0.7**
CFSRBZ 80829	10/6/08	0.111	0.003	0.069	0.758	0.12	2.283
CFSRBZ 80829 LDUI	10/6/08	0.111	0.002	0.068	0.756	0.12	2.256
% RPD		**0.5**	**7.1**	**0.7**	**0.2**	**0.3**	**1.2**

ICP-OES Analysis

Method Duplicates (Digestion Duplicates, "MDUP")

Sample ID	**Analysis**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units	**Date**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
BRMF-X 80503	6/2/08	0.058	-0.002	0.146	0.221	0.07	0.674
BRMF-X 80503 MDUP	6/2/08	0.060	-0.003	0.148	0.220	0.06	0.652
% RSD		**2.0**	**b.d.**	**1.0**	**0.4**	**8.7**	**3.2**
BRMF-X 80503	6/2/08	0.058	-0.002	0.146	0.221	0.07	0.674
BRMF-X 80503 MDUP	6/2/08	0.053	-0.003	0.142	0.210	0.06	0.624
% RSD		**9.0**	**b.d.**	**2.6**	**5.2**	**22.1**	**7.6**
CFDC 80504	6/2/08	2.641	0.069	0.130	20.400	1.75	23.710
CFDC 80504 MDUP	6/2/08	2.690	0.071	0.133	20.860	1.77	24.140
% RSD		**1.8**	**2.5**	**1.7**	**2.2**	**1.5**	**1.8**
CFDC 80504	6/2/08	2.641	0.069	0.130	20.400	1.75	23.710
CFDC 80504 MDUP	6/2/08	2.581	0.068	0.129	20.110	1.69	22.300
% RSD		**2.3**	**1.8**	**1.2**	**1.4**	**3.3**	**6.1**
CFTBX 80521	6/3/08	0.438	0.016	0.160	3.341	0.63	5.975
CFTBX 80521 MDUP	6/3/08	0.440	0.017	0.159	3.357	0.64	5.980
% RSD		**0.3**	**2.2**	**0.5**	**0.5**	**1.3**	**0.1**
CFPCX 80525	6/3/08	0.751	0.027	0.136	6.604	0.63	8.356
CFPCX 80525 MDUP	6/3/08	0.734	0.026	0.133	6.466	0.62	8.053
% RSD		**2.4**	**2.1**	**2.5**	**2.1**	**2.8**	**3.7**
CFSRX 80609	7/14/08	0.544	0.017	0.110	4.122	0.46	5.952
CFSRX 80609 MDUP	7/14/08	0.563	0.018	0.109	4.311	0.47	6.261
% RSD		**3.5**	**5.2**	**1.1**	**4.5**	**2.2**	**5.1**
FHKNX 80609	7/14/08	0.054	-0.003	0.108	0.159	0.07	0.523
FHKNX 80609 MDUP	7/14/08	0.053	-0.003	0.107	0.152	0.07	0.492
% RSD		**1.5**	**b.d.**	**1.1**	**4.8**	**7.4**	**6.1**
CFKBX 80703	7/14/08	0.394	0.018	0.130	3.306	0.46	6.141
CFKBX 80703 MDUP	7/14/08	0.409	0.019	0.135	3.408	0.46	6.287
% RSD		**3.8**	**4.9**	**3.2**	**3.0**	**0.4**	**2.3**
CFTBX 80703	7/14/08	0.523	0.017	0.179	3.478	0.65	6.619
CFTBX 80703 MDUP	7/14/08	0.486	0.016	0.170	3.256	0.61	6.345
% RSD		**7.2**	**6.0**	**5.4**	**6.6**	**7.0**	**4.2**

Sample ID	**Analysis**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units	**Date**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
BFWSX 80820	9/25/08	0.117	-0.004	0.124	0.233	0.11	0.642
BFWSX 80820 MDUP	9/25/08	0.110	-0.004	0.128	0.230	0.11	0.652
% RSD		**6.7**	**b.d.**	**2.9**	**1.3**	**4.8**	**1.6**
CFMPX 80821	9/25/08	0.724	0.028	0.148	6.007	0.66	9.770
CFMPX 80821 MDUP	9/25/08	0.719	0.028	0.147	6.067	0.67	9.966
% RSD		**0.6**	**1.2**	**0.5**	**1.0**	**1.5**	**2.0**
CFCAX 80829	10/6/08	0.776	0.048	0.176	7.959	0.98	13.600
CFCAX 80829 MDUP	10/6/08	0.787	0.050	0.172	8.199	1.01	13.980
% RSD		**1.4**	**5.0**	**2.4**	**3.0**	**3.0**	**2.8**

ICP-OES Analysis
Analytical/Laboratory Spikes ("LSPIKE", "LFB")

Sample ID	**Analysis Date**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.20	0.50	10.03	5.01	20.05
LBLANK	6/2/08	0.004	0.000	0.000	0.001	0.00	0.017
LFB	6/2/08	1.128	0.186	0.528	10.790	4.20	20.480
Spike Recovery (%)		112	93	105	108	84	102
CFHB-X 80503	6/2/08	2.651	0.071	0.130	20.540	1.71	21.200
CFHB-X LSPIKE	6/2/08	3.505	0.254	0.629	29.140	5.52	38.850
Spike Recovery (%)		112	95	102	106	80	99
CFEG 80504	6/2/08	3.390	0.085	0.120	23.880	1.80	27.160
CFEG LSPIKE	6/2/08	4.154	0.267	0.624	31.950	5.62	43.530
Spike Recovery (%)		110	95	103	104	80	95
CFSR 80504	6/2/08	2.920	0.069	0.125	21.740	1.85	23.510
CFSR LSPIKE	6/2/08	3.598	0.235	0.595	29.410	5.36	39.440
Spike Recovery (%)		97	86	96	98	74	91
CFTB-Y 80503	6/2/08	0.660	0.019	0.160	4.031	0.84	7.118
CFTB-Y LSPIKE	6/2/08	1.678	0.200	0.647	14.290	4.66	25.360
Spike Recovery (%)		108	91	100	106	78	95
LBLANK	6/3/08	0.001	0.000	0.000	0.001	0.00	0.002
LFB	6/3/08	1.129	0.189	0.517	10.740	4.20	20.210
Spike Recovery (%)		113	94	103	107	84	101
CFBFX80521	6/3/08	1.659	0.061	0.150	13.870	1.28	20.360
CFBFX80521 LSPIKE	6/3/08	2.568	0.240	0.632	22.900	5.08	37.860
Spike Recovery (%)		107	92	99	104	78	97
CFHCX80521	6/3/08	1.337	0.045	0.132	11.180	0.96	15.730
CFHCX80521 LSPIKE	6/3/08	2.272	0.226	0.612	20.530	4.82	33.230
Spike Recovery (%)		107	92	98	104	79	95

Sample ID	**Analysis Date**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.20	0.50	10.03	5.01	20.05
CFKBX80522	6/3/08	0.853	0.029	0.119	7.205	0.64	9.807
CFKBX80522 LSPIKE	6/3/08	1.835	0.207	0.598	17.020	4.40	28.170
Spike Recovery (%)		106	90	98	105	76	96
CFKCX80525	6/3/08	0.333	0.008	0.111	2.530	0.36	4.106
CFKCX80525 LSPIKE	6/3/08	1.335	0.186	0.588	12.970	4.16	22.590
Spike Recovery (%)		103	89	98	107	77	94
CFDYX80525	6/3/08	0.603	0.020	0.132	5.234	0.54	6.848
CFDYX80525 LSPIKE	6/3/08	1.579	0.198	0.611	15.490	4.40	25.930
Spike Recovery (%)		103	90	98	108	78	99
LBLANK	7/14/08	0.002	0.000	0.000	0.001	0.00	0.007
LFB	7/14/08	1.187	0.205	0.558	11.000	4.54	21.460
Spike Recovery (%)		118	102	111	110	90	107
CFSRX80609	7/14/08	0.544	0.017	0.110	4.122	0.46	5.952
CFSRX80609 LSPIKE	7/14/08	1.583	0.203	0.615	14.080	4.42	24.430
Spike Recovery (%)		109	94	103	103	80	95
CFBFY80609	7/14/08	0.709	0.023	0.136	5.334	0.61	8.880
CFBFY80609 LSPIKE	7/14/08	1.722	0.211	0.636	15.090	4.59	27.100
Spike Recovery (%)		108	95	102	103	81	95
CFPCY80610	7/14/08	0.475	0.020	0.123	4.027	0.45	5.883
CFPCY80610 LSPIKE	7/14/08	1.598	0.221	0.656	14.630	4.75	25.610
Spike Recovery (%)		117	101	109	110	87	101
CFHCX80609	7/14/08	0.725	0.026	0.116	5.503	0.56	8.789
CFHCX80609 LSPIKE	7/14/08	1.756	0.215	0.618	15.300	4.65	27.340
Spike Recovery (%)		110	96	103	103	83	97

Sample ID	**Analysis Date**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units		**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.20	0.50	10.03	5.01	20.05
CFKBX80703	7/14/08	0.394	0.018	0.130	3.306	0.46	6.141
CFKBX80703 LSPIKE	7/14/08	1.444	0.208	0.629	13.390	4.46	24.950
Spike Recovery (%)		109	95	102	104	81	97
CFTAX80703	7/14/08	0.228	0.007	0.097	1.820	0.23	3.125
CFTAX80703 LSPIKE	7/14/08	1.332	0.203	0.618	12.420	4.47	23.010
Spike Recovery (%)		112	98	106	108	85	101
CFPCX80703	7/14/08	0.344	0.015	0.126	2.988	0.40	5.100
CFPCX80703 LSPIKE	7/14/08	1.466	0.218	0.666	13.950	4.70	25.190
Spike Recovery (%)		115	102	110	112	87	103
CFDYX80703	7/14/08	0.306	0.014	0.112	2.648	0.35	4.442
CFDYX80703 LSPIKE	7/14/08	1.368	0.205	0.621	13.010	4.46	24.120
Spike Recovery (%)		109	96	104	106	83	100
FHKNX80703	7/14/08	0.059	-0.005	0.143	0.249	0.07	0.534
FHKNX80703 LSPIKE	7/14/08	1.150	0.188	0.653	10.930	4.30	20.790
Spike Recovery (%)		109	96	105	107	85	101
LBLANK	9/25/08	0.009	0.000	0.000	0.001	0.00	-0.003
LFB	9/25/08	1.161	0.196	0.543	10.800	4.55	20.620
Spike Recovery (%)		115	98	108	108	91	103
BRMFX80820	9/25/08	0.043	-0.004	0.129	0.169	0.05	0.516
BRMFX80820 LSPIKE	9/25/08	1.166	0.191	0.643	10.880	4.48	20.230
Spike Recovery (%)		112	97	105	107	88	99
CFHCX80821	9/25/08	0.836	0.030	0.146	6.504	0.71	10.080
CFHCX80821 LSPIKE	9/25/08	1.894	0.227	0.672	16.980	5.10	30.500
Spike Recovery (%)		114	100	108	111	89	107

Sample ID	**Analysis**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units	**Date**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.20	0.50	10.03	5.01	20.05
CFMPY80821	9/25/08	0.567	0.026	0.158	5.245	0.69	9.609
CFMPY80821 LSPIKE	9/25/08	1.617	0.214	0.658	15.320	4.94	28.090
Spike Recovery (%)		110	95	103	106	86	97
CFSRX80821	9/25/08	0.801	0.041	0.166	7.676	0.89	12.230
CFSRX80821 LSPIKE	9/25/08	1.818	0.225	0.662	17.380	5.06	30.260
Spike Recovery (%)		109	94	102	104	85	96
LBLANK	10/6/08	0.005	0.000	0.000	-0.003	0.00	-0.004
LFB	10/6/08	1.143	0.196	0.550	10.720	4.57	20.860
Spike Recovery (%)		114	98	110	107	91	104
CFMPY80829	10/6/08	0.485	0.036	0.168	6.245	0.77	11.410
CFMPY80829 LSPIKE	10/6/08	1.510	0.219	0.667	15.900	4.84	29.270
Spike Recovery (%)		107	93	103	103	83	95
CFSRBZ80829	10/6/08	0.111	0.003	0.069	0.758	0.12	2.283
CFSRBZ80829 LSPIKE	10/6/08	1.139	0.183	0.569	10.710	4.20	20.710
Spike Recovery (%)		104	90	101	100	82	93

ICP-OES Analysis

Method Spikes (Digestion Spikes, "MSPIKE")

Sample ID	Analysis Date	As	Cd	Cr	Cu	Pb	Zn
Units		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.2	0.5	10.000	5.000	20.000
CFTBX 80521	6/3/08	0.438	0.016	0.160	3.341	0.63	5.975
CFTBX 80521 MSPIKE	6/3/08	1.528	0.200	0.680	14.090	4.46	24.870
Spike Recovery (%)		109	92	104	107	77	94
CFPCX 80525	6/3/08	0.751	0.027	0.136	6.604	0.63	8.356
CFPCX 80525 MSPIKE	6/3/08	1.791	0.206	0.648	17.140	4.37	27.200
Spike Recovery (%)		104	90	102	105	75	94
CFHBX 80503	6/3/08	2.453	0.067	0.118	20.320	1.55	20.630
CFHBX 80503 MSPIKE	6/3/08	3.467	0.241	0.620	30.670	5.14	38.830
Spike Recovery (%)		101	87	100	104	72	91
CFDC 80504	6/3/08	2.441	0.074	0.120	20.200	1.63	22.230
CFDC 80504 MSPIKE	6/3/08	3.510	0.251	0.627	30.800	5.29	41.460
Spike Recovery (%)		107	89	101	106	73	96
CFSRX 80609	7/14/08	0.544	0.017	0.110	4.122	0.46	5.952
CFSRX 80609 MSPIKE	7/14/08	0.750	0.053	0.220	6.096	1.27	9.654
Spike Recovery (%)		106	93	113	101	83	95
FHKNX 80609	7/14/08	0.054	-0.003	0.108	0.159	0.07	0.523
FHKNX 80609 MSPIKE	7/14/08	0.268	0.035	0.225	2.265	0.91	4.476
Spike Recovery (%)		110	99	120	108	86	101
CFKBX 80703	7/14/08	0.394	0.018	0.130	3.306	0.46	6.141
CFKBX 80703 MSPIKE	7/14/08	0.630	0.057	0.245	5.562	1.27	10.120
Spike Recovery (%)		121	99	118	116	83	102
CFTBX 80703	7/14/08	0.523	0.017	0.179	3.478	0.65	6.619
CFTBX 80703 MSPIKE	7/14/08	0.722	0.054	0.290	5.545	1.44	10.430
Spike Recovery (%)		102	96	114	106	81	98

Sample ID	**Analysis**	**As**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Units	**Date**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
PQL		0.015	0.004	0.005	0.005	0.05	0.001
Spike contribution (mg/L)		1.00	0.2	0.5	10.000	5.000	20.000
BFWSX 80820	9/25/08	0.117	-0.004	0.124	0.233	0.11	0.642
BFWSX 80820 MSPIKE	9/25/08	1.224	0.188	0.685	11.060	4.32	20.490
Spike Recovery (%)		111	96	112	108	84	99
CFMPX 80821	9/25/08	0.724	0.028	0.148	6.007	0.66	9.770
CFMPX 80821 MSPIKE	9/25/08	1.808	0.216	0.690	16.530	4.82	29.470
Spike Recovery (%)		108	94	108	105	83	99
CFCAX 80829	10/6/08	0.776	0.048	0.176	7.959	0.98	13.600
CFCAX 80829 MSPIKE	10/6/08	1.850	0.235	0.717	18.370	5.52	32.840
Spike Recovery (%)		107	93	108	104	91	96

Hg Analysis
Analysis Date: 5/30/08

Laboratory (Analytical) Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
Ck1LBLANK		16	-1	1	<5
Ck1LBLANK		27	0	1	<5
LBLANK		39	0	1	<5
LBLANK		42	1	1	<5
LBLANK		55	1	1	<5
LBLANK		69	0	1	<5
LBLANK		72	0	1	<5
LBLANK		84	0	1	<5
LBLANK		87	0	1	<5
LBLANK		100	1	1	<5
LBLANK		103	1	1	<5
LBLANK		116	0	1	<5
LBLANK		119	0	1	<5
LBLANK		124	0	1	<5
LBLANK		125	0	1	<5
LBLANK		130	0	1	<5
LBLANK		143	1	1	<5
LBLANK		146	1	1	<5
LBLANK		160	1	1	<5
LBLANK		163	0	1	<5

Laboratory Reagent Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
ALL LABORATORY BLANKS PREPARED AS LRB					

Digestion (Method) Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
MBLANK	5	22	4	5	<25
MBLANK	5	63	8	5	38
MBLANK	5	88	8	5	39
MBLANK	5	135	10	5	50

Calibration Standards as Samples							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	used for calibration	fitted/true %
Ck2Chk 10		11	10	1	10	y	99
Ck3Chk 30		12	30	1	30	y	101
Ck4Chk 100		13	106	1	106	y	106
Ck5Chk 200		14	198	1	198	y	99
STD100		40	110	1	110	n	110
STD100		56	114	1	114	n	114
STD100		70	111	1	111	n	111
STD100		85	107	1	107	n	107
STD100		101	108	1	108	n	108
STD100		117	107	1	107	n	107
STD10		126	10	1	10	y	103
STD30		127	31	1	31	y	102
STD100		128	107	1	107	y	107
STD200		129	198	1	198	y	99
STD100		144	106	1	106	n	106
STD100		161	108	1	108	n	108

External Standards							
IPC 100 ng/L		Seq No	[Hg] meas.	Dilution	[Hg]		fitted/true
	100			factor	ng/L		%
Ck7IPC 100		5	99	1	99		99
Ck7IPC 100		15	108	1	108		108
Ck7IPC 100		18	104	1	104		104
Ck7IPC 100		29	63	1	63		63
Ck7IPC 100		31	105	1	105		105
IPC100		41	105	1	105		105
IPC100		57	106	1	106		106
IPC100		71	103	1	103		103
IPC100		86	100	1	100		100
IPC100		102	99	1	99		99
IPC100		118	99	1	99		99
IPC100		145	99	1	99		99
IPC100		162	100	1	100		100

Standard Reference Materials							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] mg/kg	Recovery %
NIST 2710 (Montana Soil)		**Nominal [Hg] in mg/kg:**				**32.60**	
		Measured [Hg]:					
NIST2710_1	10000 VIAL2	120	40	10000	402680	40.27	124
NIST2710_1	10000 VIAL26	121	42	10000	422639	42.26	130
NIST2710_1	10000 VIAL2	122	42	10000	416479	41.65	128
NIST2710_1	10000 VIAL26	123	42	10000	416343	41.63	128

Laboratory Duplicates		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		2(a-b)/(a+b) %
BRMFX80503	10	24	53	10	531		
BRMFX80503	10 LDUP	37	58	10	583		9
CFKBX80503	500	43	42	500	20892		
CFKBX80503	500 LDUP	53	37	500	18414		13
BFWSX80503	10	74	50	10	503		
BFWSX80503	10 LDUP	78	52	10	518		3
CFTBX80521	200	90	96	200	19252		
CFTBX80521	200 LDUP	98	64	200	12707		41
CFHCX80521	500	104	25	500	12559		
CFHCX80521	500 LDUP	114	22	500	10845		15
BRMFX80522	10	131	35	10	350		
BRMFX80522	500 LDUP	141	2	500	963		< PQL
CFPNX80525	500	150	9	500	4632		
CFPNX80525	500 LDUP	158	9	500	4495		3

Method (Digestion) Duplicates		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	Sample [Hg] mg/kg	2(a-b)/(a+b) %
BRMFX80503	10	24	53	10	531	0.0053	
BFMFX80503	10 MDUP	25	56	10	563	0.0056	6
BRMFX80503	10	24	53	10	531	0.0053	
BFMFX80503	10 MDUP	26	52	10	519	0.0052	2
CFDCX80504	500	65	36	500	18073	0.1807	
CFDCX80504	500 MDUP	66	31	500	15529	0.1553	15
CFDCX80504	500	65	36	500	18073	0.1807	
CFDCX80504	500 MDUP	67	32	500	15937	0.1594	13
CFTBX80521	200	90	96	200	19252	0.1925	
CFTBX80521	200 MDUP	91	91	200	18194	0.1819	6
CFPCX80525	500	140	24	500	12166	0.1217	
CFPCX80525	500 MDUP	147	14	500	6984	0.0698	54

Laboratory (Analytical) Spikes		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	Sample [Hg] ug/L	Recovery %
BRMFX80503	10 LDUP	37	58	10	583		
BRMFX80503	10 LSPIKE	38	156	10	1555		108
CFKBX80503	500 LDUP	53	37	500	18414		
CFKBX80503	500 LSPIKE	54	141	500	70749		105
BFWSX80503	10 LDUP	78	52	10	518		
BFWSX80503	10 LSPIKE	79	144	10	1437		102
CFTBX80521	200 LDUP	98	64	200	12707		
CFTBX80521	200 LSPIKE	99	165	200	32985		102
CFHCX80521	500 LDUP	114	22	500	10845		
CFHCX80521	500 LSPIKE	115	122	500	60876		100
BRMFX80522	500 LDUP	141	2	500	963		
BRMF80522	500 LSPIKE	142	99	500	49614		98
CFPNX80525	500 LDUP	158	9	500	4495		
CFPNX80525	500 LSPIKE	159	108	500	54145		100

Method (Digestion) Spikes		Seq No	[Hg] meas.	Dilution factor	Digest [Hg] ng/L	Sample [Hg] ug/L	Recovery %
SEDSPIKE	1000	73	110	1000	109732		
SEDSPIKE	1000	89	116	1000	116373		
				Average:	113052		
CFHBX80503	500	80	26	500	13153		
CFHBX80503	500 MSPIKE	81	55	500	27521		113
CFDC80504	500	82	29	500	14372		
CFDC80504	500 MSPIKE	83	56	500	27941		109
CFTBX80521	200 MDUP	91	91	200	18194		
CFTBX80521	200MSPIKE	92	128	200	25581		87
CFPCX80525	500 MDUP	147	14	500	6984		
CFPCX80525	500 MSPIKE	148	38	500	18872		103

Hg Analysis

Analysis Date: 7/11/08

Laboratory (Analytical) Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
Ck1LBLANK			0	1	<5
LRB			0	1	<5
Ck1LBLANK			-1	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5
LRB			0	1	<5

Laboratory Reagent Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
ALL LABORATORY BLANKS PREPARED AS LRB					

Digestion (Method) Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
MBLANK	5 VIAL 1	7	4	1	<5
MBLANK	5 VIAL 25	8	2	1	<5
MBLANK	5 VIAL 47	9	1	1	<5
MBLANK	5 VIAL 71	10	1	1	<5

Calibration Standards as Samples							
		Seq No	[Hg] meas.	Dilution	[Hg]	used for	fitted/true
				factor	ng/L	calibration	%
Ck2Chk 10		2	10	1	10	y	98
Ck3Chk 30		3	30	1	30	y	100
Ck4Chk 100		4	97	1	97	y	97
Ck5Chk 200		5	201	1	201	y	100
Ck2Chk 10		18	10	1	10	n	95
Ck3Chk 30		19	29	1	29	n	97
Ck4Chk 100		20	98	1	98	n	98
Ck5Chk 200		21	202	1	202	n	101
STD100		37	98	1	98	n	98
STD100		55	97	1	97	n	97
STD100		71	97	1	97	n	97
STD100		87	97	1	97	n	97
STD100		103	97	1	97	n	97
STD100		119	97	1	97	n	97
STD100		142	97	1	97	n	97
Ck3Chk 30		148	29	1	29	y	95
Ck4Chk 100		149	97	1	97	y	97
Ck5Chk 200		150	200	1	200	y	100
External Standards							
IPC 100 ng/L		Seq No	[Hg] meas.	Dilution	[Hg]		fitted/true
100				factor	ng/L		%
Ck7IPC 100		6	99	1	99		99
IPC100		16	97	1	97		97
Ck7IPC 100		22	99	1	99		99
IPC100		38	99	1	99		99
IPC100		56	99	1	99		99
IPC100		72	98	1	98		98
IPC100		88	99	1	99		99
IPC100		104	100	1	100		100
IPC100		143	98	1	98		98
IPC100		120	100	1	100		100
Ck7IPC 100		151	99	1	99		99
Standard Reference Materials							
		Seq No	[Hg] meas.	Dilution	[Hg]	[Hg]	Recovery
				factor	ng/L	mg/kg	%
NIST 2710 (Montana Soil)		**Nominal [Hg] in mg/kg:**				**32.60**	
		Measured [Hg]:					
NIST2710	10000 VIAL 2	11	30	10000	300837	30.08	92
NIST2710	10000 VIAL 26	12	29	10000	292502	29.25	90
NIST2710	10000 VIAL 48	13	31	10000	307911	30.79	94
NIST2710	10000 VIAL 72	14	30	10000	295789	29.58	91

Laboratory Duplicates							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		2(a-b)/(a+b) %
CFSRX80609	500	24	10	500	4770		
CFSRX80609	500 LDUP	27	10	500	4836		1
CFTBX80609	200	40	31	200	6278		
CFTBX80609	200 LDUP	52	31	200	6285		0
CFKCY80609	200	67	8	200	1560		
CFKCY80609	200 LDUP	68	8	200	1671		7
CFHBX80610	500	74	7	500	3431		
CFHBX80610	500 LDUP	84	8	500	3969		15
CFKBX80703	200	90	21	200	4122		
CFKBX80703	200 LDUP	100	20	200	4002		3
CFDCX80704	500	108	13	500	6432		
CFDCX80704	500 LDUP	116	16	500	8167		24
CFHCX80704	500	124	13	500	6533		
CFHCX80704	500 LDUP	132	15	500	7715		17
BFWSX80703	10	134	50	10	496		
BFWSX80703	10 LDUP	140	46	10	464		7

Method (Digestion) Duplicates							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	Sample [Hg] mg/kg	2(a-b)/(a+b) %
CFSRX80609	500	24	10	500	4770	0.0477	
CFSRX80609	500 MDUP	25	11	500	5264	0.0526	10
FHKNX80609	10	58	21	10	208	0.0021	
FHKNX80609	10 MDUP	59	23	10	231	0.0023	11
CFKBX80703	200	90	21	200	4122	0.0412	
CFKBX80703	200 MDUP	91	22	200	4332	0.0433	5
CFTBX80703	200	126	46	200	9146	0.0915	
CFTBX80703	200 MDUP	127	53	200	10591	0.1059	15

Laboratory (Analytical) Spikes						Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
CFSRX80609	500 LDUP	27	10	500	4836		
CFSRX80609	500 LSPIKE	28	108	500	54010		99
CFTBX80609	200 LDUP	52	31	200	6285		
CFTBX80609	200 LSPIKE	53	129	200	25809		98
CFKCY80609	200 LDUP	68	8	200	1671		
CFKCY80609	200 LSPIKE	69	106	200	21223		98
CFHBX80610	500 LDUP	84	8	500	3969		
CFHBY80610	500 LSPIKE	85	106	500	52988		98
CFKBX80703	200 LDUP	100	20	200	4002		
CFKBX80703	500 LSPIKE	101	119	500	59351		111
CFDCX80704	500 LDUP	116	16	500	8167		
CFDCX80704	500 LSPIKE	117	114	500	56905		98
CFHCX80704	500 LDUP	132	15	500	7715		
CFHCX80704	500 LSPIKE	133	114	500	56841		98

Method (Digestion) Spikes					Digest	Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
SEDSPIKE	1000	144	103	1000	102778		
CFSRX80609	500	24	10	500	4770		
CFSRX80609	500 MSPIKE	26	14	500	7179		106
FHKNX80609	10	58	21	10	208		
FHKNX80609	50 MSPIKE	60	47	50	2336		106
CFKBX80703	200	90	21	200	4122		
CFKBX80703	200 MSPIKE	92	33	200	6679		109
CFTBX80703	200	126	46	200	9146		
CFTBX80703	200 MSPIKE	128	57	200	11388		102

Hg Analysis
Analysis Date: 9/4/08

Laboratory (Analytical) Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
LRB		21	0	1	<5
LRB		24	1	1	<5
LRB		37	0	1	<5
LRB		40	0	1	<5
LRB		52	0	1	<5
LRB		56	0	1	<5
LRB		70	-1	1	<5
LRB		74	-1	1	<5
LRB		84	-1	1	<5
LRB		88	0	1	<5
Ck1LBLANK		90	-3	1	<5
LRB		109	0	1	<5
LRB		112	-1	1	<5
LRB		128	-1	1	<5
LRB		131	-1	1	<5

Laboratory Reagent Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
ALL LABORATORY BLANKS PREPARED AS LRB					

Digestion (Method) Blanks		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
MBlank	5 VIAL 1	9	5	5	26
MBLANK	5	44	7	5	34
MBLANK	5	78	1	5	<25

Calibration Standards as Samples							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	used for calibration	fitted/true %
Ck2Chk 10		2	10	1	10	y	96
Ck3Chk 30		3	30	1	30	y	99
Ck4Chk 100		4	100	1	100	y	100
Ck5Chk 200		5	200	1	200	y	100
STD100		22	97	1	97	n	97
STD100		38	96	1	96	n	96
STD100		53	96	1	96	n	96
STD100		71	91	1	91	n	91
STD100		85	93	1	93	n	93
Ck2Chk 10		91	8	1	8	n	85
Ck3Chk 30		92	28	1	28	n	93
Ck4Chk 100		93	96	1	96	n	96
Ck5Chk 200		94	195	1	195	n	97
STD100		110	101	1	101	n	101
STD100		129	100	1	100	n	100
Ck2Chk 10		132	9	1	9	n	92
Ck3Chk 30		133	30	1	30	n	98
Ck4Chk 100		134	100	1	100	n	100
Ck5Chk 200		135	204	1	204	n	102

External Standards							
IPC 100 ng/L		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		fitted/true %
100							
Ck7IPC 100	0	6	90	1	90		90
Ck7IPC 100	0	7	102	1	102		102
Ck7IPC 100	0	8	89	1	89		89
IPC100	NEW 1	23	87	1	87		87
IPC100	NEW 1	39	86	1	86		86
IPC100	NEW 1	54	85	1	85		85
IPC100	NEW 2	55	90	1	90		90
IPC100	NEW 1	72	85	1	85		85
IPC100	NEW 2	73	68	1	68		68
IPC100	NEW 1	86	83	1	83		83
IPC100	NEW 2	87	73	1	73		73
Ck7IPC 100	OLD	95	100	1	100		100
Ck7IPC 100	NEW 2	96	96	1	96		96
IPC100	NEW 2	111	93	1	93		93
IPC100	NEW 2	130	91	1	91		91
Ck7IPC 100		136	100	1	100		100

Standard Reference Materials							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] mg/kg	Recovery %
NIST 2710 (Montana Soil)		**Nominal [Hg] in mg/kg:**				**32.60**	
		Measured [Hg]:					
NIST2710	10000 VIAL 2	75	29	10000	287569	28.76	88
NIST2710	10000 VIAL 26	76	25	10000	245835	24.58	75
NIST2710	10000 VIAL 44	77	29	10000	288394	28.84	88

Laboratory Duplicates							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		2(a-b)/(a+b) %
CFCAX80821	500	18	9	500	4659		
CFCAX80821	500 LDUP	19	10	500	4842		4
CFKCX80820	100	34	34	100	3436		
CFKCX80820	100 LDUP	35	33	100	3331		3
CFKIX80820	500	42	16	500	8004		
CFKIX80820	500 LDUP	50	17	500	8321		4
CFSRX80821	500	58	13	500	6352		
CFSRX80821	500 LDUP	68	14	500	6918		9
DEERB80717	200	81	51	200	10273		
DEERB80717	200 LDUP	82	55	200	11008		7
FLINB80717	1000	106	300	1000	299753		
FLINB80717	1000 LDUP	107	317	1000	316596		b.d.
DEERA80717	200	118	45	200	8999		
DEERA80717	200 LDUP	126	44	200	8853		2

Method (Digestion) Duplicates							
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	Sample [Hg] mg/kg	2(a-b)/(a+b) %
BFWSX80820	10	10	53	10	527	0.0053	
BFWSX80820	10 MDUP	11	44	10	443	0.0044	17
CFMPX80821	500	45	11	500	5717	0.0572	
CFMPX80821	500 MDUP	66	11	500	5648	0.0565	1
KOHRA80717	200	97	13	200	2521	0.0252	
KOHRA80717	200 MDUP	98	11	200	2299	0.0230	9

Laboratory (Analytical) Spikes						Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
CFCAX80821	500	18	9	500	4659		
CFCAX80821	500 LSPIKE	20	98	500	49027		89
CFKCX80820	100	34	34	100	3436		
CFKCX80820	100 LSPIKE	36	119	100	11878		85
CFKIX80820	500	42	16	500	8004		
CFKIX80820	500 LSPIKE	51	103	500	51606		87
CFSRX80821	500	58	13	500	6352		
CFSRX80821	500 LSPIKE	69	102	500	50870		89
DEERB80717	200	81	51	200	10273		
DEERB80717	200 LSPIKE	83	140	200	28095		90
FLINB80717	1000	106	300	1000	299753		
FLINB80717	1000 LSPIKE	108	440	1000	440046		141
DEERA80717	200	118	45	200	8999		
DEERA80717	200 LSPIKE	127	138	200	27623		94

Method (Digestion) Spikes					Digest	Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
SEDSPIKE	1000	89	115	1000	115444		
				Average:	115444		
BFWSX80820	10	10	53	10	527		
BFWSX80820	100 MSPIKE	12	141	100	14091		117
CFMPX80821	500	45	11	500	5717		
CFMPX80821	500 MSPIKE	67	39	500	19430		113
KOHRA80717	200	97	13	200	2521		
KOHRA80717	200 MSPIKE	99	72	200	14414		102

Hg Analysis
Analysis Date: 10/5/08

Laboratory (Analytical) Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
LBLANK	1	29	0	1	<5
LBLANK	1	32	0	1	<5
LBLANK	1	52	0	1	<5
LBLANK	1	55	0	1	<5
LBLANK	1	69	0	1	<5
LBLANK	1	72	0	1	<5
LBLANK	1	85	0	1	<5
Ck1LBLANK	1	87	0	1	<5

Laboratory Reagent Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
ALL LABORATORY BLANKS PREPARED AS LRB					

Digestion (Method) Blanks					
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L
MBLANK	5	17	3	5	<25
MBLANK	5	58	4	5	<25

Calibration Standards as Samples		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	used for calibration	fitted/true %
Ck2Chk 10	1	12	11	1	11	y	108
Ck3Chk 30	1	13	31	1	31	y	102
Ck4Chk 100	1	14	104	1	104	y	104
Ck5Chk 200	1	15	201	1	201	y	100
STD100	1	30	100	1	100	n	100
STD100	1	53	97	1	97	n	97
STD100	1	70	97	1	97	n	97
Ck2Chk 10	1	88	7	1	7	y	74
Ck3Chk 30	1	89	30	1	30	y	98
Ck4Chk 100	1	90	99	1	99	y	99
Ck5Chk 200	1	91	199	1	199	y	100

External Standards		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		fitted/true %
IPC 100 ng/L							
100							
Ck7IPC 100	1	16	93	1	93		93
IPC100	1	31	93	1	93		93
IPC100	1	54	91	1	91		91
IPC100	1	71	90	1	90		90
Ck7IPC 100	1	92	91	1	91		91

Standard Reference Materials		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] mg/kg	Recovery %
NIST 2710 (Montana Soil)		**Nominal [Hg] in mg/kg:**				**32.60**	
		Measured [Hg]:					
NIST2710	10000 VIAL 2	82	33	10000	325348	32.53	100
NIST2710	10000 VIAL 26	83	32	10000	315508	31.55	97

Laboratory Duplicates		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L		2(a-b)/(a+b) %
CFMPX80829	500	26	12	500	6177		
CFMPX80829	500 LDUP	27	15	500	7598		21
CFMPBZ80829	50 BULK	49	11	50	571		
CFMPBZ80829	50 BULK LDUP	50	12	50	579		1
KHCFR 3B	200	64	35	200	7062		
KHCFR 3B	200 LDUP	67	31	200	6139		14
KI2-U2-295	50	74	65	50	3242		
KI2-U2-295	50 LDUP	80	67	50	3372		4

Method (Digestion) Duplicates		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	Sample [Hg] mg/kg	2(a-b)/(a+b) %
CFCAX80829	500	18	15	500	7569	0.0757	
CFCAX80829	500 MDUP	19	15	500	7458	0.0746	1
KHCFR 2A	200	61	28	200	5611	0.0561	
KHCFR 2A	200 MDUP	65	28	200	5604	0.0560	0

Laboratory (Analytical) Spikes						Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
CFMPX80829	500	26	12	500	6177		
CFMPX80829	500 LSPIKE	28	105	500	52714		93
CFMPBZ80829	50 BULK	49	11	50	571		
CFMPBZ80829	100 BULK LSPIKE	51	94	100	9417		89
KHCFR 3B	200	64	35	200	7062		
KHCFR 3B	200 LSPIKE	68	122	200	24334		87
KI2-U2-295	50	74	65	50	3242		
KI2-U2-295	100 LSPIKE	81	123	100	12259		91

Method (Digestion) Spikes					Digest	Sample	
		Seq No	[Hg] meas.	Dilution factor	[Hg] ng/L	[Hg] ug/L	Recovery %
SEDSPIKE	1000	84	116	1000	115610		
				Average:	115610		
CFCAX80829	500	18	15	500	7569		
CFCAX80829	500 MSPIKE	20	42	500	20792		109
KHCFR 2A	200	61	28	200	5611		
KHCFR 2A	200 MSPIKE	66	103	200	20633		120

Appendix D: External Data

Pre-breach conditions of bed sediment metal concentrations (mg/kg) from 2004-2006, at USGS gauges upstream of Milltown Dam at Turah Bridge (Turah), below Milltown Dam above Missoula at Deer Creek Bridge (Missoula), and below the confluence of the CFR and BRR (Below Missoula). Values are included in Figures 4-10 (green squares), and were collected from various USGS Open-File Reports by Dodge *et.al.* (2005, 2006, 2007). Results for Below Missoula were only reported by the USGS in 2004.

USGS Site	Year	Distance (km)	As	Cd	Cr	Cu	Pb	Zn
Turah	2006	-11	21	1.9	21.8	237	47	584
	2005	-11	30	3.1	17.2	307	54	686
	2004	-11	22	2.3	17.8	250	57	647
Missoula	2006	4.42	52	3.5	25.9	551	66	960
	2005	4.42	17	2.6	20.3	259	46	590
	2004	4.42	29	3.4	20.4	441	62	872
Below Missoula	2004	23.27	14	1.8	17	183	41	469

Sediment Accumulation Area sediment statistics for Milltown Reservoir (Fig. 29) (ROD, 2004)

Description	Area I	Area II	Area III	Area IV	Area V
Sediment thickness (ft)	10.25	3-18	5-10.5	2-12	3-12
Volume (million y^3)	2.6	0.76	0.86	1.2	1.52
Avg. As (mg/kg)	320	71	34	200	125
Avg. Cu (mg/kg)	2300	400	232	1303	940

The following data is provided by the USGS Clark Fork Water-Quality Monitoring Project. Montana Water Science Center, USGS. <http://mt.water.usgs.gov/projects/clarkfork/retrieve_wq_data.html>

Clark Fork at Turah Bridge near Bonner MT - Station number 12334550

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/16/08	1045	1.2895E+10	7.4	10.2	5.9	25.4	0.19	4.26	6	37.5	63	50	711
06/10/08	1015	1.2185E+10	8.1	11.3	6.5	27.9	.15	4.77	7.3	39.2	65	57	766
06/02/08	1030	1.2601E+10	6.1	9.1	4.7	24.0	.15	4.01	5.1	35.5	64	58	806
05/27/08	1100	1.2895E+10	6.5	11.1	6.2	35.5	.24	6.22	10.8	50.4	68	79	1120
05/23/08	1030	1.2675E+10	4.8	8.5	4.0	30.6	.21	6.19	4.9	41.7	65	69	965
05/19/08	1030	1.1304E+10	3.8	9.9	3.1	37.2	.12	7.71	2.9	52.5	63	151	1880
05/12/08	1020	5.5054E+09	4.3	6.1	2.2	10.5	0.07	2.35	2.5	17.4	73	21	128
05/05/08	1100	4.4043E+09	4.7	6.6	2.7	12.8	0.11	3.12	2.7	22.1	74	28	136
04/29/08	1000	3.6947E+09	5.8	8.8	3.6	21.6	0.15	5.19	4.1	36.6	74	44	179
04/22/08	1020	2.8628E+09	4.6	6.6	2.6	11.1	0.1	2.69	5.8	18.3	83	16	51
04/16/08	1130	3.6213E+09	7.5	19.1	4.3	46.5	0.23	16.9	5	87	90	122	488
04/08/08	1015	1.7055E+09	5.6	6.3	3.4	8.2	0.14	1.53	3.6	14.2	86	11	21
03/31/08	1000	1.6712E+09	5.4	6.2	4.6	8.1	0.2	1.28	4.7	13.8	88	10	18
03/24/08	930	1.7886E+09	5.8	6.8	3.4	9.4	0.12	1.57	4.3	16.3	82	14	28
03/10/08	1045	1.8229E+09	5.3	6.6	3.2	9.4	0.08	1.62	3.5	14.4	88	14	28
06/26/07	1030	5.2852E+09	7.2	7.1	3.2	6.9	0.12	0.77	2.7	8.9	73	5	29
06/19/07	1230	8.6129E+09	7.7	9.0	3.9	15.6	0.12	2.38	3.9	21.2	71	21	200
06/12/07	1030	1.3189E+10	9.5	13.2	6.2	34.8	0.07	6.08	4.8	47.5	61	74	1080
06/06/07	1100	9.0778E+09	6.8	10.5	3.8	26.6	0.12	5.38	3.5	48.5	64	55	551
05/31/07	1230	8.3438E+09	7.4	10.3	4.7	25.3	0.12	4.38	3.3	32.4	73	41	377
05/22/07	1100	8.2214E+09	4.2	5.9	2.8	16.7	0.06	2.74	3	21.3	63	32	290
05/14/07	1100	8.2214E+09	4.7	6.8	3.2	18.3	0.07	3.57	3.1	26	59	45	408
05/03/07	1100	6.7533E+09	4.4	8.1	3.6	30.7	0.18	6.5	4.0	52.5	62	92	686
04/23/07	1030	2.8873E+09	6.6	8.1	7.8	18.4	0.08	3.28	2.8	24.8	83	22	70
04/09/07	1130	2.5447E+09	5.5	6.4	3.3	12.6	0.08	2.03	3.1	18.6	81	17	48
06/26/06	1100	2.9852E+09	5.8	6	3	6.1	0.05	0.41	1.9	5	75	4	13
06/19/06	1100	4.3065E+09	6.2		3.4	14.9	0.06	2.25	3	29	71	11	52
06/13/06	1100	6.6310E+09	9.2	12.9	8	37.4	0.15	6.06	7.5	43	78	42	307
06/05/06	1130	5.5543E+09	5.1	6.1	4.5	10.4	0.22	1.46	4.5	13	66	17	104
05/31/06	1130	5.5054E+09	5.8	6.6	4.1	13.2	0.07	1.8	3	16	69	19	115
05/16/06	1100	6.6799E+09	4.3	5.6	3	10.3	0.08	1.85	2.4	16	63	36	265
05/02/06	1130	7.5118E+09	4.7	8.2	5.6	21.2	0.3	4.67	6.3	33	63	53	439
04/19/06	945	5.3097E+09	5.1	7.9	6	21.8	0.2	4.2	9.5	30	77	33	193
04/05/06	1100	2.7894E+09	4.7	7.5	4.9	21.4	0.22	4.22	5.1	35	72	40	123

Clark Fork at Turah Bridge near Bonner MT - Station number 12334550

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/16/08	1045	645	36.1	251.5	52.5	406.2	406.19	56.0	390.0	81.4	630.0
06/10/08	1015	695	39.0	260.8	56.3	388.7	451.47	56.1	375.4	81.1	559.6
06/02/08	1030	731	37.8	243.2	48.6	383.1	467.76	51.7	332.8	66.6	524.1
05/27/08	1100	1019	59.3	377.8	77.1	510.6	692.71	58.2	370.9	75.7	501.3
05/23/08	1030	875	46.9	337.1	75.8	466.4	568.46	53.6	385.5	86.7	533.3
05/19/08	1030	1707	69.0	385.5	85.8	560.7	1075.39	40.4	225.8	50.3	328.5
05/12/08	1020	116	9.9	45.7	12.6	82.0	84.40	85.7	395.2	108.6	709.5
05/05/08	1100	123	8.4	44.5	13.3	85.4	91.26	67.9	360.7	107.5	692.9
04/29/08	1000	163	11.1	66.5	18.6	120.1	120.30	68.2	409.1	114.5	738.6
04/22/08	1020	46	5.7	24.3	7.4	35.8	38.02	125.0	531.3	161.9	781.3
04/16/08	1130	442	42.0	152.8	60.4	296.9	397.62	95.1	345.9	136.6	672.1
04/08/08	1015	19	1.2	8.2	2.4	18.1	16.13	63.6	436.4	126.4	963.6
03/31/08	1000	17	1.3	5.8	1.8	15.2	14.71	80.0	350.0	108.0	910.0
03/24/08	930	25	1.8	10.7	2.6	21.5	20.53	71.4	428.6	103.6	857.1
03/10/08	1045	26	2.4	11.3	2.8	19.9	22.46	92.9	442.9	110.0	778.6
06/26/07	1030	26	-0.5	19.6	3.4	32.8	19.29	-20.0	740.0	130.0	1240.0
06/19/07	1230	181	11.2	100.8	19.5	149.0	128.42	61.9	557.1	107.6	823.8
06/12/07	1030	976	48.8	377.2	79.3	563.1	595.33	50.0	386.5	81.2	577.0
06/06/07	1100	499	33.6	207.0	47.7	408.5	319.54	67.3	414.5	95.6	818.2
05/31/07	1230	342	24.2	171.9	35.5	242.8	249.73	70.7	502.4	103.9	709.8
05/22/07	1100	263	14.0	114.3	22.0	150.5	165.74	53.1	434.4	83.8	571.9
05/14/07	1100	370	17.3	124.1	28.8	188.3	218.28	46.7	335.6	77.8	508.9
05/03/07	1100	621	25.0	183.0	42.7	327.5	385.21	40.2	294.6	68.7	527.2
04/23/07	1030	64	4.3	30.6	9.2	63.5	52.72	68.2	481.8	145.5	1000.0
04/09/07	1130	43	2.3	23.7	5.0	39.4	35.04	52.9	547.1	114.7	911.8
06/26/06	1100	12	0.6	9.3	1.1	9.3	8.96	50.0	775.0	90.0	775.0
06/19/06	1100	47		49.5	9.4	112.0	33.63	0.0	1045.5	199.1	2363.6
06/13/06	1100	279	24.5	195.0	39.2	235.4	217.23	88.1	700.0	140.7	845.2
06/05/06	1130	94	5.6	32.8	6.9	47.2	62.32	58.8	347.1	72.9	500.0
05/31/06	1130	105	4.4	50.1	9.5	71.6	72.18	42.1	478.9	91.1	684.2
05/16/06	1100	240	8.7	48.8	11.8	90.8	151.50	36.1	202.8	49.2	377.8
05/02/06	1130	398	26.3	117.2	32.8	200.6	250.82	66.0	294.3	82.5	503.8
04/19/06	945	175	14.9	83.9	21.2	108.8	134.92	84.8	478.8	121.2	621.2
04/05/06	1100	112	7.8	46.0	11.2	83.4	80.33	70.0	412.5	100.0	747.5

Clark Fork Bypass near Bonner, MT - Station 12334570

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/16/08	1315	1.2895E+10	7.6	12.2	6.6	38.4	0.19	6.45	6.9	80.1	35	116	1650
06/10/08	1210	1.2185E+10	7.9	15.5	6.9	58.1	.12	9.74	7.4	130	23	203	2730
06/02/08	1200	1.2601E+10	6.3	14.4	5.6	70.6	.14	12.5	7.1	168	21	241	3350
05/27/08	1300	1.2895E+10	6.8	20.3	7.6	124	.28	18.4	15.7	223	29	366	5210
05/23/08	1200	1.2675E+10	5.4	33.2	8.9	289	.31	36.5	18.9	476	27	669	9360
05/19/08	1230	1.1304E+10	5.4	98.5	12.2	1100	.54	183	45.0	3170	9	3780	47200
05/12/08	1140	5.5054E+09	4.5	12.2	2.6	66.5	0.09	11	4.1	118	28	144	875
05/05/08	1230	4.4043E+09	4.8	9.1	3	37.3	0.13	7.2	3.9	89.3	35	82	399
04/29/08	1200	3.6947E+09	5.9	11.8	3.7	50.8	0.14	9.32	5.2	92.1	26	188	766
04/22/08	1210	2.8628E+09	4.8	9.2	2.6	46.5	0.12	7.94	5.2	109	22	132	417
04/16/08	1300	3.6213E+09	7.7	40.2	5.4	155	0.26	35.8	11.7	436	27	518	2070
04/08/08	1200	1.7055E+09	5.6	6.9	3	10.2	0.11	1.83	4.1	19.7	36	31	58
03/31/08	1230	1.6712E+09	5.5	7.9	3.1	19.4	0.11	3.25	4.2	47	29	51	94
03/24/08	1100	1.7886E+09	5.8	9	3.3	19.4	0.1	3.51	5.1	48.4	35	74	146

Clark Fork Bypass near Bonner, MT - Station 12334570

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/16/08	1315	1496	59.3	410.1	80.7	943.9	297.9	39.7	274.1	54.0	631.0
06/10/08	1210	2474	92.6	623.9	117.2	1493.9	409.2	37.4	252.2	47.4	603.9
06/02/08	1200	3037	102.1	819.1	155.8	2027.5	484.3	33.6	269.7	51.3	667.6
05/27/08	1300	4720	174.1	1501.0	233.7	2673.1	1073.2	36.9	318.0	49.5	566.4
05/23/08	1200	8479	352.4	3550.2	458.7	5793.6	2053.3	41.6	418.7	54.1	683.3
05/19/08	1230	42731	1052.4	12297.0	2062.6	35326.4	3692.1	24.6	287.8	48.3	826.7
05/12/08	1140	793	42.4	351.8	60.1	627.1	189.6	53.5	443.8	75.8	791.0
05/05/08	1230	361	18.9	151.1	31.1	376.1	83.2	52.4	418.3	86.2	1041.5
04/29/08	1200	695	21.8	174.0	33.9	321.1	138.3	31.4	250.5	48.8	462.2
04/22/08	1210	378	12.6	125.7	22.4	297.2	73.1	33.3	332.6	59.2	786.4
04/16/08	1300	1876	117.7	541.8	128.7	1536.5	387.2	62.7	288.8	68.6	819.1
04/08/08	1200	53	2.2	12.3	2.9	26.6	12.3	41.9	232.3	55.5	503.2
03/31/08	1230	85	4.0	27.2	5.2	71.5	19.9	47.1	319.6	61.6	839.2
03/24/08	1100	132	5.7	28.8	6.1	77.4	37.6	43.2	217.6	46.1	585.1

Blackfoot River near Bonner MT - station 12340000

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/16/08	1500	1.2601E+10	0.91	1.2	1.2	3.8	0.05	0.92	2.2	3.7	83	33	459
06/10/08	1530	1.2308E+10	.96	1.5	0.8	2.0	0.08	.80	1.2	3.5	89	28	380
06/02/08	1330	1.8841E+10	.89	1.5	0.87	2.7	0.08	.98	1.8	4.7	82	69	1430
05/27/08	1400	1.9673E+10	1.1	2.5	1.6	5.8	0.1	2.78	3.9	10.9	89	128	2780
05/23/08	1330	2.0089E+10	.73	1.4	0.79	3.4	0.08	1.19	0.91	5.3	80	77	1710
05/19/08	1430	2.3025E+10	.86	3.4	1.1	9.5	0.06	4.67	1.8	15.8	79	302	7670
05/12/08	1350	9.0533E+09	0.7	0.84	0.61	0.9	0.08	0.26	1	1.5	81	13	130
05/05/08	1400	6.8512E+09	0.66	1	0.63	0.95	0.08	0.34	2	2	73	23	174
04/29/08	1330	3.6458E+09	0.88	1.1	0.71	0.82	0.08	0.23	1.8	1.4	83	15	60
04/22/08	1340	2.8383E+09	0.83	0.93	1	1.2	0.08	0.15	1.8	2	86	7	22
04/16/08	1445	2.5203E+09	1.2	1.6	0.72	0.85	0.08	0.37	0.95	1.6	85	19	53
04/08/08	1400	1.1696E+09	1.2	1.1	0.8	1.2	0.08	0.07	1.8	2	79	3	3.9
03/31/08	1100	1.1011E+09	1.1	1.3	0.59	1.1	0.08	0.06	1.8	2	84	3	3.6
03/24/08	1330	1.2087E+09	1.2	1.4	0.81	1.2	0.06	0.11		1	85	3	4
03/10/08	1230	1.1011E+09	0.95	1.1	0.69	1.2	0.04	0.06	1.8	2	88	3	3.6
06/26/07	1200	4.0128E+09	1.1	1.2	0.27	0.64	0.12	0.12	0.87	1	84	5	22
06/19/07	1400	5.4809E+09	0.96	0.99	0.4	1.26	0.12	0.19	0.65	1.43	88	7	42
06/12/07	1230	7.2427E+09	1	1.1	0.4	1.1	0.12	0.28	0.6	2	91	13	104
06/06/07	1300	8.9310E+09	0.82	1	0.4	1.1	0.12	0.35	0.6	2.1	86	19	187
05/31/07	1430	8.0991E+09	0.84	1	0.37	1.4	0.12	0.26	0.39	1.9	87	15	134
05/22/07	1300	1.0717E+10	0.78	0.98	0.5	1.1	0.12	0.35	0.92	1.9	85	18	213
05/14/07	1330	1.3017E+10	0.89	1.2	0.89	2.8	0.12	0.61	2	2.8	83	40	575
05/03/07	1300	1.3066E+10	0.74	1.4	2.0	3.0	0.17	1.3	2.5	5.1	83	84	1210
04/23/07	1230	4.6001E+09	0.91	1	0.77	0.79	0.12	0.16	1.2	1.1	84	7	36
04/09/07	1300	4.1841E+09	0.84	0.9	0.72	0.77	0.12	0.11	0.76	2	83	5	23
06/26/06	1230	4.9671E+09	0.98	1.2	0.62	0.8	0.04	0.12	0.84	2	80	5	27
06/19/06	1300	7.6097E+09	0.92	1	0.64	1.2	0.08	0.18	0.67	1	84	9	76
06/13/06	1300	1.0179E+10	0.92	1.2	2	1.4	0.09	0.39		2	86	19	213
06/05/06	1330	1.1133E+10	0.86	1	1.2	1.5	0.07	0.39	1.2	2	83	24	295
05/31/06	1400	1.0301E+10	0.85	1.1		1.3		0.37		2	86	18	205
05/16/06	1300	1.2283E+10	0.89	1.1	0.8	1.9	0.08	0.62	0.6	3	78	48	651
05/02/06	1330	1.1427E+10	0.66	1.1	0.9	1.7	0.08	0.46	1.1	3	83	25	315
04/19/06	1230	9.0044E+09	0.82	1.1	1.7	1.8	0.07	0.43	2	3	89	21	209
04/05/06	1400	4.3065E+09	1	1.4	2.1	2	0.18	0.68	3.3	3	79	39	185

Blackfoot River near Bonner MT - station 12340000

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/16/08	1500	416	3.7	32.8	11.0	18.9	345.15	8.8	78.8	26.4	45.5
06/10/08	1530	345	6.6	14.8	8.9	28.3	306.71	19.3	42.9	25.7	82.1
06/02/08	1330	1300	11.5	34.5	17.0	54.6	1066.01	8.8	26.5	13.0	42.0
05/27/08	1400	2518	27.5	82.6	52.7	137.7	2241.11	10.9	32.8	20.9	54.7
05/23/08	1330	1547	13.5	52.4	22.3	88.2	1237.46	8.7	33.9	14.4	57.0
05/19/08	1430	6954	58.5	193.4	106.1	322.3	5493.27	8.4	27.8	15.3	46.4
05/12/08	1350	118	1.3	2.6	1.6	4.5	95.33	10.8	22.3	13.8	38.5
05/05/08	1400	158	2.3	2.2	1.8	0.0	115.03	14.8	13.9	11.3	0.0
04/29/08	1330	55	0.8	0.4	0.5	-1.5	45.39	14.7	7.3	10.0	-26.7
04/22/08	1340	20	0.3	0.6	0.2	0.6	17.09	14.3	28.6	10.0	28.6
04/16/08	1445	48	1.0	0.3	0.7	1.6	40.70	21.1	6.8	15.3	34.2
04/08/08	1400	4	-0.1	0.5	0.0	0.2	2.77	-33.3	133.3	-3.3	66.7
03/31/08	1100	3	0.2	0.6	0.0	0.2	2.77	66.7	170.0	-6.7	66.7
03/24/08	1330	4	0.2	0.5	0.1	1.2	3.08	66.7	130.0	16.7	333.3
03/10/08	1230	3	0.2	0.6	0.0	0.2	2.91	50.0	170.0	6.7	66.7
06/26/07	1200	20	0.4	1.5	0.0	0.5	16.85	20.0	74.0	0.0	26.0
06/19/07	1400	38	0.2	4.7	0.4	4.3	33.76	4.3	122.9	10.0	111.4
06/12/07	1230	94	0.7	5.1	1.2	10.1	85.68	7.7	53.8	12.3	107.7
06/06/07	1300	170	1.6	6.3	2.1	13.4	145.93	9.5	36.8	12.1	78.9
05/31/07	1430	121	1.3	8.3	1.1	12.2	105.69	10.7	68.7	9.3	100.7
05/22/07	1300	193	2.1	6.4	2.5	10.5	163.97	11.1	33.3	12.8	54.4
05/14/07	1330	521	4.0	24.9	6.4	10.4	432.17	7.8	47.8	12.3	20.0
05/03/07	1300	1098	8.6	13.1	14.8	34.0	910.97	7.9	11.9	13.5	31.0
04/23/07	1230	32	0.4	0.1	0.2	-0.5	27.05	12.9	2.9	5.7	-14.3
04/09/07	1300	21	0.3	0.2	0.0	5.2	17.36	12.0	10.0	-2.0	248.0
06/26/06	1230	25	1.1	0.9	0.4	5.8	19.87	44.0	36.0	16.0	232.0
06/19/06	1300	68	0.6	4.3	0.8	2.5	57.53	8.9	62.2	11.1	36.7
06/13/06	1300	193	2.9	-6.1	3.1	20.4	166.32	14.7	-31.6	15.8	105.3
06/05/06	1330	267	1.6	3.3	3.6	8.9	221.77	5.8	12.5	13.3	33.3
05/31/06	1400	185	2.6	13.4	3.8	20.6	159.46	13.9	72.2	20.6	111.1
05/16/06	1300	590	2.6	13.5	6.6	29.5	459.88	4.4	22.9	11.3	50.0
05/02/06	1330	286	5.0	9.1	4.3	21.7	237.11	17.6	32.0	15.2	76.0
04/19/06	1230	189	2.5	0.9	3.2	9.0	168.29	13.3	4.8	17.1	47.6
04/05/06	1400	168	1.7	-0.4	2.2	-1.3	132.68	10.3	-2.6	12.8	-7.7

Clark Fork above Missoula MT - Station 12340500													
Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/16/08	1630	2.6426E+10	4.6	8.9	4.7	38.4	0.19	5.66	4.8	67.4	54	89	2600
06/10/08	1700	2.5692E+10	4.7	7.7	3.9	29.5	0.08	5.02	5	50.1	53	80	2270
06/02/08	1445	3.2788E+10	3.2	6.1	3	29.9	0.12	5.06	5.5	55.6	47	146	5280
05/27/08	1600	3.4745E+10	3.3	9.2	4.1	66.6	0.17	9.45	5.5	100	48	272	10400
05/23/08	1515	3.5479E+10	2.8	13.0	3.9	107	0.18	15.5	5.9	184	37	334	13100
05/19/08	1530	3.6213E+10	3.6	26.0	5.2	310	.45	45.6	6.8	541	36	1060	42400
05/12/08	1500	1.5293E+10	3.5	10.1	2.4	95.8	0.31	14.9	2.4	134	21	333	5620
05/05/08	1515	1.1353E+10	5.2	22.5	4.5	349	0.83	53.5	4.2	444	25	557	6980
04/29/08	1530	7.7565E+09	5	16.4	4.1	205	0.41	30.6	7.3	289	36	325	2780
04/22/08	1510	5.7501E+09	4.1	9.9	2.5	104	0.21	16.1	3.4	143	39	147	933
04/16/08	1600	6.1416E+09	6	20.8	4.9	182	0.33	32	5.5	258	55	247	1670
04/08/08	1600	2.8383E+09	5.9	11.5	3.6	126	0.4	20.5	3.6	170	84	87	272
03/31/08	1500	2.6915E+09	6.4	19.7	4.2	303	0.64	42.5	6.4	404	84	127	377
03/24/08	1530	2.8873E+09	6.3	9.2	7	11.1	0.45	1.87	7.4	19.9	84	27	86
03/10/08	1400	2.8628E+09	3.8	4.9	2.3	8.9	0.06	1.42	3.8	14.8	73	13	41
06/26/07	1300	9.9587E+09	4.5	5.4	1.8	13.5	0.06	1.69	2.6	23.1	29	40	440
06/19/07	1530	1.3189E+10	5.2	7.0	2.5	20.7	0.12	3.14	3.3	40.8	29	62	902
06/12/07	1500	1.8645E+10	6.7	12.1	4.3	58.9	0.08	9.06	3.5	104	39	160	3290
06/06/07	1430	1.7617E+10	4.1	7.2	2.3	29.5	0.12	5.05	3.2	56.5	39	93	1810
05/31/07	1630	1.5635E+10	4.5	7	2.7	26.5	0.12	4.05	2.4	45	49	62	1070
05/22/07	1430	1.8547E+10	2.4	4	1.8	15.4	0.12	2.47	2.4	25.3	47	51	1040
05/14/07	1500	2.1752E+10	2.6	4.9	2.1	22.9	0.12	3.99	2.5	47	34	126	3020
05/03/07	1530	2.0945E+10	2.4	8.1	2.0	30.4	0.07	6.53	2.9	52.8	28	281	6490
04/23/07	1430	7.3650E+09	3.6	6.1	2.2	25.4	0.07	4.39	2.2	54.4	42	68	553
04/09/07	1500	6.8512E+09	2.9	3.6	1.7	8.4	0.12	1.91	1.9	15	38	32	242
06/26/06	1400	7.4629E+09	3.2	4	1.6	17.7	0.1	1.6	2	19	61	26	214
06/19/06	1500	1.1598E+10	3.1	6.6	1.8	9.9	0.08	1.25	3.2	12	40	47	602
06/13/06	1430	1.6883E+10	4.7	8.6	3.3	42.1	0.12	6.89	2.6	91	39	117	2180
06/05/06	1500	1.6932E+10	2.5	3.4	1.9	10	0.06	1.7	1.6	18	72	38	710
05/31/06	1530	1.5342E+10	2.7	3	2	5.3	0.04	0.8	3.3	7	88	15	254
05/16/06	1500	1.9306E+10	2.1	3	2.4	8.3	0.06	1.73		14	76	40	852
05/02/06	1600	1.8425E+10	2.4	4	2.1	10.9	0.04	2.37	2	18	80	36	732
04/19/06	1430	1.3874E+10	2.5	3.6	2.5	9.7	0.07	1.82	2.9	14	87	27	413
04/05/06	1530	7.4874E+09	2.5	3.7	2.5	8.3	0.06	1.48	2.5	15	53	30	248

Clark Fork above Missoula MT - Station 12340500

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
39615	1630	2352	113.6	890.6	144.5	1654.3	1270.03	48.3	378.7	61.5	703.4
39609	1700	2055	77.1	657.7	126.9	1158.7	1089.34	37.5	320.0	61.8	563.8
39601	1445	4787	95.1	882.0	162.0	1642.7	2249.90	19.9	184.2	33.8	343.2
39595	1600	9451	205.0	2171.6	322.4	3283.4	4536.34	21.7	229.8	34.1	347.4
39591	1515	11850	361.9	3657.9	543.5	6318.9	4384.53	30.5	308.7	45.9	533.2
39587	1530	38386	811.2	11037.8	1635.0	19345.2	13819.01	21.1	287.5	42.6	504.0
39580	1500	5093	100.9	1428.3	223.1	2012.5	1069.43	19.8	280.5	43.8	395.2
39573	1515	6324	196.4	3911.2	598.0	4993.2	1580.96	31.1	618.5	94.6	789.6
39567	1530	2521	88.4	1558.3	234.2	2185.0	907.51	35.1	618.2	92.9	866.8
39560	1510	845	33.4	583.6	91.4	802.7	329.65	39.5	690.5	108.1	949.7
39554	1600	1517	90.9	1087.7	194.5	1550.8	834.33	59.9	717.0	128.2	1022.3
39546	1600	247	15.9	347.4	57.1	472.3	207.43	64.4	1406.9	231.0	1912.6
39538	1500	342	35.8	804.2	112.7	1070.2	287.13	104.7	2352.8	329.6	3130.7
39531	1530	78	8.4	11.8	4.1	36.1	65.48	107.4	151.9	52.6	463.0
39517	1400	37	3.1	18.9	3.9	31.5	27.17	84.6	507.7	104.6	846.2
39259	1300	398	9.0	116.5	16.2	204.2	115.52	22.5	292.5	40.8	512.5
39252	1530	818	23.7	240.0	39.8	494.6	237.13	29.0	293.5	48.7	604.8
39245	1500	2983	100.7	1018.0	167.4	1873.8	1163.45	33.8	341.3	56.1	628.1
39239	1430	1638	54.6	479.2	86.9	939.0	638.98	33.3	292.5	53.0	573.1
39233	1630	969	39.1	372.1	61.4	666.1	475.00	40.3	383.9	63.4	687.1
39224	1430	946	29.7	252.2	43.6	424.7	444.57	31.4	266.7	46.1	449.0
39216	1500	2741	50.0	452.5	84.2	968.0	931.88	18.3	165.1	30.7	353.2
39205	1530	5886	119.4	594.8	135.3	1045.2	1647.95	20.3	101.1	23.0	177.6
39195	1430	501	18.4	170.9	31.8	384.5	210.34	36.8	341.2	63.5	767.6
39181	1500	219	4.8	45.9	12.3	89.8	83.31	21.9	209.4	55.9	409.4
38894	1400	194	6.0	120.2	11.2	126.9	118.36	30.8	619.2	57.7	653.8
38887	1500	545	40.6	93.9	13.6	102.1	218.04	74.5	172.3	24.9	187.2
38881	1430	1975	65.8	655.1	114.3	1492.5	770.38	33.3	331.6	57.9	755.6
38873	1500	643	15.2	137.2	27.8	277.7	463.26	23.7	213.2	43.2	431.6
38868	1530	230	4.6	50.6	11.7	56.8	202.51	20.0	220.0	50.7	246.7
38853	1500	772	17.4	113.9	32.2	270.3	586.89	22.5	147.5	41.8	350.0
38839	1600	663	29.5	162.1	42.9	294.8	530.63	44.4	244.4	64.7	444.4
38826	1430	375	15.3	99.9	24.3	154.0	325.89	40.7	266.7	64.8	411.1
38812	1530	225	9.0	43.4	10.6	93.6	119.05	40.0	193.3	47.3	416.7

Bitterroot River near Missoula MT - Station 12352500

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/11/08	0730	2.0847E+10	0.35	0.48	0.89	1.2	0.05	.38	1.9	2	63	27	621
06/03/08	0745	3.0830E+10	0.31	0.55	0.91	1.8	0.06	.74	1.8	5.1	38	81	2750
05/28/08	0800	2.4053E+10	0.3	0.43	1	1.6	0.07	.51	1.2	2.8	34	68	1800
05/24/08	0745	3.0341E+10	0.31	0.47	1.2	2.7	0.14	.73	2.4	3.8	46	68	2280
05/20/08	0730	4.2086E+10	0.35	.70	1.5	4.7	0.16	1.89	7.5	8.7	30	257	11900
05/13/08	720	9.8853E+09	0.29	0.4	0.61	0.94	0.08	0.3	1.8	2.2	56	15	164
05/06/08	730	8.7108E+09	0.28	0.59	0.58	1.6	0.08	0.77	1.8	4.2	61	48	461
04/30/08	715	6.3129E+09	0.31	0.57	0.62	1.6	0.04	0.65	1.8	3.6	59	61	425
04/23/08	705	4.1596E+09	0.31	0.4	0.55	0.81	0.08	0.25	1.8	1.5	73	12	55
04/17/08	715	4.6979E+09	0.29	0.54	0.71	1.4	0.06	0.51	1.2	2.8	76	31	161
04/09/08	730	1.9232E+09	0.36	0.46	0.53	1.2	0.08	0.12	1.8	2	81	7	15
04/01/08	730	2.0382E+09	0.33	0.43	0.96	0.7	0.07	0.07	1	2	80	6	13
03/25/08	800	2.1361E+09	0.36	0.45		1.2		0.09		1	80	9	21
03/10/08	1600	1.9991E+09	0.36	0.45	0.71	1.2	0.04	0.12	1.8	2	78	5	11
06/27/07	700	5.3831E+09	0.36	0.4	0.34	0.62	0.12	0.12	0.98	1.1	80	4	24
06/20/07	700	8.6374E+09	0.35	0.37	0.47	1.03	0.12	0.15	0.74	2.10	68	7	67
06/13/07	630	1.3751E+10	0.33	0.42	0.4	0.79	0.12	0.22	0.31	1.4	39	20	303
06/07/07	700	1.7152E+10	0.28	0.34	0.24	0.83	0.12	0.28	0.83	2.2	39	32	606
06/01/07	630	1.2650E+10	0.26	0.32	0.4	0.67	0.12	0.16	0.41	1.2	48	16	223
05/23/07	700	1.6198E+10	0.31	0.34	0.62	0.92	0.12	0.25	0.97	2	32	36	643
05/15/07	730	1.9036E+10	0.27	0.32	0.66	1.3	0.12	0.42	1.6	2.9	32	68	1430
05/04/07	730	1.9085E+10	0.27	0.4	0.87	1.6	0.12	0.7	1.3	3.3	36	96	2020
04/24/07	830	5.2607E+09	0.27	0.31	0.61	0.83	0.12	0.16	0.76	1.1	73	9	52
04/10/07	0830	6.9980E+09	0.24	0.31	0.5	0.93	0.12	0.3	0.9	1.6	52	21	162
06/27/06	730	8.0501E+09	0.32	0.36	0.64	0.9	0.04	0.12	1.1	2	80	5	44
06/20/06	730	1.2234E+10	0.28	0.4	0.65	0.9	0.04	0.21	1	1	69	12	162
06/14/06	700	2.0627E+10	0.29	0.38	1.3	1.1	0.08	0.32	1.4	3	53	29	660
06/06/06	800	2.1948E+10	0.29	0.39	0.8	1.4	0.04	0.48	1.6	3	54	41	993
06/01/06	800	1.5317E+10	0.34	0.43	0.7	1.4	0.08	0.36	0.6	2	60	27	456
05/17/06	800	2.5692E+10	0.27	0.62	1.4	4	0.06	1.89	2.1	8	43	226	6410
05/03/06	745	1.4510E+10	0.27	0.48	1.3	3.7		0.49		3	53	38	608
04/20/06	800	8.1235E+09	0.28	0.44	0.8	1.1	0.08	0.27	0.8	1	68	16	143
04/06/06	900	5.3831E+09	0.26	0.63	1.2	1.9	0.06	0.88	2.4	4	76	64	380

Bitterroot River near Missoula MT - Station 12352500

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/11/08	0730	563	2.7	6.5	6.9	2.1	354.6	4.8	11.5	12.2	3.7
06/03/08	0745	2497	7.4	27.4	21.0	101.7	949.0	3.0	11.0	8.4	40.7
05/28/08	0800	1636	3.1	14.4	10.6	38.5	556.1	1.9	8.8	6.5	23.5
05/24/08	0745	2063	4.9	45.5	17.9	42.5	949.1	2.4	22.1	8.7	20.6
05/20/08	0730	10816	14.7	134.7	72.8	50.5	3244.8	1.4	12.5	6.7	4.7
05/13/08	720	148	1.1	3.3	2.2	4.0	83.0	7.3	22.0	14.7	26.7
05/06/08	730	418	2.7	8.9	6.0	20.9	255.1	6.5	21.3	14.4	50.0
04/30/08	715	385	1.6	6.2	3.9	11.4	227.2	4.3	16.1	10.0	29.5
04/23/08	705	50	0.4	1.1	0.7	-1.2	36.4	7.5	21.7	14.2	-25.0
04/17/08	715	146	1.2	3.2	2.1	7.5	110.7	8.1	22.3	14.5	51.6
04/09/08	730	13	0.2	1.3	0.1	0.4	10.9	14.3	95.7	5.7	28.6
04/01/08	730	12	0.2	-0.5	0.0	2.0	9.8	16.7	-43.3	0.0	166.7
03/25/08	800	19	0.2	2.6	0.2	2.1	15.4	10.0	133.3	10.0	111.1
03/10/08	1600	10	0.2	1.0	0.2	0.4	7.8	18.0	98.0	16.0	40.0
06/27/07	700	22	0.2	1.5	0.0	0.6	17.2	10.0	70.0	0.0	30.0
06/20/07	700	60	0.2	4.8	0.3	11.7	41.1	2.9	80.0	4.3	194.3
06/13/07	630	275	1.2	5.4	1.4	15.0	107.3	4.5	19.5	5.0	54.5
06/07/07	700	549	1.0	10.1	2.7	23.5	214.1	1.9	18.4	5.0	42.8
06/01/07	630	202	0.8	3.4	0.5	10.0	97.2	3.8	16.9	2.5	49.4
05/23/07	700	583	0.5	4.9	2.1	16.7	186.6	0.8	8.3	3.6	28.6
05/15/07	730	1294	1.0	12.2	5.7	24.7	414.2	0.7	9.4	4.4	19.1
05/04/07	730	1832	2.5	13.9	11.1	38.2	659.6	1.4	7.6	6.0	20.8
04/24/07	830	47	0.2	1.2	0.2	1.8	34.6	4.4	24.4	4.4	37.8
04/10/07	0830	147	0.5	3.0	1.3	4.9	76.4	3.3	20.5	8.6	33.3
06/27/06	730	40	0.3	2.1	0.6	7.2	32.2	8.0	52.0	16.0	180.0
06/20/06	730	147	1.5	3.1	2.1	0.0	101.3	10.0	20.8	14.2	0.0
06/14/06	700	598	1.9	-4.1	5.0	33.0	317.0	3.1	-6.9	8.3	55.2
06/06/06	800	900	2.2	13.2	9.7	30.7	485.9	2.4	14.6	10.7	34.1
06/01/06	800	414	1.4	10.7	4.3	21.4	248.1	3.3	25.9	10.4	51.9
05/17/06	800	5806	9.0	66.8	47.0	151.6	2496.7	1.5	11.5	8.1	26.1
05/03/06	745	551	3.0	34.8	7.1	43.5	292.2	5.5	63.2	12.9	78.9
04/20/06	800	130	1.3	2.4	1.5	1.6	88.4	10.0	18.8	11.9	12.5
04/06/06	900	345	2.0	3.8	4.4	8.6	261.8	5.8	10.9	12.8	25.0

Clark Fork at St. Regis MT - Station 12354500

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/11/08	1315	6.0682E+10	2.6	4.2	3	16.5	0.11	2.82	3.7	28.0	65	68	4550
06/03/08	1230	8.4416E+10	1.8	3.6	2.7	18.6	0.09	3.50	2.7	36.1	44	170	15800
05/28/08	1300	7.7320E+10	2.3	5.2	3.7	30.6	0.13	5.26	3.5	54.1	56	172	14700
05/24/08	1230	8.8087E+10	1.9	4.8	3.8	36.1	0.16	5.70	4.3	58.8	60	156	15200
05/20/08	1300	1.0350E+11	2.5	9.2	4.9	106	0.31	17.1	4.2	173	54	464	53000
05/13/08	1315	3.3767E+10	2.7	5.2	3.2	48.9	0.23	7.15	4.3	65.2	76	49	1830
05/06/08	1230	2.8139E+10	3.3	7.7	4.2	106	0.29	15.4	3.8	134	81	85	2630
04/30/08	1315	1.8572E+10	2.9	5.1	3.5	52.4	0.24	7.81	3.4	65.8	86	50	1020
04/23/08	1250	1.3874E+10	2.6	4.4	2.9	42.4	0.17	6.29	3.6	54.7	90	28	429
04/17/08	1400	1.4632E+10	5.1	11.8	4.7	127	0.35	19.2	4.6	167	92	98	1580
04/09/08	1400	6.8756E+09	3.5	4.5	5.2	24.4	0.26	3.36	3.7	25.7	91	12	91
04/01/08	1330	6.9735E+09	4.9	7.2	4.8	47.8	0.37	6.48	5.5	51.3	95	15	115
03/25/08	1400	7.3405E+09	2.4	2.8	5.3	3.3	0.34	0.52	3.8	6.4	88	7	57
03/11/08	1000	6.9246E+09	1.9	2.3	2.4	3.1	0.08	0.51	3.6	6.5	86	8	61
06/27/07	1300	1.7642E+10	2.9	2.9	2	4.5	0.12	0.46	1.6	5	83	5	97
06/20/07	1330	2.5937E+10	3.1	3.5	2	8.0	0.06	1.17	3.6	13.7	80	14	401
06/13/07	1330	3.8660E+10	3.7	5.3	3.6	21.4	0.13	3.19	5.9	31.1	71	41	1750
06/07/07	1330	4.4043E+10	2.1	3.2	2	12.6	0.12	2.23	2	21	58	49	2380
06/01/07	1300	3.6213E+10	2.4	3.2	2.1	9.7	0.12	1.62	3.6	15.3	71	23	919
05/23/07	1300	4.5267E+10	1.3	1.8	1.5	6.3	0.12	1.1	2.6	10.6	62	34	1700
05/15/07	1430	5.3341E+10	1.4	2.6	1.8	13	0.12	2.62	2.4	23.9	57	78	4590
05/04/07	1300	5.3341E+10	1.5	3.6	1.7	25.8	0.07	5.3	2.3	50.8	60	151	8890
04/24/07	1545	1.9771E+10	2	2.1	1.7	5	0.08	0.86	2.4	8.1	77	11	240
04/10/07	1430	2.0823E+10	1.5	1.7	1.5	4.5	0.07	0.72	2.5	7.6	77	12	276
06/27/06	1400	2.1239E+10	1.8	1.9	1.4	2.4	0.06	0.29	0.9	3	83	4	94
06/20/06	1400	3.2543E+10	1.7	1.9	1.3	4.5	0.07	0.72	1.7	7	82	14	503
06/14/06	1430	5.0405E+10	2.2	3.2	2.5	13.2	0.15	2.47	2.6	19	70	49	2730
06/06/06	1500	5.1873E+10	1.2	1.7	1.6	5	0.05	1.02	1.6	9	65	47	2690
06/01/06	1500	4.3554E+10	1.4	1.8	1.6	4.2	0.05	0.83	1.8	6	81	27	1300
05/17/06	1500	6.5820E+10	1.2	2.8	1.4	13.8	0.08	4.18	1.4	28	50	188	13700
05/04/06	800	4.4043E+10	1.2	2	1.7	6	0.05	1.38	2.4	11	60	42	2040
04/21/06	830	2.9852E+10	1.5	2.2	2.2	6.7	0.08	1.13	3.3	9	76	23	758
04/07/06	800	2.8873E+10	1.5	3.8	1.3	23.5	0.06	5.63	1.2	50	80	154	4910

Clark Fork at St. Regis MT - Station 12354500

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/11/08	1315	4126	97.1	819.2	164.4	1474.6	2682.1	23.5	198.5	39.9	357.4
06/03/08	1230	14351	151.9	1342.2	287.9	2819.5	6314.3	10.6	93.5	20.1	196.5
05/28/08	1300	13299	224.2	2079.9	396.7	3912.4	7447.5	16.9	156.4	29.8	294.2
05/24/08	1230	13741	255.5	2845.2	488.0	4800.7	8244.9	18.6	207.1	35.5	349.4
05/20/08	1300	48025	693.5	10464.0	1737.8	17471.1	25933.4	14.4	217.9	36.2	363.8
05/13/08	1315	1655	84.4	1543.1	233.7	2056.4	1257.5	51.0	932.7	141.2	1242.9
05/06/08	1230	2392	123.8	2864.5	425.2	3663.7	1937.4	51.8	1197.6	177.8	1531.8
04/30/08	1315	929	40.9	908.2	140.6	1158.9	798.6	44.0	978.0	151.4	1248.0
04/23/08	1250	388	25.0	548.0	84.9	708.9	349.6	64.3	1410.7	218.6	1825.0
04/17/08	1400	1434	98.0	1789.5	275.8	2376.3	1319.2	68.4	1248.0	192.3	1657.1
04/09/08	1400	83	6.9	132.0	21.3	151.3	75.1	83.3	1600.0	258.3	1833.3
04/01/08	1330	105	16.0	299.9	42.6	319.4	99.4	153.3	2866.7	407.3	3053.3
03/25/08	1400	51	2.9	-14.7	1.3	19.1	45.2	57.1	-285.7	25.7	371.4
03/11/08	1000	55	2.8	4.8	3.0	20.1	47.6	50.0	87.5	53.8	362.5
06/27/07	1300	88	0.0	44.1	6.0	60.0	73.2	0.0	500.0	68.0	680.0
06/20/07	1330	363	10.4	155.6	28.8	262.0	290.5	28.6	428.6	79.3	721.4
06/13/07	1330	1585	61.9	688.2	118.3	974.2	1125.4	39.0	434.1	74.6	614.6
06/07/07	1330	2158	48.4	466.9	92.9	836.8	1251.7	22.4	216.3	43.1	387.8
06/01/07	1300	833	29.0	275.2	54.3	423.7	591.4	34.8	330.4	65.2	508.7
05/23/07	1300	1539	22.6	217.3	44.4	362.1	954.2	14.7	141.2	28.8	235.3
05/15/07	1430	4161	64.0	597.4	133.4	1146.8	2371.6	15.4	143.6	32.1	275.6
05/04/07	1300	8055	112.0	1285.5	279.0	2587.1	4832.7	13.9	159.6	34.6	321.2
04/24/07	1545	217	2.0	65.2	15.4	112.7	167.5	9.1	300.0	70.9	518.2
04/10/07	1430	250	4.2	62.5	13.5	106.2	192.4	16.7	250.0	54.2	425.0
06/27/06	1400	85	2.1	21.2	4.9	44.6	70.5	25.0	250.0	57.5	525.0
06/20/06	1400	456	6.5	104.1	21.2	172.5	373.6	14.3	228.6	46.4	378.6
06/14/06	1430	2470	50.4	539.3	116.9	826.6	1728.9	20.4	218.4	47.3	334.7
06/06/06	1500	2438	25.9	176.4	50.3	383.9	1584.7	10.6	72.3	20.6	157.4
06/01/06	1500	1176	17.4	113.2	34.0	182.9	952.5	14.8	96.3	28.9	155.6
05/17/06	1500	12374	105.3	816.2	269.9	1750.8	6187.1	8.5	66.0	21.8	141.5
05/04/06	800	1850	35.2	189.4	58.6	378.8	1109.9	19.0	102.4	31.7	204.8
04/21/06	830	687	20.9	134.3	31.3	170.2	521.8	30.4	195.7	45.7	247.8
04/07/06	800	4446	66.4	641.0	160.8	1409.0	3557.1	14.9	144.2	36.2	316.9

Flathead River at Perma MT - Station 12388700

Date	Time	Discharge (L/day)	filtered As ug/L	unfiltered As ug/L	filtered Cu ug/L	unfiltered Cu ug/L	filtered Pb ug/L	unfiltered Pb ug/L	filtered Zn ug/L	unfiltered Zn ug/L	TSS % <63μm	[TSS] mg/L	TSS discharge tons/day
06/11/08	1100	9.0289E+10	0.39	0.57	0.58	0.62	0.04	.18	1.8	1.8	79	11	1100
06/03/08	1030	9.8853E+10	0.42	0.53	1	1.2	0.08	.15	1.8	1.8	74	10	1090
05/28/08	1000	9.2491E+10	0.41	0.54	0.61	1.2	0.08	.21	1.8	1.8	71	16	1630
05/24/08	1030	7.2916E+10	0.4	0.57	1	1.8	0.08	.31	1.8	1.8	76	24	1930
05/20/08	1100	4.6245E+10	0.41	0.49	1	1.2	0.08	.22	1.8	1.8	85	14	714
05/13/08	1030	3.3767E+10	0.39	0.45	1	1.2	0.08	0.12	1.8	2	74	8	298
05/06/08	1030	2.3123E+10	0.43	0.45	1	5.4	0.08	0.13	1.8	2	76	4	102
04/30/08	1100	2.5937E+10	0.39	0.42	1	1.2	0.08	0.09	1.9	2	85	5	143
04/23/08	1030	1.3996E+10	0.35	0.41	1	1.2	0.08	0.11	1.8	2	87	4	62
04/17/08	1200	1.3702E+10	0.4	0.52	0.88	1.2	0.05	0.1	1.8	2	77	4	60
04/09/08	1100	1.4290E+10	0.41	0.39	0.74	1.2	0.09	0.04	1.8	2	82	2	32
04/01/08	1030	1.4730E+10	0.39	0.46	1	1	0.08	0.08	1.8	2	85	2	33
03/25/08	1130	1.5195E+10	0.38	0.46	1	1.2	0.06	0.06	0.9	1	80	3	50
03/11/08	1200	1.8180E+10	0.35	0.43	1	1.2	0.08	0.08	1.8	2	70	1	20
06/27/07	1030	3.5235E+10	0.42	0.5	0.4	1.2	0.12	0.12	0.52	2	84	3	117
06/20/07	1100	4.6490E+10	0.39	0.43	0.22	1.2	0.12	0.12	0.77	2	83	4	205
06/13/07	1130	5.3831E+10	0.38	0.43	0.4	1.2	0.12	0.12	0.6	2	77	3	178
06/07/07	1100	7.9767E+10	0.4	0.47	0.4	1.2	0.12	0.25	0.36	1.1	81	15	1320
06/01/07	1030	3.6213E+10	0.37	0.43	0.4	1.2	0.12	0.07	0.67	2	79	4	160
05/23/07	1030	6.2150E+10	0.38	0.4	0.69	0.62	0.12	0.09	1	2	76	7	480
05/15/07	1130	4.5022E+10	0.46	0.46	0.46	1.2	0.12	0.12	0.71	2	75	7	348
05/04/07	1100	3.9884E+10	0.38	0.38	0.95	1.2	0.12	0.13	0.89	2	86	6	264
04/24/07	1130	3.4990E+10	0.42	0.44	0.66	1.2	0.12	0.12	0.47	2	83	3	116
04/10/07	1230	3.6458E+10	0.36	0.39	0.69	1.2	0.12	0.1	0.87	2	84	5	201
06/27/06	1100	5.0160E+10	0.38	0.51		0.5	0.05	0.09		2	81	4	221
06/20/06	1100	1.0840E+11	0.35	0.48	0.54	0.6	0.08	0.19	1.3	2	78	12	1440
06/14/06	1200	7.3405E+10	0.4	0.53	0.84	0.9	0.08	0.2	0.78	1	89	11	891
06/06/06	1200	6.1661E+10	0.42	0.42	0.6	0.6	0.08	0.09	0.9	2	80	5	340
06/01/06	1130	7.0225E+10	0.41	0.46	0.6	0.6	0.08	0.08	0.6	2	79	5	387
05/17/06	1200	6.8267E+10	0.36	0.46	0.8	0.8	0.08	0.13	2.3	2.3	77	10	753
05/03/06	1300	6.2395E+10	0.36	0.48		0.8		0.1		2	69	8	551
04/20/06	1300	2.9362E+10	0.38	0.45	0.9	0.9	0.08	0.09	1.6	2	85	5	162
04/06/06	1330	2.2071E+10	0.33	0.39	0.4	0.4	0.08	0.19	0.7	2	83	3	73

Flathead River at Perma MT - Station 12388700

Date	Time	Sed Load (1000 Kg/day)	Sed As Load (Kg/day)	Sed Cu Load (Kg/day)	Sed Pb Load (Kg/day)	Sed Zn Load (Kg/day)	% sed load <63μm	As in sed (mg/kg)	Cu in sed (mg/kg)	Pb in sed (mg/kg)	Zn in sed (mg/kg)
06/11/08	1100	993	16.3	3.6	12.6	0.0	784.61	16.4	3.6	12.7	0.0
06/03/08	1030	989	10.9	19.8	6.9	0.0	731.51	11.0	20.0	7.0	0.0
05/28/08	1000	1480	12.0	54.6	12.0	0.0	1050.70	8.1	36.9	8.1	0.0
05/24/08	1030	1750	12.4	58.3	16.8	0.0	1329.99	7.1	33.3	9.6	0.0
05/20/08	1100	647	3.7	9.2	6.5	0.0	550.32	5.7	14.3	10.0	0.0
05/13/08	1030	270	2.0	6.8	1.4	6.8	199.90	7.5	25.0	5.0	25.0
05/06/08	1030	92	0.5	101.7	1.2	4.6	70.29	5.0	1100.0	12.5	50.0
04/30/08	1100	130	0.8	5.2	0.3	2.6	110.23	6.0	40.0	2.0	20.0
04/23/08	1030	56	0.8	2.8	0.4	2.8	48.71	15.0	50.0	7.5	50.0
04/17/08	1200	55	1.6	4.4	0.7	2.7	42.20	30.0	80.0	12.5	50.0
04/09/08	1100	29	-0.3	6.6	-0.7	2.9	23.43	-10.0	230.0	-25.0	100.0
04/01/08	1030	29	1.0	0.0	0.0	2.9	25.04	35.0	0.0	0.0	100.0
03/25/08	1130	46	1.2	3.0	0.0	1.5	36.47	26.7	66.7	0.0	33.3
03/11/08	1200	18	1.5	3.6	0.0	3.6	12.73	80.0	200.0	0.0	200.0
06/27/07	1030	106	2.8	28.2	0.0	52.1	88.79	26.7	266.7	0.0	493.3
06/20/07	1100	186	1.9	45.6	0.0	57.2	154.35	10.0	245.0	0.0	307.5
06/13/07	1130	161	2.7	43.1	0.0	75.4	124.35	16.7	266.7	0.0	466.7
06/07/07	1100	1197	5.6	63.8	10.4	59.0	969.17	4.7	53.3	8.7	49.3
06/01/07	1030	145	2.2	29.0	-1.8	48.2	114.43	15.0	200.0	-12.5	332.5
05/23/07	1030	435	1.2	-4.4	-1.9	62.1	330.64	2.9	-10.0	-4.3	142.9
05/15/07	1130	315	0.0	33.3	0.0	58.1	236.37	0.0	105.7	0.0	184.3
05/04/07	1100	239	0.0	10.0	0.4	44.3	205.80	0.0	41.7	1.7	185.0
04/24/07	1130	105	0.7	18.9	0.0	53.5	87.12	6.7	180.0	0.0	510.0
04/10/07	1230	182	1.1	18.6	-0.7	41.2	153.12	6.0	102.0	-4.0	226.0
06/27/06	1100	201	6.5	25.1	2.0	100.3	162.52	32.5	125.0	10.0	500.0
06/20/06	1100	1301	14.1	6.5	11.9	75.9	1014.58	10.8	5.0	9.2	58.3
06/14/06	1200	807	9.5	4.4	8.8	16.1	718.64	11.8	5.5	10.9	20.0
06/06/06	1200	308	0.0	0.0	0.6	67.8	246.64	0.0	0.0	2.0	220.0
06/01/06	1130	351	3.5	0.0	0.0	98.3	277.39	10.0	0.0	0.0	280.0
05/17/06	1200	683	6.8	0.0	3.4	0.0	525.66	10.0	0.0	5.0	0.0
05/03/06	1300	499	7.5	49.9	6.2	124.8	344.42	15.0	100.0	12.5	250.0
04/20/06	1300	147	2.1	0.0	0.3	11.7	124.79	14.0	0.0	2.0	80.0
04/06/06	1330	66	1.3	0.0	2.4	28.7	54.96	20.0	0.0	36.7	433.3

Sediment load differences in Upper Reservoir

Eqn 5 : Bypass Channel - Turah

	Sed load	**As**	**Cu**	**Pb**	**Zn**
06/16/08	851	23	159	28	538
06/10/08	1779	54	363	61	1105
06/02/08	2306	64	576	107	1644
05/27/08	3701	115	1123	157	2162
05/23/08	7605	305	3213	383	5327
05/19/08	41024	983	11911	1977	34766
05/12/08	677	32	306	48	545
05/05/08	238	11	107	18	291
04/29/08	532	11	108	15	201
04/22/08	332	7	101	15	261
04/16/08	1434	76	389	68	1240
04/08/08	34	1	4	1	9
03/31/08	69	2.7	21.4	3.4	56
03/24/08	107.3	3.9	18.1	3.5	56.0

Sediment load differences in Lower Reservoir

Eqn 7 : Missoula - (Bypass Channel + BFR)

Date	**Sed load**	**As**	**Cu**	**Pb**	**Zn**
06/16/08	440.26	50.66	447.73	52.86	691.46
06/10/08	-762.88	-22.18	19.06	0.83	-363.52
06/02/08	450.10	-18.48	28.43	-10.74	-439.52
05/27/08	2213.08	3.37	587.99	36.06	472.61
05/23/08	1823.90	-3.93	55.31	62.55	437.08
05/19/08	-11298.12	-299.75	-1452.55	-533.72	-16303.54
05/12/08	4182.03	57.27	1073.93	161.43	1380.94
05/05/08	5805.10	175.15	3757.98	565.06	4617.08
04/29/08	1771.57	65.82	1383.86	199.70	1865.39
04/22/08	447.50	20.47	457.39	68.78	504.99
04/16/08	-406.76	-27.81	545.60	65.07	12.58
04/08/08	190.56	13.79	334.67	54.13	445.46
03/31/08	253.29	31.57	776.43	107.44	998.41
03/24/08	-58.03	2.41	-17.43	-2.06	-42.57

Sediment load differences in Total Reservoir

Eqn 6 : Missoula - (Turah + BFR)

Date	**Sed load**	**As**	**Cu**	**Pb**	**Zn**
06/16/08	1291.3	73.9	606.3	81.1	1229.2
06/10/08	1016.2	31.4	382.2	61.8	741.7
06/02/08	2756.1	45.8	604.3	96.4	1205.0
05/27/08	5913.9	118.1	1711.1	192.6	2635.1
05/23/08	9428.7	301.5	3268.3	445.4	5764.2
05/19/08	29725.7	683.7	10458.9	1443.1	18462.1
05/12/08	4859.2	89.8	1380.0	208.9	1926.0
05/05/08	6042.9	185.7	3864.6	582.9	4907.8
04/29/08	2303.6	76.5	1491.4	215.0	2066.4
04/22/08	779.6	27.3	558.7	83.8	766.4
04/16/08	1027.3	47.9	934.5	133.4	1252.2
04/08/08	224.7	14.8	338.8	54.7	454.0
03/31/08	321.8	34.2	797.8	110.9	1054.7
03/24/08	49.3	6.3	0.6	1.4	13.4
03/10/08	8.39	0.61	7.03	1.06	11.40
06/26/07	351.86	9.09	95.48	12.80	170.86
06/19/07	598.45	12.38	134.55	19.98	341.29
06/12/07	1913.09	51.16	635.75	87.01	1300.53
06/06/07	969.44	19.42	265.97	37.05	517.10
05/31/07	505.81	13.60	191.90	24.77	411.03
05/22/07	489.91	13.56	131.53	19.09	263.77
05/14/07	1850.16	28.73	303.45	49.03	769.30
05/03/07	4166.69	85.78	398.76	77.86	683.65
04/23/07	405.10	13.67	140.17	22.39	321.39
04/09/07	155.06	2.25	22.03	7.34	45.12
06/26/06	157.26	4.28	110.00	9.72	111.85
06/19/06	429.25	66.68	40.16	3.38	-12.42
06/13/06	1503.44	38.46	466.23	72.06	1236.72
06/05/06	281.80	8.13	101.04	17.32	221.57
05/31/06	-59.90	-2.38	-12.86	-1.68	-35.41
05/16/06	-57.84	6.11	51.63	13.78	149.95
05/02/06	-20.50	-1.84	35.81	5.76	72.52
04/19/06	10.28	-2.13	15.10	-0.20	36.14
04/05/06	-54.91	-0.55	-2.17	-2.68	11.48

Sediment load differences in Lower CFR

Eqn 8 : St. Regis - (Missoula + BRR)

Date	**Sed load**	**As**	**Cu**	**Pb**	**Zn**
06/11/08	1508.14	17.30509	155.0294	30.6502	313.7789
06/03/08	7066.50	49.46548	432.7887	104.9233	1075.096
05/28/08	2212.83	16.1054	-106.09	63.63469	590.5027
05/24/08	-171.77	-111.292	-858.232	-73.4446	-1560.62
05/20/08	-1177.42	-132.448	-708.485	29.95187	-1924.59
05/13/08	-3586.22	-17.6036	111.5195	8.367486	39.89341
05/06/08	-4350.15	-75.3032	-1055.6	-178.816	-1350.45
04/30/08	-1977.37	-49.2081	-656.319	-97.433	-1037.51
04/23/08	-506.72	-8.75238	-36.7076	-7.16951	-92.5227
04/17/08	-228.66	5.965415	698.5952	79.19786	817.9935
04/09/08	-177.89	-9.2114	-216.689	-35.8131	-321.421
04/01/08	-249.45	-19.9621	-503.839	-70.0594	-752.805
03/25/08	-45.80	-5.62915	-29.0823	-2.97089	-19.1417
03/11/08	8.18	-0.55918	-15.0269	-1.07578	-11.8095
06/27/07	-331.67	-9.17813	-73.9193	-10.2344	-144.817
06/20/07	-515.04	-13.5374	-89.2483	-11.2988	-244.356
06/13/07	-1673.15	-40.0642	-335.227	-50.5069	-914.573
06/07/07	-29.17	-7.1952	-22.452	3.333586	-125.679
06/01/07	-338.89	-10.8767	-100.316	-7.63294	-252.364
05/23/07	10.03	-7.52797	-39.82	-1.33011	-79.2793
05/15/07	125.33	13.02702	132.7875	43.46018	154.1049
05/04/07	336.78	-9.85101	676.7541	132.6006	1503.725
04/24/07	-330.69	-16.6459	-106.783	-16.6063	-273.55
04/10/07	-116.32	-1.12115	13.55603	0.0115	11.54668
06/27/06	-149.33	-4.16845	-101.007	-6.95345	-89.513
06/20/06	-236.32	-35.5527	7.135009	5.503451	70.41539
06/14/06	-103.67	-17.296	-111.611	-2.31031	-698.839
06/06/06	894.74	8.502797	26.04914	12.89097	75.44611
06/01/06	532.26	11.44048	51.89031	18.02348	104.7178
05/17/06	5795.60	78.9451	635.4684	190.6063	1328.957
05/04/06	635.15	2.707927	-7.57544	8.538031	40.4464
04/21/06	182.02	4.335325	32.00477	5.521802	14.53183
04/07/06	3877.28	55.43089	593.7815	145.7754	1306.788