FINAL

UBMC FLOOD PLAIN
DATA SAMPLING REPORT

PREPARED FOR
MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY

BY
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&

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June 12, 2013

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1.0 INTRODUCTION

1.1 Project Location

The Mike Horse Mine tailings impoundment is located within the Upper Blackfoot Mining Complex (UBMC) at the headwaters of the Blackfoot River. The UBMC is approximately 15 miles northeast of Lincoln Montana south of Highway 200 in Lewis and Clark County, Montana.

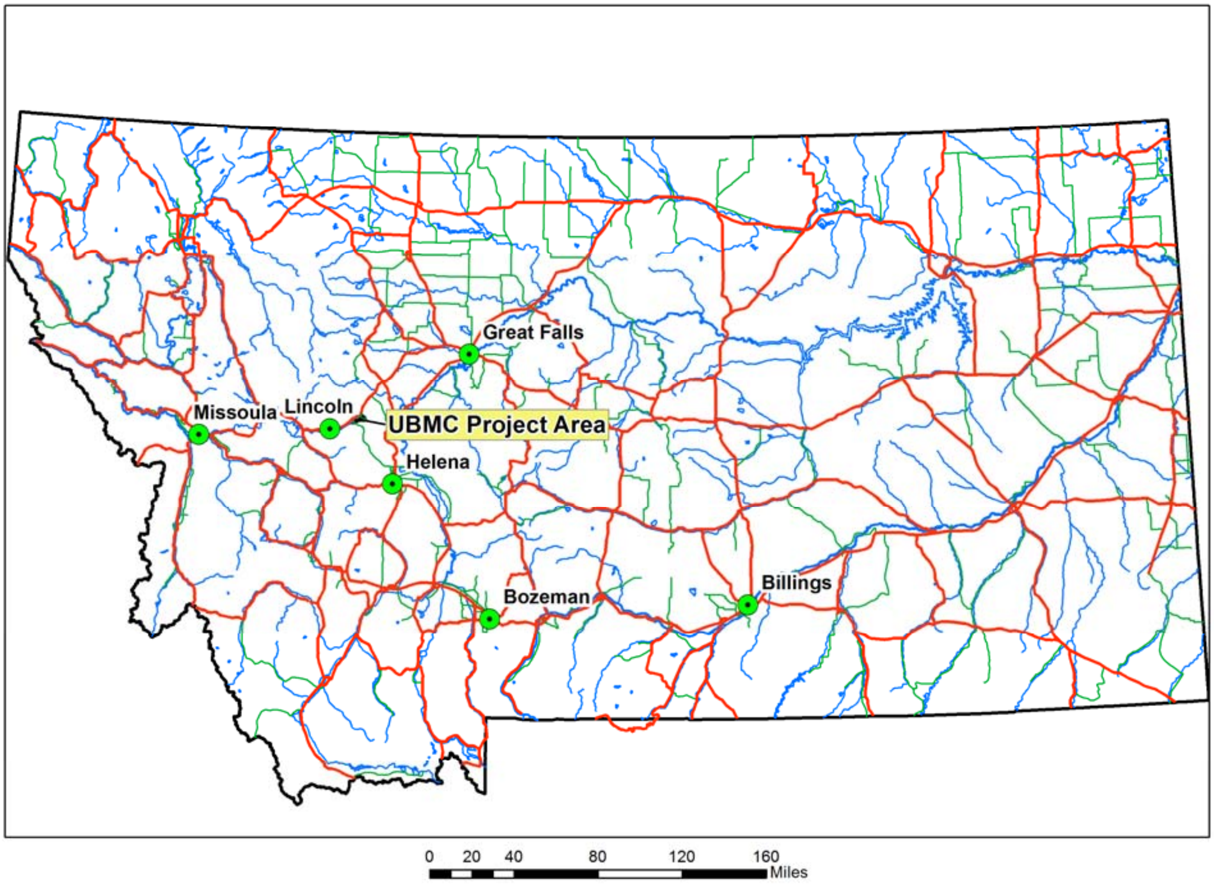

Figure 1 - Location Map

1.2 Project Description

The Montana Department of Environmental Quality (DEQ) contracted with Spectrum Engineering (Spectrum) under DEQ Contract 407040, Task Order 13, to conduct an investigation at the UBMC. The purpose of this investigation was to collect information necessary to estimate removal volumes. As required by the Task Order, Spectrum and Pioneer prepared a sampling and analysis plan (SAP) which outlined approximate sample numbers and locations, survey requirements, sample methodologies, methods of analysis, and quality assurance protocols for the investigation. (Pioneer Technical Services, 2012). The SAP included a Quality Assurance Project Plan (QAPP) and Standard Operating Procedures (SOPs) to guide the required sampling as well as a site-specific Health and Safety Plan.

The 2012 investigations included digging 134 test pits, boring 7 holes to bedrock to calibrate seismic investigations, and running 7 seismic refraction lines to determine the depth to bedrock. Seven test pits were excavated in the floodplain alluvium in order to sample the streambed gravel size distribution along the floodplain for design purposes. The other 127 test pits were aligned on transects across the floodplain and sampled from top to bottom. The samples analyzed using portable X-ray fluorescence (XRF) to determine the metals content in the -10 mesh size fraction and whether XRF would be an effective tool for field verification of removals during construction. The transects are about 750 to 1000 feet apart and range between 140 to more than 600 feet across. Four or five test pits were dug on each transect, so the spacing between the test pits along each transect varied between 50 to 150 feet. The initial plan was to collect data from 17 transects, but the new beaver dams in the marsh limited access, so test pit were dug along 13 transects. Additional test pits were “dug” in the marsh, but were not located along linear transects.

Piezometers were installed in all the test pits above the marsh to record the seasonal groundwater elevations (2 inch PVC pipe was installed in many of the marsh test pits, but since the water level is above the ground surface, these are not being monitored for water elevation). Every attempt was made to install the piezometers vertically, but it was not possible in all locations. Particularly when the sides of the test pit were actively sloughing or caving in, or when the pit had to be expanded to compensate for the instability of the sides. In these cases the slope angle of the piezometer was surveyed and incorporated into Table 1. In order to calculate the water table elevation, it is necessary to take the inclination into account as well as the slope distance from the measuring point to the water or transducer, depending on which elevation must be calculated. Trigonometry is then used to calculate the elevation by multiplying the slope distance by the cosine of the angle and subtracting it from the measuring point elevation. Recording transducers were installed in 17 piezometers (set to record every 4 hours). 17 rebar posts were embedded in concrete along the edge of the stream to measure the depth of the stream to determine the relationship between the surface and ground water elevation.

A summary showing the location and type of data collected is shown in Table 1. The locations are stored in an ArcMap file Geodatabase and an Access database. A map set showing the sample locations and the tailings thickness (6 sheets) labeled “UBMC Flood Plain 2012 Contaminated Alluvium Depth, 2012 Test Pit Locations” in in Appendix 8 and provided as a PDF file called “Map Floodplain Tailings Thickness 2012 6 maps.pdf”

1.3 Deviations from SAP

The initial plan was to collect data from 17 transects. It was only possible to collect data from 13 transects, because the 4 transects in the marsh were flooded by beaver dams. The flooding in the marsh required a change in sampling method from using an excavator to dig test pits to a manual core that was pushed through the fine sediment until refusal when it encountered gravel. To better characterize the erratic tailings deposition in the marsh, more samples were collected than initially planned. The SAP required 10% of the XRF samples to be sent to the lab for digestion and ICP analysis. Only 8.2% of the samples were replicated because the extra samples from the marsh were not replicated. This had no effect on the quality of the results.

No piezometers are being monitored in the marsh because the water level is at or above the ground, and varies depending on beaver activity. The purpose of the transects with piezometers on each transect was to correlate the groundwater and surface water elevations and to determine the minimum groundwater elevation to help define the excavation depth limits. In the marsh, the beaver activity makes this impractical.

1.3.1 Transects

Seventeen transects were designed with 4 to 6 test pits on each transect depending on the valley width. Between the time the sampling program was designed and the time it was implemented, beavers constructed dams in the marsh area that flooded the previously accessible areas, making it impossible to excavate test pits, since they would be below the water surface, and because the equipment could not easily traverse the inundated area without making a significant disturbance. Test pits were excavated as planned above the marsh, on 13 transects. Within the marsh, a manual soil sampling technique was used, where the soil sampler tube was pushed down through the sediments manually until it reached the gravels beneath the finer grained marsh sediments. The location of the marsh samples was more random in nature, depending on the water depth and access at each site.

1.3.2 Sampling Continuity

The SAP stipulated that samples should be collected continuously from the top to the bottom of the test pit. Continuous samples could not be obtained in many cases because the sides of the pits were unsafe when the depth exceeded about 4 feet, and where the sample depth was below the water table and the sides of the pit were collapsing. In these cases, the engineer/geologist could not safely enter the pit and collect the sample, so a sample was collected from the excavator bucket, or the bucket full of material was placed on the ground and then a grab sample collected from the ground.

The samples collected from the bucket and from below the water table are not continuous, and may not accurately represent the metal content of the sampled interval. When excavating under water, there is a risk of causing a jigging action that causes the denser and larger particles to settle beneath the bucket, biasing the sample.

1.3.3 Data Quality

The manmade contaminants in the floodplain are coarse mining waste that is larger than 10 mesh, stamp mill/jig tailings that are mostly coarser than 10 mesh (mostly about ¼ to ½ inch top size), and the Mike Horse mine flotation tailings that are all -100 mesh and mostly -200 mesh. The goal of the author when designing the initial version of the sampling plan was to identify the depth of man-made contamination in the flood plain by sampling and analyzing the entire particle size range in the matrix. Sampling theory (EPA, March 1999, and EPA/600/R-03/027) requires the size of the sample to vary depending on the particle size distribution, the specific gravity of the metals of interest, and the top size of the particles. Sampling alluvial gravel is notoriously difficult, especially when there is a wide difference in the specific gravity of the particles being assayed and because fluvial sorting rearranges the particles by specific gravity and size. The initial goal of the author was to determine the metal content of the entire matrix, assuming that the human contaminated matrix would have a higher metal content than the native material. This would have required measuring both the metal content of the -10 mesh and the proportion of -10 mesh in the entire matrix. The DEQ required the +10 mesh to be discarded, and to only analyze the -10 mesh. This sampling method biased the metal content of the total matrix. The amount of bias varies depending on the weight percent -10 mesh in the overall matrix. Sampling only the -10 mesh ignores the coarse contamination from the mining waste and the coarse stamp mill tailings that was dumped in the floodplain, and makes it impossible to know the metal content of the entire matrix. Fortunately, in most areas it is possible to visually discern the tailings and mining waste and stamp mill tailings.

The distribution of man-made contaminants in the floodplain is highly variable. One can stand on one side of a test pit and visually observe that the tailings contamination is a certain depth, and then go to the other side and visually observe that the depth and texture appears completely different. This rapid change within a short distance is because of the physical manner in which the mixture of tailings, colluvium from the hillside near the embankment, and other materials were swept up when the dam breached and subsequently dumped along the floodplain with the tailings and other material. This high degree of variability means that any single observation has a low confidence. The thickness of the contaminated material deposits also depends on the geometry of the surface before the 1975 event. Some of the test pits found the old channel, but most missed. This adds to the uncertainty of the depth of contamination.

Given the highly non-homogeneous nature of the floodplain deposits, the non-homogeneous manner in which fluvial action since 1975 has re-worked the deposits and segregated the minerals by specific gravity and size, and the sampling method that discarded the +10 mesh material, it is highly unlikely that any single sample is representative. A combination of the -10 mesh metal concentration and the physical description of the lithology were used in combination to estimate the depth of man made contamination along the floodplain. Given the natural accumulation of minerals in the floodplain from the surrounding heavily mineralized surroundings and the various types and sources of mining waste on can assume a wide range of mineralized particle sizes ranging from boulders to clay. Therefore, there is a good chance of encountering the nugget effect if a large mineral particle is placed against the XRF window. In this regard, during the removal process, at least 3 samples should be scanned from each location to identify and eliminate nugget effects.

The author panned a few random test pit samples using a gold pan and observed the amount of sulfide minerals that remained after the less dense non-sulfide material was washed out. In areas where there was obvious tailings contamination, a pan full of sample generated a 5-inch streak of color whereas, deeper in the test pit where the alluvium appeared undisturbed, the same size sample only produced a ½ to 1-inch streak of sulfides. The -10 mesh fraction of each sample probably contained similar metal concentrations, but the undisturbed alluvium obviously contained much less metal per ton or per cubic yard.

The purpose of this investigation was to determine how to differentiate the undisturbed from the human contaminated floodplain materials during construction removal, to calculate an estimate of the removal quantity, and to determine the low groundwater elevation for restoration purposes. In this regard, the objectives were achieved.

1.3.4 Correlation of XRF to ICP

The SAP required 10% of the XRF samples to be analyzed in a chemistry lab using acid digestion and ICP. After the first phase of sampling was completed, it became apparent that some additional samples were needed to better define the erratic tailings distribution in the marsh. No replicates of the additional marsh samples were sent for ICP analysis, so overall, replicates were analyzed using both ICP and XRF for 8.2% of the samples rather then the10% stipulated in the SAP. This had no affect on the results.

The correlation between the XRF and the ICP was acceptable for lead, zinc, iron, and copper, but not for other metals.

Table 1 Summary of 2012 Test Pit, Piezometer, and Borehole Installations

Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
SRB-01	1257233	1026285	5411.8	Bore hole for seismic calibration					
SRB-02	1256740	1027798	5347.6	Bore hole for seismic calibration					
SRB-03	1254117	1029446	5264.6	Bore hole for seismic calibration					
SRB-04	1253293	1030279	5244.6	Bore hole for seismic calibration					
SRB-05	1251900	1030697	5225.7	Bore hole for seismic calibration					
SRB-06	1250373	1031178	5196.8	Bore hole for seismic calibration					
SRB-07	1246245	1031149	5148.7	Bore hole for seismic calibration					
TP-Bulk-01	1257270.8	1026344.3	5409.0	Test Pit Bulk Sample					
TP-Bulk-02	1256810.5	1027606.9	5351.7	Test Pit with piezometer	5356.6	15°	4.9		
TP-Bulk-03	1255698.2	1028446.4	5313.1	Test Pit Bulk Sample					
TP-Bulk-04	1254465.1	1029182.8	5273.8	Test Pit with piezometer	5276.2	0°	2.3		
TP-Bulk-04A	1254401.0	1029181.0	5273.0	Test Pit Bulk Sample					
TP-Bulk-05	1252931.5	1030373.9	5239.5	Test Pit Bulk Sample					
TP-Bulk-06	1251368.5	1030242.9	5211.1	Test Pit Bulk Sample					
TP-Bulk-07	1250409.5	1030703.9	5200.8	Test Pit Bulk Sample					
TP-FP-01 East	1257029.5	1026040.9	5432.0	Test Pit					
TP-FP-01 West	1257039.5	1026050.9	5432.0	Test Pit					
TP-FP-02	1257102.5	1026135.9	5435.8	Test Pit					
TP-FP-03	1257161.3	1026267.2	5412.7	Test Pit					
TP-FP-04	1257208.9	1026254.5	5413.1	Test Pit with piezometer	5417.9	12°	4.8		
TP-FP-05	1257254.1	1026246.2	5412.1	Test Pit with piezometer	5417.1	3°	5.0		
TP-FP-06	1257286.3	1026243.9	5411.8	Test Pit with piezometer	5416.2	4°	4.3		
TP-FP-06A	1257294.9	1026240.6	5417.8	Test Pit					
TP-FP-06B	1257135.5	1026670.8	5399.5	Test Pit with piezometer	5404.7	0°	5.2		
TP-FP-07	1257034.2	1026934.1	5379.8	Test Pit with piezometer	5385.4	21°	5.5		
TP-FP-08	1257088.2	1026954.6	5378.5	Test Pit with Piezometer & Transducer	5383.3	6°	4.8	12.0	5371.4
TP-FP-09	1257106.4	1026966.2	5380.2	Test Pit with piezometer	5384.8	16°	4.7		
TP-FP-10	1257138.4	1026981.4	5379.0	Test Pit with piezometer	5383.7	35°	4.8		

Table 1 Summary of 2012 Test Pit, Piezometer, and Borehole Installations									
Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
TP-FP-10A	1257130.0	1026977.0	5377.0	Test Pit with piezometer					
TP-FP-11	1256833.0	1027428.9	5359.3	Test Pit with piezometer	5363.4	16°	4.1		
TP-FP-12	1256895.1	1027451.4	5358.8	Test Pit with piezometer	5363.1	8°	4.2		
TP-FP-13	1256925.8	1027486.5	5358.5	Test Pit with piezometer	5363.3	22°	4.9		
TP-FP-14	1256911.0	1027466.8	5358.0	Test Pit with piezometer	5363.1	7°	5.1		
TP-FP-15	1256614.8	1027809.1	5344.6	Test Pit with Piezometer & Transducer	5351.6	5°	7.0	15.4	5336.2
TP-FP-15A	1256619.8	1027814.1	5342.6	Test Pit					
TP-FP-16	1256674.1	1027826.3	5346.7	Test Pit with piezometer	5351.3	3°	4.6		
TP-FP-17	1256724.5	1027838.8	5346.8	Test Pit with piezometer	5350.5	8°	3.7		
TP-FP-18	1256780.8	1027851.5	5346.5	Test Pit with Piezometer & Transducer	5350.0	19°	3.5	14.6	5336.1
TP-FP-19	1256825.0	1027853.8	5348.0	Test Pit with piezometer	5351.7	45°	3.6		
TP-FP-19A	1256853.0	1027867.0	5349.0	Test Pit					
TP-FP-20	1256565.6	1027958.8	5340.8	Test Pit with Piezometer & Transducer	5345.9	2°	5.0	15.5	5330.3
TP-FP-21	1256610.2	1027986.2	5339.5	Test Pit with Piezometer & Transducer	5345.7	17°	6.1	11.2	5335.0
TP-FP-22	1256576.5	1028096.3	5338.3	Test Pit with piezometer	5345.9	7°	7.6		
TP-FP-25	1256293.3	1028071.6	5331.1	Test Pit with piezometer	5336.1	0°	5.0		
TP-FP-25A	1256291.0	1028064.0	5329.1	Test Pit					
TP-FP-26	1256316.3	1028120.2	5328.9	Test Pit with Piezometer & Transducer	5333.7	20°	4.8	11.9	5322.5
TP-FP-27	1256345.0	1028181.9	5332.0	Test Pit with piezometer	5337.3	10°	5.2		
TP-FP-28	1256369.9	1028234.5	5331.1	Test Pit with Piezometer & Transducer	5336.1	12°	5.0	11.2	5325.2
TP-FP-30	1255597.2	1028444.3	5313.1	Test Pit with piezometer	5318.1	8°	5.1		
TP-FP-31	1255621.7	1028496.0	5312.6	Test Pit with Piezometer & Transducer	5317.7	5°	5.1	13.3	5304.5
TP-FP-32	1255636.4	1028521.8	5311.5	Test Pit with piezometer	5317.2	7°	5.6		
TP-FP-33	1255647.9	1028553.4	5309.8	Test Pit with Piezometer & Transducer	5314.9	19°	5.1	11.0	5304.5
TP-FP-34	1254363.0	1029054.0	5281.0	Test Pit with Piezometer &Transducer	5283.6	5°	2.6	14.8	5268.8
TP-FP-35	1254309.8	1029154.1	5276.4	Test Pit with piezometer	5281.1	23°	4.7		

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Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
TP-FP-35A	1254314.0	1029158.0	5278.4	Test Pit					
TP-FP-36	1254353.2	1029190.6	5274.8	Test Pit with piezometer	5278.5	0°	3.6		
TP-FP-37	1254398.3	1029253.4	5275.2	Test Pit with Piezometer & Transducer	5279.0	0°	3.8	19.1	5259.9
TP-FP-38	1254439.2	1029306.1	5277.8	Test Pit with piezometer	5281.6	0°	3.8		
TP-FP-38A	1254442.0	1029312.0	5277.8	Test Pit					
TP-FP-38B	1254435.0	1029300.0	5277.8	Test Pit					
TP-FP-39	1254374.0	1029405.5	5276	Test Pit with piezometer					
TP-FP-39A	1254370.0	1029402.0	5276	Test Pit					
TP-FP-40	1253720.3	1029521.3	5264.3	Test Pit with piezometer	5268.8	8°	4.5		
TP-FP-41	1253712.6	1029588.6	5260.1	Test Pit with piezometer	5263.0	17°	2.9		
TP-FP-42	1253753.0	1029653.6	5259.3	Test Pit with Piezometer & Transducer	5263.2	10°	3.9	17.6	5245.9
TP-FP-43	1253787.3	1029679.6	5257.4	Test Pit with piezometer	5261.5	3°	4.2		
TP-FP-44	1253826.2	1029744.3	5258.8	Test Pit with piezometer	5262.5	4°	3.7		
TP-FP-44A	1253823.0	1029739.0	5258.8	Test Pit					
TP-FP-45	1253867.4	1029781.1	5261.3	Test Pit with piezometer	5264.8	5°	3.5		
TP-FP-45A	1253894.2	1029820.5	5261.8	Test Pit with Piezometer & Transducer	5265.1	5°	3.3	15.9	5249.3
TP-FP-46	1252680.6	1030308.5	5236.4	Test Pit with Piezometer & Transducer	5240.0	12°	3.5	11.8	5228.4
TP-FP-47	1252726.7	1030327.7	5235.5	Test Pit with piezometer	5239.7	6°	4.1		
TP-FP-48	1252852.1	1030416.0	5237.7	Test Pit with Piezometer & Transducer	5240.9	9°	3.1	14.7	5226.3
TP-FP-49	1252908.2	1030475.5	5238.8	Test Pit with piezometer	5241.7	8°	2.9		
TP-FP-50	1253005.2	1030636.1	5239.4	Test Pit with piezometer	5242.0	9°	2.6		
TP-FP-50A	1253015.2	1030675.0	5239.4	Test Pit with piezometer					
TP-FP-51	1253026.4	1030675.0	5238.9	Test Pit with piezometer	5242.3	14°	3.3		
TP-FP-51A	1253023.0	1030670.0	5238.9	Test Pit					
TP-FP-52	1251918.1	1030356.4	5221.2	Test Pit with piezometer					
TP-FP-53	1251929.5	1030397.5	5222.1	Test Pit with Piezometer & Transducer	5224.9	8°	2.8	14.4	5210.7
TP-FP-54	1251972.8	1030437.4	5222.7	Test Pit with piezometer	5226.5	6°	3.9		

Table 1 Summary of 2012 Test Pit, Piezometer, and Borehole Installations

Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
TP-FP-55	1252030.8	1030509.6	5222.6	Test Pit with Piezometer & Transducer	5226.6	13°	4.0	10.6	5216.3
TP-FP-56	1252226.7	1030693.8	5229.7	Test Pit with piezometer	5234.1	6°	4.4		
TP-FP-57	1251403.2	1030161.7	5216.1	Test Pit with piezometer	5221.1	5°	5.0		
TP-FP-58	1251336.7	1030315.3	5211.1	Test Pit with piezometer	5215.9	6°	4.8		
TP-FP-59	1251343.7	1030387.1	5213.5	Test Pit with piezometer	5216.5	8°	3.0		
TP-FP-60	1251376.2	1030584.2	5215.3	Test Pit with piezometer	5218.9	15°	3.6		
TP-MS-01	1250072.2	1030400.3	5197.7	Test Pit	5201.5	6°	3.86		
TP-MS-03	1250220.5	1030557.8	5198.0	Test Pit	5201.8	8°	3.71		
TP-MS-04	1250296.5	1030688.6	5199.1	Test Pit	5202.7	9°	3.60		
TP-MS-04A	1250318.6	1030801.3	5199.0	Test Pit	5201.3	0°	2.30		
TP-MS-05	1250643.7	1030983.2	5199.8	Test Pit	5203.9	0°	4.10		
TP-MS-06	1250682.8	1031040.4	5200.3	Test Pit	5204.5	8°	4.20		
TP-MS-07	1249168.1	1030777.5	5185.2	Test Pit	5189.5	5°	4.30		
TP-MS-08	1249590.4	1031128.8	5188.8	Test Pit	5192.8	0°	4.00		
TP-MS-09	1249646.4	1031168.3	5190.0	Test Pit	5195.1	4°	5.02		
TP-MS-100	1250551.5	1030523.4	5203.1	Test Pit					
TP-MS-101	1250353.2	1030903.7	5198.6	Test Pit					
TP-MS-102	1249916.4	1030836.8	5194.8	Test Pit					
TP-MS-103	1250128.3	1031363.8	5194.1	Test Pit					
TP-MS-104	1249739.0	1031312.8	5191.6	Test Pit					
TP-MS-105	1249464.7	1031584.5	5185.5	Test Pit					
TP-MS-106	1249633.1	1031791.1	5188.5	Test Pit					
TP-MS-107	1249289.3	1031802.4	5185.1	Test Pit					
TP-MS-108	1248897.9	1031698.2	5178.4	Test Pit					
TP-MS-109	1249091.4	1031476.2	5178.1	Test Pit					
TP-MS-10a	1249699.7	1031459.1	5189.2	Test Pit	5192.4	0	3.21		
TP-MS-10b	1249656.0	1031491.0	5188.4	Test Pit	5192.3	0	3.90		
TP-MS-10c	1249894.9	1031575.3	5190.0	Test Pit	5193.5	0	3.45		

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Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
TP-MS-10d	1249867.2	1031613.3	5189.9	Test Pit	5193.1	0	3.25		
TP-MS-110	1248475.1	1031271.3	5170.3	Test Pit					
TP-MS-111	1249899.2	1031164.5	5192.5	Test Pit					
TP-MS-112	1248848.5	1031450.6	5175.2	Test Pit					
TP-MS-113	1248335.5	1031027.0	5169.8	Test Pit					
TP-MS-114	1248234.4	1031202.8	5170.3	Test Pit					
TP-MS-115	1247938.5	1031258.8	5168.1	Test Pit					
TP-MS-116	1247853.3	1031126.8	5167.2	Test Pit					
TP-MS-117	1247592.9	1030857.7	5163.1	Test Pit					
TP-MS-118	1247248.4	1030867.7	5159.7	Test Pit					
TP-MS-119	1247711.5	1031015.2	5166.4	Test Pit					
TP-MS-11a	1249332.6	1031593.3	5183.5	Test Pit	5189.2	10	5.73		
TP-MS-11b	1249306.4	1031574.1	5181.5	Test Pit	5186.6	0	5.08		
TP-MS-11c	1249377.1	1031619.0	5183.2	Test Pit	5188.6	0	5.44		
TP-MS-12	1248846.4	1031096.1	5175.3	Test Pit	5178.5	0	3.20		
TP-MS-120	1249086.6	1031641.6	5180.9	Test Pit					
TP-MS-121	1249860.0	1031170.0	5192.0	Test Pit					
TP-MS-122	1249880.0	1031100.0	5192.0	Test Pit					
TP-MS-13	1248761.6	1031217.5	5172.5	Test Pit	5176.1	4	3.60		
TP-MS-14	1248656.9	1031319.3	5172.5	Test Pit	5176.2	6	3.65		
TP-MS-15	1248629.7	1031528.4	5175.1	Test Pit	5178.9	5	3.74		
TP-MS-16	1248109.9	1030826.4	5167.9	Test Pit	5171.6	3	3.69		
TP-MS-17	1247950.0	1030799.6	5165.3	Test Pit	5168.7	6	3.40		
TP-MS-19	1247800.4	1031265.0	5166.7	Test Pit	5170.2	5	3.45		
TP-MS-20	1247452.8	1030571.9	5165.0	Test Pit	5168.7	4	3.73		
TP-MS-21	1247270.6	1030763.2	5160.4	Test Pit	5163.7	5	3.31		
TP-MS-22	1247355.6	1030967.9	5160.9	Test Pit	5164.6	6	3.63		
TP-MS-23	1247378.2	1031059.6	5162.5	Test Pit	5165.9	8	3.40		

Table 1 Summary of 2012 Test Pit, Piezometer, and Borehole Installations

Name	X State Plain NAD83 Int'l ft.	Y State Plain NAD83 Int'l ft.	Ground Elevation NAVD88	Description	Piezometer Measuring Point Elevation	Piezo Angle from Vertical	Vertical Stickup	Slope distance to transducer	Transducer Elevation
TP-MS-24	1246796.7	1030881.4	5154.7	Test Pit	5158.8	2	4.11		
TP-MS-25	1246716.1	1030947.9	5150.7	Test Pit	5152.7	0	1.91		
TP-MS-26	1246663.5	1031024.5	5149.8	Test Pit	5152.5	0	2.73		
TP-MS-27	1246518.3	1031212.7	5151.3	Test Pit	5156.2		4.90		
TPR-01	1257180.0	1026269.1	5410.0	River gauge	5415.1		5.05		
TPR-02	1257089.9	1026934.1	5378.2	River gauge	5383.8		5.53		
TPR-03	1256920.1	1027479.2	5357.4	River gauge	5362.5		5.10		
TPR-04	1256624.0	1027808.0	5344.2	River gauge	5348.6		4.44		
TPR-05	1256554.6	1027935.0	5340.1	River gauge	5344.6		4.47		
TPR-06	1256259.4	1028081.2	5329.8	River gauge	5331.7		1.95		
TPR-07	1255677.0	1028537.5	5308.7	River gauge	5312.9		4.13		
TPR-08	1254261.2	1029228.6	5269.3	River gauge	5273.3		3.95		
TPR-09	1253798.2	1029732.9	5257.1	River gauge	5261.5		4.36		
TPR-10	1252737.6	1030392.2	5233.9	River gauge	5237.6		3.67		
TPR-11	1252277.8	1030501.3	5223.6	River gauge	5226.3		2.68		
TPR-13	1250428.0	1030748.1	5199.5	River gauge	5202.5		3.05		
TPR-14	1249839.3	1031452.7	5192.0	River gauge	5195.2		3.27		
TPR-15	1248787.8	1031381.2	5172.2	River gauge	5174.9		2.75		
TPR-16	1247876.2	1030890.9	5164.7	River gauge	5168.2		3.48		
TPR-17	1247248.5	1030986.6	5159.1	River gauge	5162.0		2.87		
TPR-18	1246193.3	1030920.8	5144.3	River gauge	5148.1	37	3.80		
TP-TS-01	1256949.8	1026068.5	5457.3	Test Pit					
TP-TS-02	1257025.0	1026101.9	5452.0	Test Pit					
TP-TS-03	1257060.1	1026185.3	5449.8	Test Pit					

This table only shows the new data collected during the 2012 field season. Additional data were collected by Hydrometrics, TetraTech, and TerraGraphics. This additional information is included in the appendices, and was merged with the new data to create the 3D modeling of the water table and the thickness and base elevation of the tailings impacted floodplain and naturally high metal alluvium in the floodplain.

2.0 RESPONSIBLE ORGANIZATIONS

2.1 Agencies (USFS And DEQ)

The U.S. Department of Agriculture/Forest Service (USFS) owns a portion of the UBMC. DEQ is implementing remedial actions at the Facility under an agreement with the USFS as well as a settlement agreement with the liable parties. The DEQ Construction Manager, Ms. Shellie Haaland, was responsible for coordinating all planning phases of the project. The USFS On-Scene Coordinator was Ms. Beth Ihle. These agency personnel provided overall project guidance, design review, construction oversight, and contractor supervision throughout the project.

Agency contact information is:

Montana Department of Environmental Quality/Remediation Division
1100 North Last Chance Gulch
P.O. Box 200901
Helena, Montana 59620-0901
Telephone: 1-406-841-5000
Fax: 1-406-841-5050

USFS's contact information is:

Helena National Forest
415 S. Front
Townsend, MT 59644
Telephone: 1- 406- 266-3425
Fax: 1-406-841-5050

2.2 Engineering and Planning

Spectrum provided engineering services for the project including planning, developing appropriate decision-making tools, coordinating subcontractors, managing the daily operation, and preparing this report. Spectrum sub-contracted suppliers and other engineering and surveying firms to complete specific aspects of the project. Don Sutton was the primary engineer in charge of the work.

Spectrum's contact information is:

Spectrum Engineering, Inc.
1413 4th Ave. North
Billings, MT 59101
Telephone: 406-259-2412
Fax: 406-259-1456

2.3 Subcontactors

2.3.1 Pioneer Technical Services

Pioneer Technical Services assisted in developing the SAP, collected all the field data and performed the XRF analyses. Pioneer also evaluated and validated the data and assisted in preparing this report.

2.3.2 Earth Stabilization

Earth Stabilization excavated the test pits.

2.3.3 DJ&A

DJ&A provided the survey control and staked out the excavation centerline and cut depths. They were able to use the new GPS technology that utilizes the Russian and European satellite constellations. The steep mountainous terrain at Mike Horse only allows a narrow window for the conventional US satellites. By using the new technology, the surveying was faster and less expensive than conventional total station surveying. This work was billed directly to DEQ.

2.3.4 Axis Drilling

Axis Drilling drilled the bore holes used to calibrate the seismic survey to determine the depth to bedrock for ground water control purposes.

2.3.5 Energy Laboratories

Energy Laboratories completed acid digestion and ICP on approximately 10% of the XRF samples for quality assurance purposes. This work was billed directly to DEQ.

3.0 MODELING METHODOLOGY

Chemical and geotechnical samples were obtained from one hundred and thirty four (134) locations along the flood plain. The samples were described using the universal soil classification system (USCS) with gallon sized samples collected for metal content using a portable X-ray fluorescence analyzer. Size analysis was obtained for each sample. In addition to the USCS classification, a layer/bed (Tailings, Undisturbed - High Metals, or Undisturbed) was defined based on the physical characteristics and metal content. Spectrum used the Carlson geologic modeling software to model the thickness and elevation of each layer type. The same software was used to model the groundwater elevation. The nomenclature used in the modeling software defines strata as the lithology (the USCS classification). The software uses the name “bed” to define the classification of contaminated, high metal, fill, etc., so these can be individually mapped and modeled.

The “beds” were classified as follows:

Tailings	Tailings included all high metal content (Pb or Zn greater than 1000 ppm) that are in the top layer of alluvium and obviously or probably associated with the 1975 flood event and lying above the layer of alluvium that is orderly and not jumbled by the flood event. This distinction is usually apparent in each test pit. Typically, but not always, the Fe is much higher in the tailings (>75,000 to 100,000 ppm) but sometimes the other metals are high and the iron is in the 50,000 ppm range which is typical of background observed in this sampling program.
Jig Tailings	During the late 1800’s and early 1900’s the sulfide minerals (Pyrite, sphalerite, and arsenopyrite were coarsely crushed using a stamp mill and then gravity concentrated using a combination of jig and tables. Jig tailings were found in the flood plain below the Mike Horse Mine, the Anaconda Mine and the Iron Hill Mine. They are typically -1/4 inch compared to -200 mesh for the flotation tailings
Undisturbed - High Metals	The Undisturbed – High metals is the alluvium that appears undisturbed by the 1975 flood event, but contains lead or zinc concentrations greater than 1000 ppm in the -10 mesh portion of the sample. This classification also includes any other material (such as a mineralized vein outcrop) that contains metals, but is not believed to be related to any human activity.
Undisturbed	This is the native undisturbed ground that has low metal content (<1,000 mg/kg lead and/or zinc). In the field, this was logged as alluvium, native, and undisturbed. It includes alluvium, colluvium, and any other lithology that was observed to be uncontaminated or undisturbed by human activity or the 1975 flood event.
Fill	Fill is man-made fill that overlies alluvium or tailings or mine waste. It was noted below the town site, where fill was pushed over jig tailings and mine waste when the town site bench was constructed, and it was noted just below Anaconda Creek where a test pit was excavated into an old roadbed. This classification is also used to describe the material that was used to fill the 1975 tailings embankment breach and to raise and cover the tailings embankment in 1980.

The data was organized in EXCEL, then imported into the geological modeling software (Carlson) allowing it to be plotted as 2D and 3D cross sections along the 13 transects. The following table is a count of the different types of entries in the table for the 2012 program. The Excel table also includes all the test pits and samples collected by previous investigations. All new and old data was used to estimate the tailings contamination depth and distribution in the floodplain.

2012 Floodplain Sampling Statistics from Excel Master Data File (some samples spanned more than one interval)			Note that in some cases a single sample spanned two different lithologic intervals. When this occurred, the same values were applied to both intervals, so there are more sample intervals than samples.
	Intervals logged	Intervals Sampled	
Tailings	501	288	
Jig Tailings	6	4	
Native	654	316	
Mine Waste	22	9	
NHM	223	111	
Fill	22	7	
Bedrock	6	2	
Total	1434	737	

The long narrow curving shape of the valley and the wide spacing of the data between each transect did not lend itself to direct computer modeling of the data without some additional interpretation between the transects. Some previous data collected by Hydrometrics and TetraTech was used, but in many instances those samples were not deep enough to determine the tailings thickness or the Undisturbed - High Metals thickness, but they did indicate that the thickness must be greater than the depth of the bottom of the test pit at each site.

To create a 3-dimensional model, the surfaces of each geologic feature must be defined as some type of array of 3 dimensional points, usually expressed as (X,Y,Z) where (X,Y) is the geographic coordinate and Z is the elevation or the value of some attribute such as the water table elevation, the ground surface, or the metal content of one of the geologic units. There are two basic methods to model geologic features. One is to model using the elevations of the data points, and the other is to model using the thickness and to subtract or add the thickness from one of the other surface elevations to calculate the elevation of the resulting surface. The best method typically depends on the data distribution and the physical characteristics of the item being modeled. In this case, the ground surface is reasonably well defined by a Lidar survey; there are detailed thickness and elevation data on each transect, but a relatively long distance between transects. Spectrum initially attempted to model the elevations of the tailings bottom, but the result did not appear accurate. Spectrum then modeled the thickness by using all the available data points, and then added or subtracted an estimate of the thickness in places that enhanced the reasonableness of the model. Given that the tailings thickness tends to vary significantly over a short distance, some adjustments were required to accommodate the changing thickness near the stream channels and to maintain the thickness around corners in the flood plain. After the site was modeled using the thickness, cross sections were created every 100 feet and the elevation of the removal base was then edited slightly to fine tune the depth of the tailings contaminated material. The removal surface model will be revised one more time after the groundwater monitoring is complete. Due to the highly variable thickness, the accuracy is estimated to be ±25%, but given the variable nature, additional sampling and test pitting is not warranted.

The 3D model can be represented as an array of regularly spaced points or grids for each surface (ground, water table, bottom of tailings, etc.), or as irregularly spaced triangles with vertices at each data point, called a TIN (triangulated irregular network). The TIN is more accurate when there are abrupt changes in the terrain (such as benches or cliffs), but the TIN requires more computing and is therefore slower when calculating the model output. Spectrum made some of the interpretations using TINS and then converted the TINS to a 10’ x 10’ grid. The grid logic tends to smooth the surfaces, and does not precisely match the data point values, but is mathematically accurate for calculating volumes.

4.0 SUMMARY OF FINDINGS

The thickness of the layer containing the Mike Horse flotation tailings varies significantly between test pits and sometimes varies radically between each side of a single test pit. This is especially noticeable in the upper reaches where a jumble of tailings, colluvium from the side hill adjacent to the impoundment, and the native floodplain alluvium were mixed together and dumped somewhat randomly along the flood plain. In some places, clods of tailings were observed, but in most cases, the tailings were well mixed into the coarser materials. In some areas scouring of the undisturbed alluvium was evident, but there appears to be more deposition than scouring, and the areas that were scoured by the initial flood event were subsequently filled with flood material as the magnitude of the event waned and seasonal flooding rearranged the flood plain sediments. Since 1975, normal spring run-off events have scoured the stream channel and some side channels and re-deposited the contaminated alluvium throughout the system, moving it downstream. By observing the shifting location of the stream channel on the air photos and contour maps since 2007, it is evident that annual spring flooding rearranges the flood plain and probably transports tailings and other materials in the flood plain further downstream each year.

While in the field, digging the test pits, the field engineers could generally observe a physical difference in the gravel characteristics and alluvium stratification between the alluvium that was obviously affected by the 1975 flood event that transported the tailings (a jumbled mix of colluvium, alluvium and tailings) and the undisturbed well stratified alluvium that did not contain visible tailings or waste rock, though in some cases has high metals concentrations (<1,000 mg/kg of lead or zinc).

4.1 Townsite Fill

The Mike Horse townsite was constructed by cutting into the hillside on the uphill side and dozing material over the edge into Mike Horse Creek to create a flat bench. The material that was dozed into the creek is covering some of the jig tailings and/or mine waste dumps that can be seen as a 1 to 2 foot thick layer of oxidized gravel at the base of the fill along the creek. Some of the fill is eroding into the creek. Test pits TP-FP-01 and TP-FP-02 show that coarse jig tailings from the initial Mike Horse milling process are present beneath the fill. TetraTech collected 6 samples (BC-01, BC-02, BC-03, MHTS-COMP 1, MHTS-COMP 2, MHTS-COMP 3) along the townsite bench that were all low in metals. Their data is tabulated in the 2013 RI in the Eco Risk and Mine Waste tables.

Some iron staining was evident at the upstream end near the top of the bench. Three test pits were excavated along the crest of the fill (TP-TS-01, 02, & 03). Some of the samples from the upper few inches of all three test pits contained over 100,000 ppm iron and over 2,000 ppm lead indicating that mineralized material may have been placed on the fill. Spectrum found some fist sized galena specimens at the down stream end of the townsite that could have been samples collected by miners, or perhaps mine waste. The test pits indicate that there is a veneer of contamination along the southwest edge of the fill, so additional sampling will be required during construction to adequately separate the material.

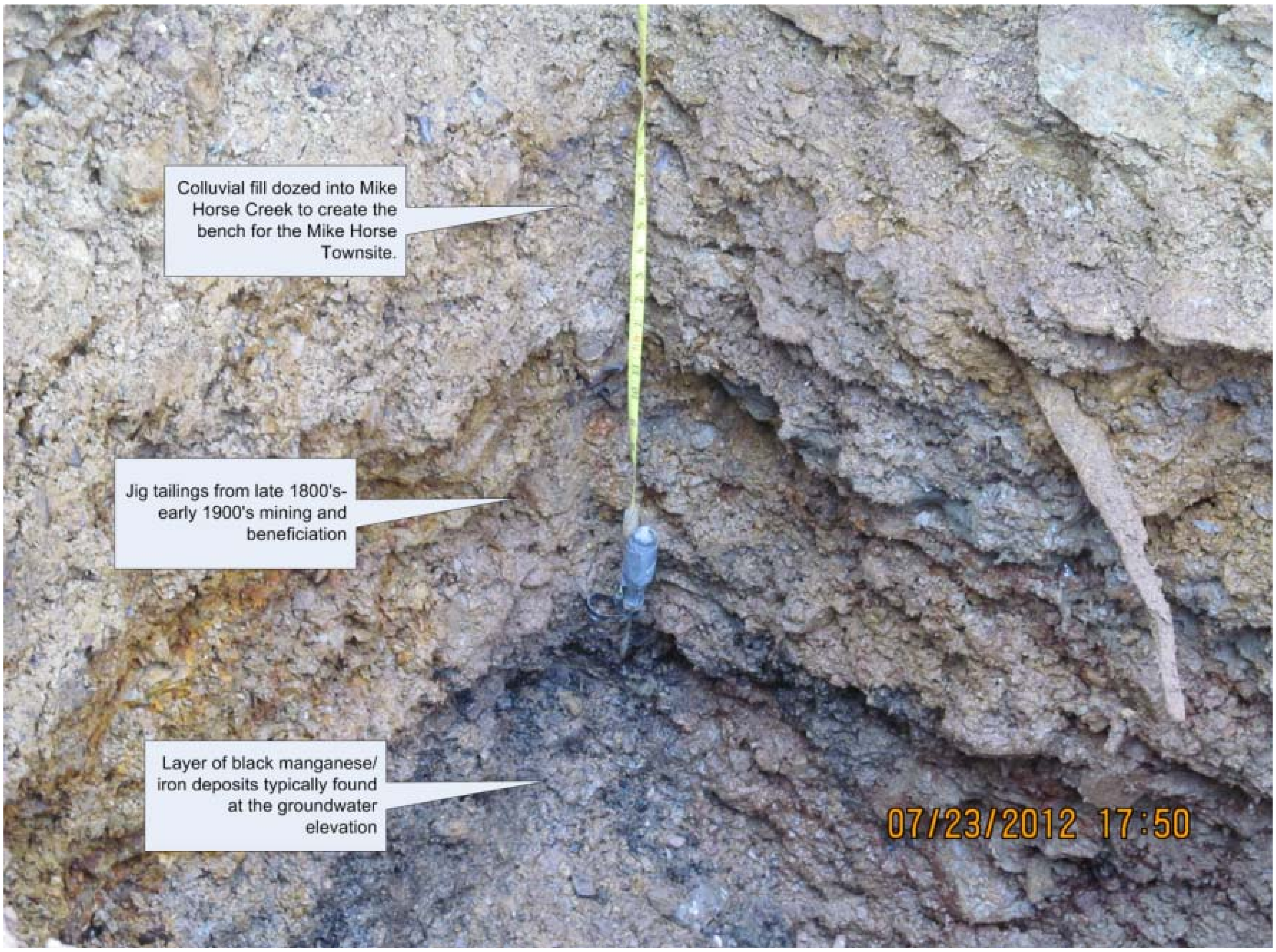


Figure 2 Test Pit showing jig tailings buried under Mike Horse townsite fill

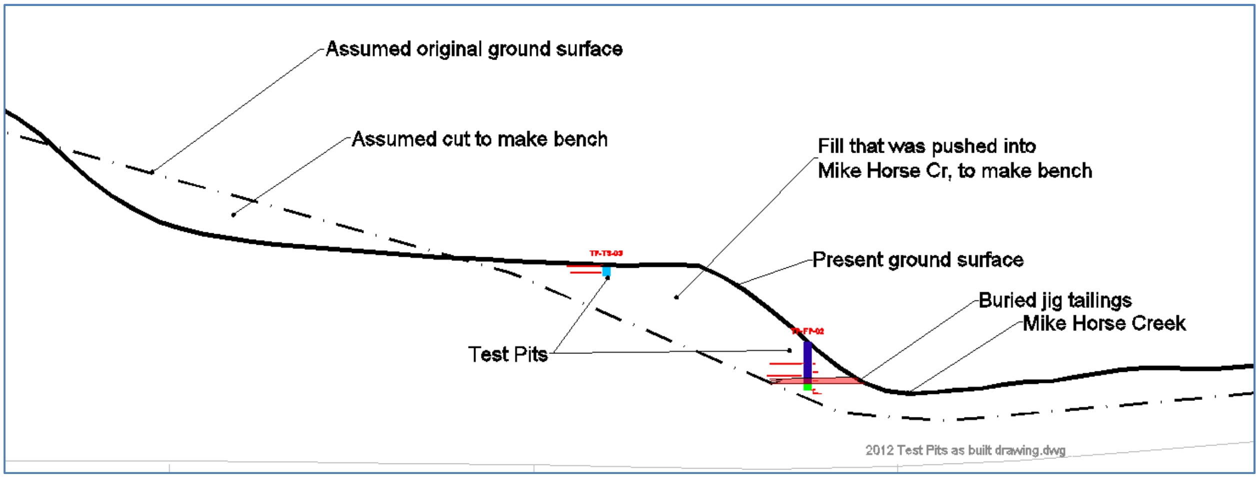


Figure 3 Cross section showing Townsite fill on top of jig tailings

4.2 Tailings distribution in flood plain

Above the marsh, the physical difference between the undisturbed alluvium and the contaminated 1975 event material is usually apparent by observing the color and texture. This physical difference is not always obvious in the marsh where the flood energy had dissipated (the tailings settled on top of the original surface, but were not mixed into the alluvium. Generally, above the marsh, the water table fluctuates up and down seasonally through the tailings contaminated zone which has oxidized the pyrite in most places, creating a rusty hue on the gravel. However, there are areas in the marsh (and a few above the marsh) where the tailings have remained inundated and have not oxidized, making visual recognition more difficult, because the color of the un-oxidized tailings is similar to the native sand/silt. In all cases, where tailings are present, sulfides (mostly pyrite) can be concentrated and observed by hand panning a sample. The sulfides are very apparent in the bottom of the pan. In the marsh, some of the black organic material did not appear to contain tailings, but did have high metals. This could be because the tailings weren't apparent, or because the organics had adsorbed the metals from the water.

The test pits excavated along the flood plain in 2012 exposed various combinations of tailings contaminated sediments (both from the 1975 flood and jig tailings); ferricrete deposits that may have predated human activity (but may also be accreting due to human activity); zones containing elevated zinc and sometimes elevated copper that appears to be in undisturbed alluvium; zones that have iron staining and elevated metals that appear in both undisturbed alluvium and tailings contaminated alluvium; and undisturbed alluvium/colluvium with low metal content. The distinction between undisturbed and human related iron staining and metal concentrations is usually, but not always visually apparent.

4.3 Determination of Groundwater Depth

The groundwater level in the test pits was observed to be 2 to 10 feet below the bottom of Anaconda Creek and the Upper Blackfoot River throughout many portions of the 9 transects above the marsh. On November 7, 2012, the water level in each of the piezometers that were installed in the test pits was measured, and continuous recording transducers installed in 17 piezometers. Groundwater levels are presented on the transect cross-sections in Appendix 8. These measurements confirmed the initial observations that the low groundwater level in some reaches was below the bottom of the stream channel.

4.4 Metal Concentrations Along The Floodplain

A “centerline” was drawn up the center of the flood plain beginning at the Meadow Creek bridge, and ending at the upper end of the tailings impoundment. The centerline was labeled 00+00 at Meadow Creek bridge, and 159+30 in the trench excavated at the upper end of the impoundment. The location of each test pit was tagged with the distance along the centerline. The position of each test pit relative to the centerline was determined by projecting a line from each test pit to the orthogonal intersection of the centerline. The metal concentrations for the -10 mesh fraction for each classification of alluvium (Tailings, Undisturbed - High Metals, and Undisturbed) were plotted with the y-axis representing the metal content and the X-axis the distance along the centerline. The location of the centerline in relation to the floodplain is shown in Figure 4, below.

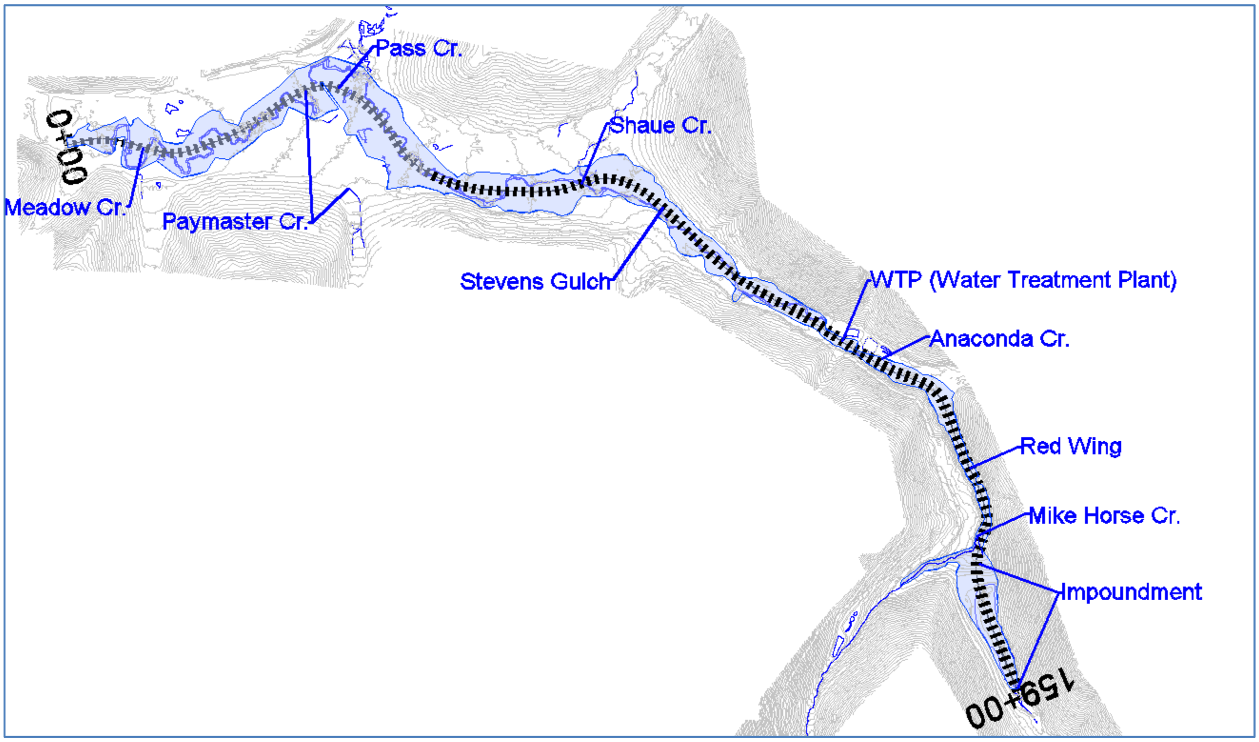


Figure 4 Illustration of centerline along the valley bottom starting at Meadow Creek bridge and ending above the tailings impoundment

Source: 2012 Test Pits as Built Jan 22 2013.dwg

4.4.1 Tailings Contaminated Alluvium Metal Content

The metal content of the -10 mesh portion of alluvium that appeared mixed with tailings, wood debris, and rocks eroded from the hillside east of the impoundment along the valley is shown below.

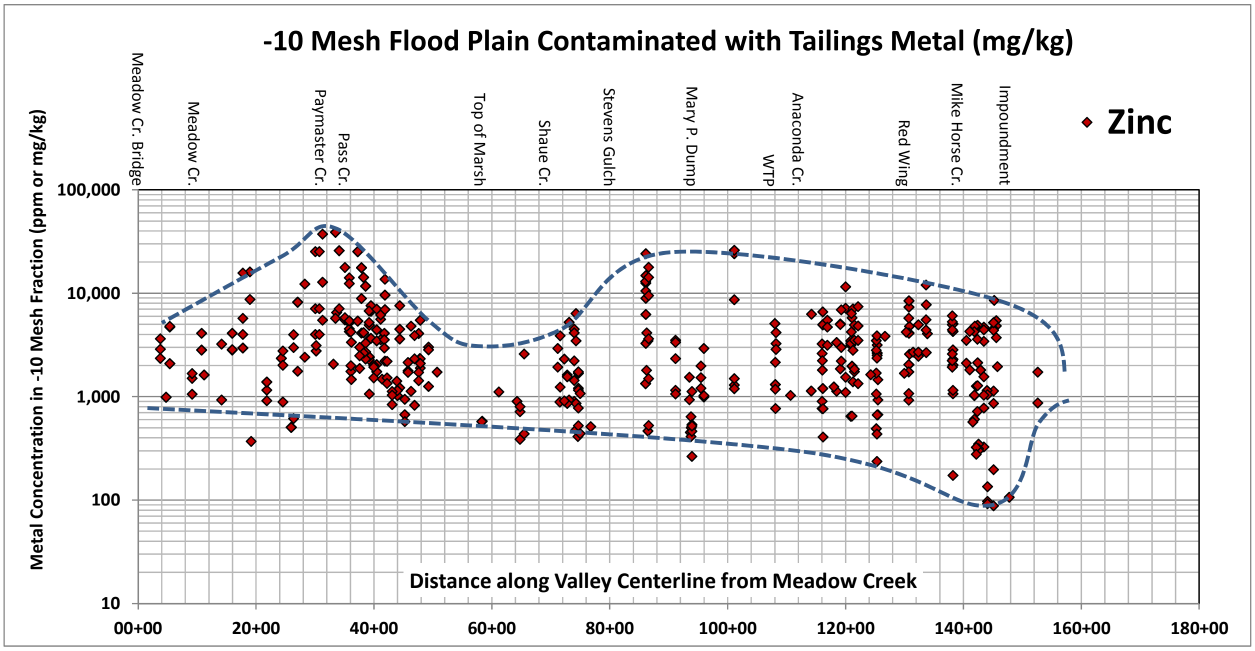


Figure 5 Zinc in contaminated -10 Mesh alluvium

Notice that the zinc appears to be increasing further downstream until Stevens Gulch, and then drops until midway through the marsh, where it increases again before dropping off at the lower end of the marsh towards the Meadow Creek Bridge. It appears that the marsh sediments are accumulating zinc.

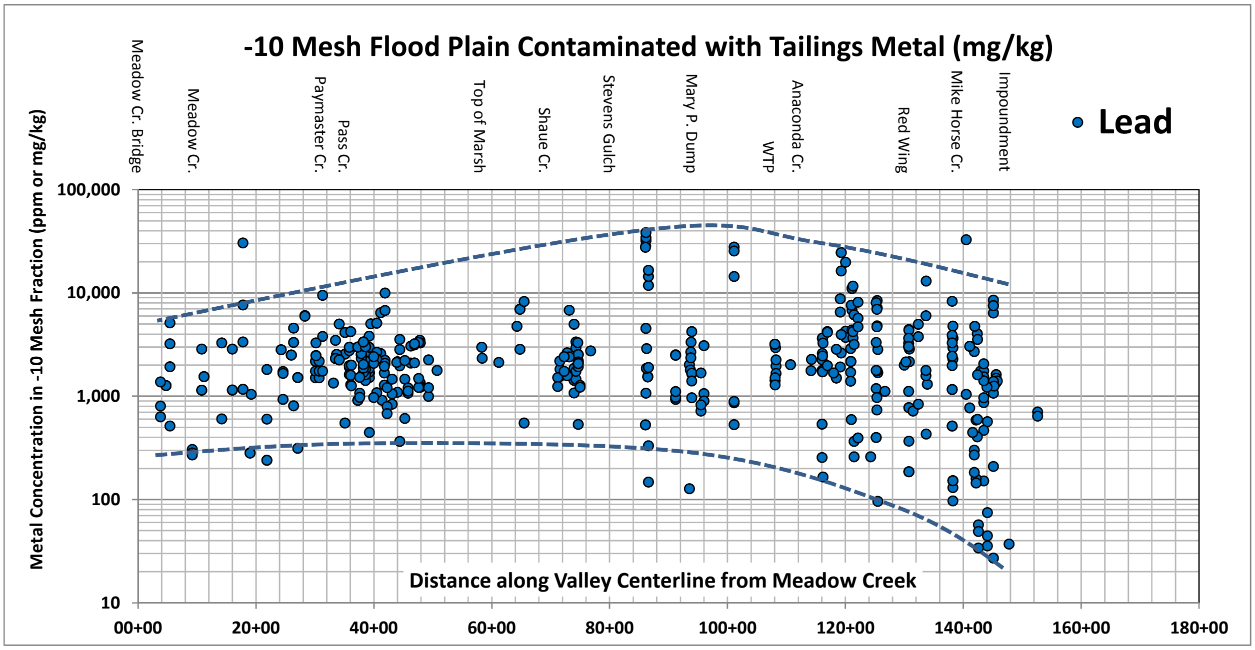


Figure 6 Lead in contaminated -10 Mesh alluvium

Notice how the lead concentration increases downstream from the impoundment. This is probably related to the denser lead settling out closer to the source. It may also be related to the waste dumps in Mike Horse Creek, and the mines downstream from Anaconda Creek.

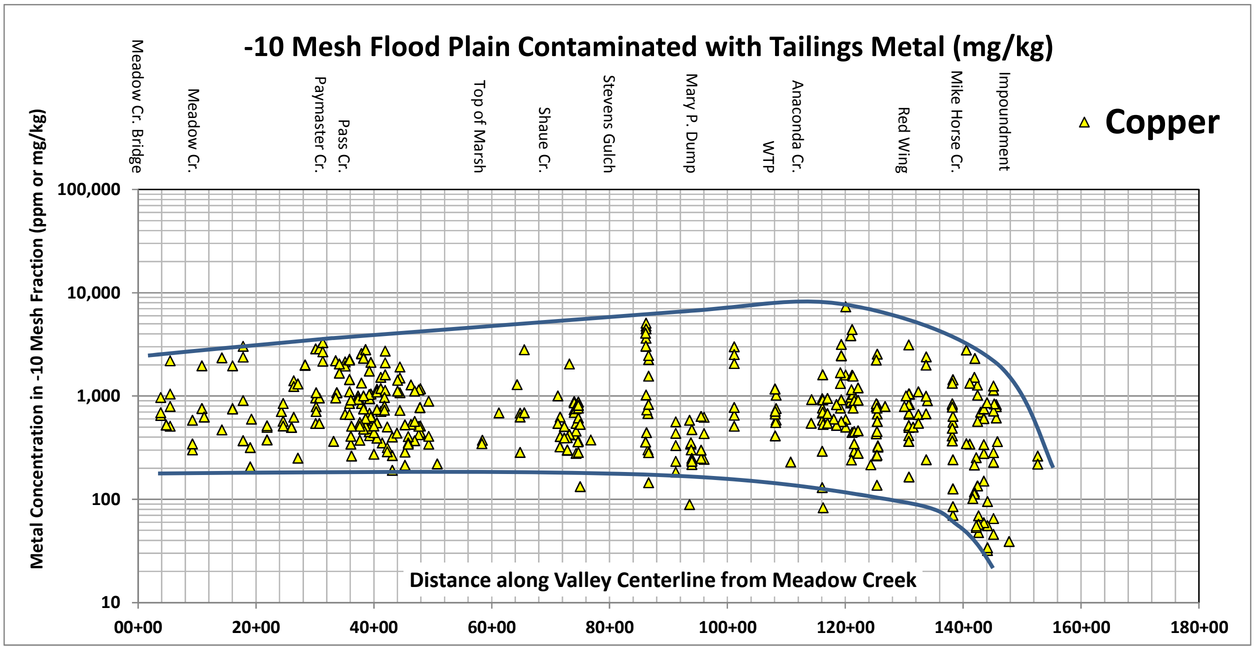


Figure 7 Copper in contaminated 10 Mesh alluvium

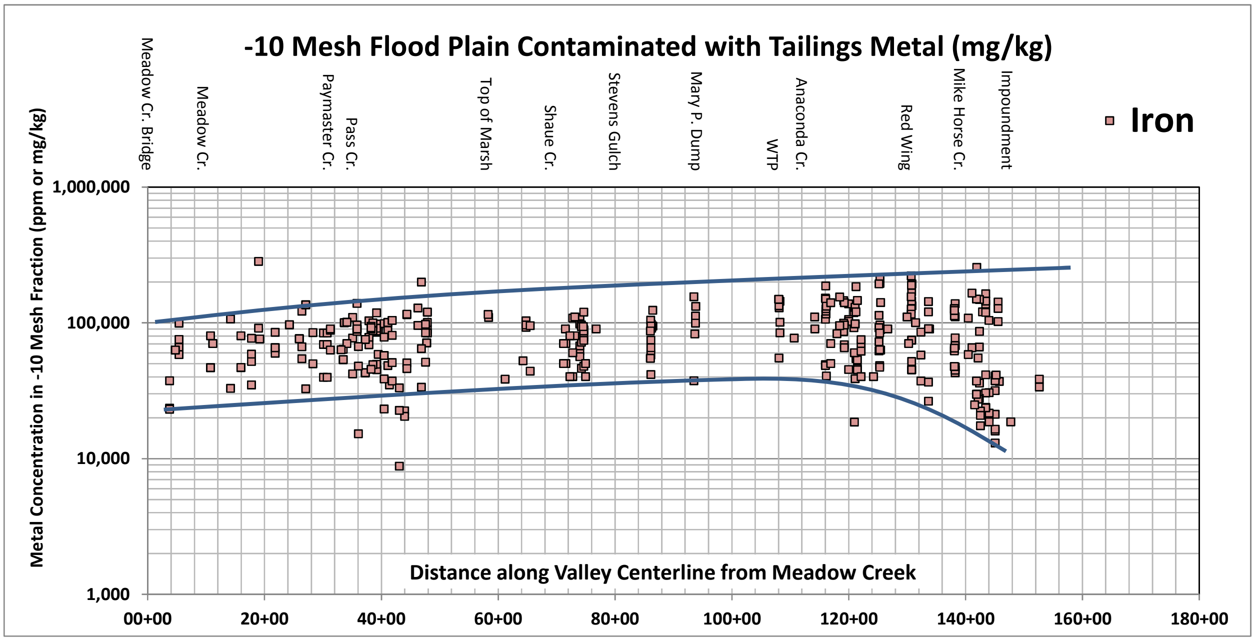


Figure 8 Iron in contaminated -10 Mesh alluvium

4.4.2 *Undisturbed - High Metals Content in -10 Mesh*

The alluvium in many samples appeared to be undisturbed by the 1975 flood event. Sometimes it is stained with iron, however, many of the samples appeared "clean", but the XRF indicated more than 1000 ppm of lead, zinc, or copper.

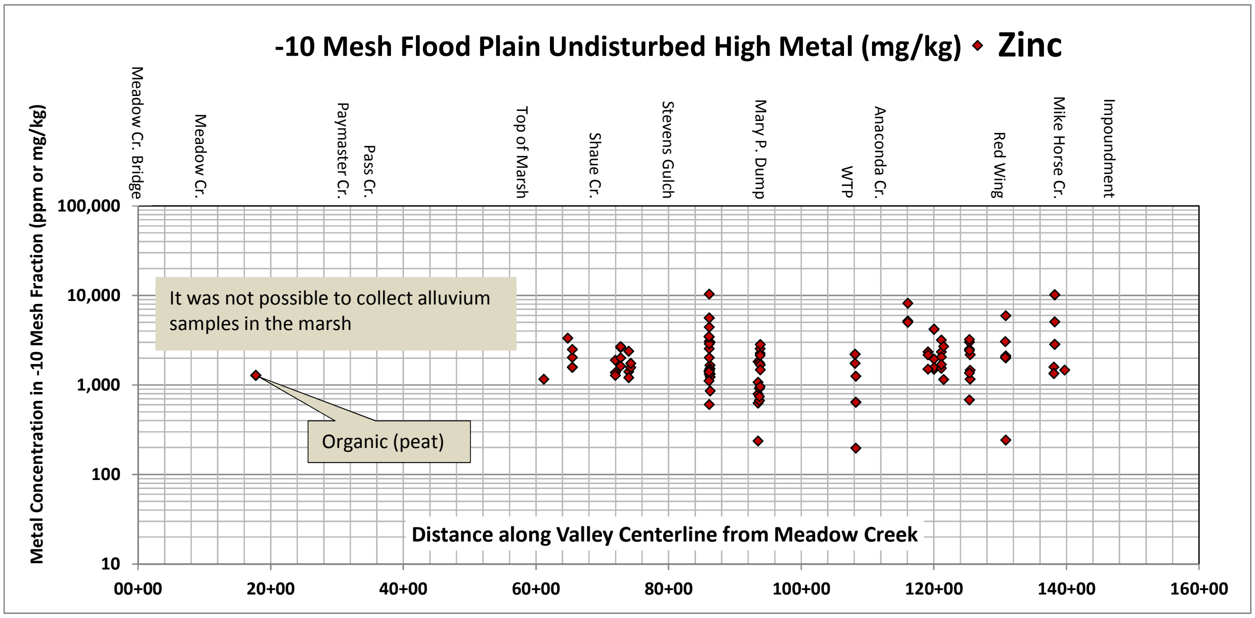


Figure 9 Zinc in Undisturbed - High Metals -10 Mesh alluvium

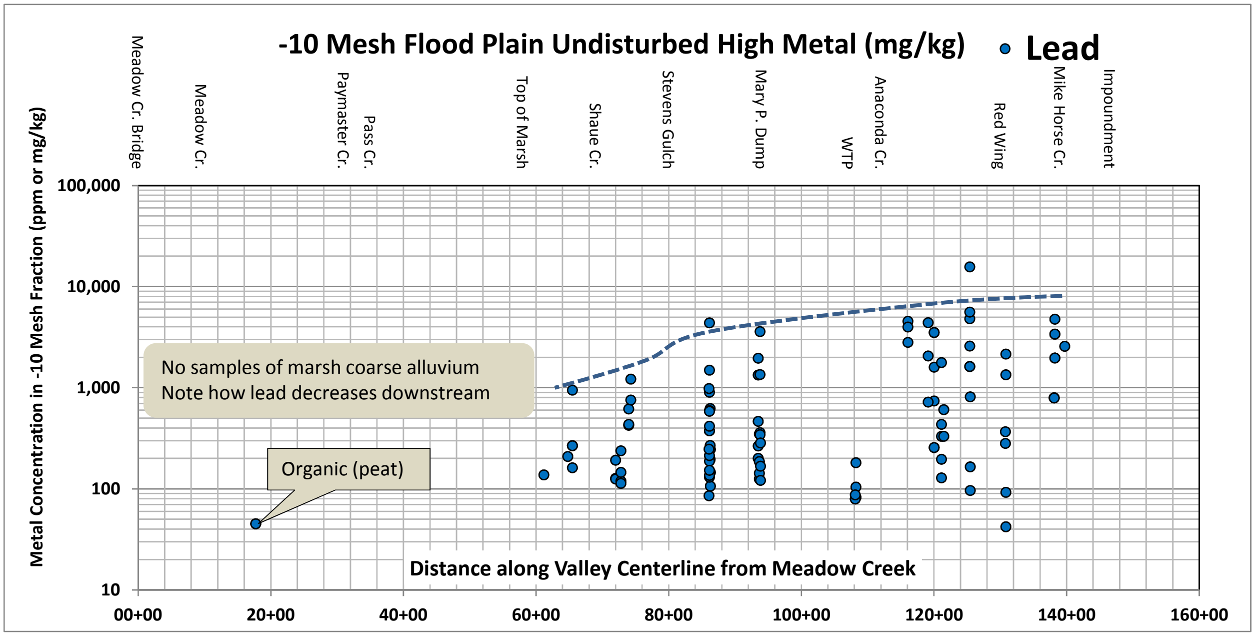


Figure 10 Lead in Undisturbed - High Metals -10 Mesh alluvium

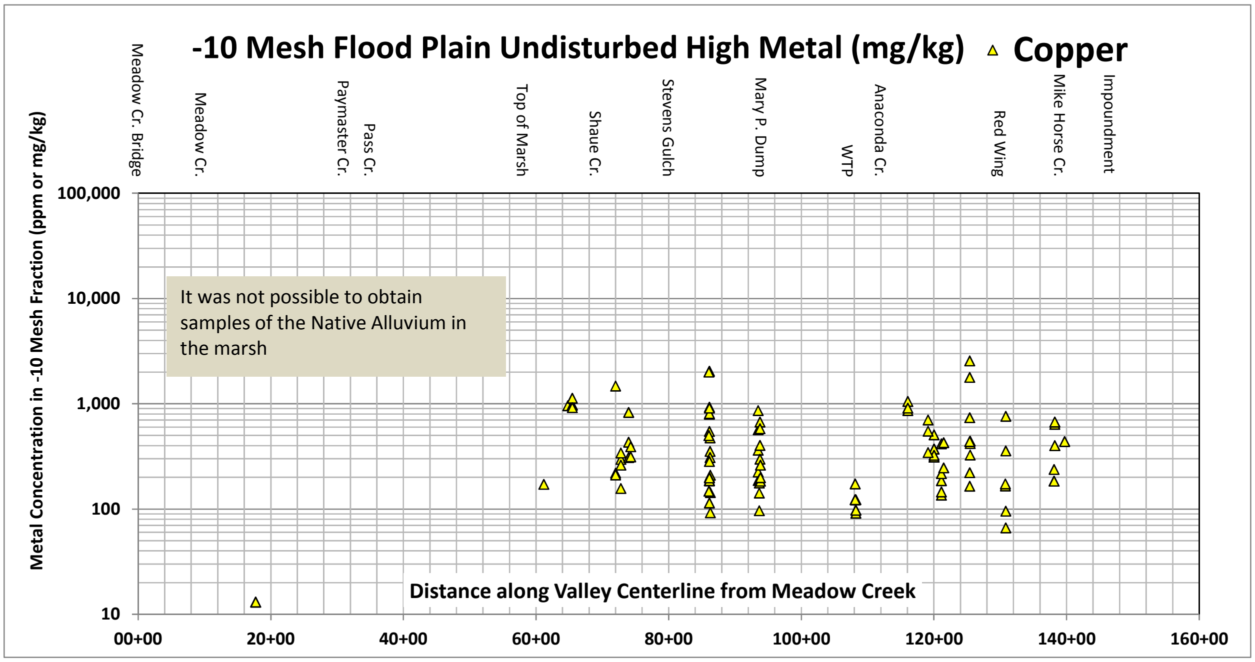


Figure 11 Copper in Undisturbed - High Metals -10 Mesh alluvium

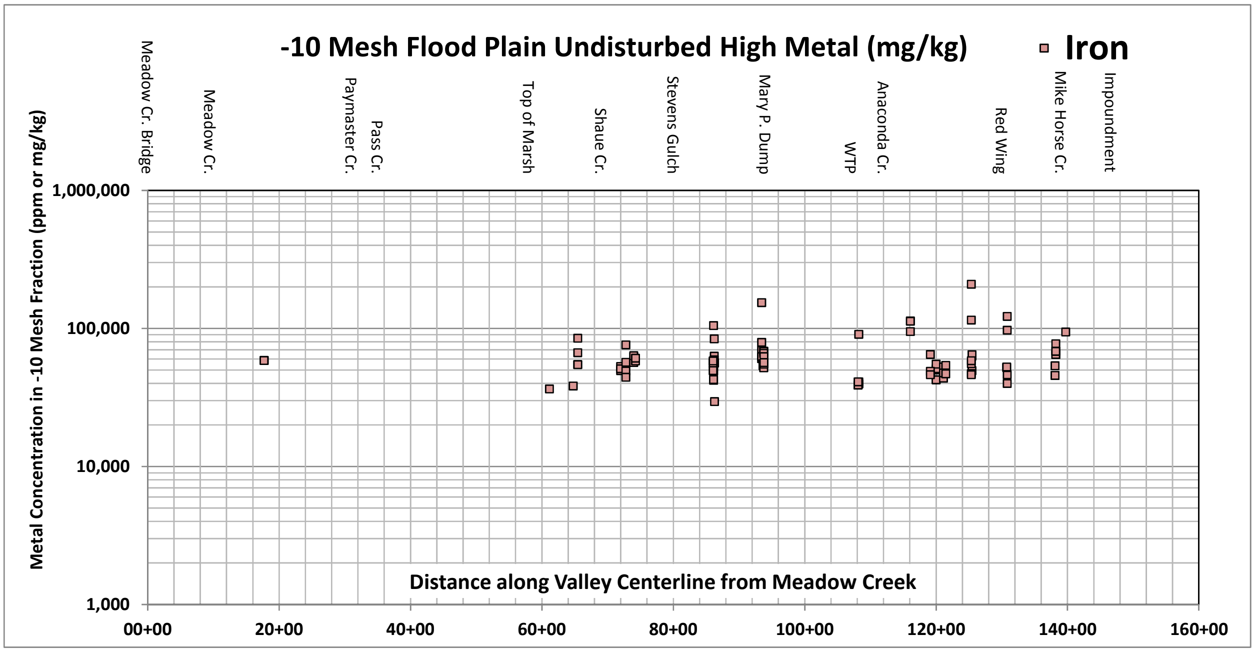


Figure 12 Iron in Undisturbed - High Metals -10 Mesh alluvium

4.4.3 Undisturbed Metal Content along Valley

Undisturbed is defined here as the stream sediments that were not disturbed by the 1975 flood and that are not iron stained and do not contain high concentrations of metals in the -10 mesh fraction. The graphs do show several samples where the metal content is greater than 1000 ppm lead or zinc, however. This is because when the data was interpreted on cross sections, the higher metal samples did not match the character of nearby High Native Metal (HNM) alluvium. The zinc concentration is highly variable.

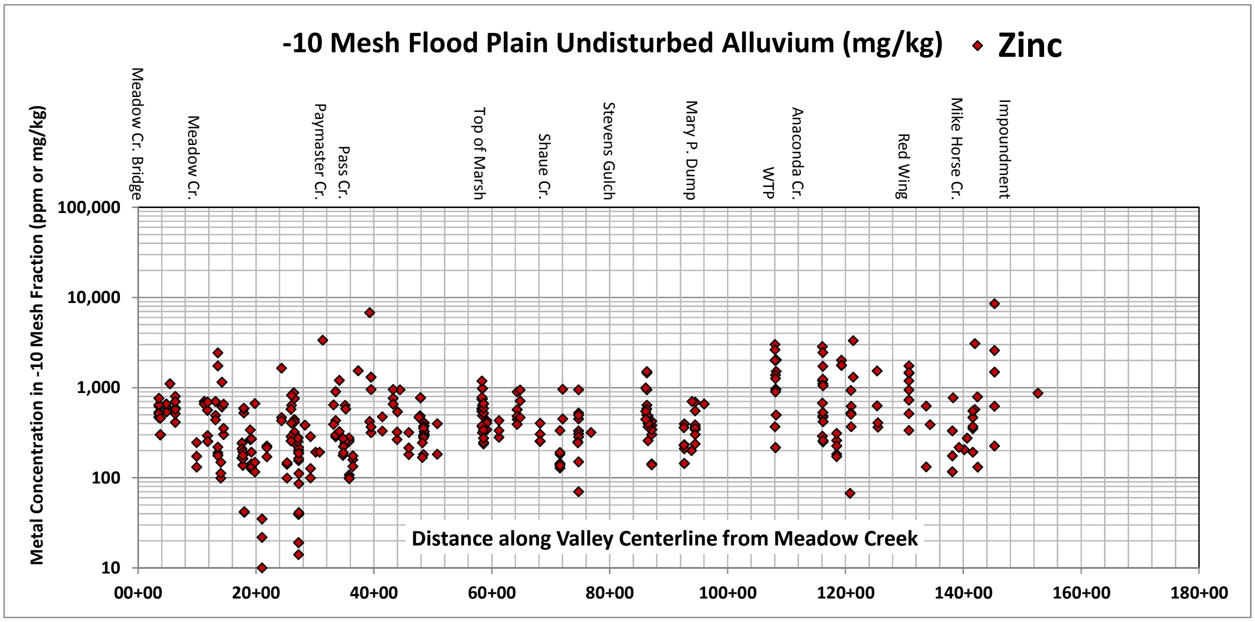


Figure 13 Zinc in Undisturbed -10 Mesh alluvium

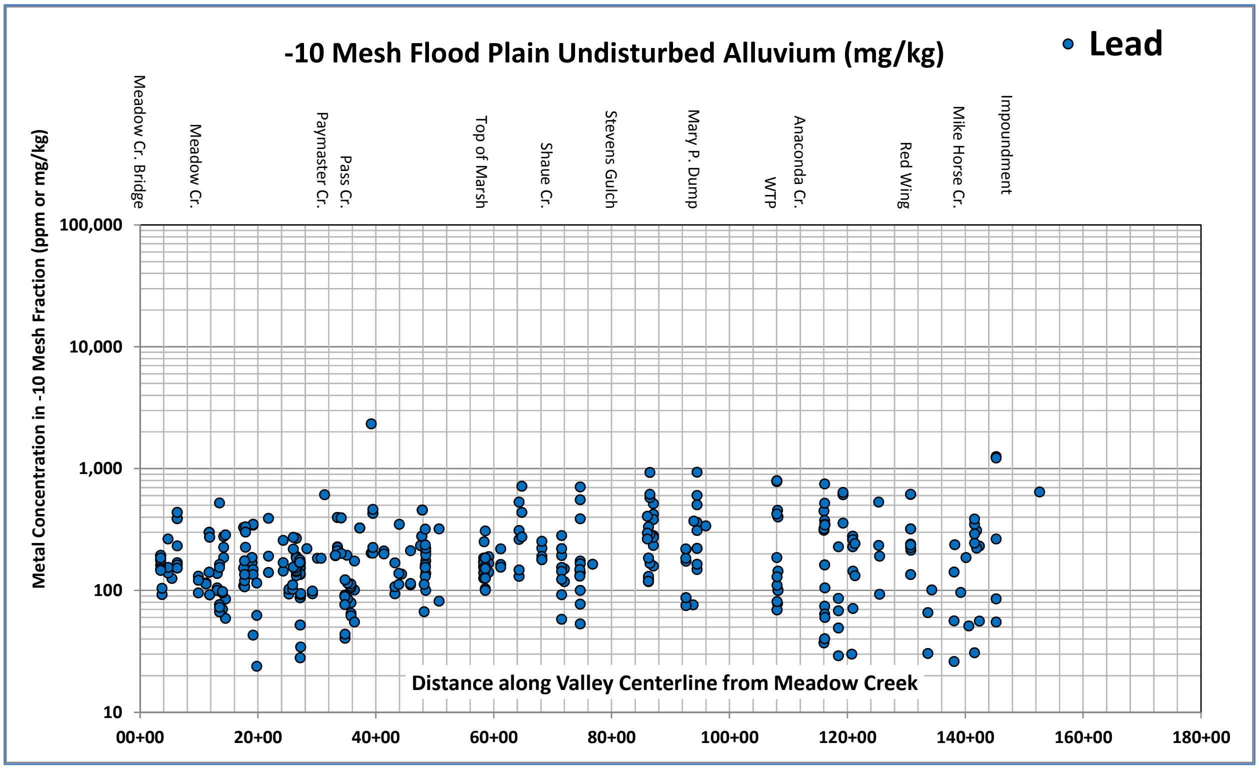


Figure 14 Lead in Undisturbed -10 Mesh alluvium

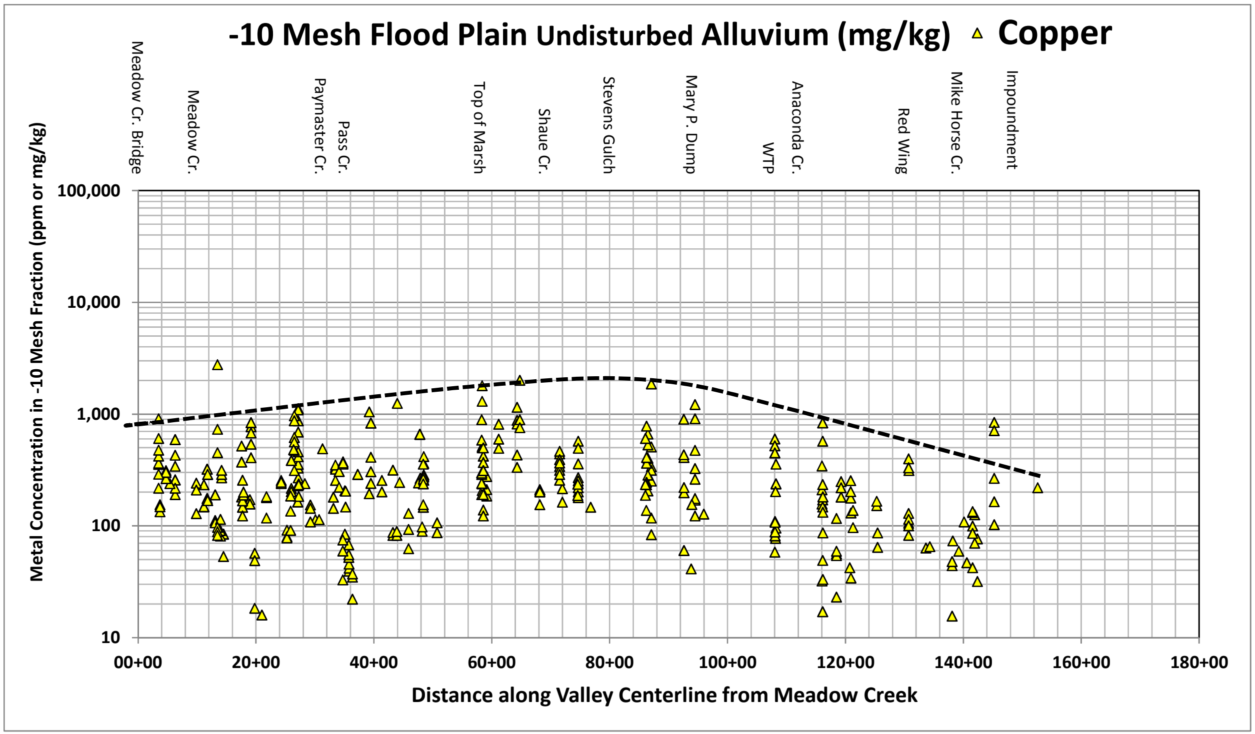


Figure 15 Copper in Undisturbed -10 Mesh alluvium

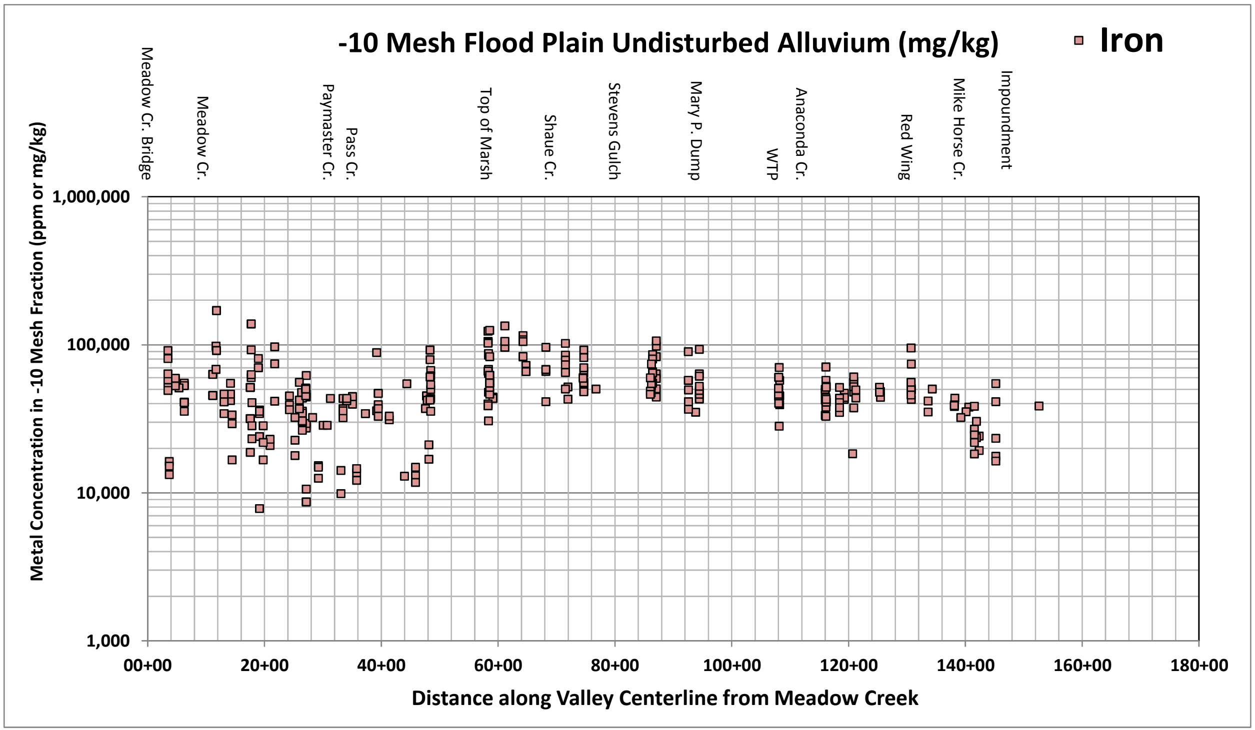


Figure 16 Iron in Undisturbed -10 Mesh alluvium

4.4.4 *Groundwater pH*

No groundwater samples were obtained during the test pitting, but the pH was monitored. Typically the pH dropped over time as the water in the test pits became oxidized. This is because the iron oxidized from ferrous to ferric, creating $Fe(OH)_3$ precipitates. With the (OH) removed, a surplus of H+ ions caused the pH to drop, because pH is the negative of the log to the base 10 of the hydrogen ion concentration. $pH=-\log_{10}(H+)$, and with the (OH) bound in the precipitates, there is a surplus of hydrogen ions.

The pH of the groundwater in each test pit was measured when the water was initially encountered, and then after the water level stabilized in the pit. The pH varied considerably. Sometimes it dropped over time, sometime it increased as shown on the following graphs.

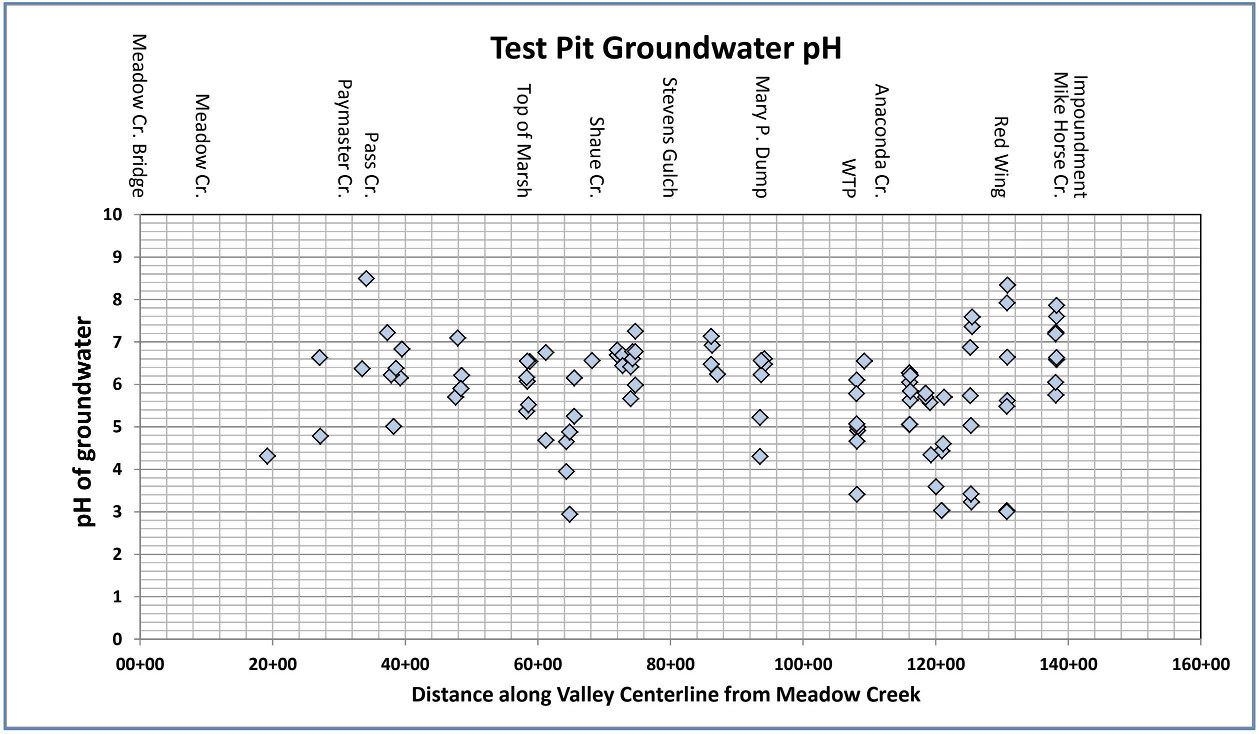


Figure 17 Test Pit Groundwater pH

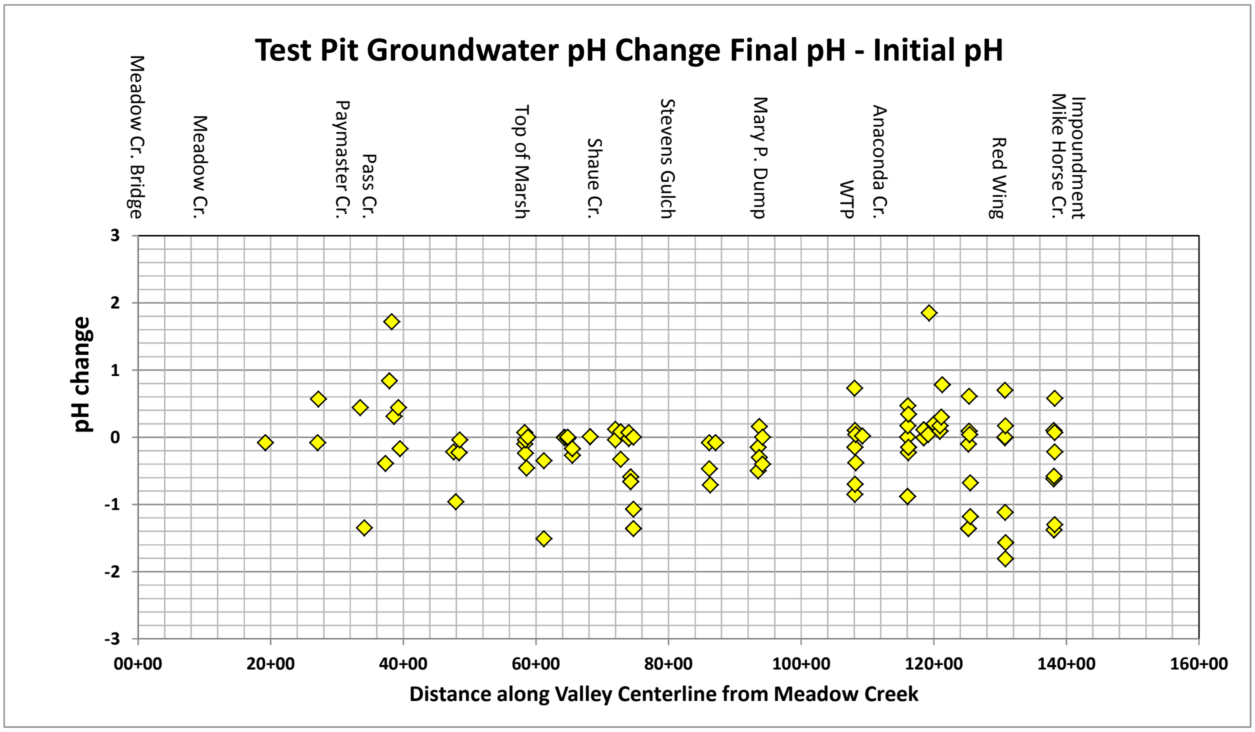


Figure 18 Change in pH in test pit groundwater

It was initially thought that the pH would drop over time as the iron oxidized. This happened most of the time, but as shown above, in some cases the pH increased.

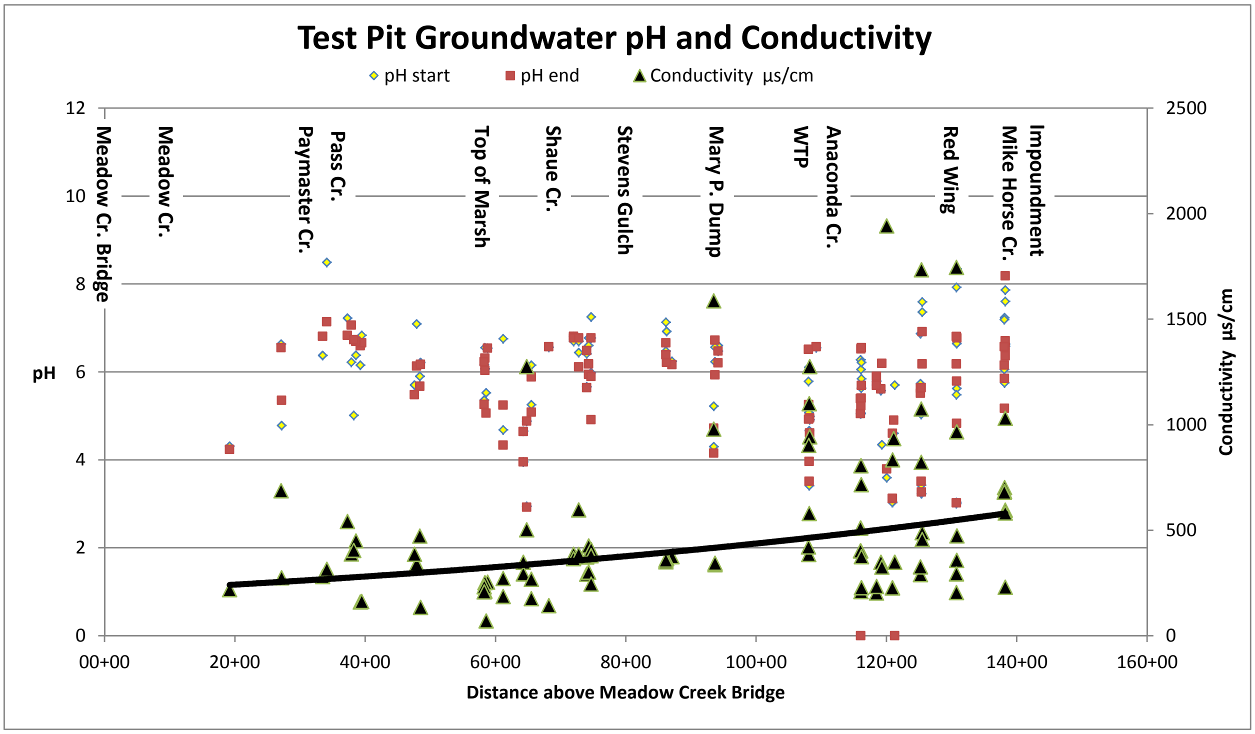


Figure 19 Test Pit Groundwater pH and Conductivity

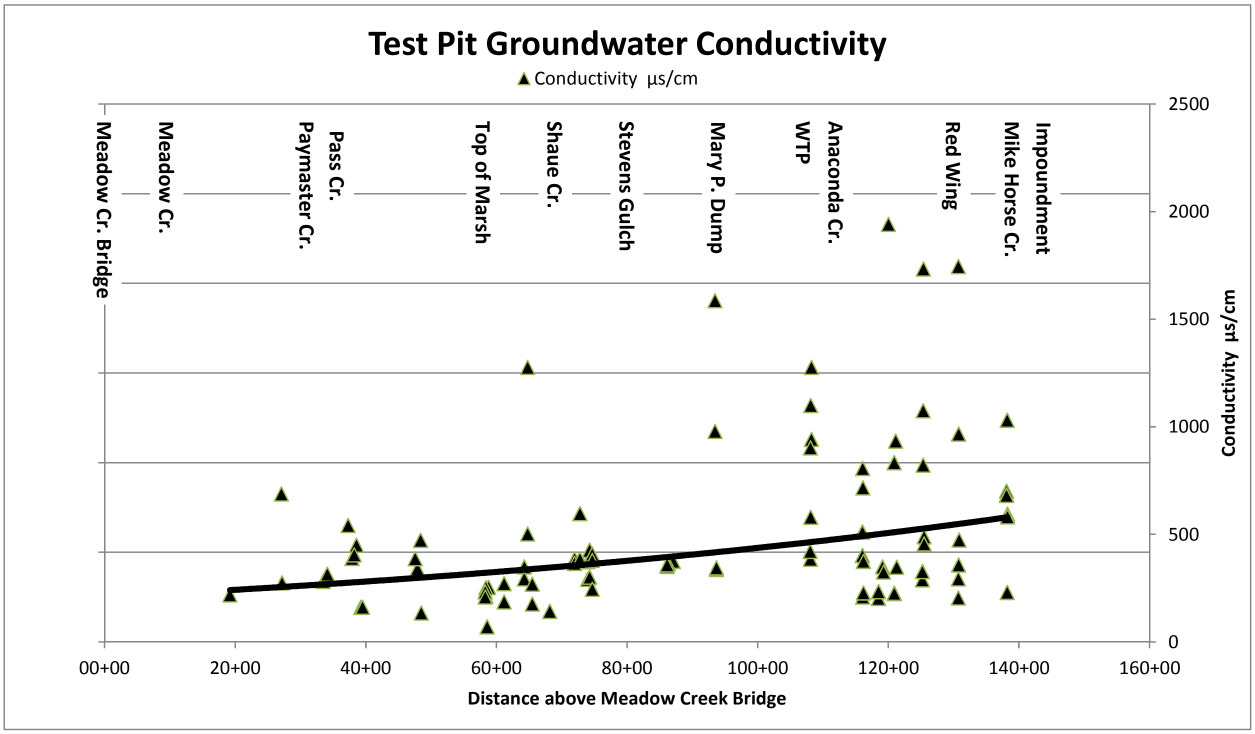


Figure 20 Test Pit Groundwater Conductivity

The solid black line represents a trend line showing that the conductivity is higher near the impoundment, dropping in the test pits further downstream, but there is a wide range of scatter. The highest conductivity occurs where the seeps are apparent near the Red Wing site. The high values near the Mary P. and just downstream from Shaue may be related to seeps or high sulfates and iron from the concentrated tailings and mine waste.

4.5 Piezometer Installation And Groundwater Depth

The elevation of the groundwater was recorded when the pits were excavated, and then rechecked on November 7, 2012. Throughout some reaches, the groundwater is 2 to 10 feet below the elevation of the bottom of the stream channel.

The low water (November 7, 2012) was observed to be present above, below and within the tailings contaminated alluvium, the undisturbed but high metal alluvium, and the undisturbed alluvium. **Error! Reference source not found.** illustrates one of the typical relationships between the low groundwater elevation and the metals in the alluvium.

The elevation of the groundwater on November 7, 2012 was modeled and plotted on the transect cross sections in Appendix 8.

4.6 Seismic Investigation To Identify Depth To Bedrock

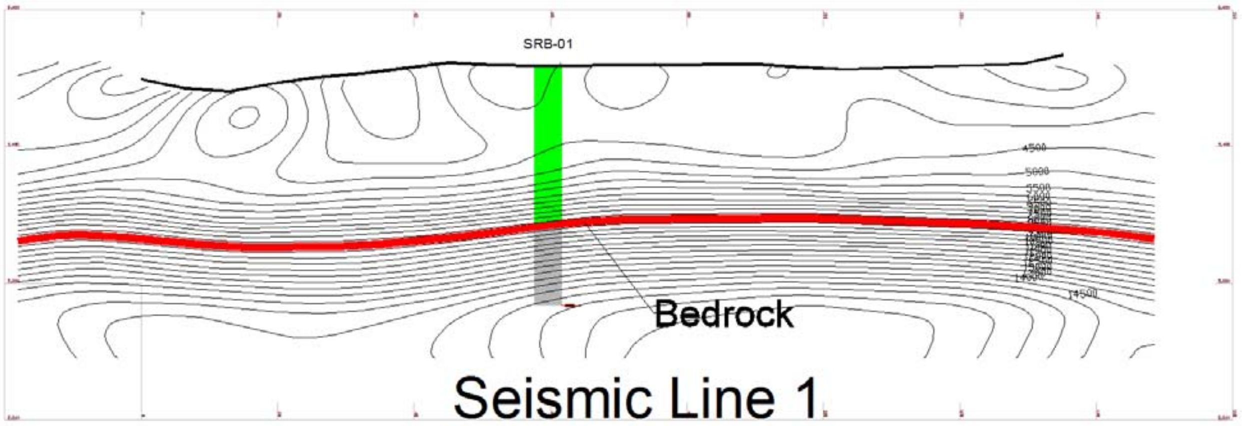
There were very few places along the flood plain where the depth to bedrock was known. One of the remediation options being considered is to manipulate the groundwater elevation in order to keep the naturally-occurring metals beneath the water table where they will not oxidize. One method of manipulating the water table is to construct a barrier from the bedrock to near the surface to force the water table up, but this is only practical if the bedrock is not too deep. The depth to the bedrock was unknown, so a program was initiated to determine the depth. The previously known data points were wells that were drilled to bedrock, but these were along the edge of the valley, not in the middle. Refraction seismic surveying was chosen as a method to determine the depth to bedrock. To calibrate the seismometer, seven borehole locations were selected where the hole was drilled down to bedrock.

Seismic lines were run at the locations shown below:

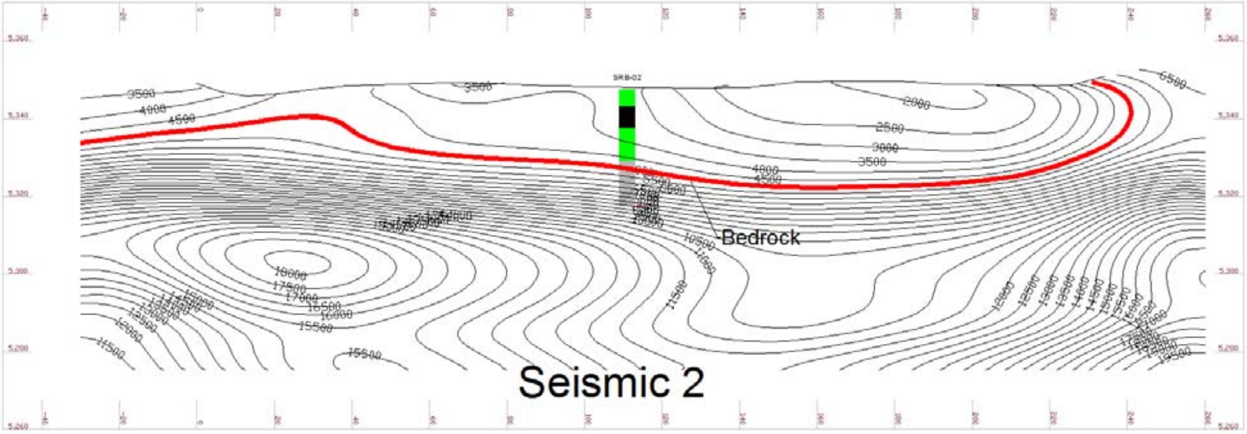
Line	Station along valley Distance from Meadow Creek Bridge	Bore hole Depth to bedrock
1	137+90	23
2	121+80	18.5
3	90+20	18.0
4	78+50	40.0
5	63+00	49.0
6	45+00	37 (on edge of valley)
7	0+80	>44 (quit in silt)

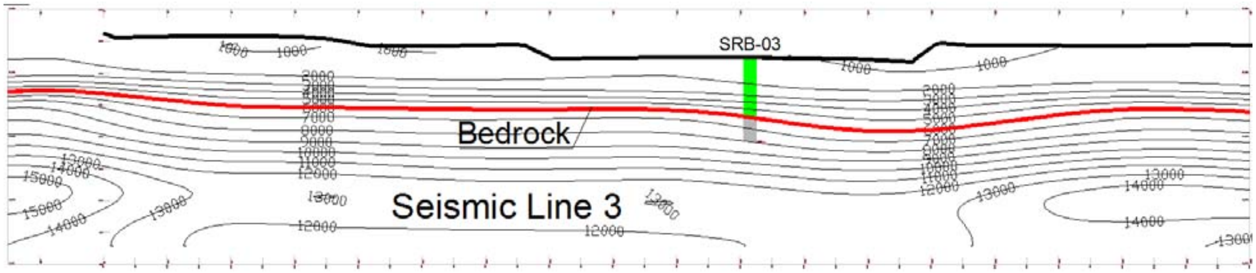
In general, the depth to bedrock was deeper than expected. The bore holes drilled in the marsh encountered what appears to be lake sediments. The borehole near the Meadow Creek bridge was terminated in elastic silt at 44 feet deep, because the drill was not equipped to drill sticky clayey material.

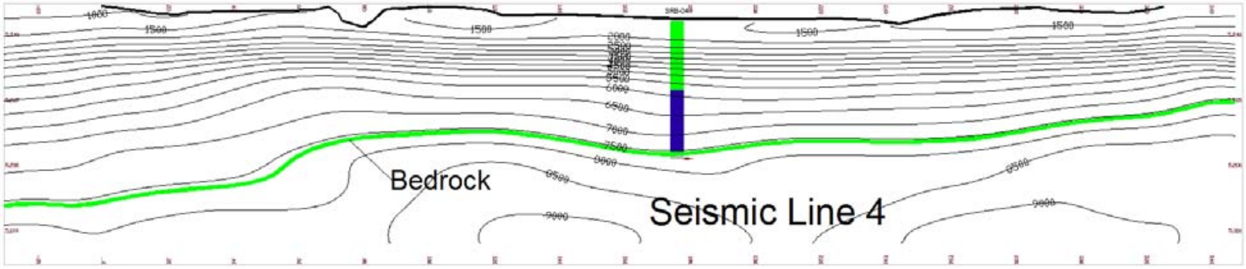
The following figures show the seismic velocity isopleths versus depth along the seismic lines.



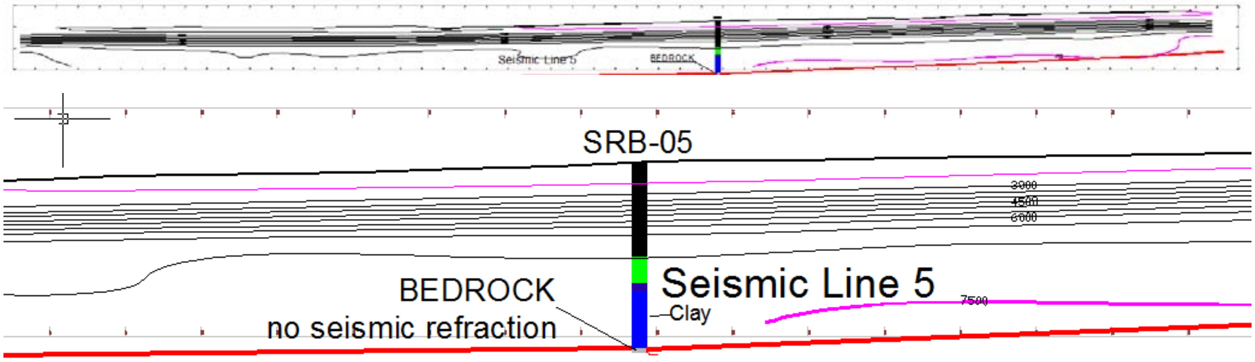
Seismic Line 1







Seismic line 4 is the last line where the seismic refraction could “see” bedrock. The manual sledge hammer technique did not provide sufficient input energy to pass through the soft marsh sediments to reach bedrock in lines 5, 6, and 7. The boreholes encountered silt and clay in the marsh deposits which absorbed the energy.



Lines 6 and 7 look similar to line 5, and did not have sufficient energy to reach bedrock, so are of no value.

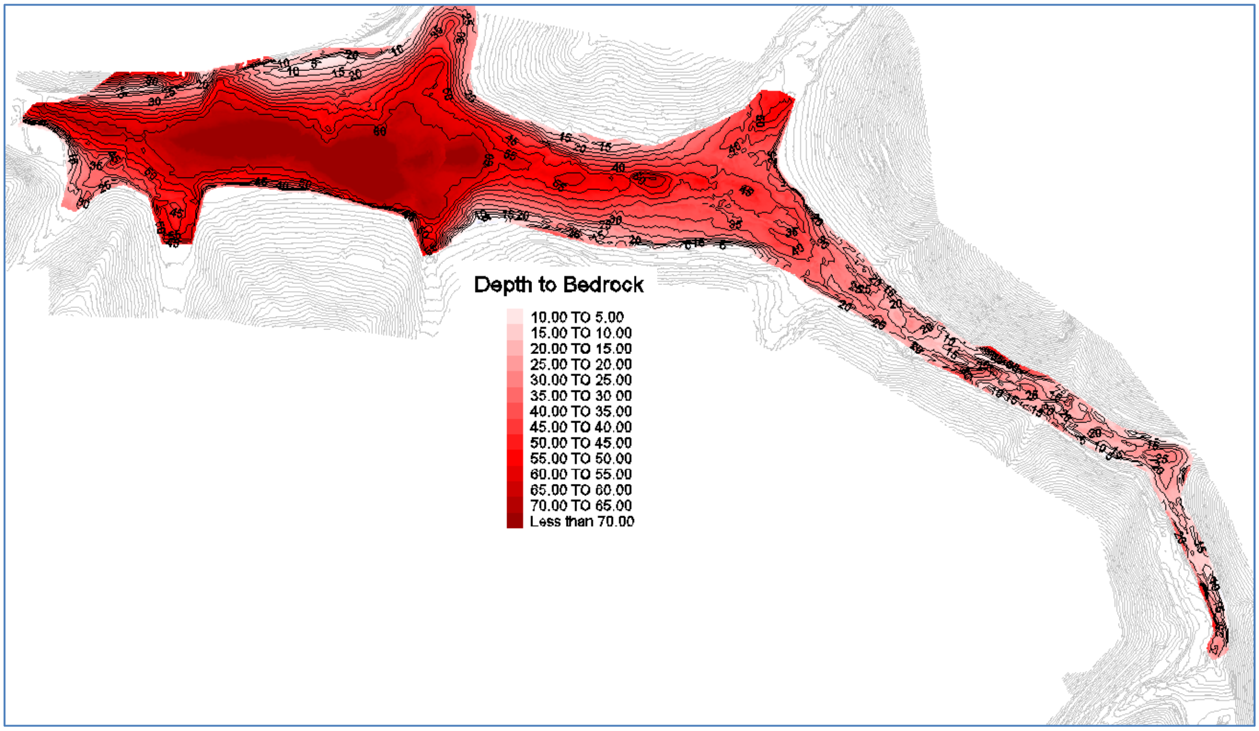


Figure 21 Floodplain Bedrock Depth

A pdf map showing the depth to bedrock and the bedrock elevation is included in the map section of the appendices.

4.7 Quantity Of Floodplain Sediments Contaminated With Tailings

The total quantity of alluvium that is contaminated by tailings, plus the alluvium that does not appear affected by the 1975 flood, but contains high metal content (Pb or Zn above 1,000 mg/kg) is shown below in Table 2. The various areas used to classify the quantities is shown in Figure 22.

The quantities were calculated by estimating the thickness of tailings contaminated alluvium and naturally high metals alluvium using the Carlson geologic modeling software. The model converts the thickness to elevations, and can calculate the quantities of material above and below the water table on Nov 7, 2012.

Table 2 Quantity of Tailings contaminated alluvium and Undisturbed - High Metals both above and below the water table

AREA Total Quantity including below water table	Strata	C.Y. ± 25%	Thickness feet ± 25%
1 Above Redwing	Undisturbed - High Metals (NHM)	4,884	2.75
2 Redwing to Anaconda Cr	Undisturbed - High Metals (NHM)	15,523	4.77
3 Anaconda Cr to WTP	Undisturbed - High Metals (NHM)	5,430	2.62
4 WTP to MaryP	Undisturbed - High Metals (NHM)	26,160	4.81
5 MaryP to Stevens	Undisturbed - High Metals (NHM)	35,783	6.56
6 Stevens to Marsh	Undisturbed - High Metals (NHM)	73,711	4.29
7 Marsh above Rd	Undisturbed - High Metals (NHM)	591	0.70
8 Marsh at Pass Cr	Undisturbed - High Metals (NHM)	0	0.00
9 Marsh below pass Cr	Undisturbed - High Metals (NHM)	1	0.00
1 Above Redwing	Tailings	17,443	4.24
2 Redwing to Anaconda Cr	Tailings	20,966	3.86
3 Anaconda Cr to WTP	Tailings	16,236	2.07
4 WTP to MaryP	Tailings	21,568	2.13
5 MaryP to Stevens	Tailings	11,901	1.59
6 Stevens to Marsh	Tailings	76,991	1.88
7 Marsh above Rd	Tailings	35,576	1.07
8 Marsh at Pass Cr	Tailings	8,602	0.91
9 Marsh below pass Cr	Tailings	33,606	0.73

Undisturbed - High Metals (NHM)	162,082
TAILINGS	242,890
Both	404,972

The quantity of tailings contaminated alluvium and Undisturbed - High Metals that is above the Nov 7, 2012 water table is shown below in Table 3.

Table 3 Quantity of Tailings contaminated alluvium and Undisturbed - High Metals above the Nov 7, 2012 water table.

AREA Quantity only <u>above</u> water table	Strata	C.Y. ± 25%	Thickness feet ± 25%
1 Above Redwing	Tailings & NHM	12,696	3.33
2 Redwing to Anaconda Cr	Tailings & NHM	17,699	3.35
3 Anaconda Cr to WTP	Tailings & NHM	17,767	2.36
4 WTP to MaryP	Tailings & NHM	27,210	2.81
5 MaryP to Stevens	Tailings & NHM	41,676	5.28
6 Stevens to Marsh	Tailings & NHM	120,276	2.95
		237,324	3.35

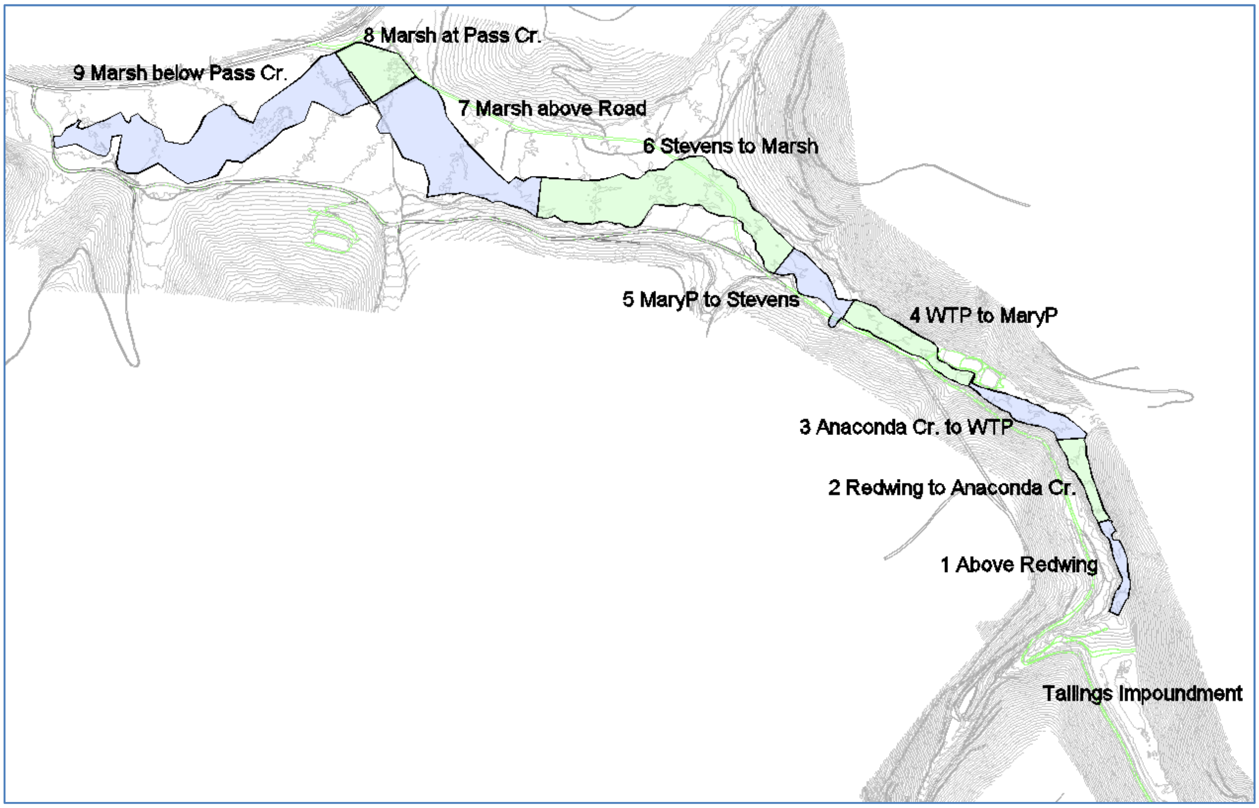


Figure 22 Floodplain Areas for tailings quantity estimates

Figure 23, below illustrates the relationship between the water table and the different classifications of alluvium. This section is 250 feet below the impoundment near valley station 138+00. In this zone, it is evident that the there was a substantial thickness of deposition, and that the pre 1975 surface was below the water table. Downstream from the water treatment plant, the valley widens and the depositional patterns are different.

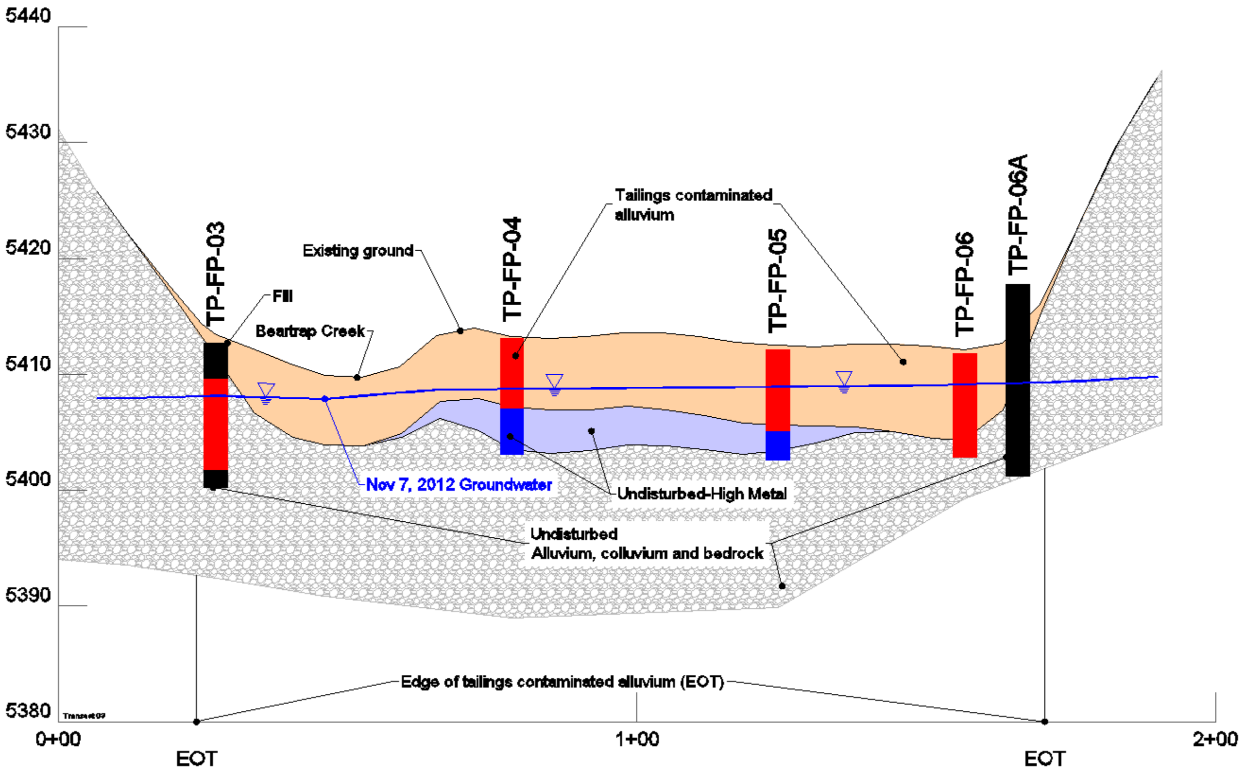


Figure 23 Transect 03, illustrating the relationship between the water table and the different classifications of alluvium

4.8 Riverbed Gravel Size

Seven test pits were excavated along the floodplain in order to determine the size distribution of the native river gravel. The objective was to dig each pit below the level of the 1975 contamination event.. The data is included in APPENDIX 6 SCREEN ANALYSIS BULK SAMPLES

5.0 DATA VALIDATION

Data validation of the Energy Laboratories ICP testing can be found following the lab data in Appendix 1.

The XRF reports the estimated metal concentration and the estimated error for each sample. If the concentration is lower than the Limit of Detection (<LOD) for each sample, then <LOD is reported rather than a value.

The XRF reported values for silver (Ag), aluminum (Al), arsenic (As), gold (Au), bismuth (Bi), cadmium (Cd), chlorine (Cl), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn). As described below, only the Fe, Pb, Zn, and Cu data were used. The other elements either did not correlate with the Inductively Coupled Plasma (ICP) laboratory duplicates, or are not considered contaminants of concern at the UBMC.

There was a slight mix up on the labeling of some of the duplicate XRF samples when an “A” was appended to the XRF sample name to designate an XRF duplicate. The problem is that a couple of test pits were added and given the same name in the field. The problem was resolved by changing the duplicate sample ID by appending “DUP” rather than “A”

5.1 Data Quality Control

A Thermo Scientific Niton XL3T portable XRF unit was used to scan the -10 mesh samples after they had been dried and screened to -10 mesh. A riffle was used to split the samples down to ±14 grams that were placed in a plastic cup. Every 10th cup was sent to Energy Laboratories for acid digestion and ICP. The XRF and the chemistry lab used the same sample. A description of the XRF sample preparation technique is provided in Section 0 APPENDIX 7 SAMPLE PREPARATION FOR XRF ANALYSIS.

The XRF data was downloaded from the device to a comma delimited file that was converted to an Excel file. There were some Sample ID labeling inconsistencies that were edited for consistency so that the sample ID and sample interval would precisely match the field log ID and sample interval. The two datasets were combined using computer logic that could not tolerate inconsistent sample names. The most common error was an extra space in the sample number, or a space when there should be a hyphen.

The field log description intervals and the sample intervals were not always the same interval, because when deeper than 4 feet, the samples were collected from the excavator bucket rather than the side of the test pit, and the bucket contents didn't always match the lithologic intervals. The geological modeling software created new intervals to accommodate the overlaps. Gaps in the sample interval were left blank. The merged datasets were exported to an Excel spreadsheet where the combination of metal content and lithology was used to classify the lithology as Tailings Contaminated, Undisturbed - High Metals, or Undisturbed.

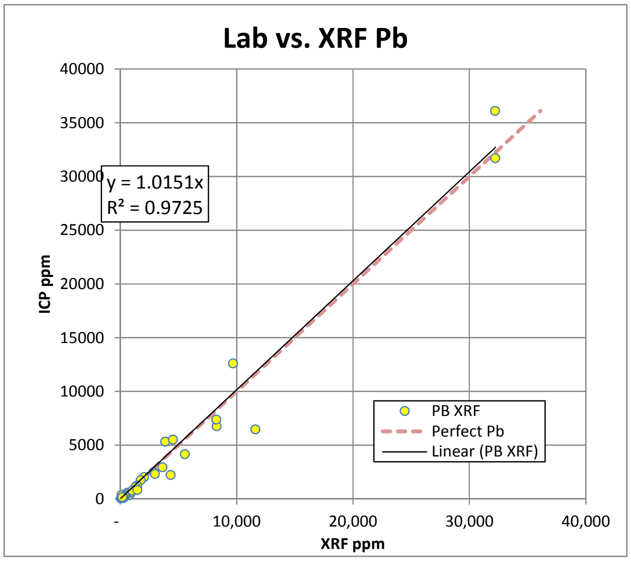
The edited XRF file and the resulting Master Data File (that incorporates the XRF data) are included in APPENDIX 10 LITHOLOGY AND METAL CONTENT OF SAMPLES.

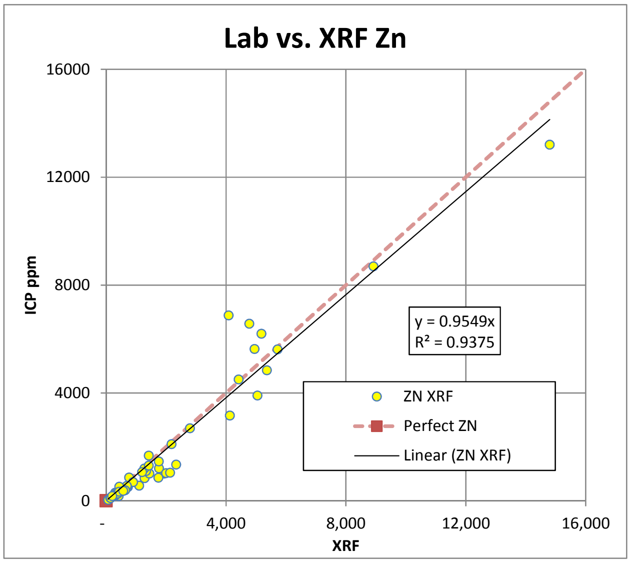
5.1.1 Comparison of XRF to ICP Analysis

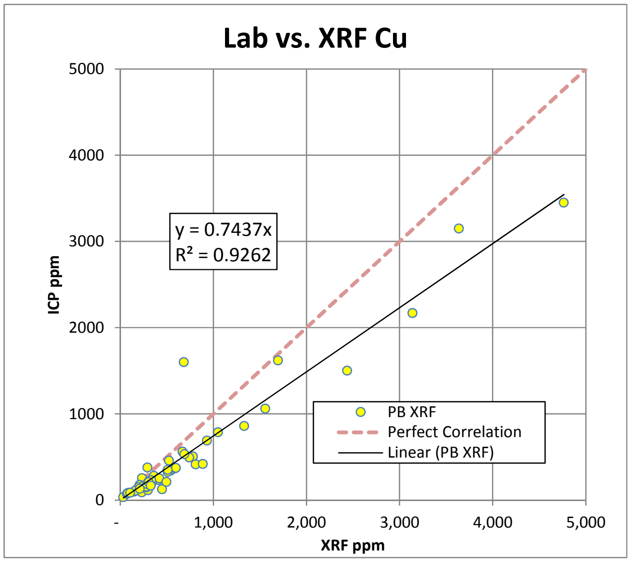
Fifty seven lab sample replicates were sent to Energy Laboratories to compare the XRF to conventional laboratory analysis. The correlation of the XRF results to the laboratory results for the metals of concern (lead, zinc, and copper) was very good, with a Pearson correlation coefficient greater than 90%. The correlation of other metals such as manganese and aluminum was not good. The comparisons are displayed graphically below. The Energy Laboratory reports are combined in a single PDF file and are included as a hard copy in Section 0.

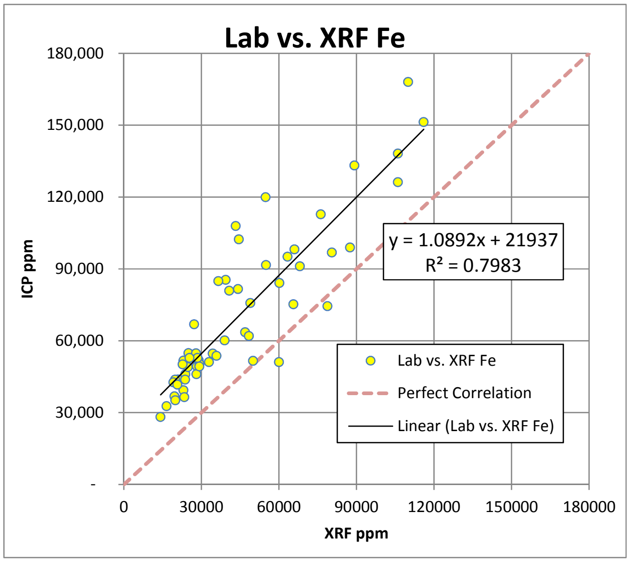
The lead and zinc are the two metals used as indicators of tailings contamination. There was no need to adjust the XRF readings because the correlation is greater than 90%. The copper correlates fairly well, but the XRF tends to overestimate the concentration by about 8%.

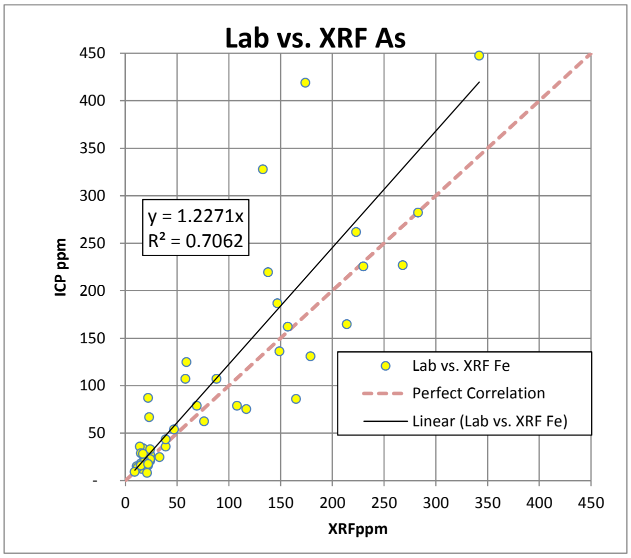
The iron doesn't correlate as well. The XRF tends to systematically underestimate the concentration by about 22,000 mg/kg. The range of iron concentrations is much wider than the other metals because the iron is found in many more forms at this Facility. It is commonly found in the native bedrock minerals as well as the pyrite, arsenopyrite, chalcopyrite, magnetite, and oxidation products such as Fe(OH)x, etc. The iron concentration was only used as a secondary indicator when deciding if the alluvium was contaminated or not. When the unadjusted XRF concentration for iron exceeded ±70,000 mg/kg, it was assumed to be tailings related. This is because the bulk of the sulfides in the impoundment are pyrite. There are many samples with low iron and high lead or zinc, probably because the fluvial processes separated them.

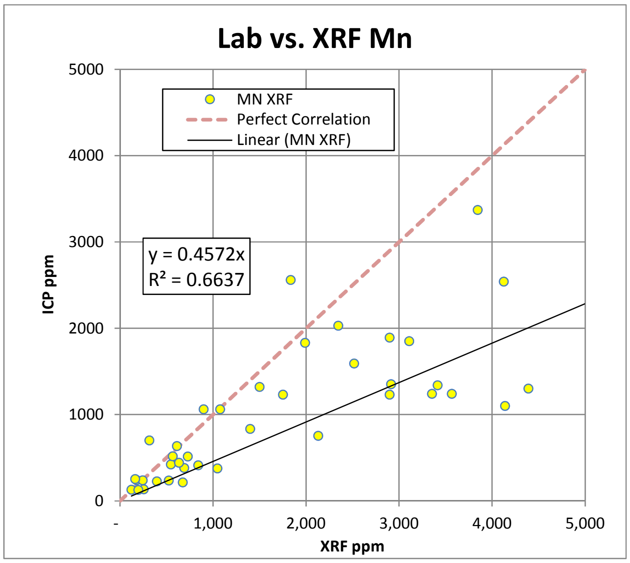

Lab vs. XRF Pb
40000
35000
30000
25000
20000
15000
10000
5000
0
-
10,000
20,000
30,000
40,000
ICP ppm
XRF ppm
y = 1.0151x
R² = 0.9725
PB XRF
Perfect Pb
Linear (PB XRF)


Lab vs. XRF Zn
16000
12000
8000
4000
0
-
4,000
8,000
12,000
16,000
ICP ppm
XRF
y = 0.9549x
R² = 0.9375
ZN XRF
Perfect ZN
Linear (ZN XRF)


Lab vs. XRF Cu
5000
4000
3000
2000
1000
0
-
1,000
2,000
3,000
4,000
5,000
ICP ppm
XRF ppm
y = 0.7437x
R² = 0.9262
PB XRF
Perfect Correlation
Linear (PB XRF)


Lab vs. XRF Fe
180,000
150,000
120,000
90,000
60,000
30,000
-
0
30000
60000
90000
120000
150000
180000
ICP ppm
XRF ppm
y = 1.0892x + 21937
R² = 0.7983
Lab vs. XRF Fe
Perfect Correlation
Linear (Lab vs. XRF Fe)


Lab vs. XRF As
450
400
350
300
250
200
150
100
50
-
0
50
100
150
200
250
300
350
400
450
ICP ppm
XRFppm
y = 1.2271x
R² = 0.7062
Lab vs. XRF Fe
Perfect Correlation
Linear (Lab vs. XRF Fe)


Lab vs. XRF Mn
5000
4000
3000
2000
1000
0
-
1,000
2,000
3,000
4,000
5,000
ICP ppm
XRF ppm
y = 0.4572x
R² = 0.6637
MN XRF
Perfect Correlation
Linear (MN XRF)

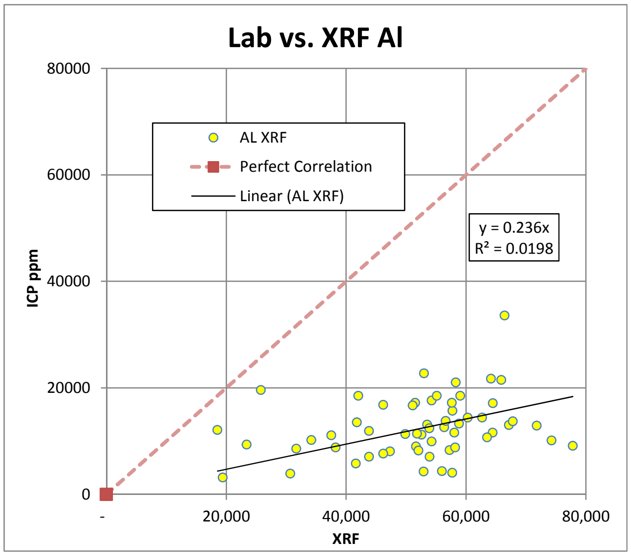
	All the host rocks are aluminum silicates, so aluminum can’t be used as an indicator of tailings contamination. Because of the poor correlation between the XRF and laboratory concentrations, neither arsenic nor manganese XRF concentrations were used to determine the presence of tailings in the alluvium. EPA Method 6200 states that lead can interfere with arsenic, especially when the lead concentration is more than 10 times the arsenic concentration, which is the case here.

Figure 24 Graphs showing correlation between XRF and ICP

Relative Percent Difference between the Original XRF result and the replicate ICP result.

Relative percent difference between the original XRF result and the replicate ICP result were calculated using the equation:

$$\mathrm{RPD} = \frac{|S - D|}{(S + D)/2} \times 100$$

Where,

RPD = Relative Percent Difference
S = Sample Result (original)
D = Duplicate Result

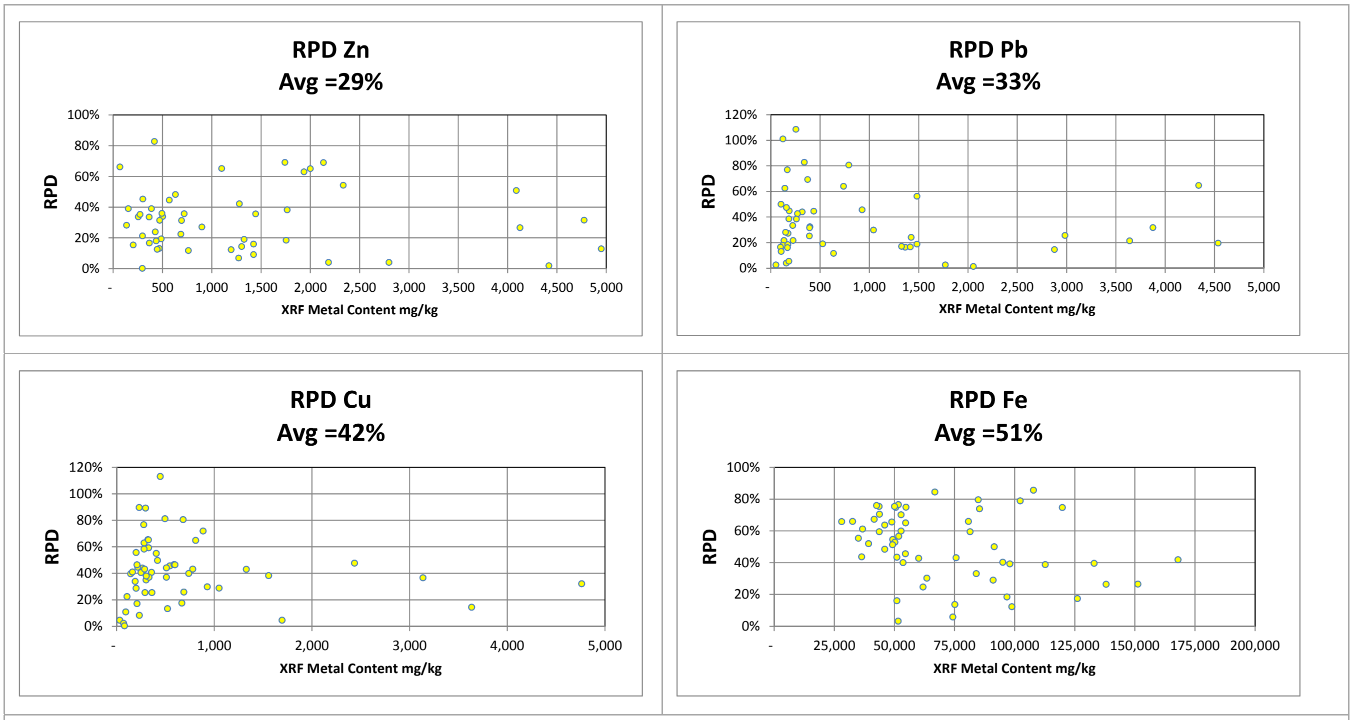


Figure 25 Graphs showing Relative Percent Difference between XRF and ICP values

The relative percent difference between the XRF and the ICP is illustrated in the graphs above. There is a substantial scatter in the RPDs, probably related to the nugget effect and the fact that even though the same sample cup (not a split) was analyzed, the XRF only “sees” a couple of millimeters deep and an area of about 0.6 cm^2, whereas the cup dimensions are about 24mm diameter x24mm deep so contains much more sample than the XRF measures. When the lab takes the sample out of the cup, it will probably analyze a different portion of the cup’s contents. 10 mesh is 2 mm, so the XRF only measures the top layer of 10 mesh particles. If there is a nugget of 10 mesh galena or sphalerite in the top layer, the XRF will measure it and average it into the result. If this nugget is not found in the sub sample analyzed by the ICP procedure, then there will be a difference in the results.

The results are sufficiently accurate for identifying the tailing contaminated floodplain. If better XRF accuracy was desired for some other purpose, then it would be advisable to take several XRF readings on different parts of the sample and average the results. The XRF accuracy could also be enhanced by pulverizing and mixing the sample, but this takes extra time and effort and is not practical for field removals. Therefore, it is advisable to take 3 to 5 field readings if there is any doubt about the accuracy, or if more accuracy is required. It is important to note that the material sampled is not homogeneous, and even the -10 mesh sample is not homogeneous so far as what the XRF can “see”.

Table 4 Comparison of XRF to Lab ICP

	CU XRF	Cu	RPD Cu	FE XRF	Fe	RPD Fe	PB XRF	Pb	RPD Pb	ZN XRF	Zn	RPD Zn
TP-FP-05(6.0-7.0)	1,330	860	43%	63,580	46900	30%	8,286	6750	20%	4,952	5630	13%
TP-FP-06(7.0-8.0)	782	505	43%	61,991	48400	25%	3,878	5330	32%	4,421	4500	2%
TP-FP-08(2.4-2.9)	683	1600	80%	168,066	110000	42%	4,340	2220	65%	4,089	6870	51%
TP-FP-09(3.2-3.3)	3,139	2170	37%	126,224	106000	17%	3,641	2940	21%	5,719	5610	2%
TP-FP-10A(2.1-2.6)	329	179	59%	49,334	28200	55%	320	205	44%	723	504	36%
TP-FP-13(2.4-2.7)	264	169	44%	91,609	55000	50%	398	287	32%	489	403	19%
TP-FP-15(0.0-0.2)	234	254	8%	84,076	60200	33%	1,365	1160	16%	1,281	835	42%
TP-FP-15A(8.5-9.0)	202	114	56%	51,858	29000	57%	228	184	22%	503	357	34%
TP-FP-16(11.5-12.0)	323	164	65%	54,867	25000	75%	739	381	64%	1,937	1010	63%
TP-FP-18(0.6-0.8)	1,559	1060	38%	119,945	54800	75%	11,621	6470	57%	2,799	2690	4%
TP-FP-19(1.8-2.4)	280	125	77%	46,000	23800	64%	256	76	108%	1,743	849	69%
TP-FP-20(8.0-8.5)	546	344	45%	46,028	28100	48%	2,056	2030	1%	2,334	1340	54%
TP-FP-21(10.0-10.5)	219	139	45%	43,829	21000	70%	637	568	12%	1,767	1200	38%
TP-FP-25(0.4-0.9)	292	377	25%	151,339	116000	26%	1,772	1730	2%	765	860	12%
TP-FP-26(4.0-4.5)	1,050	786	29%	112,793	76200	39%	4,538	5520	20%	5,181	6190	18%
TP-FP-27(6.5-7.0)	233	89	89%	43,718	19800	75%	375	182	69%	1,102	561	65%
TP-FP-28(9.0-9.5)	33	35	5%	42,655	19200	76%	105	63	50%	419	174	83%
TP-FP-30(10.0-10.5)	95	85	11%	39,306	23100	52%	144	275	62%	496	345	36%
TP-FP-32(0.0-0.4)	670	563	17%	133,149	89200	40%	1,416	1200	16%	1,305	1130	14%
TP-FP-33(8.0-8.5)	449	125	113%	50,667	23100	75%	794	338	81%	2,001	1020	65%
TP-FP-35(0.5-0.7)	72	74	2%	36,448	23400	44%	136	169	22%	297	297	0%
TP-FP-36(3.5-4.0)	191	136	34%	54,726	27900	65%	186	126	38%	1,755	1460	18%
TP-FP-37(11.5-12.0)	297	114	89%	51,695	23100	76%	342	142	83%	2,134	1040	69%
TP-FP-38A(1.0-1.5)	1,696	1620	5%	51,588	50000	3%	9,699	12600	26%	4,778	6560	31%
TP-FP-40(1.5-2.0)	83	83	0%	50,296	29300	53%	158	152	4%	300	242	21%
TP-FP-41(2.0-2.5)	284	148	63%	85,438	39400	74%	928	584	45%	257	183	34%
TP-FP-42(6.6-7.0)	407	232	55%	52,844	28500	60%	124	104	18%	1,446	1010	35%
TP-FP-44(0.0-0.7)	3,637	3150	14%	96,862	80500	18%	32,223	36100	11%	8,917	8690	3%
TP-FP-45(0.5-1.0)	4,763	3450	32%	74,391	78800	6%	32,233	31700	2%	14,798	13200	11%
TP-FP-45A(0.8-1.2)	359	238	41%	54,659	34400	45%	528	437	19%	1,330	1100	19%

Table 4 Comparison of XRF to Lab ICP

	CU XRF	Cu	RPD Cu	FE XRF	Fe	RPD Fe	PB XRF	Pb	RPD Pb	ZN XRF	Zn	RPD Zn
TP-FP-46(8.5-9.0)	210	177	17%	49,278	29200	51%	125	381	101%	1,275	1190	7%
TP-FP-48(1.5-2.0)	740	495	40%	98,099	66000	39%	1,425	1120	24%	4,127	3160	27%
TP-FP-49A(2.8-3.2)	362	281	25%	80,875	40800	66%	2,878	2490	14%	469	412	13%
TP-FP-50(9.0-10.0)	201	151	29%	53,678	35800	40%	174	145	18%	449	396	12%
TP-FP-50A(8.5-9.0)	252	167	41%	81,555	44200	59%	53	52	2%	70	35	66%
TP-MS-05(1.8-2.0)	282	155	58%	66,859	27200	84%	100	85	16%	302	191	45%
TP-MS-19(1.0-2.0)	146	98	39%	138,133	106000	26%	107	94	13%	137	103	28%
TP-MS-25(0.5-1.0)	2,437	1500	48%	60,152	39000	43%	5,560	4160	29%	5,049	3900	26%
TP-MS-09(6.0-7.0)	304	214	35%	32,693	16500	66%	225	161	33%	366	261	34%
TP-MS-04(1.0-2.0)	511	327	44%	51,109	32900	43%	1,483	1230	19%	1,424	1300	9%
TP-MS-27(2.0-2.5)	420	253	50%	48,985	24800	66%	176	134	27%	473	345	31%
TP-MS-03(1.0-2.0)	523	458	13%	98,889	87500	12%	1,327	1120	17%	2,186	2100	4%
TP-MS-10B(1.0-2.0)	931	690	30%	75,210	65600	14%	2,985	2310	25%	5,361	4840	10%
TP-MS-15(3.0-3.7)	163	108	41%	50,080	22700	75%	170	145	16%	274	192	35%
TP-MS-11B(2.0-3.0)	333	229	37%	36,827	19600	61%	396	288	32%	901	687	27%
TP-MS-24(5.3-5.75)	589	367	46%	52,805	25400	70%	437	278	44%	695	507	31%
TP-MS-23(0.0-1.0)	288	186	43%	91,120	68100	29%	273	177	43%	689	550	22%
TP-MS-16(0.1-0.2)	598	373	46%	75,738	48900	43%	1,043	773	30%	368	312	17%
TP-MS-07(2.75-3.5)	328	167	65%	28,121	14200	66%	152	115	28%	154	104	39%
TP-FP-53(9.5-10.0)	811	414	65%	107,922	43300	85%	262	178	38%	390	263	39%
TP-MS-04(1.0-2.0)	511	352	37%	51,109	60000	16%	1,483	833	56%	1,424	1670	16%
TP-FP-55(0.6-1.0)	690	533	26%	95,106	63300	40%	8,253	7380	11%	437	523	18%
TP-FP-57(0.5-1.0)	210	131	46%	43,741	23700	59%	189	120	45%	429	338	24%
TP-FP-58(6.0-6.5)	496	210	81%	84,903	36600	80%	160	99	47%	632	387	48%
TP-FP-59(12.0-12.5)	887	418	72%	102,361	44500	79%	169	75	77%	571	363	44%
TP-TS-02(1.5-2.0)	108	86	22%	35,113	19900	55%	186	176	5%	204	175	15%
Average RPD			**42%**			**51%**			**33%**			**29%**

LOD = Limit of Detection

5.1.2 DUPLICATES and REPLICATES

5.1.3 XRF Duplicate Field Samples

Duplicate samples were collected in the field per Pioneer standard operating procedure PTS-SOP-SA-03, found in Appendix B of the SAP. The duplicates were labeled so that they were submitted blind for analysis, with the true name (Test pit and interval) recorded in the field notebook. The correct name was assigned and matched to the sample after it was dried, split, and analyzed with the XRF.

Table 5 Duplicate Field Sample Comparison

All values are mg/kg

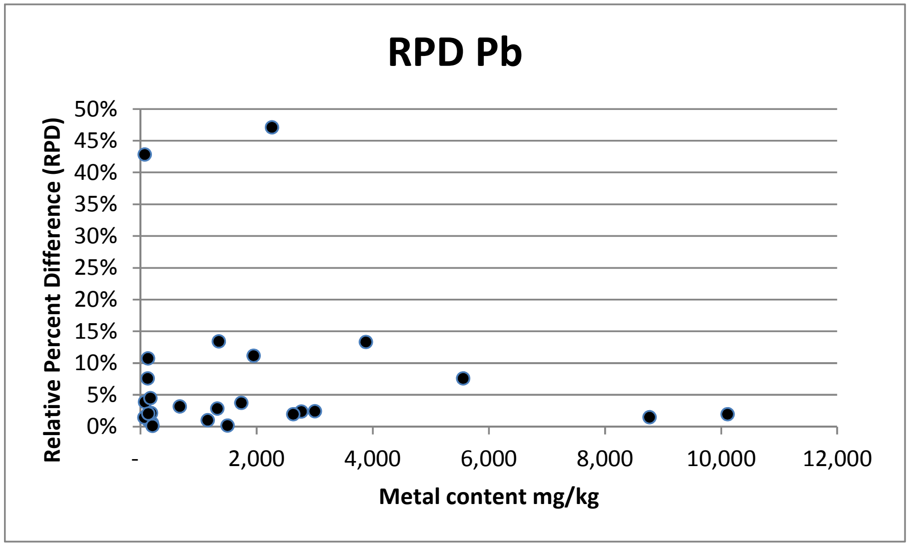
SAMPLE	Cu	Cu Duplicate	RPD Cu	Fe	Fe Duplicate	RPD Fe	Pb	Pb Duplicate	RPD Pb	Zn	Zn Duplicate	RPD Zn
TP-FP-05(1-3)	412	634	11%	126,569	155,030	5%	1,159	2,072	14%	1,923	2,534	7%
TP-FP-15A(0.5-1)	780	887	3%	138,726	129,338	2%	2,772	2,883	1%	871	645	7%
TP-FP-16(3-3.4)	530	502	1%	111,766	105,521	1%	3,884	4,267	2%	1,020	1,094	2%
TP-FP-18-(4-4.5)	137	180	7%	49,262	47,241	1%	132	227	13%	3,314	4,282	6%
TP-FP-20(2.1-2.4)	1,688	1,128	10%	85,992	114,821	7%	8,768	5,669	11%	4,973	4,046	5%
TP-FP-22(0.7-1.2)	826	765	2%	94,989	92,601	1%	1,501	1,591	1%	3,335	3,291	0%
TP-FP-25A(1.3-1.8)	773	684	3%	100,327	106,099	1%	2,266	2,252	0%	2,644	2,606	0%
TP-FP-27(0.5-0.8)	170	1,961	42%	39,861	126,684	26%	74	2,488	47%	467	6,701	43%
TP-FP-30(0.5-0.8)	95	1,188	43%	39,306	95,036	21%	144	1,855	43%	496	3,845	39%
TP-FP-35(4-4.3)	860	583	10%	152,999	154,953	0%	1,949	2,020	1%	626	931	10%
TP-FP-35(8.5-9)	360	89	30%	60,137	37,365	12%	200	127	11%	1,067	1,537	9%
TP-FP-38A(0.5-1)	2,222	2,311	1%	66,965	62,189	2%	10,113	10,334	1%	8,626	8,510	0%
TP-FP-39(0.9-1.6)	68	60	3%	39,444	36,514	2%	81	75	2%	150	144	1%
TP-FP-47(0.1-0.3)	298	494	12%	107,821	127,915	4%	2,631	3,072	4%	1,616	719	19%
TP-FP-49(1.7-2.4)	279	645	20%	93,357	85,932	2%	1,737	1,606	2%	476	2,965	36%
TP-FP-50A(3.5-4)	151	178	4%	48,251	55,287	3%	66	77	4%	238	282	4%
TP-FP-54(0.6-1)	366	285	6%	106,903	103,149	1%	3,003	2,839	1%	455	385	4%
TP-FP-57(1-1.5)	289	275	1%	43,772	43,283	0%	184	167	2%	445	404	2%
TP-MS-03(1-2)	523	445	4%	98,889	83,739	4%	1,327	1,218	2%	2,186	2,094	1%
TP-MS-08(1-2)	455	415	2%	91,406	97,505	2%	1,352	1,515	3%	2,402	2,391	0%
TP-MS-11C(2-3)	549	305	14%	44,305	41,656	2%	680	393	13%	2,072	1,198	13%

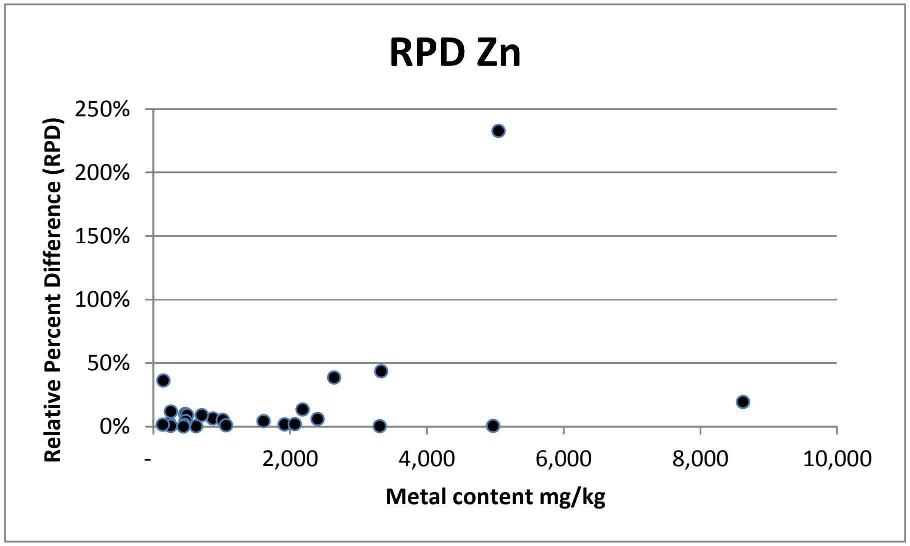
Table 5 Duplicate Field Sample Comparison

All values are mg/kg

SAMPLE	Cu	Cu Duplicate	RPD Cu	Fe	Fe Duplicate	RPD Fe	Pb	Pb Duplicate	RPD Pb	Zn	Zn Duplicate	RPD Zn
TP-MS-12(1.5-2)	672	473	9%	40,923	35,480	4%	208	184	3%	253	319	6%
TP-MS-15(1-2)	215	228	1%	48,735	45,058	2%	169	169	0%	257	278	2%
TP-MS-16(0.5-1)	461	535	4%	25,857	34,211	7%	124	148	4%	139	142	0%
TP-MS-20(1-2)	146	106	8%	50,576	34,166	10%	136	100	8%	711	438	12%
TP-MS-25(0.5-1)	2,437	2,197	3%	60,152	65,708	2%	5,560	5,127	2%	5,049	4,758	1%
Average RPD			**10%**			**5%**			**8%**			**9%**

Table 3 in the DEQ approved Quality Assurance Project Plan states that an acceptable RPD for solids is 35%. This type of comparison is not valid for field duplicates, since the homogeneity of the sampled matrix is an uncontrollable variable, nevertheless, the RPD's are surprisingly low for this project.





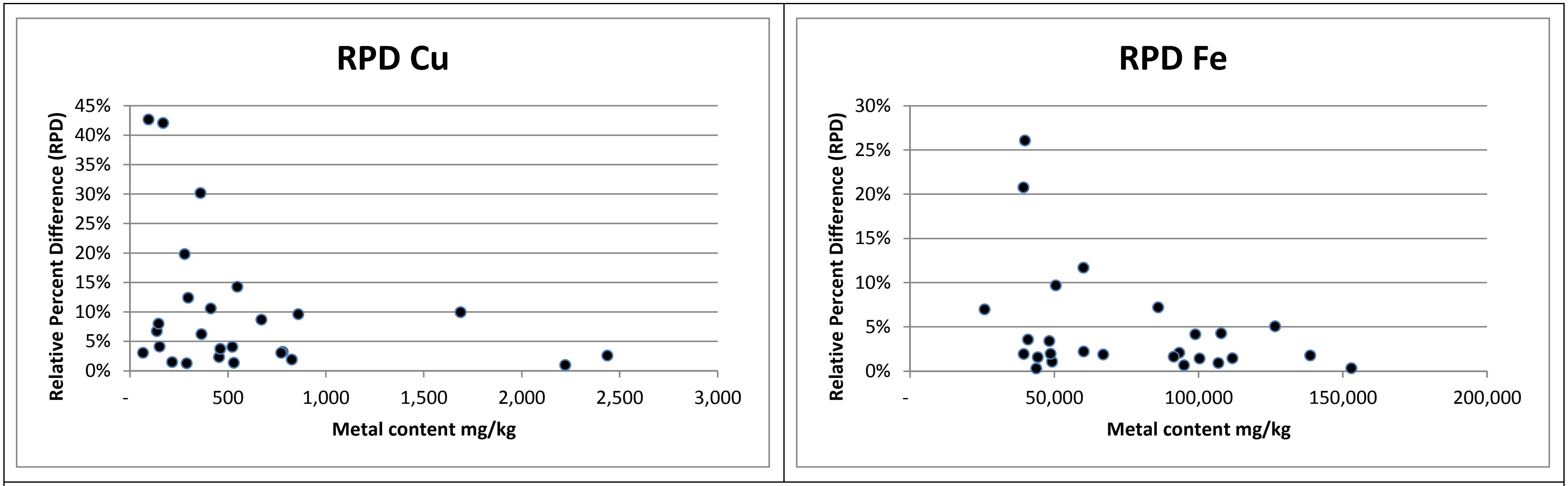
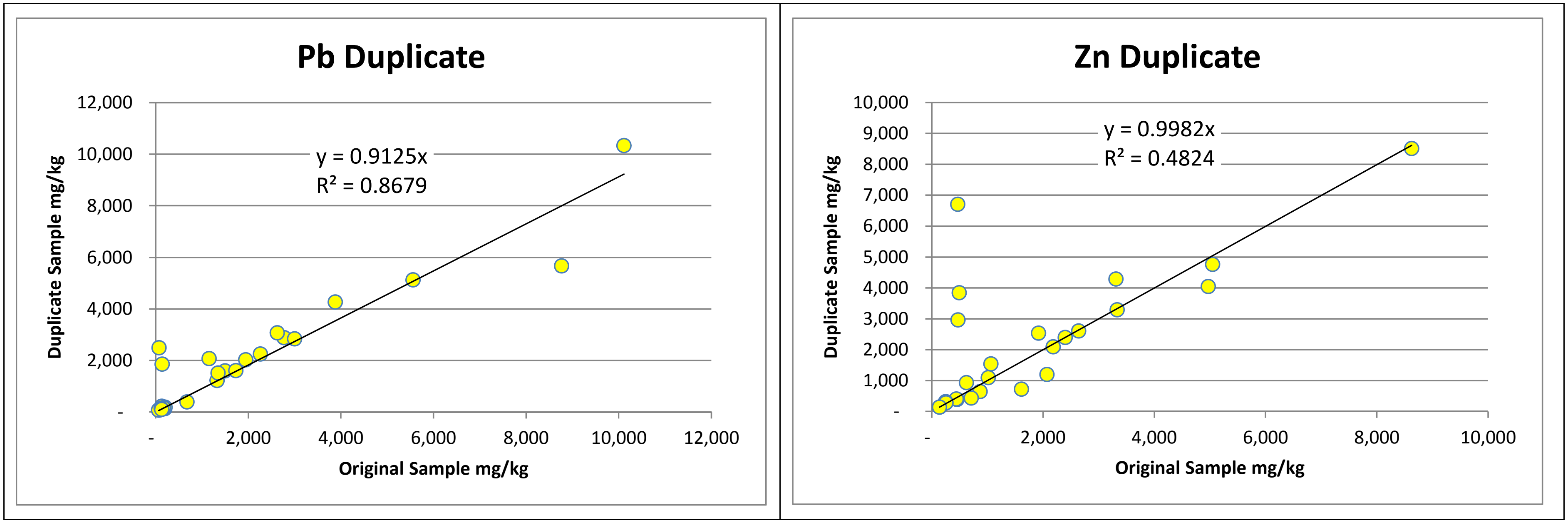


Figure 26 Graphs showing Relative Percent Difference of Field Duplicate Field Samples



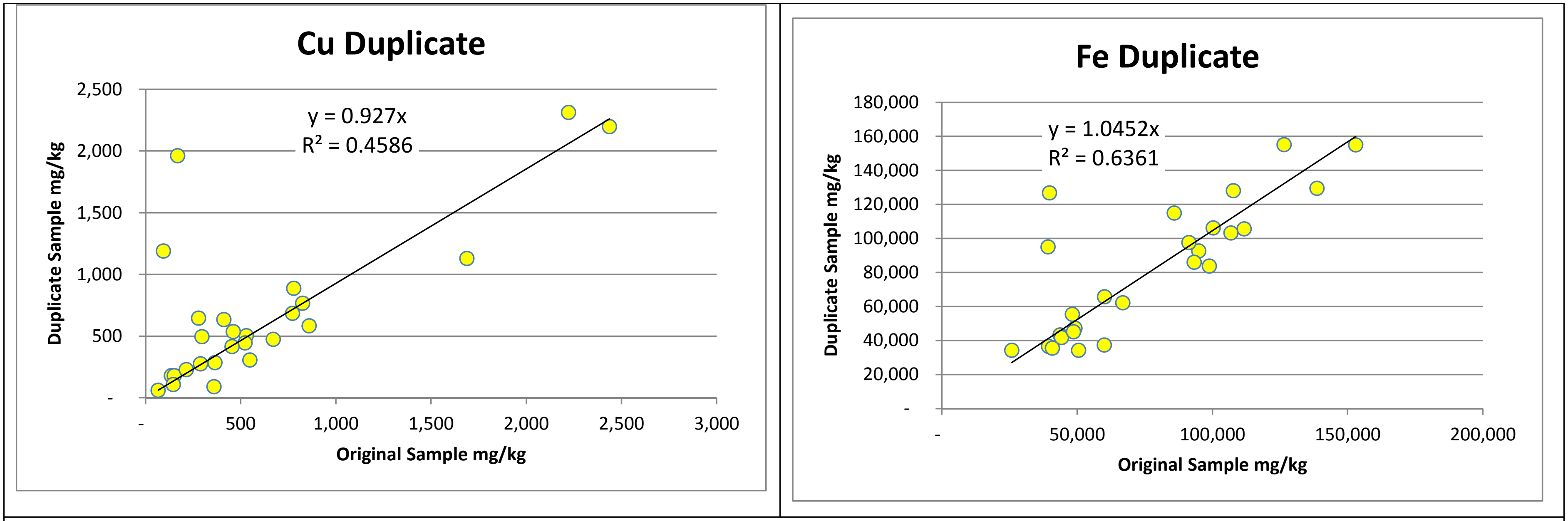


Figure 27 Graphs showing Correlation of Duplicate Field Samples.

These are separate samples representing the same interval in the same test pit.

Generally, the duplicates correlated better than expected considering the biased sampling method, the non-homogeneous nature of the fluvial system and the potential nugget effect (which may account for the outliers). Visually, the appearance of the tailings contaminated alluvium varied considerably over a very short distance, so any sample taken adjacent to a previous sample can be expected to be different.

It is interesting to note that the slope of the linear best fit line is close to 1.0 for all the duplicate samples, but the Pearson correlation coefficient ranges from 45 to 87%, which as mentioned above is surprisingly high for this type of deposit.

5.1.4 XRF Replicates

The following samples were analyzed twice and the results were compared to determine the XRF sampling variance. The samples were prepped and placed in a cup per the manufacturers recommendations. Each sample cup was analyzed twice.

Table 6 Replicate XRF Lab Sample Comparison

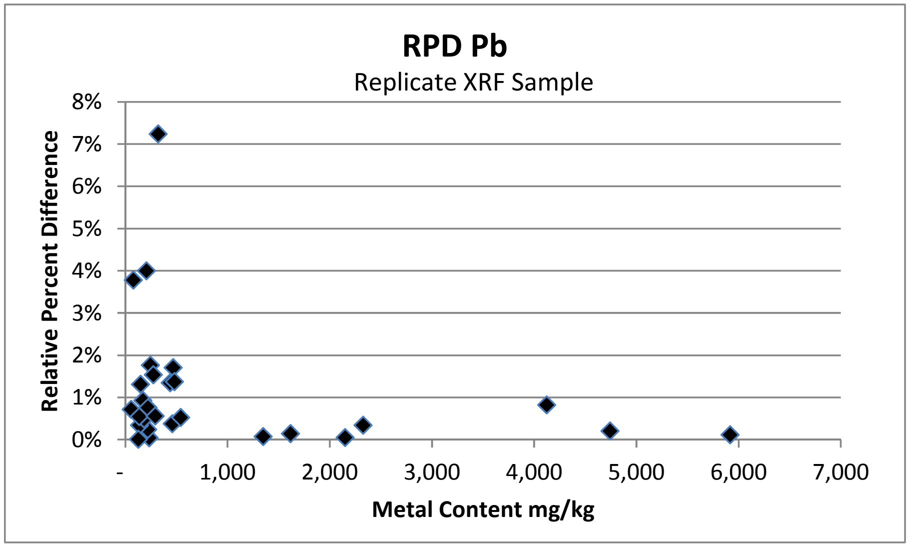
All values are mg/kg

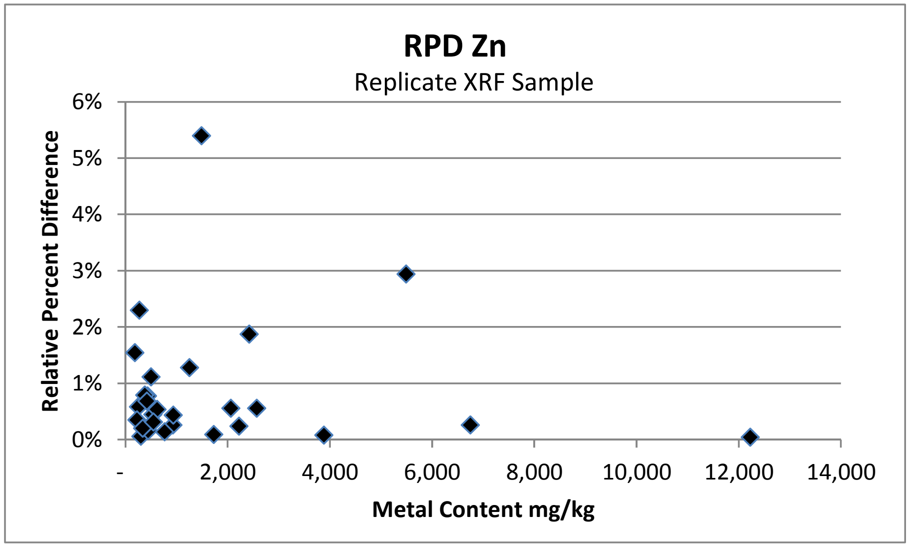
SAMPLE	Cu	Cu Replicate	RPD Cu		Fe	Fe Replicate	RPD Fe		Pb	Pb Replicate	RPD Pb		Zn	Zn Replicate	RPD Zn
TP-FP-07(0.5-1)	833	864	1%		192,764	192,768	0%		2,151	2,147	0%		2,570	2,628	1%
TP-FP-10(5.5-6)	143	129	3%		48,989	48,938	0%		235	236	0%		1,733	1,739	0%
TP-FP-14(4-4.6)	778	764	0%		46,795	46,864	0%		4,743	4,704	0%		3,883	3,870	0%
TP-FP-28(4.6-5)	99	86	3%		54,647	52,337	1%		58	60	1%		255	250	1%
TP-FP-31(9-9.5)	186	202	2%		69,128	70,135	0%		459	453	0%		933	943	0%
TP-FP-34(10-10.5)	937	906	1%		59,493	61,098	1%		470	503	2%		539	549	0%
TP-FP-37(7.5-8)	585	578	0%		67,730	67,743	0%		1,351	1,348	0%		2,224	2,246	0%
TP-FP-39A(9.5-10)	430	408	1%		57,365	57,199	0%		219	217	0%		229	232	0%
TP-FP-42(2-2.6)	178	209	4%		48,212	55,836	4%		209	245	4%		1,258	1,324	1%
TP-FP-44A(8-8.5)	203	197	1%		57,097	54,618	1%		439	416	1%		2,063	2,017	1%
TP-FP-45A(13.5-14)	179	187	1%		52,268	46,067	3%		246	264	2%		431	444	1%
TP-FP-48(13.5-14)	395	307	6%		80,329	63,145	6%		323	433	7%		1,491	1,201	5%
TP-FP-50A(2.3-2.5)	218	219	0%		47,931	47,971	0%		140	142	0%		306	305	0%
TP-FP-53(12-12.5)	1,262	1,146	2%		104,371	104,624	0%		542	530	1%		504	482	1%
TP-FP-57(1-1.5)	289	288	0%		43,772	44,085	0%		184	181	0%		445	442	0%
TP-FP-60(.2-.5)	145	138	1%		46,451	46,327	0%		149	157	1%		340	337	0%
TP-MS-03(2-2.75)	270	265	0%		43,842	42,072	1%		481	456	1%		771	767	0%
TP-MS-06(0.5-1)	246	261	1%		42,682	42,817	0%		130	130	0%		381	370	1%
TP-MS-07(3.5-4.5)	278	268	1%		29,261	29,061	0%		173	167	1%		189	201	2%
TP-MS-09(0-0.5)	1,046	1,048	0%		88,402	87,218	0%		2,326	2,295	0%		6,753	6,683	0%
TP-MS-102(2.5-2.75)	243	266	2%		54,304	54,623	0%		136	139	1%		941	958	0%

Table 6 Replicate XRF Lab Sample Comparison

All values are mg/kg

SAMPLE	Cu	Cu Replicate	RPD Cu		Fe	Fe Replicate	RPD Fe		Pb	Pb Replicate	RPD Pb		Zn	Zn Replicate	RPD Zn
Tp-Ms-105(0.7-1.0)	1,960	1,999	0%		109,193	106,329	1%		4,123	4,260	1%		5,492	4,882	3%
TP-MS-10c(2-3)	529	488	2%		85,085	86,365	0%		1,616	1,625	0%		2,422	2,610	2%
TP-MS-112(0.5-1)	1,997	2,008	0%		49,591	49,675	0%		5,919	5,945	0%		12,226	12,245	0%
TP-MS-117(1-1.5)	268	276	1%		41,927	42,709	0%		277	294	2%		620	634	1%
TP-MS-11B(3-4)	327	321	0%		41,731	43,203	1%		221	228	1%		419	431	1%
TP-MS-22(0-1)	330	320	1%		95,718	97,555	0%		293	299	1%		553	560	0%
TP-MS-23(1-2)	157	168	2%		169,338	169,496	0%		79	92	4%		277	253	2%
RPD Average			**1%**				**1%**				**1%**				**1%**





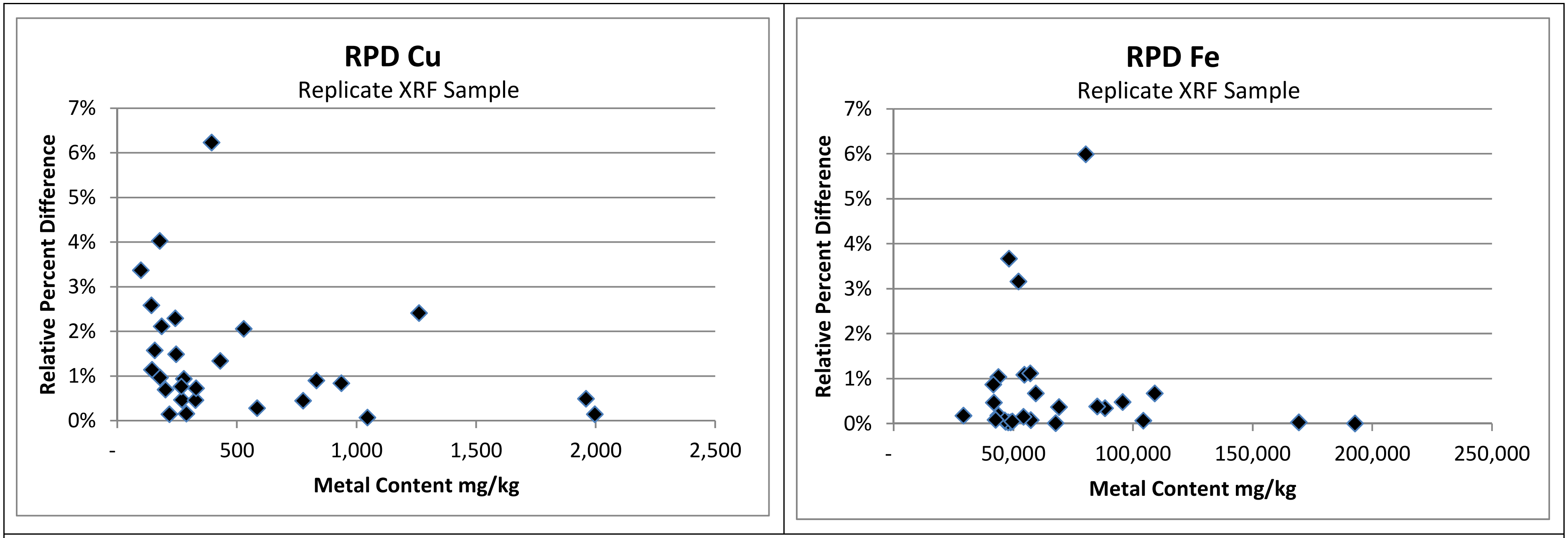


Figure 28 Graphs showing Correlation of Replicate XRF Samples
(same prepared sampled XRF'd two different times)

The low RPD values indicate that there is good repeatability with the XRF on the same prepared sample.

The following graphs of the replicate analysis show that the XRF results are internally consistent. This indicates a high degree of XRF precision within each sample. The Pearson correlation coefficient is greater than 99%. This high degree of precision does not mean that the values are accurate because any bias would remain constant.

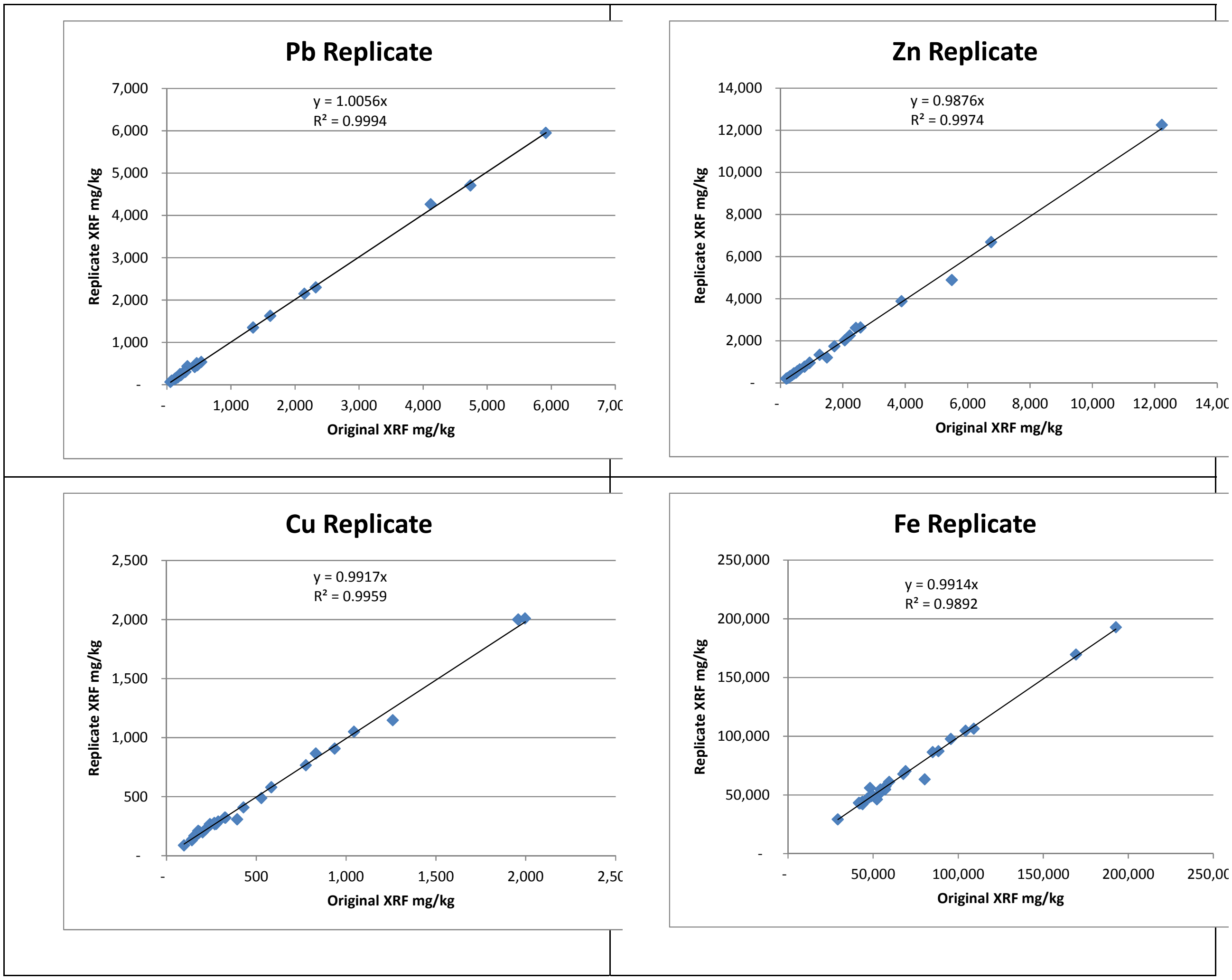


Figure 29 Graphs showing correlation of XRF replicate to original XRF samples

5.1.5 Test to determine difference between metal content in wet compared to dry XRF samples

The manufacturer recommends that the samples be dried before being analyzed using the portable XRF analyzer, since water content can affect the accuracy of the reading. According to EPA Method 6200, page 5, when the moisture content is between 5 and 20 percent, the overall error from moisture may be minimal. During construction, it will be more convenient and economical if the metal content can be immediately determined without taking the time to dry the sample. To determine the affect of water on the XRF accuracy, a group of samples were re-saturated and the XRF of the saturated samples compared to the dried samples.

Table 7 Test to determine difference between metal content in wet compared to dry XRF samples

Note that the metal concentrations are based on different moisture contents

Sample ID	From	To	Wet Pb	Dry Pb	RPD Pb	Wet Pb 20% H_20	Wet Zn	Dry Zn	RPD Zn	Wet Cu	Dry Cu	RPD Zn	Wet Fe	Dry Fe	RPD Fe
TP-FP-08	1.3	2.0	3,218	4,405	31%	3,524	3,289	4,135	23%	619	667	8%	138,257	168,838	20%
TP-FP-13	2.4	2.7	376	398	6%	318	444	489	10%	204	264	26%	86,205	91,609	6%
TP-FP-12	0.9	1.3	5,682	8,427	39%	6,742	1,586	3,154	66%	472	826	55%	140,430	194,435	32%
TP-FP-07	2.5	3.0	42	42	0%	34	212	242	13%	45	66	38%	37,117	39,710	7%
TP-FP-39A	0.9	1.6	62	75	19%	60	135	144	6%	59	60	1%	31,530	36,514	15%
TP-MS-110	1.0	1.5	103	144	34%	115	378	466	21%	195	254	26%	27,836	36,304	26%
TP-MS-25	0.5	1.0	4,116	5,560	30%	4,448	3,703	5,049	31%	1,890	2,437	25%	45,710	60,152	27%
TP-FP-16	4.2	4.3	15,669	17,658	12%	14,127	11,433	9,421	19%	6,590	7,863	18%	77,813	87,929	12%
TP-FP-10	2.0	2.4	249	240	3%	192	464	512	10%	73	82	12%	38,697	42,625	10%
TP-FP-44A	0.0	0.7	24,078	28,280	16%	22,624	8,730	6,228	33%	3,186	3,048	4%	92,147	104,098	12%
TP-FP-38A	1.0	1.5	6,176	9,699	44%	7,759	5,087	4,778	6%	1,350	1,696	23%	51,354	51,588	0%
TP-MS-114	1.0	1.5	143	191	29%	153	175	215	20%	176	182	3%	58,773	74,166	23%
TP-MS-11C	1.0	2.0	3,450	4,984	36%	3,987	6,285	7,063	12%	1,339	1,667	22%	51,805	70,058	30%
TP-MS-112	0.5	1.0	4,509	5,919	27%	4,735	9,378	12,226	26%	1,565	1,997	24%	37,126	49,591	29%
TP-FP-21A	2.8	3.0	10,484	16,294	43%	13,035	4,706	6,892	38%	2,154	3,170	38%	38,745	68,869	56%
TP-MS-12	1.5	2.0	186	208	11%	167	222	253	13%	573	672	16%	35,910	40,923	13%
TP-FP-15A	5.5	5.7	274	278	1%	222	474	518	9%	164	177	7%	43,967	55,969	24%
TP-MS-09	6.0	7.0	195	225	15%	180	317	366	14%	293	304	4%	30,026	32,693	9%
TP-MS-05	6.0	6.5	203	195	4%	156	315	325	3%	231	255	10%	50,063	49,626	1%
Average RPD					**21%**				**20%**			**19%**			**19%**

C:\Projects\Mike Horse\Flood Plain Sampling\2012 Field sample data\XRF Data\[Comparison of Wet and Dry XRF samples.xlsx]Sheet1

The results of this test indicates that the samples saturated with water contain lower metal values than the dry samples because the extra water makes the sample weigh more than the dry sample, and thus dilutes the metal concentration. If the samples are mathematically adjusted to the same moisture content, the difference is much smaller. This verifies the EPA comments in Method 6200 regarding moist samples not being adversely affected if the moisture is less than 20%. This indicates that so long as the flood plain samples are not dripping wet, the field XRF accuracy will be adequate.

To adjust to a dry basis, one must know the moisture content. This can be done by drying a few samples and comparing the wet weight to the dry weight.

For example, consider the following example where the concentration of dry metal in the sample remains constant, and only the water content varies. Note how the wet metal concentration drops as the water content increases, even though the metal concentration on a dry basis remains constant. If the moisture content od the sample is known or estimated, then the wet concentration can be converted to dry basis as follows:

$$Dry\ Basis = Wet\ Basis/(1 - \%water)$$

Table 8 Example showing how moisture content affects metal concentration				
% moisture (water/solids)	5%	11%	18%	25%
Total Weight	100 kg	100 kg	100 kg	100 kg
Water weight	5 kg	10 kg	15 kg	20 kg
Solids Weight	95 kg	90 kg	85 kg	80 kg
Dry metal concentration	1,000 mg/kg	1,000 mg/kg	1,000 mg/kg	1,000 mg/kg
Metal Quantity	95,000 mg	90,000 mg	85,000 mg	80,000 mg
Wet Metal Concentration	950 mg/kg	900 mg/kg	850 mg/kg	800 mg/kg

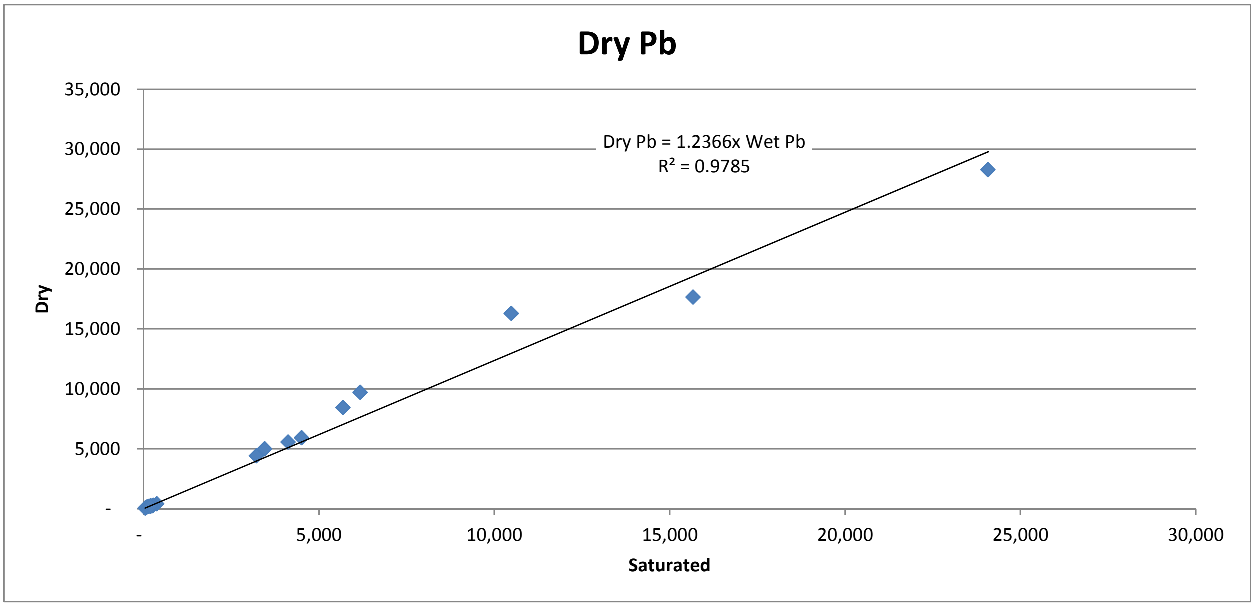


Figure 30 Correlation of Dry sample to saturated sample

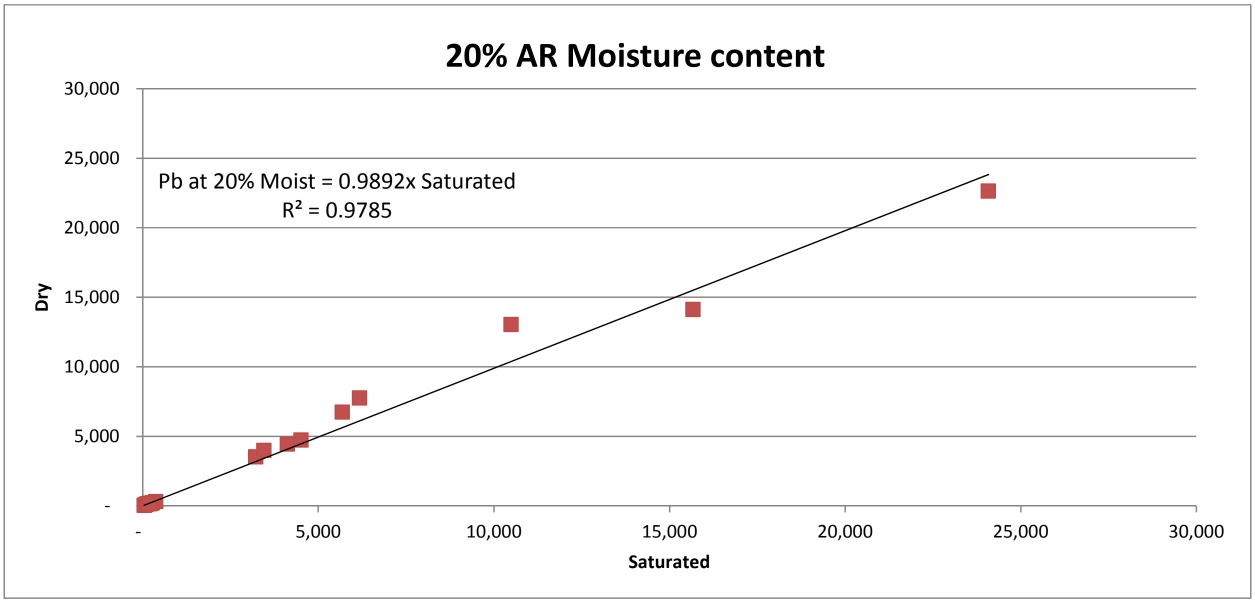


Figure 31 Same data as above, but concentrations adjusted assuming 20% moisture content

Note the different in the slope between Figure 30 and Figure 31 (1.24 versus 0.99). This is a reflection of the moisture content.

When the lead concentration is adjusted for moisture, the concentrations determined on the dry and saturated results are similar.

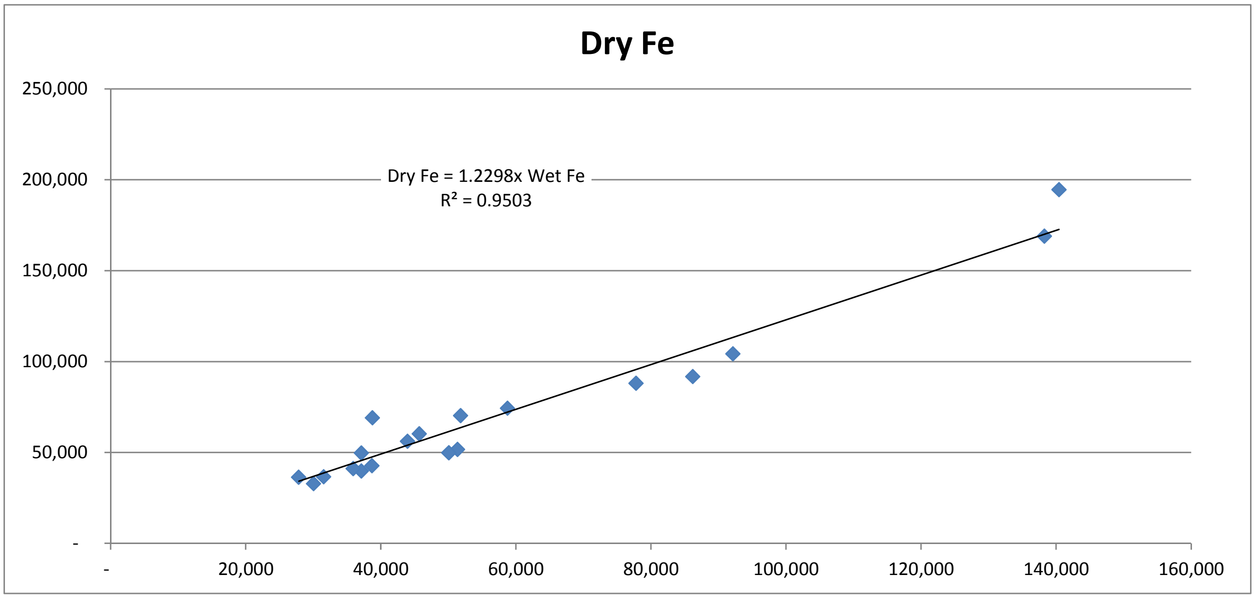


Figure 32 Comparison of dry XRF to saturated XRF for Iron (Fe)

The correlations for lead and iron are very similar to each other and significantly different from zinc and copper. The difference in correlation between the dry and saturated lead and iron can be explained by the moisture content. However, the XRF metal concentrations for the zinc and copper are nearly identical.

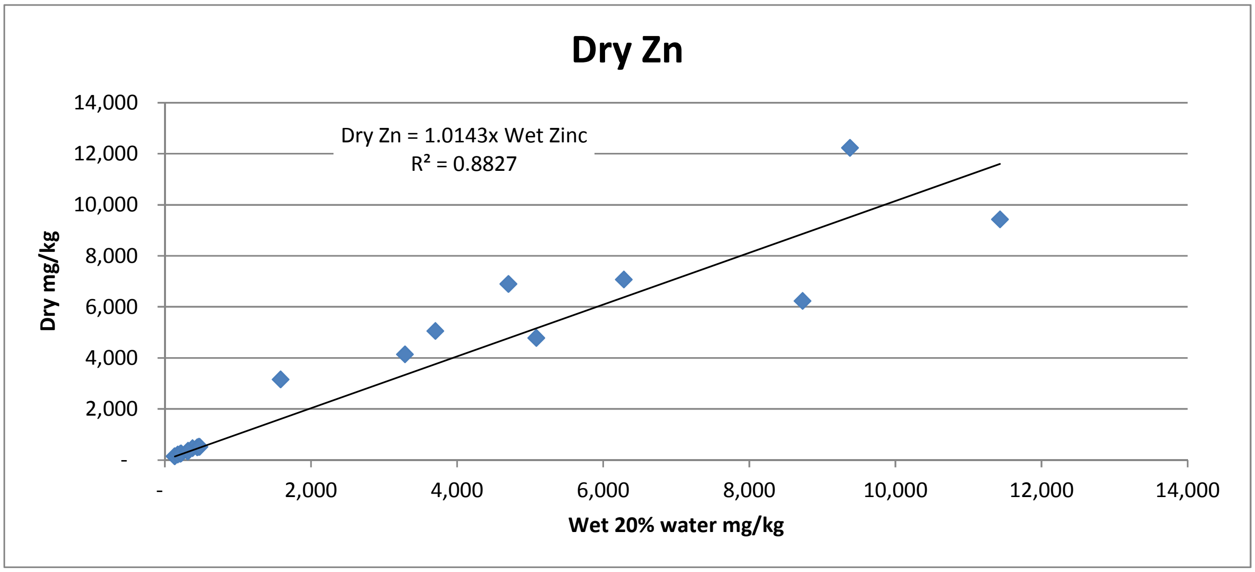
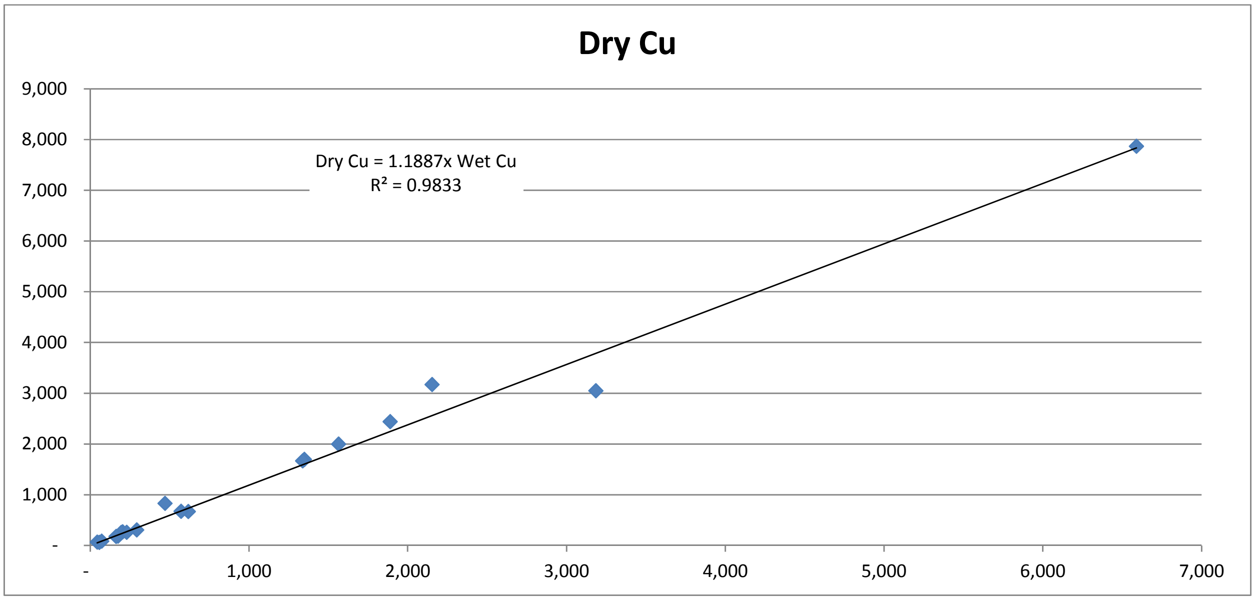


Figure 33 Comparison of dry XRF to saturated XRF for Zinc (Zn)



These analyses indicate that it is possible to use the XRF under field conditions (wet or dry) to confirm removals.

5.2 Laboratory Data Validation

The specific needs for data to be collected during the sampling and investigation work were examined to ensure that project objectives were achieved. The Data Quality Objectives (DQOs) of the investigation are summarized in Tables 1 and 2 of the QAPP for this investigation (DEQ-Pioneer Technical Services, 2012b). The data quality assurance/quality control (QA/QC) review for the 57 samples submitted to Energy Laboratories in Helena, Montana, between September 6 and October 18, 2012 is provided in the Data Validation Report provided in Appendix 10.

5.2.1 Overall Data Summary

There was a total of 456 data points associated with the laboratory analysis of the Upper Blackfoot Mining Complex Floodplain Investigation samples. Fifty-seven samples were submitted to Energy Laboratories, Inc. in Helena, Montana and analyzed by ICP/MS for aluminum, arsenic, cadmium, copper, iron, lead, manganese and zinc. All 456 (100%) were assessed and based on matrix spike concentrations outside of laboratory control limits, 9.4% (43 data points) were qualified as J-, an estimated quantity but the result may be biased low and 7.5% (34 data points) were qualified as J+, an estimated quantity but the result may be biased high. The matrix spike results resulted in a total of 17% of the laboratory results being qualified. No data points were rejected and all the data may be used to assess the site conditions.

QC criteria for precision, accuracy, representativeness, and completeness were used to assess and qualify the data and are summarized in the following sections.

5.2.2 PRECISION

Precision is the amount of scatter or variance that occurs in repeated measurements of a particular analyte. Acceptance or rejection of precision measurements is based on the relative percent difference (RPD) of the laboratory and field duplicates. For example, perfect precision would be a 0% RPD between duplicate samples (both samples have the same analytical result). For total metals, acceptable precision would be a RPD of plus or minus 35% in solid samples and plus or minus 20% in water samples. Precision requirements are derived from the Contract Laboratory Program (CLP) Statement of Work (SOW) (EPA, 1992). For these investigations, precision was assessed based on only laboratory prepared duplicate sample analysis. The procedures used to assess precision followed the DEQ guidance provided in Appendix A of the QAPP (DEQ-Pioneer Technical Services, 2012b). No RPD results for the laboratory generated duplicate sample exceeded 35% as designated in QAPP. The precision was determined to be acceptable for all samples submitted to the laboratory for analysis.

5.2.3 ACCURACY

Accuracy is the ability of the analytical procedure to determine the actual or known quantity of a particular substance in a sample. The standard deviation (SD) of the laboratory matrix spike was used to measure accuracy statements for inorganic data. Accuracy acceptance or rejection was based on the percent recovery (% R) of the laboratory matrix spike. Perfect recovery would be 100% (the analysis result is exactly the known concentration of the matrix spike). For total metals, an acceptable accuracy range would be 75% to 125% in solids and in water. Accuracy requirements for this project are derived from the CLP SOW (EPA, 1992). Accuracy was only assessed for the laboratory analysis of metals. The procedures used to calculate accuracy followed the DEQ guidance provided in Appendix A of the QAPP (DEQ-Pioneer Technical Services, 2012b). Seventeen percent of the data points were qualified as estimated based on the review of the matrix spike results. Accuracy was determined to be acceptable for all samples collected for analysis.

5.2.4 REPRESENTATIVENESS

Representativeness is a qualitative parameter that is addressed through proper design of the sampling program. The sampling program described in the SAP was designed to obtain a sufficient number of samples that adequately represent the range of conditions present in the medium being sampled and specified suitable sampling methods and procedures.

The laboratory results have been reviewed and qualitatively assessed by Pioneer and have been determined to be representative of the conditions in the Upper Blackfoot Mining Complex floodplain and meet the purpose of this investigation.

5.2.5 COMPLETENESS

Completeness is assessed to determine if enough valid data have been collected (see Section 10.0 of the QAPP, DEQ-Pioneer Technical Services, 2012b) to meet the investigation needs. Completeness is assessed by comparing the number of valid sample results to the number of samples planned for the investigation. The completeness targets for these investigations is 90% or greater. As discussed in the SAP (see section 2.6.1, XRF Analysis) 10% of the samples analyzed by the portable XRF will be submitted to the laboratory and the results will be used to verify XRF results and to develop a statistical relationship of the laboratory results to the XRF results. Approximately 660 samples were collected for XRF analysis, of those 57 samples were submitted to the laboratory to be tested for metals, resulting in an 86% completeness for laboratory submittal to the laboratory for this investigation. No laboratory results were rejected due to data validation, resulting in 86% laboratory sample analysis completeness for this investigation.

More samples were collected in the marsh area and analyzed by XRF than planned in the SAP. This change came about because the high water levels in the marsh made the original plan to collect samples on transects infeasible. Hand augured samples were collected in the marsh, and based on visual observations of the samples, a decision was made to collect additional samples from more hand augured sample locations in order to obtain a better representation of the tailings distribution in the marsh. No duplicates of the additional marsh samples were sent to the chemistry lab.

The decision to not have 10% of the additional samples tested using chemical analysis had no effect on the interpretation of the data because the 57 samples that were duplicated gave a clear understanding of how the two analytical techniques compared. The additional expense of additional testing of biased samples was unwarranted.

5.2.6 COMPARABILITY

Comparability is assessed to determine if one set of data can be compared to another set of data. Comparisons are made by examining the methods used to collect the samples and the laboratory and field methods used to acquire sample data, for two distinct data sets. The data summarized in this report includes soil/sediment samples collected from test pits and soil borings and then analyzed by a field XRF with a subset sent to Energy Laboratories for confirmation of the field XRF results.

The samples were collected using analytical methods and SOP’s for this investigation that were included in the QAPP (DEQ-Pioneer Technical Services, 2012b) and the SAP (DEQ-Pioneer Technical Services, 2012a). The SOP’s and project design are based on EPA and other industry standard practices. Sample collection was completed by professionals who were properly trained in the Pioneer SOP’s and equipment use. Proper chain of custody and sample handling were observed during sample collection, delivery to the laboratory and analysis. The analytical laboratory performed the sample analysis using industry standard methods.

As a result, if future evaluations in the area sampled require that this data set be considered to support decision making, the laboratory data is of known quality based on these factors. If the other data set is acquired using comparable sampling and analytical methods, the data from those event(s) may be used in concert with this data set.

6.0 REFERENCES

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APPENDIX 1a ANALYTICAL DATA REPORTS FROM ENERGY LABORATORY

All the reports from Energy Laboratories are merged into a single PDF file named "Appendix 1 All Floodplain Sediment ICP analyses from EnergyLabs.pdf".

Energy Labs also provided the data as comma delimited ASCII files (CSV) that were merged with the Comma delimited files produced by the XRF.

APPENDIX 1b DATA VALIDATION REPORT

APPENDIX 2 XRF SUMMARY

This is a 48 page PDF 11x17 file called “Appendix 2 All XRF Data Merged and sorted 12-17-2012.pdf”

APPENDIX 3 FIELD LOGS

The field logs were entered into gINT and displayed in the PDF filed named *Appendix 5 Test pit logs.pdf*

APPENDIX 4 PHOTOS OF TEST PITS

Appendix 6 Photo Log - Flood Plain.pdf

APPENDIX 5 SCREEN ANALYSIS OF TEST PIT SAMPLES

Selected samples were screened to determine the particle size distribution.

Appendix 7 Screen Sizes - Compiled Lab Data 12-28-12.pdf.

APPENDIX 6 SCREEN ANALYSIS BULK SAMPLES

Seven bulk samples of native stream bed material were collected and screened to determine the size consist of the native stream bed alluvium along the valley.

Appendix 8 Bulk Sieve Samples 2-4-13.pdf.

APPENDIX 7 SAMPLE PREPARATION FOR XRF ANALYSIS

All the field samples were brought into the lab and dried. The dried samples were screened at 10 mesh (2mm) and the -10 mesh fraction split until the sample size was approximately 14g. The sample was placed in the XRF sample cup provided by the XRF manufacturer as described below.

Appendix 9 XRF Sample Preparation for XRF Analysis.pdf

APPENDIX 8 MAPS AND TRANSECT CROSS SECTIONS

A. Map Transect Cross Sections Above Marsh
B. Map Floodplain Depth to Bedrock 2012
C. Map Floodplain Tailings Thickness 2012 6 maps
D. Map Groundwater Elevation Nov 7 2012 on air photo
E. Map Groundwater Elevation Nov 7 2012

APPENDIX 9 LOCATIONS OF NEW AND EXISTING TEST PITS

In addition to the test pits excavated during this task order, other data relating to the depth and distribution of the tailings contaminated alluvium were incorporated into the data analysis.

The location of all the 2012 and pre 2012 sites in Montana State Plane NAD83, International feet and Elevations in NAVD88 are listed in this section. It also includes the measuring point elevations and elevations of the piezometers and transducers.

The data is in a PDF file named Appendix 3 Flood Plain Master Data File Report Data Header.pdf it contains six 11x17 pages. The original data is found in the Excel file named C:\Projects\Mike Horse\Flood Plain Sampling\2012 Flood Plain Data Sampling Report\[Flood Plain Master Data File Report.xlsx]Data Header

This file is merged dynamically with the *Flood Plain Master Data File Report Test Pit Lithology and Metal Content.pdf* in the geologic modeling software to provide the 3D spatial references.

APPENDIX 10 LITHOLOGY AND METAL CONTENT OF SAMPLES

This is a spreadsheet with 2297 rows and 34 columns of data that organizes all the lithologic and XRF data in each test pit or bore hole. It includes the 2012 and pre 2012 data from all sources.

This data is dynamically merged with the header data (coordinates and elevation of each site) and imported into the Carlson Geologic modeling software which was used to interpolate the water table and contamination thickness between each sample location, to create a continuous 3D mathematical representation of the thickness and elevation of each unit being modeled.

The spreadsheet is available as an EXCEL document and as a PDF. The Excel file is C:\Projects\Mike Horse\Flood Plain Sampling\2012 Flood Plain Data Sampling Report\[Flood Plain Master Data File Report.xlsx]Data Header

The PDF is named “Appendix 4 Flood Plain Master Data File Report Test Pit Lithology and Metal Content.pdf” it is 132 11x17 pages.

APPENDIX 11a Test Pit Field Log Notes

APPENDIX 11b Combined Field Notes

APPENDIX 12 SAMPLINGS AND ANALYSIS PLAN

The approved SAP is in document Appendix 12 FINAL UBMC Flood Plain SAP 07-13-12.pdf.