TETRA TECH

MEMO

To:	Mr. Jim Ford, NRDP
From:	Mr. William H. Craig, LHG, Tetra Tech
Date:	July 21, 2016
Subject:	Data Gap Investigation – Silver Bow Creek and Blacktail Creek Corridors

This technical memorandum presents results of soil, sediment, surface water, groundwater, and pore water sampling pertaining to characterization of mine wastes located at the Blacktail Creek (BTC) Berm area and within the historical floodplain deposits associated with the BTC and Silver Bow Creek (SBC) riparian corridors. The sampling results are being utilized to address data gaps and satisfy design needs for the integration of restoration with remedy of mining and mineral processing wastes in the SBC and BTC Corridors **(Figure 1; Appendix A)** and to support integration of restoration design. Removal of wastes is described in the 2006 Butte Priority Soils Operable Unit (BPSOU) Record of Decision (ROD) Section 12.3.3.2 (EPA 2006a) which requires excavation of contaminated sediment, streambanks, and floodplain wastes from the reach of Blacktail Creek just above the confluence with upper Silver Bow Creek down to the reconstructed floodplain and stream channel in Lower Area One, and the 2015 Preliminary Conceptual Restoration Plan (Confluence, 2015). Field methods and procedures used in this data gap investigation generally followed procedures outlined in the draft final sampling and analysis plan (SAP) and quality assurance project plan (QAPP) (Tetra Tech 2016a).

BACKGROUND

In 1983, the State of Montana filed a lawsuit in federal District Court against the Atlantic Richfield Co. (ARCO) for injuries to the natural resources in the Upper Clark Fork River Basin, which extends from Butte to Milltown, Montana. The *Montana v. ARCO* lawsuit, brought under federal and state Superfund laws, sought damages from ARCO, contending that decades of mining and smelting in the Butte and Anaconda areas had greatly harmed natural resources in the basin and deprived Montanans of the use of these resources.

The state settled *Montana v. ARCO* through a series of settlement agreements, or consent decrees, completed and approved by the court in 1999, 2005 and 2008. One of the three injured areas in the Upper Clark Fork River Basin covered under the 2008 settlement agreement was the Butte Area One (BAO) injured groundwater and surface water site.

The 2008 *Montana v. ARCO* Consent Decree allocated $28.1 million, plus interest, to restore, replace or acquire the equivalent of the injured groundwater and surface water of BAO. Then-Governor Schweitzer created the Butte Natural Resource Damage Restoration Council (BNRC) to give the citizens of Butte a strong voice in how this fund should be spent. The nine member volunteer council, with assistance from the NRDP, developed the 2012 Butte Area One Final Restoration Plan (BNRC 2012) to guide the expenditure of these funds. It was approved by the governor in January 2013.

Injury to groundwater in BAO has been demonstrated by the occurrence of concentrations of contaminants (including cadmium, zinc, iron, lead, copper, arsenic and sulfate) that exceed drinking water standards in the alluvial aquifer. The areal extent of the known contamination above drinking water standards of the alluvial aquifer is about one square mile and extends from the Parrot Tailings area down gradient along the SBC channel. The highest known concentrations of dissolved contaminants in groundwater coincide with wastes from the Parrot Tailings area and the BRW. Other waste areas known as the Diggings East and Northside Tailings also contain waste materials that are leaching contaminants into the groundwater which discharges to adjacent surface waters. In Lower Area One (LAO), west of Montana Street, some of the mine waste tailings were previously removed by ARCO; however, some slag, tailings, and other wastes from the BRW and Colorado Smelter remain in place and have the potential to leach contaminants to ground and surface water.

The discharge of contaminated mine wastes, groundwater and surface water to SBC and BTC in BAO results in floodplain, surface water and instream sediment contamination. Surface runoff from storms and snowmelt carry hazardous substances from waste sources to the Creeks through surface drainages and the stormwater collection system.

The BAO Plan calls for removal of mine wastes left in place along the floodplain of upper Silver Bow Creek through BAO, with an allocation of $10 million towards that removal. The BAO Plan identifies these wastes, which include the Parrot Tailings, Diggings East, Northside Tailings, and other isolated areas of mine wastes in the Blacktail and Upper Silver Bow Creek floodplains, as the primary sources supplying inorganic contaminants to the alluvial groundwater, surface water, and in-stream sediment resources within the Upper Silver Bow Creek corridor. The 2015 Preliminary Conceptual Restoration Plan (PCRP), issued by NRDP for public input in February 2015, focused on the Upper Silver Bow Creek corridor. The June 2016 draft Parrot Tailings Waste Removal Amendment addresses the removal of the Parrot Tailings waste. This technical memorandum presents results related to the BTC Berm area and historical floodplain deposits associated with the BTC and SBC riparian corridors.

SITE DESCRIPTION

BTC receives the majority of its base flow contributions from Summit Valley groundwater in Butte, Montana. The stream intersects both the BAO injured area restoration site and BPSOU, and is a focal point for past and current remediation and restoration activities. The SBC and BTC Corridors study area that is the focus of this data gap investigation extends from below the LAO boundary on lower SBC (west of Montana Street), through the BAO and the confluence of BTC, and continues upstream above the BAO along BTC to Father Sheehan Park above Harrison Avenue (**Figure 2; Appendix A**).

In 1879, the first large-scale mineral processing smelter (Colorado Smelter) was built on SBC, at the west end of the valley. Between 1879 and 1888, at least three more smelters of consequence (BRW, Parrot Smelter and Montana Ore Purchasing Company (M.O.P)) were constructed upstream of the Colorado Smelter, which significantly altered the geomorphology and hydrology of both SBC and the lower portion of BTC. A fifth smelter of consequence, the Bell Smelter, located west of present day Harrison Avenue on the north bank of BTC, was constructed in 1881; and reached a peak production of approximately 30 tons per day in 1883 (primarily silver ore). Production quickly tapered and the smelter was dismantled sometime in the early 1890s.

Water demands during this period increased dramatically, and the stream channels were altered significantly to keep up with the demand. At least three dams were constructed on upper SBC and the confluence area for tailings impoundment and water clarification. The dam at Montana Street (Weed, 1904) was constructed for settlement of tailings from upstream smelters and resulted in significant ponding on both sides of the stream.

Over time, mining and smelting waste materials aggraded in the SBC and BTC channels and floodplain, causing frequent and substantial flooding (Meinzer, 1914). In an attempt to mitigate flooding issues, berms made mostly of readily available waste were constructed throughout the confluence area. The known waste area referred to as the BTC Berm, is an historic remnant of these flood control berms.

PREVIOUS SITE INVESTIGATIONS

Data characterizing contaminated materials in the vicinity of the Blacktail berm are limited. In May 2013, the Montana Bureau of Mines and Geology (MBMG) conducted trenching, test pit, and borehole investigations in known and suspected mine waste areas of the BTC and SBC confluence in Butte (MBMG 2014a). In particular, the BTC Berm area was evaluated for contaminant concentrations and volumes of impacted sediments. This work was done to quantify the aerial extent and depth of tailings and impacted sediments. Its purpose was to provide an updated characterization and volume estimate of tailings and mining impacted sediments for the State of Montana. Five soil borings were advanced in the BTC Berm to characterize the subsurface material.

The MBMG 2014a report concluded the following:

- The BTC Berm contained tailings/impacted soils (T/IS) that exceeded criteria for constituents of concern (COC) concentrations established in the 2013 MBMG study's SAP.
- T/IS in the BTC Berm is not overlain by thick units of fill material as those at the Diggings East Tailings site. They are closer to the surface, and surficial at times.
- The majority of soil samples collected just above the water table in the BTC Berm, exceeded the COC criteria. Therefore, it was recommended that any potential future removal boundaries include soils down to the water table.
- The majority of organic silt samples met the classification of impacted sediment.
- The average concentrations of arsenic and lead in tailings samples from the BTC Berm area were comparable to the average concentrations of arsenic and lead in Parrot Tailings samples (Tucci, 2010). However, concentrations of average copper concentrations in tailings samples from the BTC Berm, as well as zinc concentrations, were greater than the average copper and zinc concentrations in Parrot Tailings samples.
- In total, T/IS and potential removal volumes for the BTC Berm was estimated at 14,000 cubic yards.

During baseflow conditions in 2011, the MBMG conducted a continuous bromide tracer injection in the BTC and upper SBC confluence area on behalf of the NRDP (MBMG 2014b). The work evaluated streamflow, chemistry, metals loading, and groundwater and surface-water interactions in a reach of stream impacted by more than a century of mining and milling related activities, land development, land use change, and streambed manipulation. The continuous tracer injection test was performed using a sodium bromide solution with a bromide concentration of 22.5 percent wt./wt. to obtain creek bromide concentrations of roughly 3 milligrams per liter (mg/L). Manual measurements of discharge were obtained at 15 sites over a total stream length of 10,500 feet using a SonTek Flow Tracker®. Steady-state conditions with respect to bromide were reached after 11 hours of injection. The tracer results were combined with synoptic sampling of main stem, tributary, and drive point piezometer data. Samples from 30 groundwater wells, 17 main stem locations, 8 tributary locations, and 5 drive point piezometer locations in the BTC streambed and two wetland sites were analyzed for bromide, common cations and anions, and 36 minor and trace analytes. The MBMG 2014b report concluded the following:

- Results from the tracer injection and manual Flow Tracker® measurements were consistent, and suggest that discharge in BTC between Oregon Avenue and George Street increased by 2.2 cubic feet per second (cfs); approximately 22 percent.
- Wetlands located adjacent to BTC received the majority (99 percent) of recharge from local groundwater sources, and contributed 39 percent of the flow increase observed in the studied reach of BTC (Oregon Avenue to George Street).
- The remaining baseflow contributions (61 percent) in BTC were groundwater inputs into the stream.
- Results of the tracer study also indicate that two reaches of BTC are non-gaining reaches, and may be net-losing reaches (MBMG 2014b). Gains in stream flow were not observed in SBC, from a point just downstream of Slag Wall Canyon at surface sample site SS-06 to the pumping vault on upper SBC.
- Results from metals loading assessments indicate that while there appears to be source areas for copper and zinc loading to the stream, concentrations of contaminants of concern (arsenic, cadmium, copper,

lead, and zinc) remained below Circular DEQ-7 (DEQ 2012) acute and chronic life standards for dissolved concentrations throughout the study area (MBMG 2014).

  - Total recoverable copper and zinc concentrations were elevated in surface water samples collected from the BTC reach from near the Lexington Avenue overpass to the confluence of BTC with SBC.
  - Surface water samples collected from one main stem, one wetland, and two tributary samples exceeded Circular DEQ-7 acute and chronic life standards for total copper, while the two tributary samples exceeded Circular DEQ-7 acute and chronic life standards for total zinc.
  - The sources of total recoverable copper and zinc to this area of BTC are thought to be either bed sediment loads or nearby streambank sediment (i.e., BTC Berm) or loading from historic Grove Gulch discharges.

- Surface water samples collected from the two wetlands, located along BTC in the BTC Berm area, exhibited water quality with elevated concentrations of copper and zinc. Both of the wetlands contributed measurable flow into BTC and are potential point sources.
- Concentrations of contaminants in the groundwater that recharges the wetlands near Lexington Avenue were not assessed during this investigation. Therefore, groundwater entering the wetlands could not be ruled out as a potential source.

PREVIOUSLY IDENTIFIED DATA GAPS

In order to fill data gaps in information concerning the extent and magnitude of T/IS and to obtain additional data necessary for integration of restoration with remedy, Tetra Tech conducted a limited soil, surface water and groundwater investigation within the SBC and BTC Corridors focused on the following data gaps identified in the Preliminary Conceptual Restoration Plan (PCRP) (Confluence 2015):

- Further define extent and magnitude of T/IS within floodplain soils to assess waste areas and depths;
- Characterize the near-surface aquifer to quantify construction dewatering requirements;
- Evaluate COCs in the in-stream and pond sediments, surface water and the stream banks within the SBC and BTC Corridors to identify potential contaminant loading;
- Collect additional groundwater quality data to define the extent of alluvial impacts and their potential impacts on post-restoration groundwater and surface water quality; and
- Evaluate metals loading from alluvial aquifers to SBC and BTC riparian corridors.

PURPOSE AND OBJECTIVES

The purpose and objectives of the SBC and BTC Corridors investigation were to:

- Evaluate surface water, in-stream and pond sediment, and floodplain soils in areas within the SBC and BTC Corridors that were not previously investigated;
- Confirm the lateral and vertical extent of the contamination that may require remedial action(s);
- Complete groundwater monitoring of selected monitoring wells to gather pre-construction aquifer and groundwater quality data; and
- Evaluate contaminant loading to SBC and BTC riparian corridors.

In order to meet the site investigation purpose and objectives, the draft final SAP and QAPP (Tetra Tech 2016a) was developed to address data gaps and obtain and analyze data to make sound decisions regarding the restoration efforts within the SBC and BTC Corridors. The draft final SAP outlined the sampling approach, procedures, instrumentation, and analytical requirements for each location and media sampled. The QAPP defined the data quality objectives (DQOs) for this and similar projects that are being conducted for NRDP for BAO and related work.

Soil sample results are compared to Streamside Tailings Operable Unit (SST OU) field screening criteria. The SST OU is adjacent to BPSOU, addressing SBC after it leaves BPSOU.

Water quality sample results are compared to Montana Department of Environmental Quality Circular DEQ-7 standards. In-stream and pond sediment pore water samples are compared to DEQ-7 surface water and groundwater standards.

Sediment sample results are compared to the EPA Region 3 BTAG Freshwater Sediment Screening Benchmarks, which serve as a Tier 1 screening tool to indicate if sediment contaminant concentrations may indicate potential adverse effects. Montana is located within EPA Region 8, which currently has no sediment screening numbers and uses many of the same reference values relied upon by Region 3 BTAG.

Groundwater sample results are compared to DEQ-7 groundwater standards.

FLOOD PLAIN SOILS AND MINE WASTE SAMPLING AND ANALYSIS

Three different methods were used to sample and characterize subsurface mine waste deposits, impacted soil, and miscellaneous fill materials deposited in and around the BTC berm area and floodplain. Seventeen test pits were excavated, screened and sampled in the locations shown on **Figure 2** (**Appendix A**). In addition, three direct push technologies (DPT) soil borings were advanced in the berm area and wetland pond #1 (**Pond #1**; **Figure 2**) in order to access deeper subsurface soils at depths below the maximum excavation depths from the test pits. Multiple samples were collected from each test pit and DPT boring based on the various material types encountered and XRF screening results. Lastly, fourteen stream bank soil and opportunity samples were collected by hand tools and sampled for the same constituents as the test pits and DPT borings (**Figure 3; Appendix A**). Logging and screening procedures were followed as described in the draft SAP, except as noted:

- Two additional test pits were excavated at the discretion of the Tetra Tech field geologist and approval of the Tetra Tech project manager.

- Five opportunity samples were collected; one sample was collected in the Slag Canyon portion of SBC, two from the BTC berm area on the south side of the creek, one from the banks of Grove Gulch, and one from an island located in the eastern end of wetland pond #3 (**Pond #3; Figure 3**).

- Only four samples, plus one duplicate, were selected for SPLP, ABA, NAG-pH analysis out of 61 test pit and DPT boring natural samples. This ratio is less than the 20% specified in the SAP and was inadvertent. Only two SPLP, ABA, NAG-pH samples were collected from 14 natural bank soil samples. This ratio is also slightly less than the 20% specified in the SAP.

- DPT boring sample designations followed the SAP naming procedures (e.g. BTC-WS-03 (2-5)-BT) however it should be noted that the soil boring lithology consisted of more than just organic rich wetland sediment layers as evidence by the DPT logs and the soil type naming designations (OB, AL, BC, YT, and BT).

  XRF screening of soils generally followed the procedures specified in the SAP except for thoroughly drying and sieving to a 10-mesh prior to analysis. In order to conduct the investigation in a timely and efficient manner a field decision to forego preparing and drying XRF samples in the field was made by the supervising geologist.

- Test pit logs, DPT boring logs, XRF field screening tables, and field sampling notes are included in **Appendix B. Table 1** (**Appendix C**) presents results of the total metals analyses with sample results that exceed the SST OU floodplain soil screening criteria (Pioneer 2011) highlighted in yellow. **Figure 2** presents the highest total metals results for each sample test pit and DPT sample point; soil screening criteria exceedances are indicated in red. Bank and opportunity soil sample results are summarized in **Table 2** (**Appendix C**), with sample results that exceed EPA Region III Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks (EPA 2006b) highlighted in yellow. EPA established a hierarchy for selection of freshwater sediment screening benchmarks:

  - Preference was given to benchmarks based on chronic direct exposure, non-lethal endpoint studies designed to be protective of sensitive species;
  - Values derived by statistical- or consensus-based evaluation of multiple studies were given first priority;
  - Equilibrium partitioning values were selected for contaminants with 2.0< log Kow <6.0 if empirical values based on multiple studies were not available;
  - Absent consensus or equilibrium partitioning values, single study toxicity values were selected; and
  - Marine values were used for freshwater only if a suitable freshwater value did not exist.

Figure 3 presents the highest total metals results for each bank and opportunity sample location, with bank soil sample results that exceed EPA Freshwater Sediment Screening Benchmark criteria indicated in red.

As summary of the results and discussion follows:

- Arsenic: Total arsenic concentrations of the 41 test pit samples, 10 DPT samples, and 14 bank and opportunity soil samples ranged from 7 to 1,080 milligrams per kilogram (mg/kg). Stream bank soil samples (note not actually in-stream sediment) were screened to EPA Region III BTAG Freshwater Sediment Screening Benchmarks due to their proximity to the streams. All 14 stream bank soil and opportunity samples exceeded the Freshwater Sediment Screening Benchmark of 9.8 mg/kg. As a comparison, 27 of 61 natural soil samples from test pits and DPT soil borings exceeded the SST OU screening criteria of 200 mg/kg for arsenic. The high concentrations of arsenic amongst the various soil types (overburden, black and yellow colored tailings deposits, black clay, and alluvium) appears to be randomly distributed, though overburden/fill and alluvium appear to exhibit much lower concentrations on average than obvious mine waste or tailings deposits.

- Cadmium: Total cadmium concentrations ranged from 1.1 to 70.2 mg/kg in all the soil samples analyzed. Thirteen of 14 natural bank and opportunity soil samples exceeded the EPA Freshwater Sediment Screening Benchmark of 0.99 mg/kg. Ten test pit and DPT boring samples and one opportunity bank soil sample exceeded the SST OU floodplain soils screening criteria of 20 mg/kg. All of the exceedances but two were samples collected from alluvium.

- Copper: Total copper concentrations in test pit, DPT, and stream bank soil samples ranged from 36 to 20,400 mg/kg. The highest copper concentration measured was from test pit 1 in alluvium from 10-11.5 feet bgs depth. All 14 stream bank soil and opportunity samples exceeded the EPA Freshwater Sediment Screening Benchmark criteria of 31.6 mg/kg. Twenty-six test pit and DPT boring samples and three stream bank soil and opportunity samples exceeded the SST OU floodplain soils screening criteria of 1,000 mg/kg.

- Lead: Total lead concentrations in test pit, DPT, and stream bank soil samples ranged from 20 to 3,570 mg/kg. Similar to copper, the highest lead concentration measured was from test pit 1 in alluvium from 10-11.5 feet bgs depth. Nine test pit and DPT boring samples and two stream bank soil and opportunity samples exceeded the SST OU floodplain soils screening criteria of 1,000 mg/kg. Thirteen of 14 natural bank and opportunity soil samples exceeded the Freshwater Sediment Screening Benchmark of 35.8 mg/kg.

- Zinc: Total zinc concentrations in test pit, DPT, and stream bank soil samples ranged from 78 to 22,000 mg/kg. The highest zinc concentration measured was from test pit 2 in alluvium from 3-4 feet bgs depth. Thirty-six test pit and DPT boring samples and six bank soil and opportunity samples exceeded the SST OU floodplain soils screening criteria of 1,000 mg/kg. Thirteen of 14 natural bank and opportunity soil samples exceeded the Freshwater Sediment Screening Benchmark of 121 mg/kg.

- XRF Screening: XRF results were used primarily to select soil sample intervals for laboratory analysis from various lithologies encountered and from soil horizons suspected to be impacted from mine wastes such as oxidized staining. XRF results were not used to compare to soil criteria. In general XRF results are lower than the total metals values measured in the laboratory; however for most of the COC metals, the XRF screening results (**Table 3; Appendix C**) compare within the same order of magnitude of the total metals lab analyses. The RPD between XRF and laboratory total metals ranged from 0 to over 300%. The mean RPDs for As, Cd, Cu, Pb, and Zn were 74%, 89%, 74%, 75% and 82%, respectively. The RPD variability is likely due to multiple factors. One common factor often cited is matrix or instrument interferences, as interferences may affect detection limits and precision of the instrument. Other common interferences are as follows (EPA 2004):

  - Moisture content above 20% may interfere with sample analysis as moisture alters the soil matrix in relation to the XRF calibration matrix. Given the expedited time frame for sample collection, XRF analysis, and selection and submittal of samples for laboratory analysis, samples were not thoroughly dried prior to analysis, and thus, may have had moisture content above 20%. XRF samples were not screened with a 10-mesh sieve prior to analysis. In contrast, laboratory total metals samples were first dried by the laboratory prior to sieving to 10-mesh size and analysis. Also note that the extractable total metals concentrations are reported by the laboratory on a dry weight basis not as received (i.e. the XRF analysis).
  - Chemical matrix effects such as iron absorption of copper x-rays, etc.
  - Position of samples in front of the probe window; which results in natural variability in the sample results based upon the position of the instrument and the vector of the narrow X-ray beam. This type of sampling bias is similar to sub-sample selection by the laboratory prior to extractable analysis; the laboratory only takes a small portion of the prepared sample for extraction.
  - Instrument resolution limitations may result in problems analyzing some elements, such as the instrument's inability to resolve energy differences. For example, the arsenic peak may overlap with the lead peak and the instrument may not accurately calculate the concentrations. This may particularly be the case where there is a lead-to-arsenic ratio of 10 to 1 or more as the lead peak will overwhelm the arsenic peak.
  - RPD variability may also be due the sample selection and field screening process itself, particularly during the test pit investigation where samples from the same depth but opposite walls of the test pit may represent differing material types, such as dealing with miscellaneous fill material/overburden deposits. Some of the XRF material descriptions differ from the laboratory sample material designations.
  - The length of time the sample was analyzed. Given the expedited manner in which the field work was conducted, each of the XRF-Field sample was analyzed with the XRF for 75 seconds. A greater analysis time of 120 to 180 seconds may have resulted in better correspondence (i.e. lower RPDs) between the XRF and laboratory results.

- <u>Field Quality Control Samples</u>: Based on a comparison of natural and blind field duplicate samples taken on a 5% frequency (1 per 20 natural samples) during bank and opportunity sampling, test pit excavation, and DPT boring for total metals analysis, the relative precision for the sampling methods can be qualitatively assessed based on the RPD between the two samples. The mean RPDs for As, Cd, Cu, Pb, and Zn were 69%, 34%, 65 %, 58%, and 44%, respectively. The RPD variability is likely due to multiple factors. One common factor often cited is matrix or instrument interferences, as interferences may affect detection limits and precision of the instrument. Other common interferences for the natural and blind field duplicate samples, which are similar to the XRF sample variability are:

  - Sample matrix effects such as sample heterogeneity, uniformity, and particle size.
  - Chemical matrix effects identified or attributable to the ICP/MS laboratory analysis.
  - Sample selection/splitting effects in the field methods; particularly in dealing with blind duplicate samples selected from the DPT borings since the amount of sample needed by the laboratory precludes exact sample splitting over a specified sample interval from a macro-liner DPT sample.

- <u>Waste Removal Volume Estimation</u>: Based on results of the test pits, DPT borings, and stream bank soil samples along with in-stream and pond sediment samples, a removal volume was made using the following assumptions, previous estimations details are also provided:

- The berm and large pond/wetland area (**Pond #1; Figure 2**) was the only portion covered in the PCRP (Confluence 2015); the estimated removal volume was 14,000 cubic yards (CY) (MBMG 2014b).
- An alternative initial removal volume estimate was presented in the draft Conceptual Remediation Plan Cost Estimate (CRPCE) (Tetra Tech 2016b) for NRDP under Task Order #5 used an assume removal depth of 4 feet below the base of the sediment/surface water interface and the estimated depth to groundwater. The estimated removal volume for the CRPCE BTC Berm and Pond area was 149,290 CY covering approximately 14.6 acres.
- Mine waste, impacted soil, fill material, and the native black clay soil horizon which underlies most of the BTC berm area is impacted with BAO COC metal levels that exceed SST OU floodplain soils screening criteria and should be targeted for removal. In some places, there may be more than one black clay soil horizon. The depth to the deepest occurrence of black clay at each sample location (DPT boring, existing well log, test pit) was chosen as the base of excavation for removal volume estimation purposes.
- The ground surface elevations used to estimate thickness of impacted materials was based off a LIDAR survey provided by the City of Butte.
- The small wetland pond (**Pond#2; Figure 2**) located between the KOA campground and Kaw Avenue overpass, and north of the walking path should no longer be targeted for removal because historical mining related impacts to this wetland are now considered minimal (sediment, surface water and pore water impacts are at or near background levels).
- The northern bank/berm and walkway along BTC from Kaw Avenue to the BTC/SBC confluence should be targeted for removal because the stream bank materials as well as the bulk of the berm materials sampled (garbage, mine waste, tailings, etc.) greatly exceeded screening criteria.

Based on contamination, the revised estimated volume for the BTC Berm area after applying the additional site data, revising the assumptions and kreiging the base surface elevation is 100,185 CY. **Figure 4** (**Attachment A**) shows the outline and approximate depths.

Table 4 (**Appendix C**) presents results of the physical and chemical characteristics, nutrients (nitrate), Synthetic Precipitation Leaching Procedure (SPLP), acid-base accounting (ABA), and net acid generating (NAG) pH analysis for floodplain soils and mine waste. The SPLP extraction method followed the standard EPA method protocol resulting in an extraction fluid pH of 5.0 +/- 0.05. SPLP and ABA analyses were performed on four of 61 test pit and DPT boring samples; BTC-TP-01 (8.5-9.5)-BT, BTC-TP-07 (4.5-5)-AL, BTC-TP-17 (2.5-3.5)-GC, and BTC-WS-02 (5-11)-BC. **Table 5** (**Appendix C**) present results of the physical and chemical characteristics, nutrients (nitrate), ABA, SPLP, and NAG pH analysis for bank soil samples. SPLP and ABA analyses were performed on two of sixteen bank soil samples; BTC-SBS-02S (0-12"), and GG-OSBS-01 (0-12").

The relationship between SPLP leachate and total metals concentrations differ by the constituent, the type of mineralization and strength of the sorption to substrate. The total metal concentration (mg/kg) is the total amount of potential load to the environmental, while the SPLP leaching concentration (mg/L) represents the desorption/dissolution of that metal upon exposure to acidic-water. However, since the relative amount/ratio of soil and water in the laboratory SPLP testing (EPA method 1312 calls for a 20:1 water to rock ratio) is not the same as the actual amount/ratio observed in the field, a distribution coefficient/multiplier is needed, which is referred to as the soil water partition coefficient K*d*. Because of this fact, estimated field leachate concentrations (C*l*) must be calculated by their respective SPLP and their total metal concentrations through the development of soil water-partition coefficients (K*d*) for each constituent and each major lithologic unit. This calculated field leachate concentration (C*l*) can then be compared to calculated leachate criterion (L*c*) established from DEQ Circular-7 water quality standards. While comparisons of SPLP leachate to surface water quality standards for floodplain soil/mine waste leaching to groundwater then discharging to surface water can provide a qualitative assessment of metals leaching they cannot be directly compared without further geochemical analysis. Development of soil water partition coefficients (K*d*) and estimated field leachate concentrations (C*l*) for each SPLP sample was outside the scope of this study. Therefore, **Tables 4** and **5** compare SPLP leachate concentration to surface water human health standards (HHS; DEQ Circular 7) for qualitative comparison purposes.

In addition to the SPLP leachate qualitative analysis for leaching potential, ABA analysis provides a rough guide as to the potentially acid generating (PAG) nature of sediment and, therefore, provides an estimate whether acidic drainage/leachate may occur.

Results of the SPLP and ABA analysis are summarized as follows:

- Arsenic, lead, and mercury SPLP extractions were the three COCs that exceeded their respective HHS for surface water in test pit, DPT boring, and bank soil samples. Note that SPLP extraction is run as dissolved (extract is filtered as per the method) and surface water standards are based on total metals. Also note that only two lead and no mercury sample results from surface water or groundwater sampling were above their respective water quality standards; therefore the SPLP procedure only provides an assessment of the leaching potential to water resources and not the actual fate and transport mechanisms or impacts. *In situ* geochemical processes determine the fate and transport effects of desorption and leachate migration/mixing. In layman's terms, SPLP leachate concentrations measured in the laboratory are not equivalent to actual field for a variety of reasons.

- No samples were considered potentially acid generating using the Price method (Price et al 1997) (i.e. no samples exhibited total sulfur greater than 0.3%) or the BLM method (no samples resulted in a NP:AP < 3 and NNP < -20 tons/kton).

- Saturated paste pH for test pit, DPT boring, and bank soil samples ranged from 3.8 to 8.1 S.U. with the majority of samples in the moderately acidic and neutral range (5.6 to 6.0 S.U. is moderately acidic, 6.1 to 6.5 S.U. is slightly acidic, and 6.6 to 7.3 S.U. is neutral). Also note that NAG pH can used as a secondary screening tool to provide an estimate of pH upon complete oxidation of all sulfides, thus providing a method for calibrating the effect of sulfides on acid contribution.

IN-STREAM SEDIMENT AND WETLAND POND SEDIMENT SAMPLING AND ANALYSIS

The in-stream sediment and pond sediment sampling portion of the data gap site investigation of the SBC and BTC riparian corridors consisted of collecting and sampling sediment at 18 stream and three pond stations, plus one opportunity pond sediment sample (**Figure 5; Appendix A**); with the in-stream sediment samples corresponding to the station number and a 'SS' designation and the pond sediment samples corresponding to station number with a 'PS' designation. These sample locations were co-located with surface water sampling and with pore water sampling and were sampled concurrently on March 7 through 15, 2016. Field sampling and analysis procedures followed the procedures put forth in the SAP; with the following key points and notable exceptions:

- In-stream sediment and pond sediment samples were screened by the laboratory as received (i.e. wet) to a No. 230 mesh (<63 µm) fraction for metals analysis prior to drying for moisture content and extraction.

- Sediment sample collection was limited to 0 to 12 inches below sediment/water interface. Sampling the deeper sediment sample intervals of 24 to 36 inches below grade as proposed in the SAP with an AMS® sludge and sediment sampler was not possible in the stream channels due to the coarse nature of the streambed sediments and only possible at one pond sediment location (BTC-PS-01) due to the cohesive nature of the fine grained pond sediments. Multiple attempts to sample the deeper depth interval resulted in little- to no-return and eventually broke the sampler on two separate occasions.

- Multiple in-stream sediment sample points were collected from two surface water station locations (BTC-SS-7 and BTC-SS-8) to determine the spatial variability within the stream channel deposits at stations. Two samples were collected from BTC-7; one in the approximate center of the stream channel (BTC-SS-7) and one from the channel nearest the north bank (BTC-SS-07N). Three samples were collected from BTC-8; BTC-SS-8 was collected from the center portion of the stream channel, BTC-SS-8S from nearest the south bank, and BTC-SS-8N from nearest the north bank.

- One opportunity pond sediment sample (BTC-OSS-01) was collected from a wetland pond discharge channel (western end of pond #3) from 0 to 12” depth interval.

- In-stream sediment and pond sediment sample results were compared to EPA Region III BTAG Freshwater Sediment Screening Benchmarks.

In-stream sediment and pond sediment sampling field notes are included in **Appendix B**. **Table 6** (**Appendix C**) presents results of the total metals analyses with sample results that exceed the EPA BTAG Freshwater Sediment Screening Benchmarks (EPA 2006) highlighted in yellow. **Figure 5** presents the highest total metals results for each sample point; BTAG Freshwater Sediment Screening Benchmarks exceedances are indicated in red. A summary of the results and discussion follows:

- Arsenic: Total arsenic concentrations in the twenty six in-stream sediment and pond sediment samples ranged from 22 to 4,410 milligrams per kilogram (mg/kg). All twenty six natural in-stream and pond sediment samples exceeded the EPA BTAG Freshwater Sediment Screening Benchmark for arsenic of 9.8 mg/kg. By comparison only five in-stream sediment samples and three pond sediment samples exceeded the SST OU soil screening threshold concentration of 200 mg/kg. Both shallow (0 to 12 inches) and deep (24 to 36 inches) sediment samples exceeded the screening criteria for location BTC-PS-01. All three in-stream sediment samples from SBC stream reach exceeded screening criteria; including the highest arsenic sample result measured which was from SBC-SS-02. Note that the in-stream sediment sample from Grove Gulch (GG-SS-01) also exceeded the screening criteria.

- Cadmium: Total cadmium concentrations ranged from 1.0 to 26 mg/kg. All of the in-stream sediment and pond sediment samples exceeded the EPA BTAG Freshwater Sediment Screening Benchmark for cadmium of 0.99 mg/kg; however several of the in-stream sediment samples standout: Sample SBC-SS-02 (0-12”) from the SBC reach contained 26 mg/kg total cadmium, sample BTC-PS-01 (0-12”) from wetland pond #1 contained 21.8 mg/kg, and sample BTC-PS-01 (24-36”) contained 23.2 mg/kg.

- Copper: Total copper concentrations in the in-stream sediment and pond sediment samples ranged from 194 to 10,500 mg/kg. Streambed concentration were highest in three SBC reach sample locations and lower (downstream) BTC sample locations. Note that the streambed sediment sample from Grove Gulch also exceeded the screening criteria. All twenty six natural in-stream sediment and pond sediment samples exceeded the BTAG Freshwater Sediment Screening Benchmark for copper of 31.6 mg/kg, and six in-stream sediment and two pond sediment samples exceeded the SST OU floodplain screening criteria of 1,000 mg/kg.

- Lead: Total lead concentrations in streambed sediment and pond sediment samples ranged from 125 to 1,420 mg/kg. Total lead concentrations were highest in the Grove Gulch sample location (highest measured), the three SBC reach sample locations, and the wetland pond #1 location (BTC-PS-01; both depths). All twenty six in-stream sediment and pond sediment samples exceeded the BTAG Freshwater Sediment Screening Benchmark for lead of 35.8 mg/kg.

- Mercury: Mercury was detected in five samples with concentrations ranging from 0.99 to 6.0 mg/kg. The Mercury Freshwater Sediment Screening Benchmark is lower than the analytical method reporting limit.

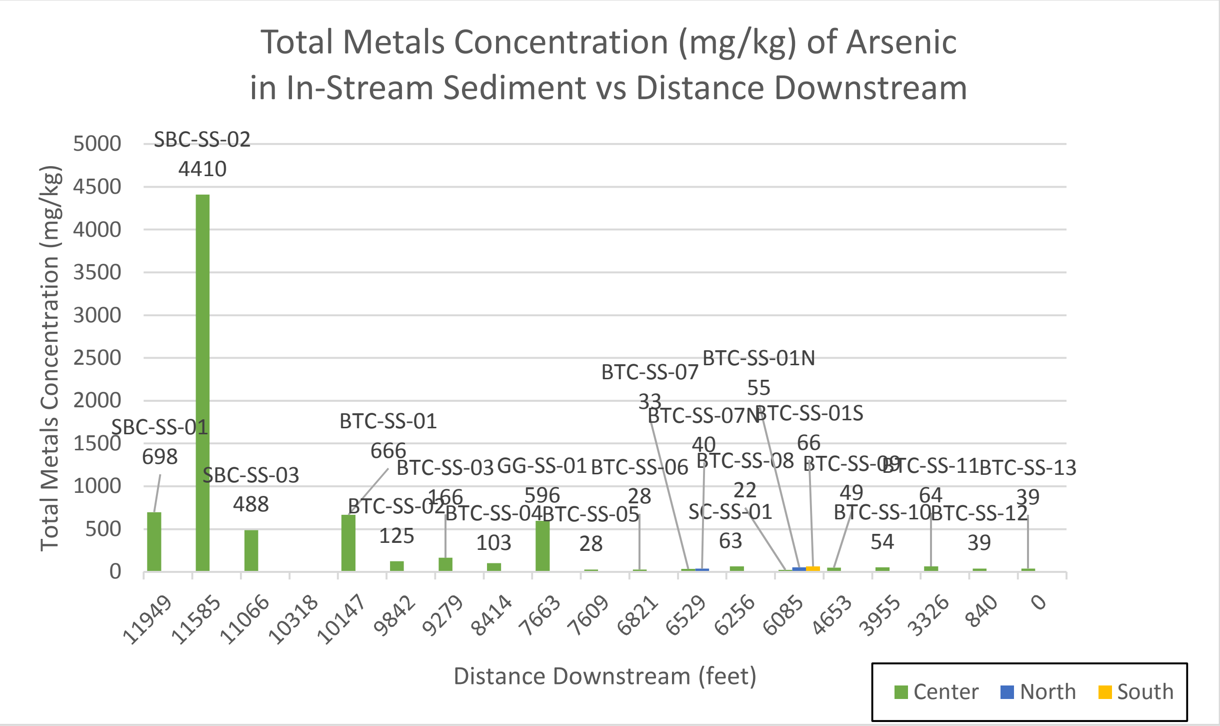
- Zinc: Total zinc concentration in in-stream and pond sediment samples ranged from 232 to 6,510 mg/kg. Total zinc concentrations were highest in the pond sediment samples (highest measured), the Grove Gulch sample location, the three SBC reach sample locations, and the BTC reach sample locations below Grove Gulch. All twenty six in-stream sediment and pond sediment samples exceeded the BTAG Freshwater Sediment Screening Benchmark for zinc of 121 mg/kg.

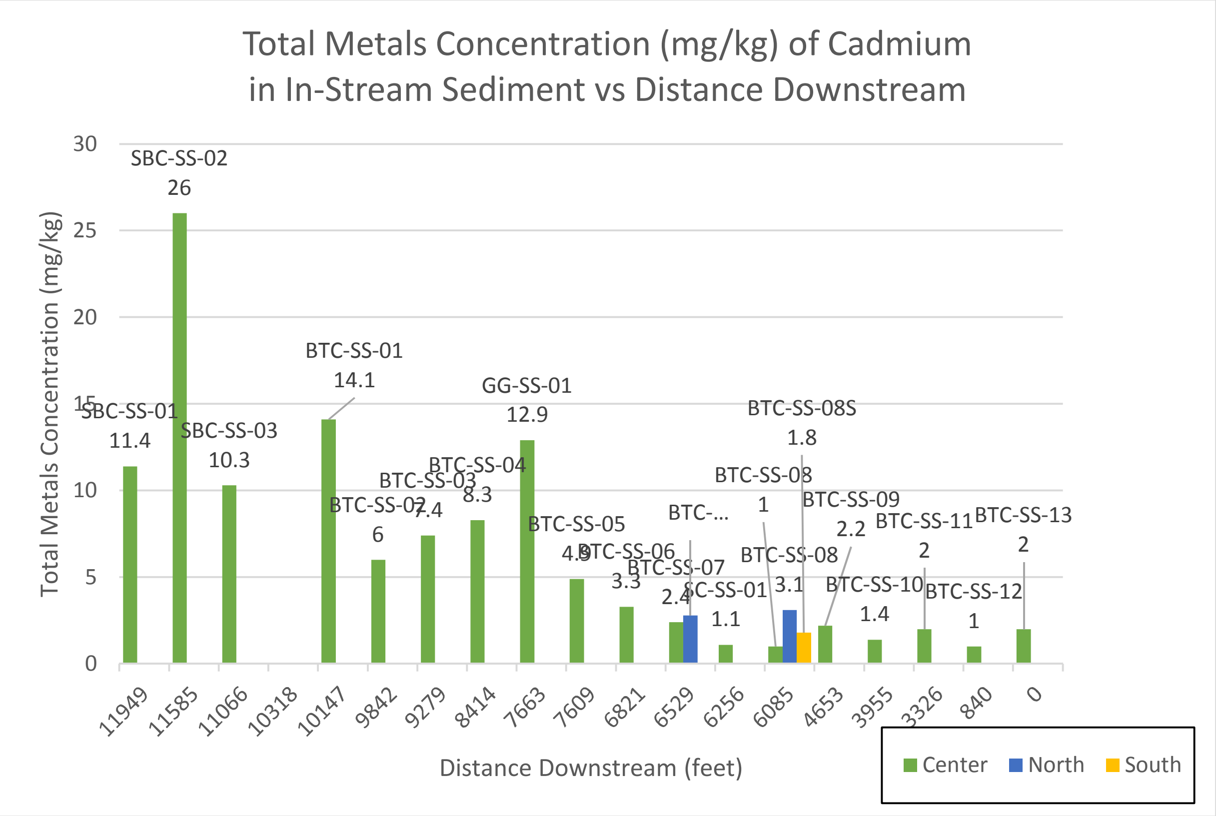
- Other Metals: Other metals concentrations measured in in-stream and pond sediment samples exceeded the BTAG Freshwater Sediment Benchmarks. These benchmark failures include chromium (43.4 mg/kg;

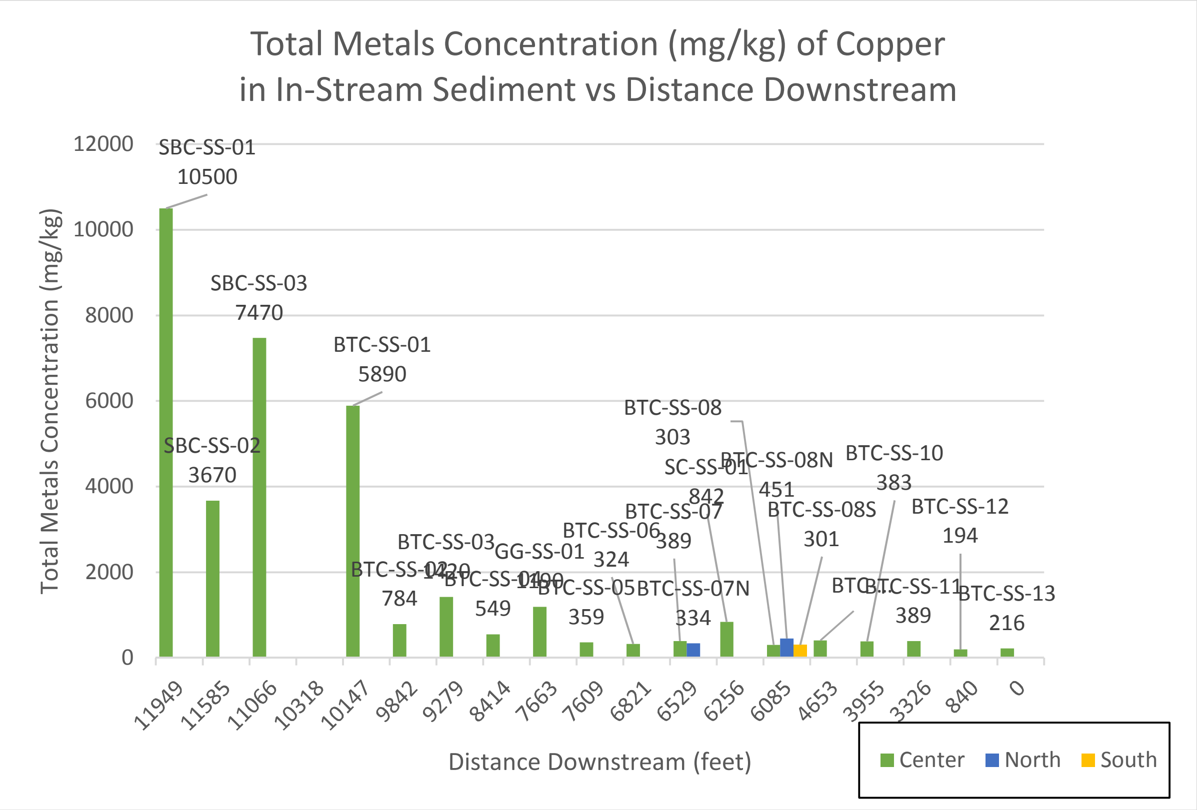
17 of 26 samples), iron (20,000 mg/kg; all twenty six samples), and manganese (460 mg/kg; 21 of 26 samples). Some of these exceedance may be naturally occurring due to the location of BTC and SBC (Butte mineralized zone), and in the case of the pond samples, may be a result of natural wetland bog/pond conditions.

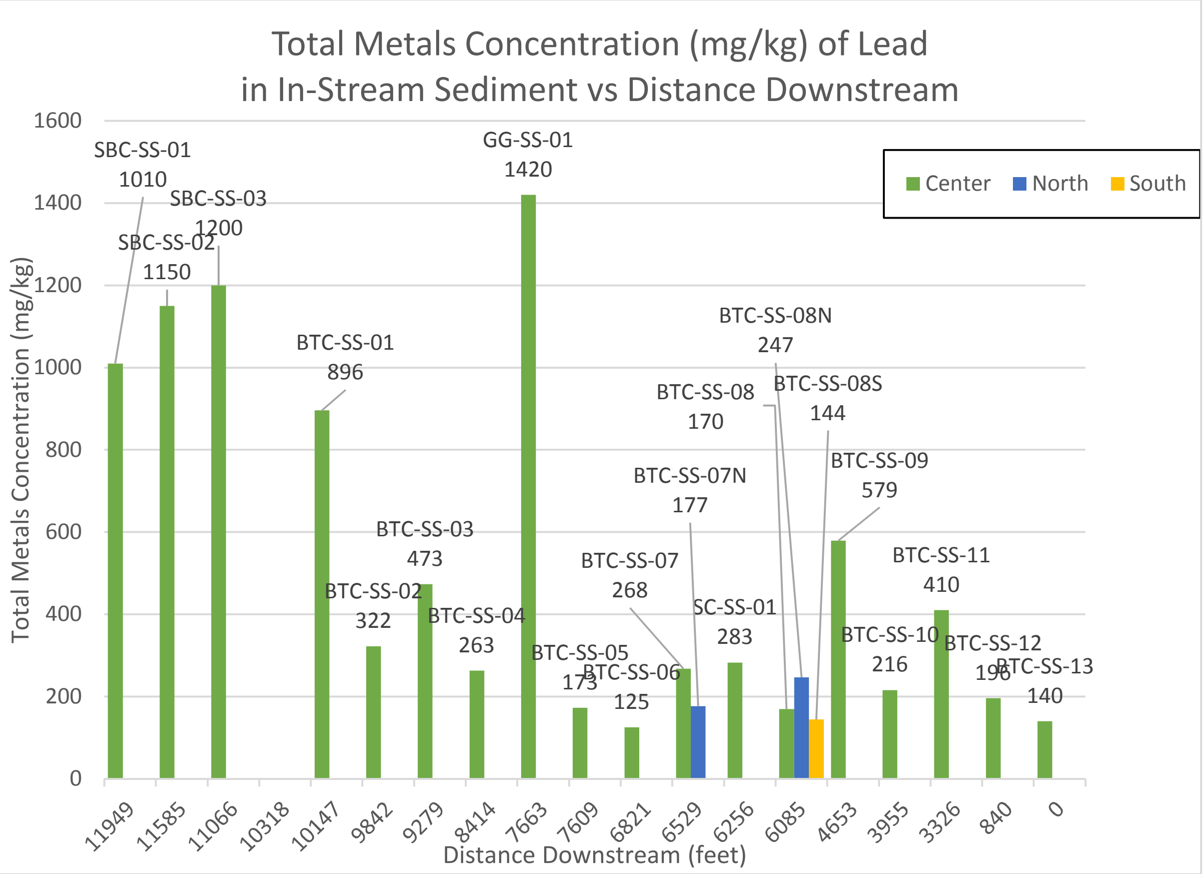
- Field Quality Control Samples: Based on a comparison of natural and blind field duplicate samples taken on a frequency greater than 5% (2 per 26 natural samples) during in-stream sediment and pond sediment sampling, the relative precision for the sampling method can be qualitatively assessed based on the RPD between the two samples. The mean RPDs for As, Cd, Cu, Pb, and Zn were 42%, 23%, 29 %, 29%, and 18%, respectively. The RPD variability is likely due to multiple factors. One common factor often cited is matrix or instrument interferences, as interferences may affect detection limits and precision of the instrument. Other common interferences for the natural and blind field duplicate samples are:
    - Sample matrix effects such as sample heterogeneity, uniformity, and particle size.
    - Chemical matrix effects identified or attributable to the ICP/MS laboratory analysis.
    - Sample selection/splitting effects from the field method.

- In general, total metals appear to concentrate in the in-stream sediments from the mouth of Grove Gulch down to the confluence with SBC and continue downstream through Slag Canyon and Butte Reduction Works area. In addition, metals appear to concentrate in pond sediments in two of the three wetland ponds. Plots of total metals versus distance downstream from the upper-most in-stream sediment sample location above Father Sheehan Park on BTC illustrate the increasing concentration of metals in sediment, particularly below the mouth of Grove Gulch and the Kaw/Lexington Avenue overpass. The increasing metals load to BTC below the mouth of Grove Gulch indicate that a possible source of metals to BTC is the Grove Gulch tributary and the former zinc mill site located in its headwaters. Other metals trend somewhat differently with obvious increases noted downstream of the former Bell Smelter site on BTC just downstream of Harrison Avenue as well as below the mouth of Grove Gulch. Dissolved metals transport in groundwater and precipitation on the mineral grains of the in-stream sediments and pond sediments can also not be discounted as a potential source of metals loading to the SBC and BTC riparian corridors since the gaining reaches of BTC and SBC correspond to the reaches below the Kaw/Lexington Avenue Overpass and mouth of Grove Gulch.


Total Metals Concentration (mg/kg) of Arsenic in In-Stream Sediment vs Distance Downstream


Total Metals Concentration (mg/kg) of Cadmium in In-Stream Sediment vs Distance Downstream


Total Metals Concentration (mg/kg) of Copper in In-Stream Sediment vs Distance Downstream



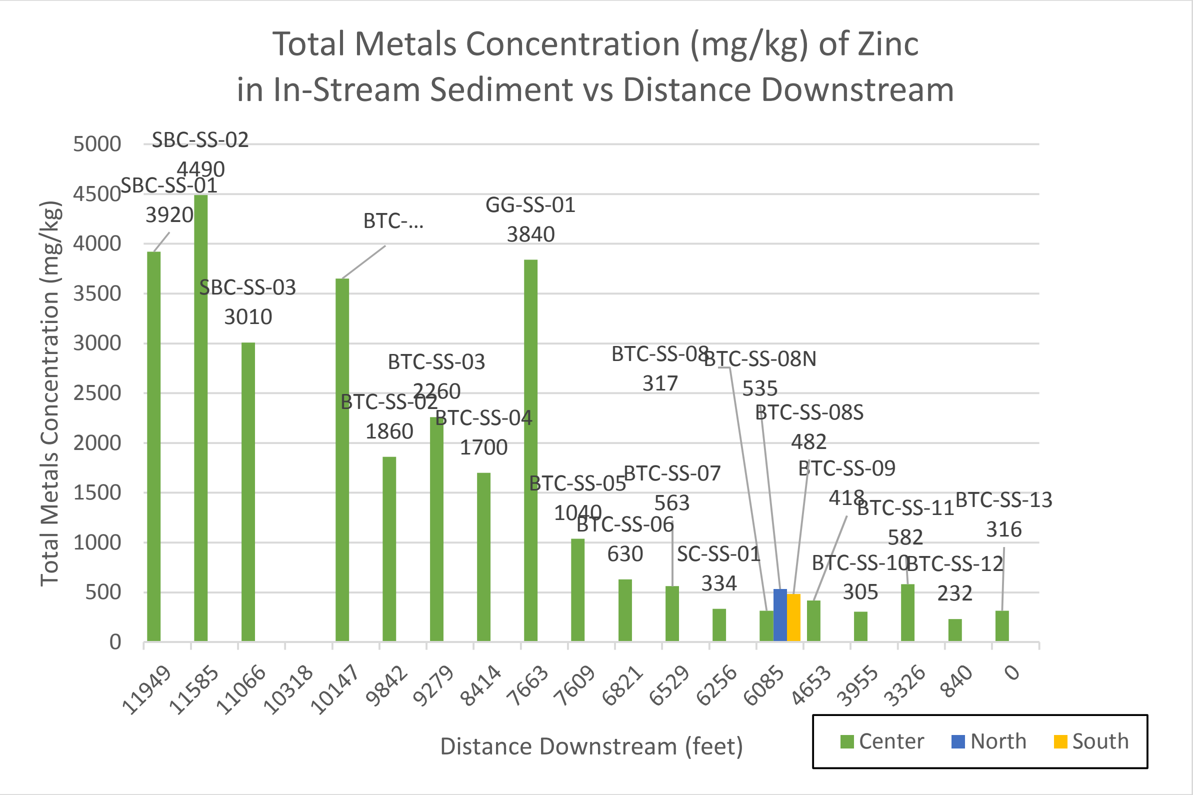


Table 7 (**Appendix C**) presents results of the physical and chemical characteristics, nutrients, ABA, SPLP, and NAG pH analysis. SPLP and ABA analyses were performed on five of twenty six (approximately 20%) of the in-stream and pond sediment samples (SBC-SS-02, SBS-SS-03, BTC-SS-08S, BTC-SS-11, and BTC-SS-13).

The relationship between SPLP leachate and total metals concentrations differ by the constituent, the type of mineralization and strength of the sorption to substrate. **Table 7** compares SPLP leachate concentration to surface water human health standards (HHS; Circular DEQ-7). Three of five SPLP leachate samples exceeded the HHS for arsenic of 0.010 mg/L, and four of five samples exceeded the HHS for lead of 0.015 mg/L. While comparisons of SPLP leachate to surface water quality standards for in-stream sediment and pond sediment leaching potential can provide a useful qualitative tool to assess metals leaching potential; they cannot be directly compared without further geochemical testing and analysis.

ABA analysis provides a rough guide as to the PAG nature of sediment and, therefore, provides an estimate whether acidic drainage may occur. One in-stream sediment sample (SBS-SS-03 (0-12") is considered potentially acid generating using the Price method; it contains total sulfur greater than 0.3%. It is also qualified as potentially acid generating using the BLM method; the ratio of NP:AP was less than 3 and the NNP was less than -20 tons/kton.

The saturated paste pH for in-stream and pond sediment samples ranged from 6.5 to 7.5 S.U., which is considered neutral; however the NAG-pH on two of the SBC in-stream sediment samples was considerably lower than the saturated paste pH indicating that the sulfide content of the sediment has the potential to drive the soil pH to acidic conditions (pH of 5.6 and 4.4 S.U.) upon complete oxidation of all sulfides.

SURFACE WATER SAMPLING AND ANALYSIS

The surface water and pond water sampling portion of the data gap site investigation was conducted by Tetra Tech on March 8 through March 16, 2016. Surface water and pond water sample locations correspond to eighteen surface and three pond water sample stations presented on **Figure 6** (**Appendix A**); with the stream surface water samples corresponding to the station number and a 'SW' designation and the pond water samples corresponding to station number with a 'PD' designation. These sample locations were co-located with in-stream sediment and pond sediment sampling and with streambed and pond pore water sampling. Field sampling and analysis procedures followed the procedures put forth in the SAP. Surface water and pond water sampling field notes are included in **Appendix B**.

Results of field parameters, physiochemical, common anions, common cations, nutrients and physical parameters that were measured and/or analyzed are presented in **Table 8** (**Appendix C**). The pH (as measured by the laboratory) of surface waters ranged from 7.4 to 8.7 S.U.; with the lowest pH corresponding to a sample collected from the Slag Canyon portion of SBC (SBS-SW-01). Note that the dissolved oxygen meter was malfunctioning and that even though values presented in **Table 8** correlate well with temperatures; the measured values for some of the samples exceed oxygen solubility limits. The low temperatures measured are understandable given the early spring sampling event and are more likely reflective of the time of day sampling took place rather than due to some groundwater / surface water interaction; though some thermal enhancement from groundwater is likely occurring in gaining sections of SBC, BTC, and the wetland ponds. ORP values ranged from 17 to 335 mV; from near neutral potential to oxidizing.

Results of the total metals and dissolved metals concentrations measured in the surface water and pond water samples are presented in **Table 9** (**Appendix C**) and **Table 10** (**Appendix C**), respectively Results of surface water and pond water sampling were compared to Circular DEQ-7 water quality standards. Chronic and acute aquatic life standards that are hardness dependent were calculated for each sample and were compared to the total metals concentration (**Table 9**). Concentrations that exceeded the surface water quality standards are highlighted yellow in **Table 9**, and highlighted in various shades of red (dark red color for HHS, red color for the acute aquatic life standard, and pink color for the chronic aquatic life standards) on **Figure 6** (**Appendix A**). A summary of the results follow:

- Arsenic: The total metal concentration of arsenic in eighteen surface water and three pond water samples ranged from 0.003 to 0.021 mg/L. Arsenic in surface water exceeded the human health based water quality standard of 0.010 mg/L in two wetland ponds samples but no other surface water samples; BTC-PD-01 contained 0.021 mg/L total arsenic and BTC-PD-01 contained 0.012 mg/L total arsenic.

- Cadmium: The total metal concentration of cadmium in surface water and pond water samples ranged from <0.00003 to 0.00067 mg/L. Cadmium in surface water exceeded the chronic aquatic life standard of 0.0003 mg/L in one surface water sample; BTC-PD-02 contained 0.00067 mg/L.

- Copper: The total metal concentration of copper in surface water and pond water samples ranged from 0.003 to 0.021 mg/L. Copper in surface water exceeded the acute and chronic aquatic life standards in two wetland pond water samples but not in any stream water samples. BTC-PD-01 contained 0.018 mg/L total copper and BTC-PD-02 contained 0.021 mg/L total copper.

- Iron: The total metal concentration of iron in surface water and pond water samples ranged from 0.25 to 1.55 mg/L. Iron in surface water exceeded the chronic aquatic life standard of 1.0 mg/L in six stream and pond water natural samples.

- Lead: The total metal concentration of lead in surface water and pond water samples ranged from 0.0004 to 0.0104 mg/L. Lead in surface water exceeded the chronic aquatic life standard in two pond water samples but did not fail any other lead water quality standards in any other samples. BTC-PD-01 contained 0.0049 mg/L total lead and BTC-PD-01 contained 0.0104 mg/L total lead.

- Field Quality Control Samples: Based on a comparison of natural and blind field duplicate samples taken on a frequency greater than 5% (2 per 21 natural samples) during surface water sampling, the relative precision for the sampling method can be qualitatively assessed based on the RPD between the two samples. The mean RPDs for As, Cd, Cu, Pb, and Zn were 0%, 9%, 9%, 0%, and 3%, respectively. The RPD differences were all with the allowable range as stipulate in EPA's National Functional Guidelines for Inorganic Superfund Data Review (EPA 2014).

- Based on these results, surface water with the highest concentration of total metals of arsenic, cadmium, copper, and lead were from wetland pond samples (BTC-PD-01 and BTC-PD-02) located immediately west of Kaw Avenue within the BTC Berm area and not from the active stream channels or tributary channels within the study area.

IN-STREAM AND POND SEDIMENT PORE WATER SAMPLING

The in-stream sediment pore water and pond sediment pore water sampling portion of the data gaps site investigation of the SBC and BTC riparian corridors consisted of collecting and analyzing 53 natural in-stream sediment pore water samples from within the active stream channels and 4 pond sediment pore water samples from three wetland ponds.

Samples were collected using a push-point interstitial water sampler "wand" at specified depths of 12 and 36 inches below the sediment/water interface on March 8 through 16, 2016. Pore water sampling points were co-located with surface water and sediment sample stations (1 through 13). However at each station pore water sample were collected from the stream channel nearest both banks for a total of 4 pore water samples collected at each station (where feasible). In-stream and pond sediment pore water sample locations correspond to eighteen surface and two pond water sample stations presented on **Figure 7 (Appendix A)**; with each in-stream sediment pore water sample designated by the letters "SBC- or BTC-", for Silver Bow Creek and Blacktail Creek Corridors area; "SPW-" for the in-stream sediment pore water sample; followed by the consecutive number of the sample; then either "N" for northern bank or "S" for southern bank; followed by the depth designation of the sample (in inches). Each in-stream sediment pore water sample collected from the tributaries was designated by the letters "GG- or SC-", for tributaries Grove Gulch and Sand Creek and "SPW-" for the stream pore water sample; followed by the location number of the sample; then the bank location "N", "S", "E", "W"; followed by the depth designation (in inches). Each interstitial pore water sample from the wetland pond sediments was designated by the letters "BTC-", for the Blacktail Creek area; "WPPW-" for wetland pond pore water; then the number of the sample labeled consecutively; followed by the sample depth (in inches). In-stream and pond sediment pore water sampling field notes are included in **Appendix B**. Field sampling and analysis procedures followed the procedures put forth in the SAP; with the following key points and notable exceptions:

- It was not possible to sample some of the proposed streambed and pond pore water sites due to the coarse nature of the streambed substrate in the active stream channels (push point refusal), and due to clogging the sampler ‘wand’ with mud/muck at other refusal locations (particularly wetland pond #3). Thirteen in-stream and two wetland pond sediment pore water proposed sample points were not able to be sampled using the push-point interstitial water sampler. Multiple attempts at each refusal point were made prior to deeming the point unsuccessful.

- It was not possible to measure depth to water inside of the push-point metal tube during pore water sampling as proposed in the SAP due to the small diameter of the tube. Therefore it was impossible to determine relative vertical gradients at each sample point compared to the hydraulic head in the surface water body being sampled (stream or pond). Even though vertical gradients could not be quantified, anecdotal evidence of artesian head at some of the sample points (Blacktail Creek: BTC-SPW-04 (36”) and Sand Creek: SC-SPW-01E (36”)) indicate that upward vertical gradients exist which may correspond to gaining reaches of stream. Other anecdotal evidence of the gaining reaches within the lower BTC drainage are the discharge flows out of the two wetland ponds located north of the creek on either side of the Kaw/Lexington Avenue overpass. There were no other sources of surface water flow into the two ponds as observed in March 2016; therefore any discharge out of the ponds into BTC is attributable to groundwater discharge into the wetland ponds.

- Even though pore water samples were analyzed for dissolved metals, like groundwater, they are being compared to surface water quality standards as well as groundwater standards because in gaining reaches of stream, the surface water and sediments are the receptors from both groundwater and pore water discharge. Some of the surface water quality standards are hardness dependent; therefore hardness values used to calculate chronic and acute standards for pore water samples were based on hardness of the receiving waters nearest the sample point (i.e. nearest surface water quality samples).

- The accuracy of the field measurement results for dissolved oxygen (DO) is suspect due to sampling methodology. During surface water sampling values measured with the DO meter exceeded the feasible range of dissolved oxygen over the range of temperatures measured.

Results of field parameters, physiochemical, common anions, common cations, nutrients and physical parameters that were measured and/or analyzed are presented in **Table 11 (Appendix C)**. The pH of pore waters ranged from 4.2 to 7.7 (as measured in the laboratory); with the lowest pH corresponding to a sample collected from the Slag Canyon/Butte Reduction Works portion of SBC. Note that the dissolved oxygen meter was malfunctioning/reading out of range and the values presented in **Table 11** are suspect. ORP values ranged from 17 to 335 mV; from near neutral potential to oxidizing.

Results of the dissolved metals concentrations measured in the in-stream and pond sediment pore water samples are presented in **Table 12 (Appendix C)**. Results of stream water and pond pore water sampling were compared to DEQ Circular 7 surface water quality standards for total metals and DEQ Circular 7 groundwater quality standards for dissolved metals. Chronic and acute aquatic life standards for pore water that are hardness dependent were calculated for each sample based on the nearest receiving surface water sample result for hardness. Stream and pond pore water concentrations that exceeded the surface water quality standards are highlighted yellow in **Table 12** and are shown in **Figure 7**.

A summary of the results and discussion follows:

- <u>Arsenic</u>: Total arsenic concentrations of the 57 natural in-stream and pond sediment pore water samples ranged from <0.001 to 5.1 milligrams per liter (mg/L). Eighteen of 53 in-stream and 2 of 4 pond sediment pore water samples exceeded the water quality standards. Most of the exceedances were based on the human health standard (HHS) of 0.01 mg/L; however some of the samples exceeded the HHS and the acute and chronic standards (0.34 and 0.15 mg/L, respectively). The depth integrated results, where sampled, were interesting. In almost all sample sets, water quality standards that exceeded water quality criteria at the shallow depth (12 inches) also exceeded criteria at the deep depth (36 inches). The highest arsenic sample results measured were from pore water collected in the Slag Canyon portion of SBC and corresponding to the sample location nearest the north bank. Another interesting observation is the results from the Grove Gulch sample location; neither pore water samples (both sample depths) exceeded the surface water quality standard even though the arsenic sediment sample from this location exceeded the BTAG sediment criteria.

- Cadmium: Dissolved cadmium concentrations ranged in pore water from <0.00003 to 0.155 mg/L. Seven of 53 in-stream sediment pore water and 1 of 4 pond sediment pore water samples exceeded the surface water quality standard. Sample SBC-SPW-02N (12") and SBC-SPW-02N (36") from the Slag Canyon reach of SBC contained the highest pore water results for dissolved cadmium of 0.155 and 0.109 mg/L, respectively.

- Copper: Dissolved copper concentrations in in-stream and pond sediment pore water samples ranged from <0.002 to 39.7 mg/L. Five of 53 in-stream sediment pore water and 1 of 4 pond sediment pore water samples exceeded the DEQ-7 surface water quality standards (two in-stream sediment pore water samples exceeded the HHS and the remainder of the samples exceeded the chronic and/or acute standards). The pore water sample concentrations were highest in the Slag Canyon reach of SBC nearest the north bank (SBC-SPW-02N; both depths), one of the lower BTC locations nearest the south bank (BTC-SPW-02S at 36 inches), and in the wetland pond #1 location (BTC-WPPW-01 at 12 inches).

- Iron: The dissolved iron concentrations in pore water samples ranged from <0.02 to 633 mg/L. Twenty eight of 53 in-stream sediment pore water and 3 of 4 pond sediment pore water samples exceeded the chronic aquatic life standard.

- Lead: The dissolved lead concentrations in streambed and pond sediment pore water samples ranged from <0.0003 to 0.0096 mg/L. The pore water sample from the Slag Canyon portion of SBC (SBC-SPW-02N (36")) and the wetland pond #1 pore water sample (BTC-WPPW-01 (12")) exceeded the chronic aquatic life standards.

- Zinc: The dissolved zinc concentrations in streambed and pond sediment pore water samples ranged from <0.008 to 95 mg/L. Four of 53 in-stream sediment pore water and 1 of 4 pond sediment pore water samples exceeded the DEQ-7 surface water quality standards. The highest concentration for zinc was found in the Slag Canyon reach of SBC nearest the north bank (SPBS-SPW-02N), from both depths.

- In general dissolved contaminants in pore water appears to be highest in sections of streams or wetland ponds that contain elevated contaminants in sediment, with notable exceptions such as Grove Gulch (sediment pore water did not exceed surface water quality standards) or in a few upstream reaches on BTC that are only marginally impacted with respect to streambed metals yet exceed the arsenic surface water quality standard (2 samples), the copper standard (1 sample), and the iron standard (multiple samples). Also note that the iron concentrations in pore water may not be related to mining activities, as any reducing conditions due to decay of organic material in groundwater or pore water can mobilize naturally occurring iron.

GROUNDWATER SAMPLING AND ANALYSIS

Tetra Tech conducted the groundwater sampling portion of the data gap site investigation on 32 existing wells between March 7 through March 11, 2016 and on three newly installed DPT piezometers on April 8, 2016. In addition, MBMG collected 12 split samples concurrent with Tetra Tech sampling for laboratory analysis on March 7, 2016. Groundwater sampling and analysis followed the procedures and analysis list presented in the draft SAP with the following exceptions:

- Three wells were not sampled: Wells BPS07-9A (abandoned), MF-1 (casing obstruction), MT98-3 (casing obstruction).
- Two additional wells were sampled: Replacement wells AMW-13B2 and BT99-4 were sampled at MBMG's suggestion.

- Groundwater split samples AMW-13A, AMW-13B, AMW-13B2, AMW13C, BT98-01, BT98-05, BT99-01, BT99-04, GS-29D, GS-29SR, MT98-05, and MT98-06 were collected by MBMG

Appendix B provides groundwater sampling field logs. **Figure 7** (**Appendix A**) shows the groundwater sampling locations. **Table 11** (**Appendix C**) presents field parameters and laboratory physical parameters and **Table 12** (**Appendix C**) presents the dissolved metals analytical results. Circular DEQ-7 groundwater quality exceedances on **Table 12** are shaded yellow. **Figure 7** also presents the dissolved metals results for each sampling point and compares them to Circular DEQ-7 groundwater water quality standards. Exceedances are highlighted in red.

Groundwater sampling results are discussed as follows:

- <u>Arsenic</u>: Concentrations of dissolved arsenic in groundwater from the 35 wells/piezometers ranged from <0.001 to 0.302 mg/L. Eight natural groundwater samples with concentrations ranging from 0.013 to 0.302 mg/L, exceeded the water quality standard (HHS; 0.01 mg/L) in wells/piezometers located between the BTC berm area and Slag Wall Canyon reach adjacent to the BRW. These include piezometer BTC-DPT-01 and wells AMW-11, GS-29D, BPS07-08A, BPS07-14A, BPSO7-15A, BPS07-25, and FP98-1. Arsenic in groundwater did not exceed the water quality standard in wells north or east of the BTC berm area with the exception of wells MF-10 (0.019 mg/L) and BPS07-24 (0.001 mg/L) in the Diggings East Area.

- <u>Cadmium</u>: Concentrations of dissolved cadmium in groundwater from the 35 wells/piezometers sampled ranged from <0.0001 to 0.037 mg/L. The highest concentrations were measured in water from wells FP98-1 (0.037 mg/L) in the BRW area and in BPS07-24 (0.0175 mg/L) in the Diggings East Area, Cadmium groundwater concentrations exceeded the Circular DEQ-7 standard for groundwater in 5 of 35 natural groundwater samples.

- <u>Copper</u>: Concentrations of dissolved copper in groundwater ranged from <0.002 to 0.667 mg/L. The highest concentrations of the wells sampled were found in BPS07-24 (0.667 mg/L), FP98-1 (0.531 mg/L), and in GS-29SR (0.505 mg/L). Copper did not exceed the Circular DEQ-7 standard for groundwater in any of the wells sampled.

- <u>Lead</u>: Dissolved lead in groundwater was detected in two wells, BPS07-14A (0.0013 mg/L) and BTC-DPT-01 (0.0005 mg/L). Lead did not exceed the Circular DEQ-7 standard for groundwater in any of the wells sampled.

- <u>Zinc</u>: Concentrations of dissolved zinc in groundwater sampled from the 35 wells/piezometers ranged from <0.008 to 24.1 mg/L. The highest concentrations of dissolved zinc were found in groundwater samples from BRW wells BPS07-14A (4.07 mg/L) and FP98-1 (24.1 mg/L) and Diggings East wells MF-10 (16 mg/L) and BPS07-24 (4.05 mg/L). Zinc groundwater concentrations exceeded the Circular DEQ-7 standard for groundwater in 4 of 35 natural groundwater samples.

- <u>Iron and Manganese</u>: Groundwater sample concentrations for iron ranged from <0.02 to 17.5 mg/L. There is no Circular DEQ-7 standard for iron in groundwater; although many sample concentrations would exceed the secondary drinking water MCL of 0.300 mg/L. Groundwater sample concentrations for manganese ranged from <0.02 to 56.9 mg/L. There is no groundwater Circular DEQ-7 standard for manganese, though concentrations were quite high in several samples which would certainly exceed the secondary drinking water MCL of 0.050 mg/L.

- <u>Field Quality Control Samples</u>: Based on a comparison of natural and blind field duplicate samples taken on a frequency greater than 5% (2 per 36 natural samples) during surface water sampling, the relative precision for the sampling method can be qualitatively assessed based on the RPD between the two samples. The mean RPDs for As, Cd, Cu, Pb, and Zn were 5.4%, 1.7%, 0.4%, 0%, and 1.4%, respectively. The RPD differences were all with the allowable range as stipulate in EPA's National Functional Guidelines for Inorganic Superfund Data Review (EPA 2014). Groundwater split samples collected by MBMG compared favorably, generally within 10% or less of the concentrations measured and analyzed by Tetra Tech.

- Based on these results, groundwater with the highest concentrations of arsenic, cadmium, and/or zinc were observed in three primary areas of the BAO during this data gap investigation. These include SWC/BRW area, SBC/BTC confluence and BTC Berm area, and Northside Tailings/Diggings East areas.

Groundwater east of Lexington Avenue did not exceed water quality standards for the metals analyzed during this investigation.

AQUIFER TESTING AND ANALYSIS

Tetra Tech conducted two, limited-duration, single-well pumping tests on Blacktail Creek Berm Area monitoring well AMW-11 (GWIC# 161962) (**Figure 7**) on April 28, 2016. The purpose of the testing was to determine aquifer properties that would be expected to occur during construction dewatering.

Well AMW-11 was selected to be representative of the site because the well is located on the BTC Berm which is comprised of a mixture of soil types and fill material prevalent throughout the berm area. The screened interval for the well is 4 to 14 feet below ground surface (bgs) (**Appendix B**). The completion log for the well indicates the material type in the screened interval of the well consists of sandy silt, clay, sand, silt and slag fill, and silty sand (in sequential order). The static water level measured in the well immediately preceding the pumping test was approximately 5.5 feet bgs, which corresponds with the water level recorded on the well completion log.

A portable Grundfos™ Rediflo-2 submersible pump was used to pump the well at an approximate rate of 2.5 gallons per minute (gpm), which was determined to be the maximum sustainable pumping rate for the available hydraulic head and the permeability of the upper-most alluvial aquifer beneath the BTC Berm area. In addition to the submersible pump, the test well was also fitted with a transducer and data logger to measure and record aquifer response to pumping withdrawals. The SAP indicated that other nearby monitoring wells and piezometers were to be monitored for drawdown; however, no aquifer responses were noted in other wells, therefore the aquifer testing was limited to single-well observations.

The pumping test data was analyzed with aquifer testing software (Aqtesolv 4.5 Professional). A total aquifer thickness of 10 feet was used in the aquifer test analysis and calculations. Theis (1935) and Cooper-Jacob (1946) analysis methods were utilized, and both analyses assumed unconfined conditions. Results are summarized below, and **Appendix D** provides graphical curve matches of the data:

Method[1]	Aquifer Thickness (in feet)	Transmissivity (ft^2/day)	Hydraulic Conductivity[2] (ft/day)
Cooper-Jacob 1	10	501.7	50.2
Cooper-Jacob 2	10	781.2	78.1
Theis 1	10	499.6	50.0
Theis 2	10	582.0	58.2
Mean Value		**591**	**59**

Notes: [1] Methods of analysis were based on assumption of unconfined conditions and using two sets of time versus drawdown data (test 1 and test 2).

[2] Hydraulic conductivities were calculated from the transmissivity of the aquifer based off of a best-fit curve or line match of the time versus drawdown data and an assumed aquifer thickness of 10 feet; where the hydraulic conductivity K=transmissivity T/aquifer thickness b.

ft^2 /day – square feet per day

ft/day – feet per day

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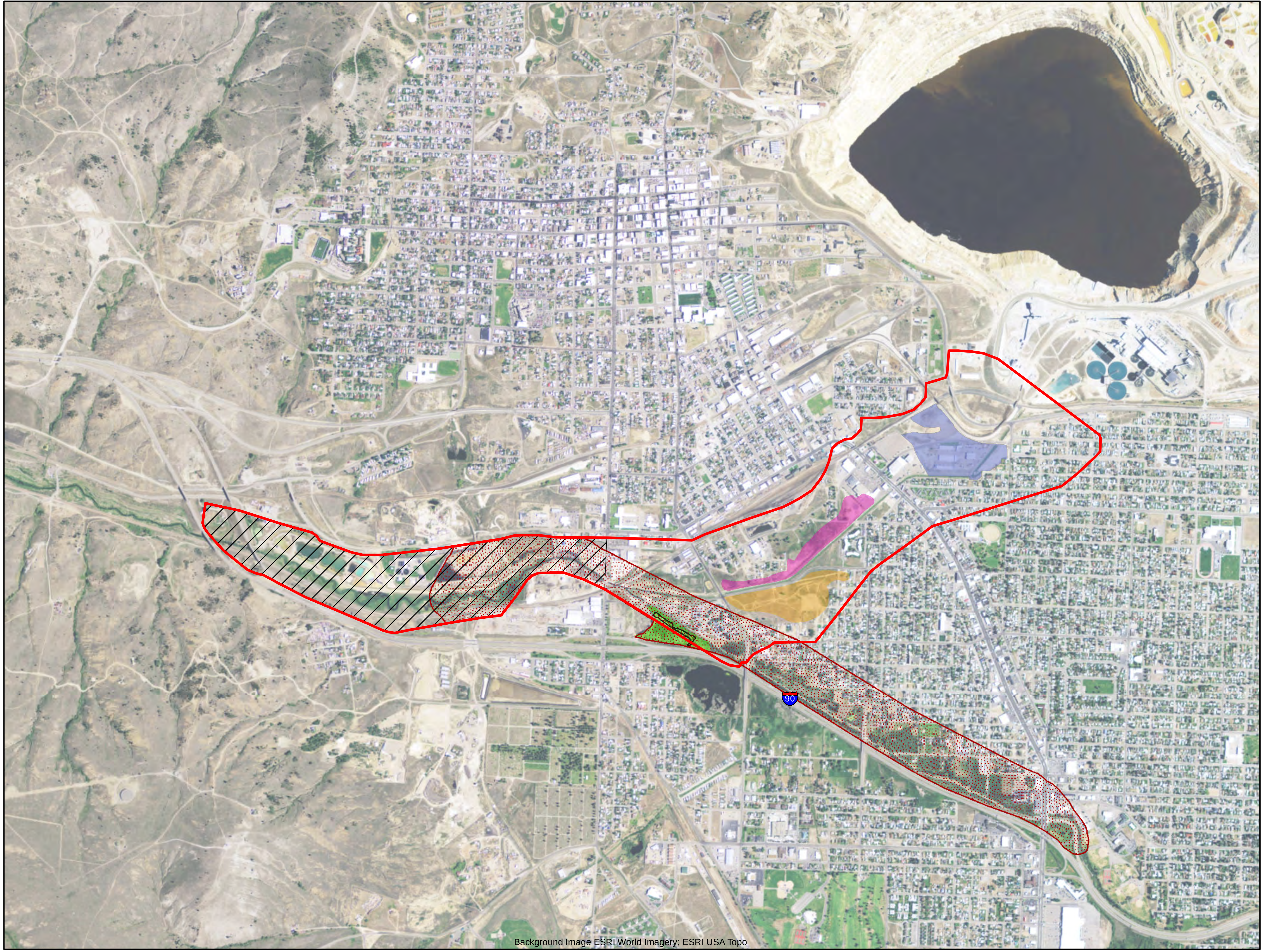
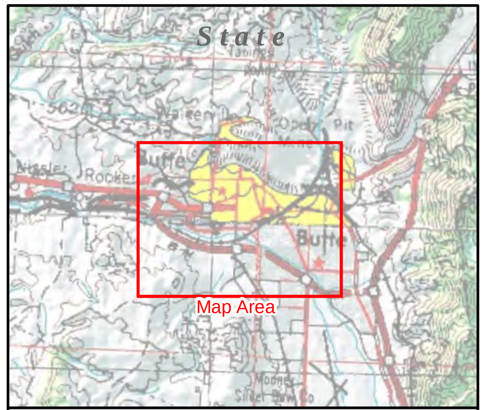
APPENDIX A
FIGURES

O:\H-M\Montana Dept of Justice\ButteAreaOne\114-570956_ButteAreaOne\GIS\ArcMap\SB_BT_Fig1.mxd



Background Image ESRI World Imagery; ESRI USA Topo



Legend

☐ Butte Area 1 Boundary
▨ Lower Area 1 (Subunit of BAO)
▩ Silver Bow Cr. and Blacktail Cr. Corridor Study Area
🟦 Parrot Tailings Removal Area
🟪 Northside Tailings
🟧 Diggings East Tailings
▦ Berm
🟩 Impacted Wetland Sediments

TETRA TECH

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12/9/2015

Butte Area One
Removal / Restoration
Removal Areas
Butte, Montana

Figure 1

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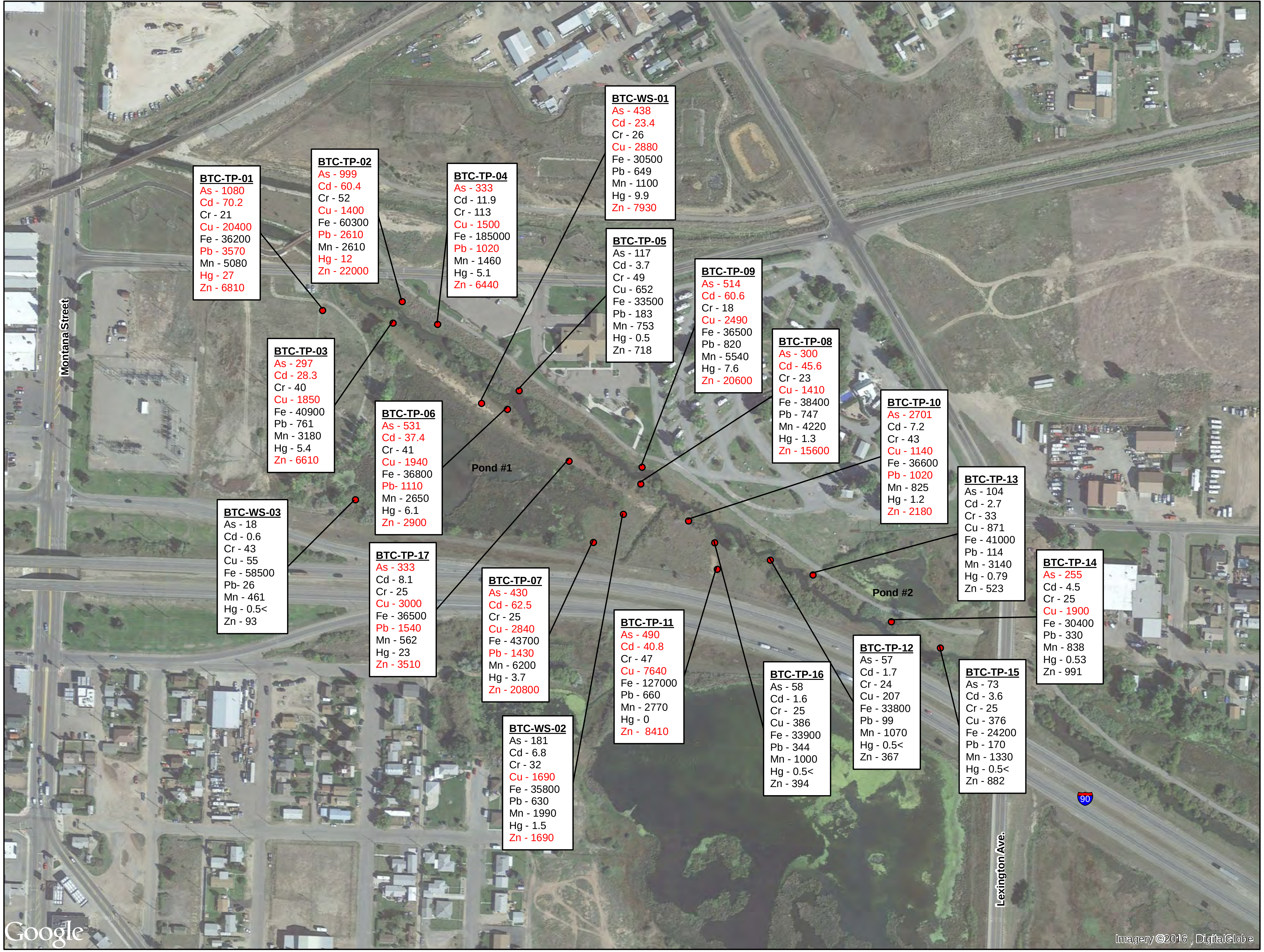

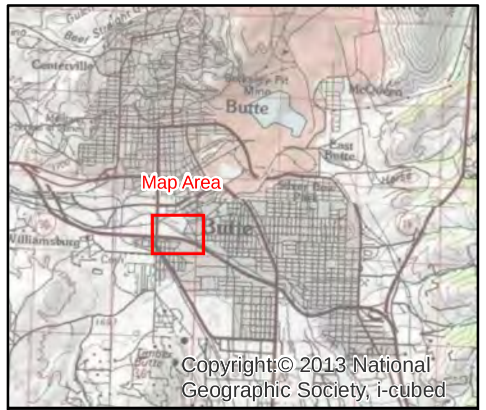

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● Sample Location
(Units in mg/kg)

Screening Criteria (mg/kg)	
Arsenic	200
Cadmium	20
Chromium	*
Copper	1000
Iron	*
Lead	1000
Manganese	*
Mercury	10
Zinc	1000
** - Not established*	

Screening Criteria utilized in site investigations from Field Screen Criteria and Procedures Phase 7 and 8 Remedial Action, SST OU Subarea 4, Reaches R and S (Pioneer 2011)

TETRA TECH

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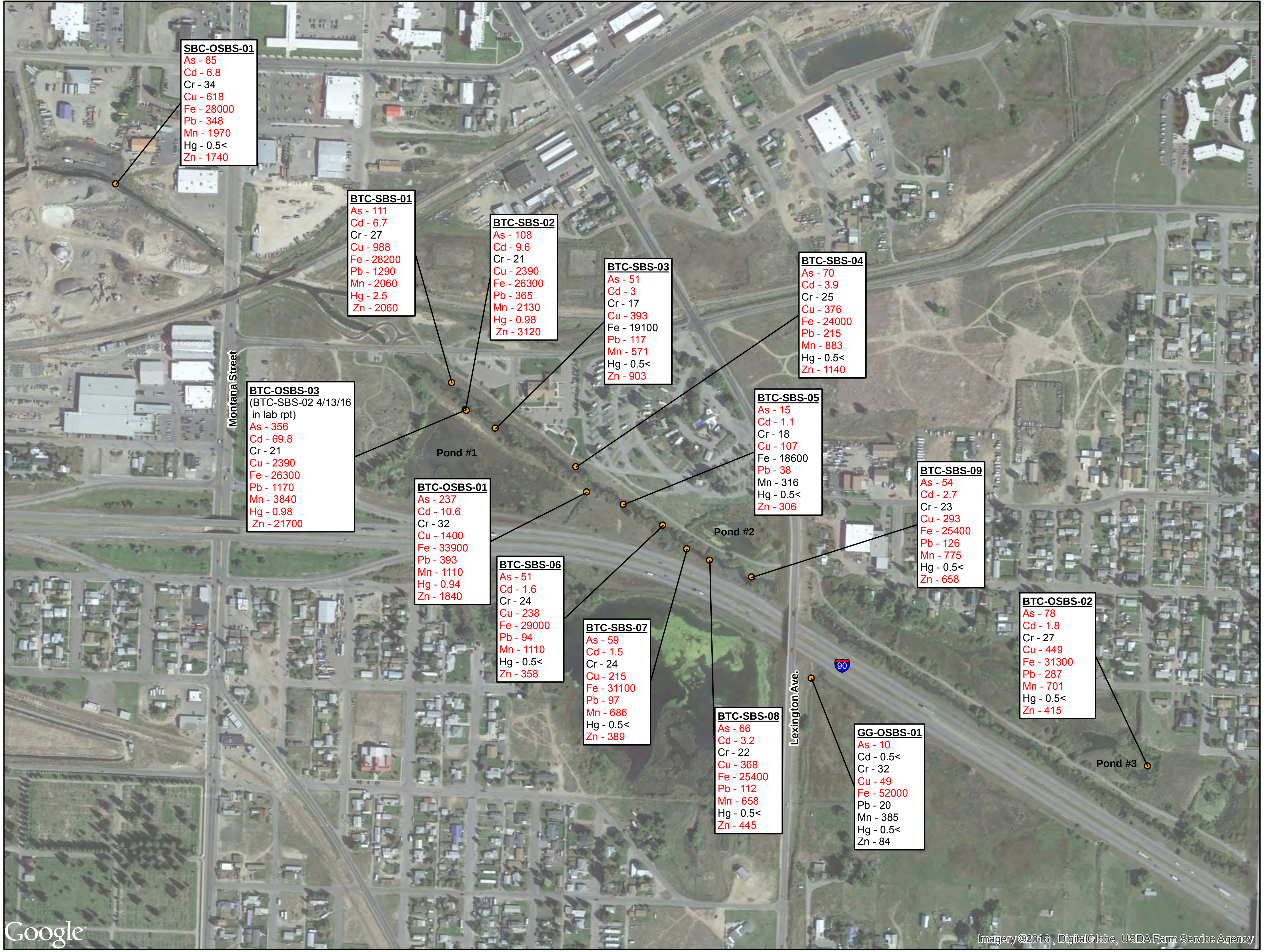
7/20/2016

Floodplain Soils / Mine Wastes Sampling Silver Bow Creek and Blacktail Creek Corridors

Figure 2



SBC-OSBS-01
As - 85
Cd - 6.8
Cr - 34
Cu - 618
Fe - 28000
Pb - 348
Mn - 1970
Hg - 0.5<
Zn - 1740

BTC-SBS-01
As - 111
Cd - 6.7
Cr - 27
Cu - 988
Fe - 28200
Pb - 1290
Mn - 2060
Hg - 2.5
Zn - 2060

BTC-SBS-02
As - 108
Cd - 9.6
Cr - 21
Cu - 2390
Fe - 26300
Pb - 365
Mn - 2130
Hg - 0.98
Zn - 3120

BTC-SBS-03
As - 51
Cd - 3
Cr - 17
Cu - 393
Fe - 19100
Pb - 117
Mn - 571
Hg - 0.5<
Zn - 903

BTC-SBS-04
As - 70
Cd - 3.9
Cr - 25
Cu - 376
Fe - 24000
Pb - 215
Mn - 883
Hg - 0.5<
Zn - 1140

BTC-OSBS-03
(BTC-SBS-02 4/13/16
in lab rpt)
As - 356
Cd - 69.8
Cr - 21
Cu - 2390
Fe - 26300
Pb - 1170
Mn - 3840
Hg - 0.98
Zn - 21700

BTC-SBS-05
As - 15
Cd - 1.1
Cr - 18
Cu - 107
Fe - 18600
Pb - 38
Mn - 316
Hg - 0.5<
Zn - 306

BTC-OSBS-01
As - 237
Cd - 10.6
Cr - 32
Cu - 1400
Fe - 33900
Pb - 393
Mn - 1110
Hg - 0.94
Zn - 1840

BTC-SBS-09
As - 54
Cd - 2.7
Cr - 23
Cu - 293
Fe - 25400
Pb - 126
Mn - 775
Hg - 0.5<
Zn - 658

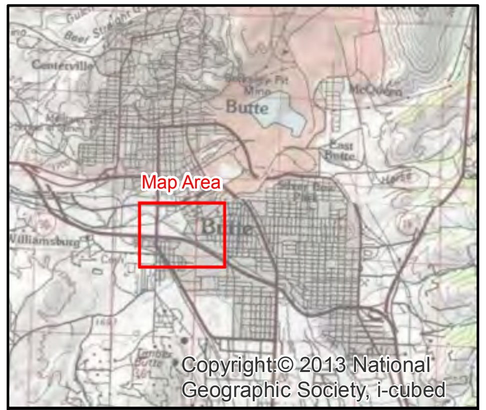
BTC-SBS-06
As - 51
Cd - 1.6
Cr - 24
Cu - 238
Fe - 29000
Pb - 94
Mn - 1110
Hg - 0.5<
Zn - 358

BTC-SBS-07
As - 59
Cd - 1.5
Cr - 24
Cu - 215
Fe - 31100
Pb - 97
Mn - 686
Hg - 0.5<
Zn - 389

BTC-OSBS-02
As - 78
Cd - 1.8
Cr - 27
Cu - 449
Fe - 31300
Pb - 287
Mn - 701
Hg - 0.5<
Zn - 415

BTC-SBS-08
As - 66
Cd - 3.2
Cr - 22
Cu - 368
Fe - 25400
Pb - 112
Mn - 658
Hg - 0.5<
Zn - 445

GG-OSBS-01
As - 10
Cd - 0.5<
Cr - 32
Cu - 49
Fe - 52000
Pb - 20
Mn - 385
Hg - 0.5<
Zn - 84



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● Sample Location
(Units in mg/kg)

Freshwater Sediment Screening Benchmarks (EPA)	
Arsenic	9.8
Cadmium	0.99
Chromium	43.4
Copper	31.6
Iron	20,000
Lead	35.8
Manganese	460
Mercury	0.18
Zinc	121

EPA Region III BTAG Freshwater Sediment Screening Benchmarks 8/2006

Hierarchy for Selection of Freshwater Sediment Benchmarks
- Preference was given to benchmarks based on chronic direct exposure, non-lethal endpoint studies designed to be protective of sensitive species
- Values derived by statistical- or consensus-based evaluation of multiple studies were given first priority
- Equilibrium partitioning values were selected for contaminants with 2.0< log Kow <6.0 if empirical values based on multiple studies were not available
- Absent consensus or equilibrium partitioning values, single study toxicity values were selected

TETRA TECH

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7/21/2016

Bank and Opportunity Soil Sampling

Silver Bow Creek and Blacktail Creek Corridors

Figure 3

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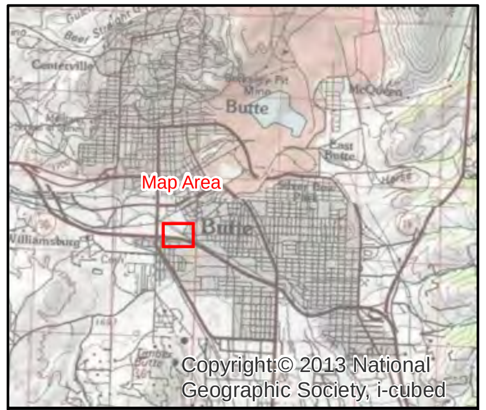

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● Sample Location
Depth to Bottom of
Black Clay (feet)

\+ Grid Point Interpolated Depth
to Bottom of Black Clay (feet)
(NAD 83 Montana State Plane, Itl. feet)

— Depth Contour
1 foot contour Interval

🟩 Blacktail Berm Area

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7/20/2016

Vertical Extent of Contamination

Silver Bow Creek and
Blacktail Creek Corridors

Figure 4

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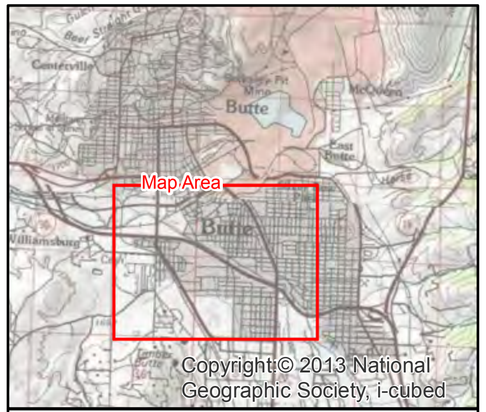
Imagery ©2016 , DigitalGlobe, USDA Farm Service Agency



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● Sample Location
(Units in mg/kg)

Freshwater Sediment Screening Benchmarks (EPA)	
Arsenic	9.8
Cadmium	0.99
Chromium	43.4
Copper	31.6
Iron	20,000
Lead	35.8
Manganese	460
Mercury	0.18
Zinc	121

EPA Region III BTAG Freshwater Sediment Screening Benchmarks 8/2006

Hierarchy for Selection of Freshwater Sediment Benchmarks
- Preference was given to benchmarks based on chronic direct exposure, non-lethal endpoint studies designed to be protective of sensitive species
- Values derived by statistical- or consensus-based evaluation of multiple studies were given first priority
- Equilibrium partitioning values were selected for contaminants with 2.0< log Kow <6.0 if empirical values based on multiple studies were not available
- Absent consensus or equilibrium partitioning values, single study toxicity values were selected

TETRA TECH

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7/21/2016

In-Stream and Pond Sediment Sampling

Silver Bow Creek and Blacktail Creek Corridors

Figure 5

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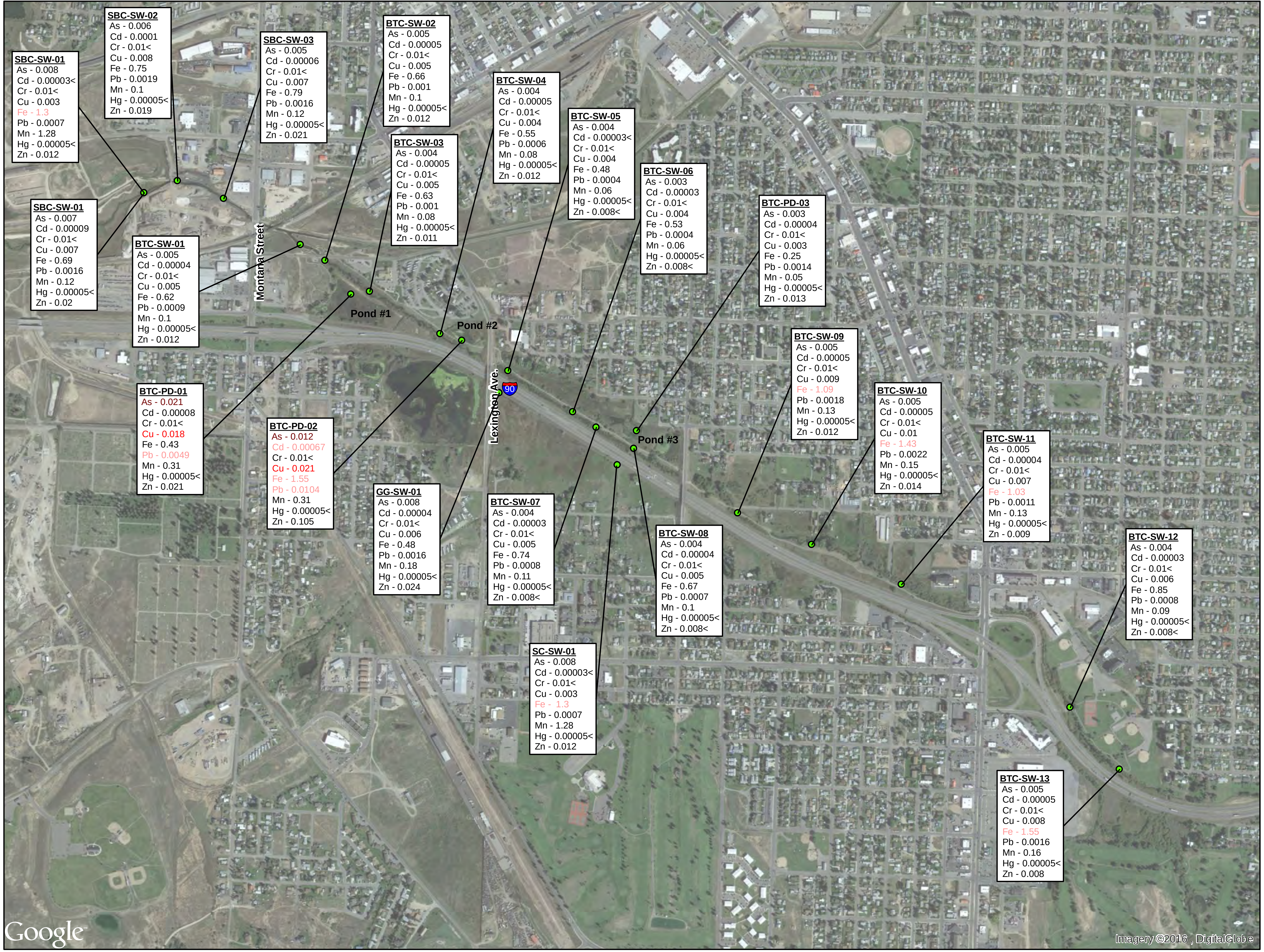


SBC-SW-01
As - 0.008
Cd - 0.00003<
Cr - 0.01<
Cu - 0.003
Fe - 1.3
Pb - 0.0007
Mn - 1.28
Hg - 0.00005<
Zn - 0.012

SBC-SW-02
As - 0.006
Cd - 0.0001
Cr - 0.01<
Cu - 0.008
Fe - 0.75
Pb - 0.0019
Mn - 0.1
Hg - 0.00005<
Zn - 0.019

SBC-SW-03
As - 0.005
Cd - 0.00006
Cr - 0.01<
Cu - 0.007
Fe - 0.79
Pb - 0.0016
Mn - 0.12
Hg - 0.00005<
Zn - 0.021

BTC-SW-02
As - 0.005
Cd - 0.00005
Cr - 0.01<
Cu - 0.005
Fe - 0.66
Pb - 0.001
Mn - 0.1
Hg - 0.00005<
Zn - 0.012

BTC-SW-03
As - 0.004
Cd - 0.00005
Cr - 0.01<
Cu - 0.005
Fe - 0.63
Pb - 0.001
Mn - 0.08
Hg - 0.00005<
Zn - 0.011

BTC-SW-04
As - 0.004
Cd - 0.00005
Cr - 0.01<
Cu - 0.004
Fe - 0.55
Pb - 0.0006
Mn - 0.08
Hg - 0.00005<
Zn - 0.012

BTC-SW-05
As - 0.004
Cd - 0.00003<
Cr - 0.01<
Cu - 0.004
Fe - 0.48
Pb - 0.0004
Mn - 0.06
Hg - 0.00005<
Zn - 0.008<

BTC-SW-06
As - 0.003
Cd - 0.00003
Cr - 0.01<
Cu - 0.004
Fe - 0.53
Pb - 0.0004
Mn - 0.06
Hg - 0.00005<
Zn - 0.008<

BTC-PD-03
As - 0.003
Cd - 0.00004
Cr - 0.01<
Cu - 0.003
Fe - 0.25
Pb - 0.0014
Mn - 0.05
Hg - 0.00005<
Zn - 0.013

SBC-SW-01
As - 0.007
Cd - 0.00009
Cr - 0.01<
Cu - 0.007
Fe - 0.69
Pb - 0.0016
Mn - 0.12
Hg - 0.00005<
Zn - 0.02

BTC-SW-01
As - 0.005
Cd - 0.00004
Cr - 0.01<
Cu - 0.005
Fe - 0.62
Pb - 0.0009
Mn - 0.1
Hg - 0.00005<
Zn - 0.012

BTC-SW-09
As - 0.005
Cd - 0.00005
Cr - 0.01<
Cu - 0.009
Fe - 1.09
Pb - 0.0018
Mn - 0.13
Hg - 0.00005<
Zn - 0.012

BTC-PD-01
As - 0.021
Cd - 0.00008
Cr - 0.01<
Cu - 0.018
Fe - 0.43
Pb - 0.0049
Mn - 0.31
Hg - 0.00005<
Zn - 0.021

BTC-PD-02
As - 0.012
Cd - 0.00067
Cr - 0.01<
Cu - 0.021
Fe - 1.55
Pb - 0.0104
Mn - 0.31
Hg - 0.00005<
Zn - 0.105

BTC-SW-10
As - 0.005
Cd - 0.00005
Cr - 0.01<
Cu - 0.01
Fe - 1.43
Pb - 0.0022
Mn - 0.15
Hg - 0.00005<
Zn - 0.014

BTC-SW-11
As - 0.005
Cd - 0.00004
Cr - 0.01<
Cu - 0.007
Fe - 1.03
Pb - 0.0011
Mn - 0.13
Hg - 0.00005<
Zn - 0.009

GG-SW-01
As - 0.008
Cd - 0.00004
Cr - 0.01<
Cu - 0.006
Fe - 0.48
Pb - 0.0016
Mn - 0.18
Hg - 0.00005<
Zn - 0.024

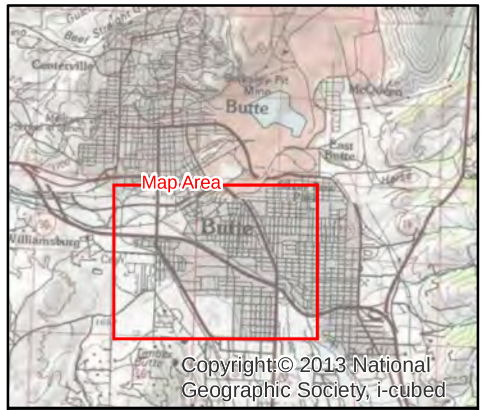
BTC-SW-07
As - 0.004
Cd - 0.00003
Cr - 0.01<
Cu - 0.005
Fe - 0.74
Pb - 0.0008
Mn - 0.11
Hg - 0.00005<
Zn - 0.008<

BTC-SW-08
As - 0.004
Cd - 0.00004
Cr - 0.01<
Cu - 0.005
Fe - 0.67
Pb - 0.0007
Mn - 0.1
Hg - 0.00005<
Zn - 0.008<

BTC-SW-12
As - 0.004
Cd - 0.00003
Cr - 0.01<
Cu - 0.006
Fe - 0.85
Pb - 0.0008
Mn - 0.09
Hg - 0.00005<
Zn - 0.008<

SC-SW-01
As - 0.008
Cd - 0.00003<
Cr - 0.01<
Cu - 0.003
Fe - 1.3
Pb - 0.0007
Mn - 1.28
Hg - 0.00005<
Zn - 0.012

BTC-SW-13
As - 0.005
Cd - 0.00005
Cr - 0.01<
Cu - 0.008
Fe - 1.55
Pb - 0.0016
Mn - 0.16
Hg - 0.00005<
Zn - 0.008



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● Sample Location
(Units in mg/L, analyzed and reported as total metals)

Exceedances are based on MDEQ Circular DEQ-7 Water Quality Human Health Standard, Acute Standard and/or Chronic Standard (October 2012).

Value exceeds Human Health Standard
Value exceeds Acute Standard
Value exceeds Chronic Standard

	HHS	Acute	Chronic
Arsenic	0.01	0.34	0.15
Cadmium	0.005	0.00052*	0.000097*
Chromium	0.1	0.579*	0.0277*
Copper	1.3	0.00379*	0.00285*
Iron	--	--	1
Lead	0.015	0.01398*	0.000545*
Manganese	--	--	--
Mercury	0.05	0.0017	0.00091
Zinc	2	0.037*	0.037*

Notes: MDEQ Circular 7 Water Quality Standards converted from µg/L (parts per billion) to mg/L (parts per million)

* Hardness dependent metals aquatic life standards are based on an assumed hardness of 25 mg/L. Please refer to the surface water total metals results table for sample specific hardness dependent standards.

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7/20/2016

Surface Water Sampling

Silver Bow Creek and Blacktail Creek Corridors

Figure 6

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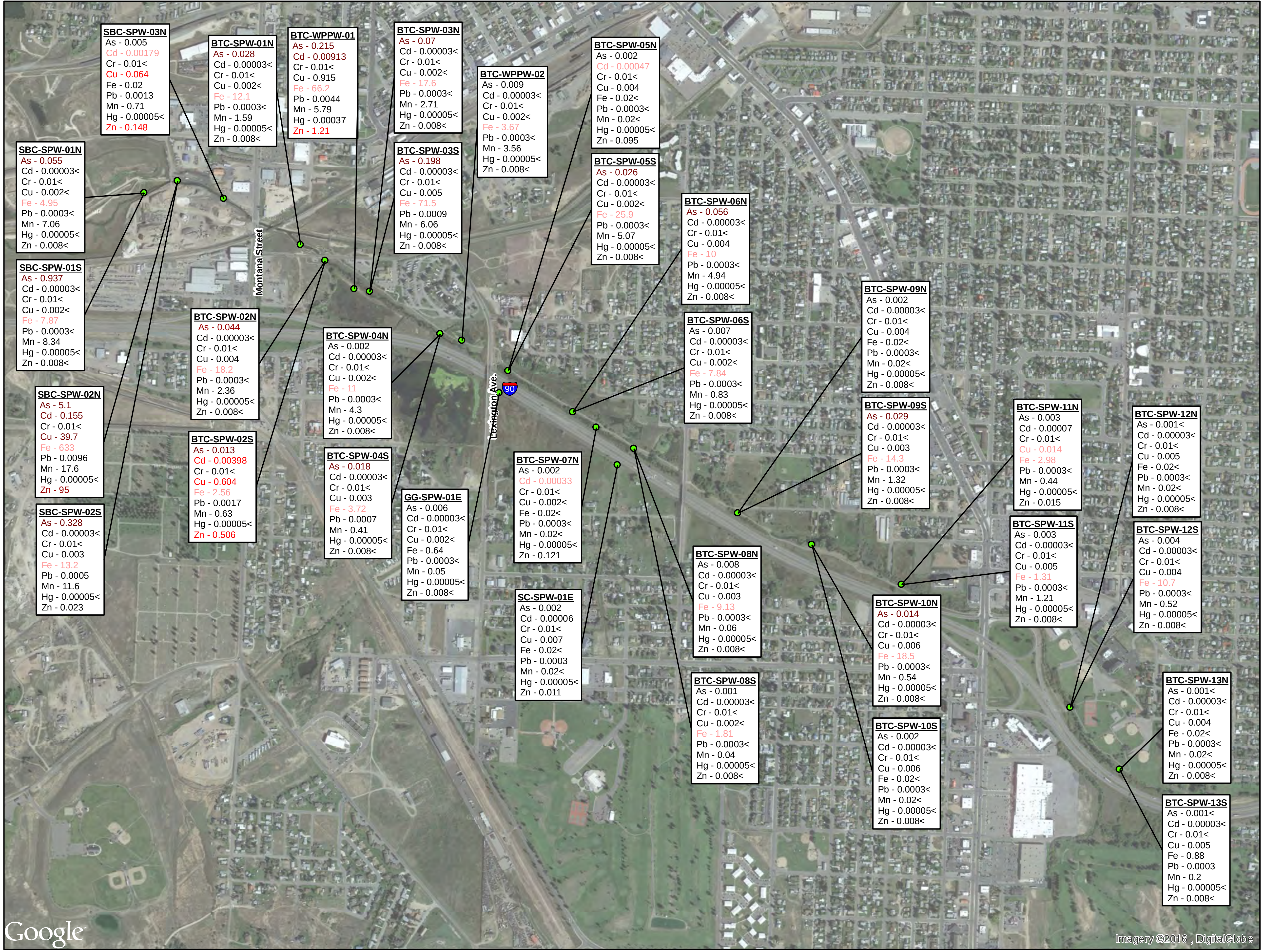

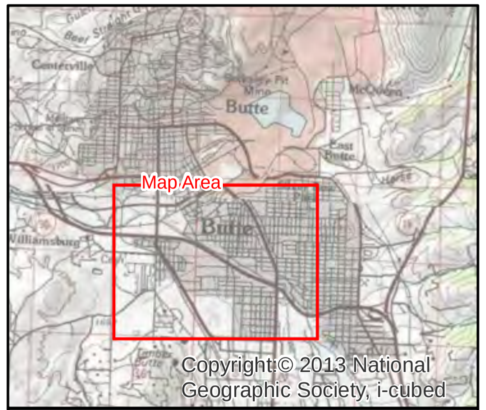

● Sample Location
(Units in mg/L, analyzed and reported as dissolved metals)

Exceedances are based on Human Health Standard, Acute Standard and/or Chronic Standard.

Value exceeds Human Health Standard
Value exceeds Acute Standard
Value exceeds Chronic Standard

	HHS	Acute	Chronic
Arsenic	0.01	0.34	0.15
Cadmium	0.005	0.00052*	0.000097*
Chromium	0.1	0.579*	0.0277*
Copper	1.3	0.00379*	0.00285*
Iron	--	--	1
Lead	0.015	0.01398*	0.000545*
Manganese	--	--	--
Mercury	0.05	0.0017	0.00091
Zinc	2	0.037*	0.037*

Notes: MDEQ Circular 7 Water Quality Standards converted from µg/L (parts per billion) to mg/L (parts per million)

* Hardness dependent metals aquatic life standards are based on an assumed hardness of 25 mg/L. Please refer to the pore water dissolved metals results table for sample specific hardness dependent standards.

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7/20/2016

In-Stream and Pond Sediment Pore Water Sampling

Silver Bow Creek and Blacktail Creek Corridors

Figure 7

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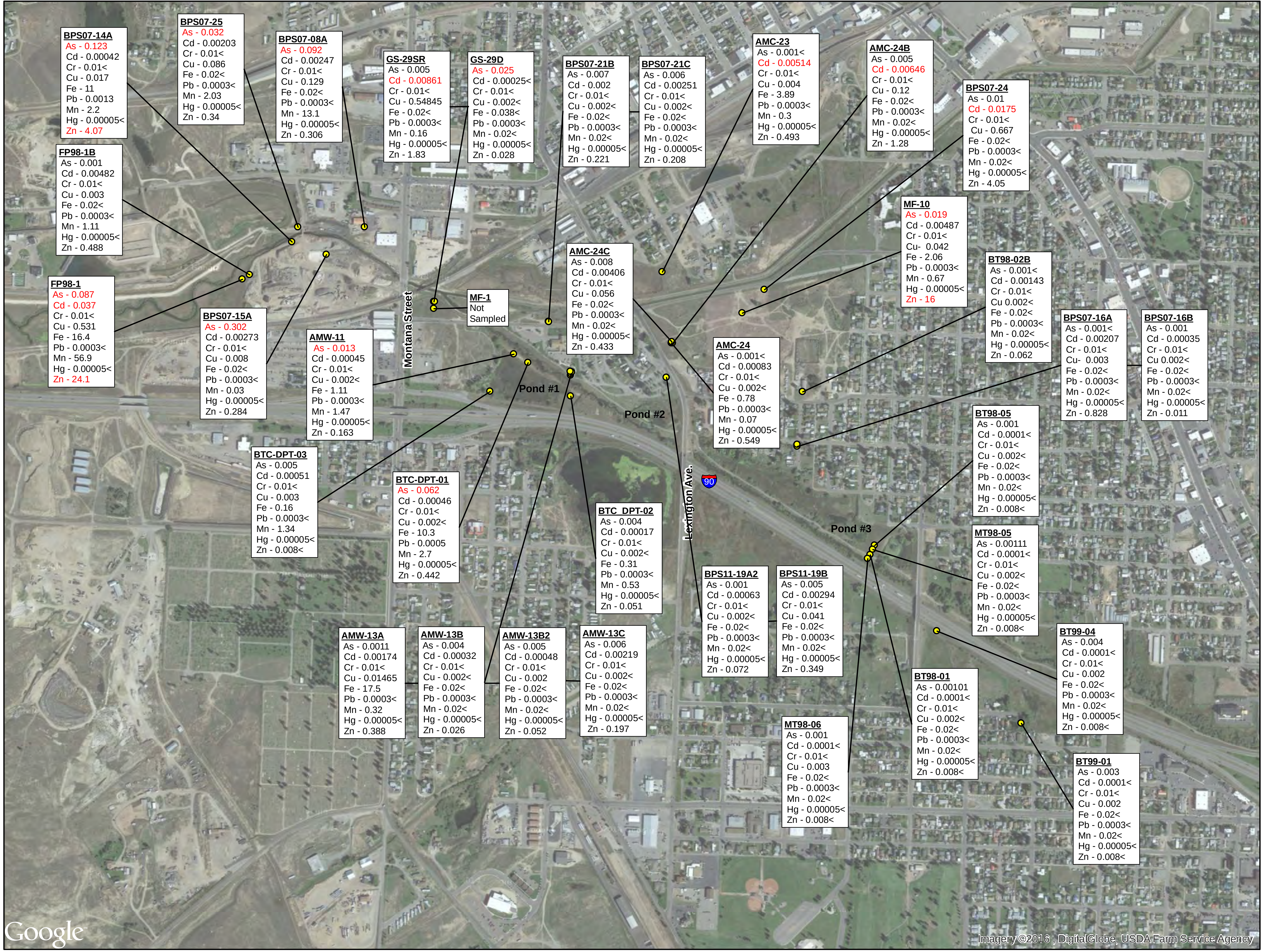

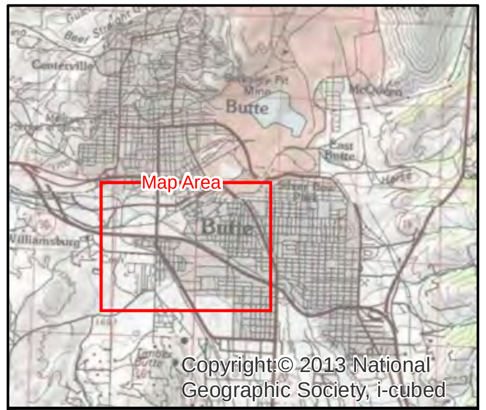

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● Monitor Well Location
(Units in mg/L, analyzed and reportetd as dissolved metals)

Groundwater Standards	
MT DEQ-7 (mg/L)	
Arsenic	0.01
Cadmium	0.005
Chromium	0.1
Copper	1.3
Iron	*
Lead	0.015
Manganese	*
Mercury	0.002
Zinc	2
** - Not established*	

TETRA TECH

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Feet

0 212.5 425 850

7/19/2016

Groundwater Sampling

Silver Bow Creek and Blacktail Creek Corridors

Figure 8