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**2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA  
INVESTIGATION AT THE FORMER EAST HELENA SMELTER**

**-FINAL-**

Prepared for:

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## EXECUTIVE SUMMARY

The Montana Environmental Trust Group, LLC, Trustee of the Montana Environmental Custodial Trust, completed a supplemental groundwater contaminant source area investigation (SAI) at the former ASARCO East Helena lead smelter (former smelter) in 2014. Based on an inventory of known or suspected groundwater contaminant source areas, the 2014 SAI focused on two specific areas; the West Selenium Source Area and North Plant Site Arsenic Source Area. Contaminated soils in these areas have been identified as major contributors to groundwater selenium and arsenic plumes originating from the former smelter, respectively. The purpose of the 2014 SAI, which was conducted as part of the Corrective Measures Study (CMS), was to further characterize the occurrence and distribution of contaminants in the source area soils to support development of a groundwater flow and contaminant transport model, and evaluate potential remedies for each source area.

The 2014 SAI included completion of six soil borings in the West Selenium Source Area and two borings in the North Plant Site Arsenic Source Area, collection of soil samples for total and leachable metals testing, and collection of groundwater samples for rapid turnaround analysis. All borings were advanced to the base of the shallow aquifer, in which the contaminant plumes occur, represented by a low permeability tertiary ash/clay unit. Two of the soil borings were completed as monitoring wells with the remaining borings abandoned in accordance with State regulations and project protocol. Leach testing included both synthetic precipitation leaching procedure (SPLP) and saturated paste analyses to evaluate the leachability of soils at varying soil to water ratios and better assess potential in-situ leaching rates. A limited number of soil samples also underwent mineralogical analyses in an attempt to identify mineral assemblages associated with the selenium and arsenic source materials which may control contaminant leaching to groundwater.

Subsurface conditions documented through the 2014 drilling program were consistent with previous drilling results, with the stratigraphy comprised of a relatively thin veneer of earthen fill material underlain by 25 to 40 feet of alluvial sand, gravel and cobbles, underlain in turn by the low permeability ash/clay unit. The depth to the ash/clay unit ranged from 30 feet in the extreme western portion of West Selenium Source Area, to 47 feet in the North Plant Site Source Area. As noted in previous investigations, an abrupt drop off in the ash/clay unit surface was identified in the extreme western portion of the West Selenium Source Area, with the ash/clay surface diving from west to east. This “ledge” in the low permeability ash/clay unit forms the western edge of the shallow aquifer and the West Selenium Area selenium plume.

No slag, ore, construction debris or other apparent primary contaminant source materials were encountered during the 2014 drilling although similar materials have been encountered in the shallow West Selenium Area soils during previous investigations. Consistent with previous investigations, weathered petroleum hydrocarbon-stained soils were encountered near the water table in both North Plant Site Source Area soil borings. Hydrocarbons were also encountered at soil boring EHSB-1 located south of the West Selenium Area, which represents the first time hydrocarbons have been encountered in the western portion of the

former smelter. The presence of hydrocarbons is of note since it can affect groundwater redox conditions and arsenic and selenium mobility.

Total metals concentrations in the 2014 soil samples were generally consistent with previous soil testing results. Comparison of the 2014 total metals concentrations to calculated “regional background” values show that selenium and cadmium are enriched relative to background in the West Selenium Source Area soils and arsenic and zinc are enriched in the North Plant Site Arsenic Source Area soils. Concentrations of aluminum, iron, lead and manganese were not enriched relative to background.

In 33 soil samples from the West Selenium Source Area, total selenium concentrations ranged from <0.5 to 44.7 mg/kg with the highest total and leachable selenium concentrations (up to 33 mg/L in leachate) occurring in the unsaturated zone. Despite the relatively high unsaturated zone leachate concentrations, the apparent lack of infiltration in this area (due to the asphalt/concrete cover) suggests that unsaturated zone soils are not a significant current source of selenium loading to groundwater, although they may have been historically or could be in the future if infiltration through the soils was to increase. Saturated zone samples from two of the West Selenium Area soil borings, EHSB-6 and EHSB-7, generated leachate concentrations as high as 9.3 mg/L, similar to the seasonally high selenium concentrations (8 mg/L) in the West Selenium groundwater plume. Several saturated zone soils from this area also leached sulfate, with concentrations in the range of 440 to 1,700 mg/L, also similar to local groundwater concentrations. The relatively high leachability of selenium from the West Selenium Area saturated soils (25 to 44% of the total selenium mass in the samples was removed via leaching), and comparability of leachate concentrations with local groundwater concentrations indicate that saturated soils within the West Selenium Area are the most likely source of current selenium loading to groundwater in this area.

Although arsenic concentrations are relatively low in the West Selenium Area groundwater, one objective of the 2014 SAI was to determine if changes in groundwater geochemical conditions, resulting from remedial activities or other natural or imposed changes to the groundwater system, could cause remobilization of arsenic currently immobilized through adsorption to aquifer matrix material and/or inclusion in secondary mineral assemblages. Based on the low total and leachable concentrations of arsenic documented in the West Selenium Area soils, remobilization of arsenic from soils is not expected to be significant, particularly in comparison to the high groundwater arsenic concentrations (30 to 40 mg/L) in the North Plant Site Area, even if groundwater redox conditions within the West Selenium Source Area were to change.

In the North Plant Site Arsenic Source Area, total arsenic concentrations in unsaturated zone soil samples ranged from 5 to 241 mg/kg and leach test results ranged from 0.58 to 1.0 mg/L. Given the typical groundwater arsenic concentrations in the North Plant Site Area of 10 to 35 mg/L, unsaturated zone soils are not believed to be a current significant source of arsenic loading to groundwater. Conversely, saturated zone soil samples generated saturated paste leach test concentrations of 1.9 to 17 mg/L. The leaching results indicate that North Plant Site saturated zone soils are capable of generating leachate concentrations on the order of local groundwater concentrations, and are a likely source of the North Plant Site arsenic

plume. Comparison of arsenic concentrations in saturated soils (40 to 45 foot depth) at 2014 soil boring EHSB-9 (average 163 mg/kg) to samples collected in 1986 from adjacent well borings DH-16/DH-17 located 10 to 15 feet away (662 mg/kg), may indicate the release of arsenic from saturated zone soils in this area over the past few decades. This supports the saturated zone soils as being the primary current source of arsenic loading to groundwater in the North Plant Site Area.

Leach test results showed that North Plant Site Area saturated soils can generate selenium concentrations from 0.004 to 0.11 mg/L, from soils with total selenium concentrations ranging from <0.5 to 1.8 mg/kg. These total selenium concentrations are similar to concentrations observed in West Selenium Area saturated zone samples. Although groundwater selenium concentrations in North Plant Site wells are typically <0.001 mg/L, selenium mobility in groundwater is likely inhibited by the reducing groundwater conditions in this area. The combined selenium leaching results from North Plant Site Area borings EHSB-8, EHSB-9 and similar information collected during the Phase II RFI, indicates that selenium remobilization from the North Plant Site Area soils under changing geochemical conditions is possible and should be considered when evaluating potential groundwater remedies in the North Plant Site Arsenic Source Area.

The 2014 SAI results are consistent with previous observations which indicate that saturated zone soils are the most likely source of current contaminant loading in both the West Selenium and North Plant Site Arsenic Source Areas. Based on the selenium plume geometry and the leach test/ groundwater sampling results from the 2014 soil borings, the extent of West Selenium Area source material may range in area from about 0.25 to 0.75 acres, with a vertical thickness of about 3 to 7 feet (the saturated zone thickness in this area), and a depth below ground surface of 40 to 45 feet. Based on similar information, the North Plant Site Arsenic Source Area (i.e., the area with significant quantities of leachable arsenic in saturated zone soils) is up to 450 feet long in the north-south direction (along the arsenic groundwater plume axis), and 150 to 250 feet wide. The saturated thickness in this area ranges from 10 to 15 feet with the depth to groundwater 30 to 35 feet. In both cases, additional investigation would be needed to better define these preliminary source area dimensions and to support a final groundwater remedy design.

In evaluating current groundwater conditions and potential groundwater remedies, it is of interest to note that the highest total metals concentrations at a number of soil borings in both the West Selenium and North Plant Site Arsenic Source Areas were encountered in unsaturated soils within one or two feet of the current water table. Although currently above the saturated zone, these soils would have been saturated and most likely contributed to groundwater contaminant loading prior to the November 2011 initiation of the South Plant Hydraulic Control (SPHC) interim measure. The potential effects of these recent hydrologic changes on local groundwater quality most likely have yet to be fully realized and should be considered when evaluating final groundwater remedies for the site.

# **2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER**

**-FINAL-**

## **1.0 INTRODUCTION**

The Montana Environmental Trust Group, LLC (Custodial Trust), Trustee of the Montana Environmental Custodial Trust, completed a supplemental contaminant source area investigation (SAI) at the former ASARCO East Helena lead smelter (former smelter) in 2014. The supplemental SAI is one of several technical evaluations being conducted by the Custodial Trust as part of a Corrective Measures Study (CMS) for the East Helena Facility<sup>1</sup>. The CMS is one of the RCRA Corrective Actions being conducted pursuant to the First Modification to the 1998 Resource Conservation and Recovery Act (RCRA) Consent Decree (U.S. District Court, 2012). Soils and non-native fill material (i.e., slag, ore, concentrates, demolition debris) located in the operating areas of the former smelter contain elevated concentrations of a number of contaminants, primarily arsenic, selenium and certain trace metals. Contaminants within site soils and fill material are the result of more than a century of ore handling and processing; storage and disposal of smelting wastes and byproducts; and periodic releases of high contaminant-concentration plant process waters. The contaminated soils/fill represent primary current and/or historic sources of contaminant loading to groundwater, with the primary groundwater contaminant source areas delineated during previous site investigations and shown in Figure 1-1. The 2014 supplemental SAI included additional data collection and characterization of specific current groundwater contaminant source areas to support evaluation and design of potential groundwater remedial actions as discussed below.

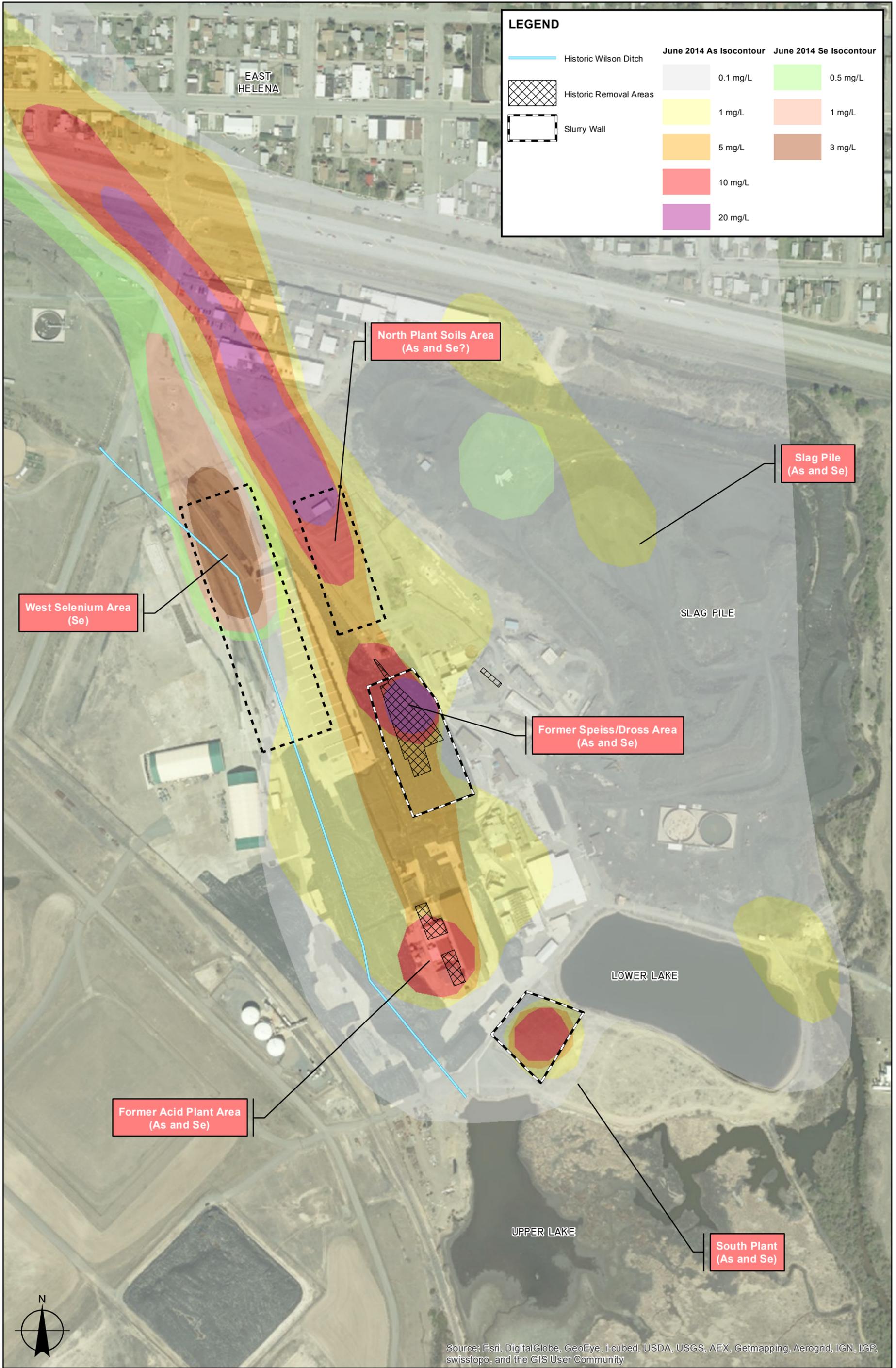
### **1.1 PROJECT BACKGROUND**

#### **1.1.1 Groundwater Conditions**

The presence of groundwater contaminants at the former smelter has been known for the past few decades. A groundwater plume with elevated arsenic concentrations had been identified on the smelter site by the mid-1980s, with arsenic concentrations of more than 700 mg/L

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<sup>1</sup> The former smelter refers to the approximately 142 acres previously occupied by the East Helena Lead Smelter. East Helena Facility refers to the former smelter site and surrounding properties previously owned by ASARCO and currently owned by the Montana Environmental Custodial Trust.



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2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER	<b>POTENTIAL GROUNDWATER CONTAMINANT SOURCE AREAS</b>	<b>FIGURE</b>
		<b>1-1</b>

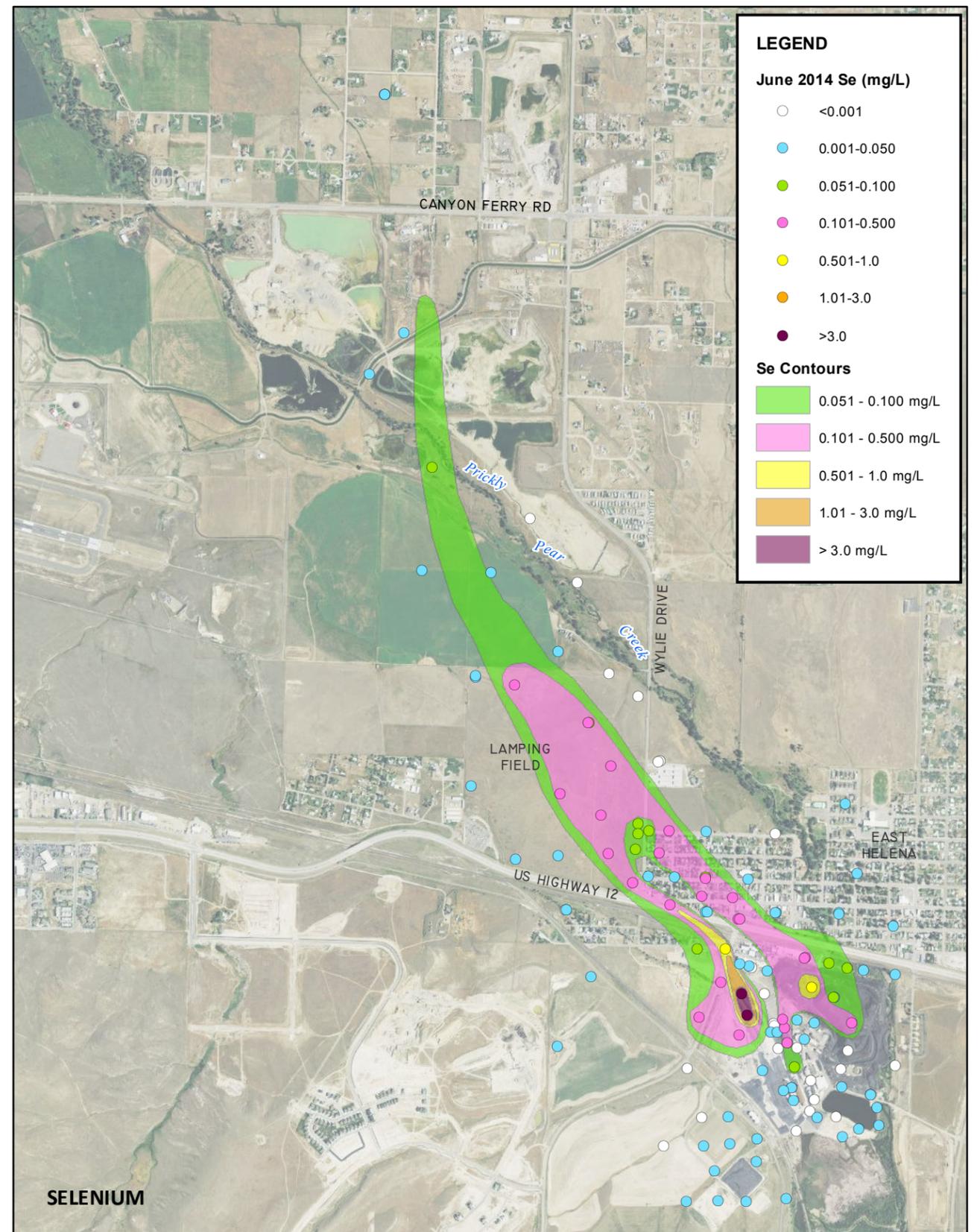
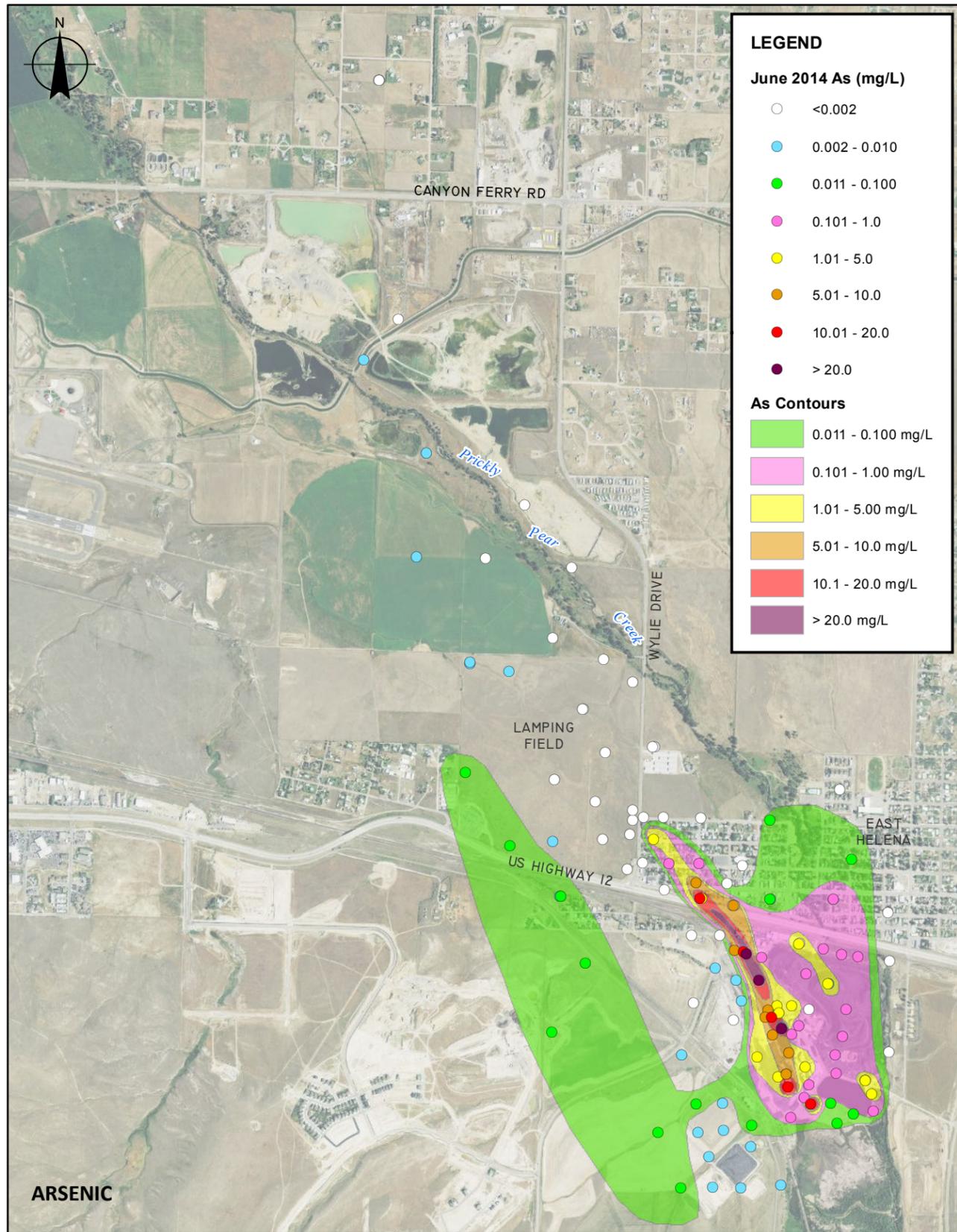
within portions of the former smelter (Hydrometrics, 1990). By 2006, additional investigations had delineated the downgradient extent of the arsenic plume approximately 2,500 feet downgradient (north) of the former smelter boundary (Figure 1-2). Based on groundwater quality data from the past ten years, the downgradient extent of the arsenic plume appears to be stable (i.e., the plume margin is not expanding or contracting appreciably). Currently, the highest arsenic concentrations in groundwater (outside of areas contained within slurry walls) are 30 to 40 mg/L in the north-central portion of the former smelter (Figure 1-1).

Unlike arsenic, selenium was not identified as a contaminant of concern in groundwater beneath the former smelter until 2007, six years after the smelter shutdown. Since then, groundwater characterization efforts have focused in part on delineation of the downgradient extent of the selenium plume and potential source areas on the former smelter site. Based on current information, the portion of the selenium plume exceeding the 0.05 mg/L groundwater human health standard (MDEQ, 2012) extends approximately two miles downgradient of the former smelter, with lower selenium concentrations extending beyond this point (Figure 1-2). Due to the limited dataset available for downgradient groundwater selenium concentrations (the furthest downgradient monitoring wells were completed in 2012), the status of the selenium plume is still being evaluated.

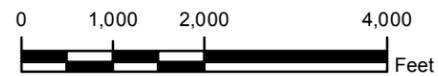
The hydrostratigraphy of the former smelter includes a shallow aquifer and a deeper groundwater system separated by a low permeability ash/clay layer. The shallow aquifer occurs within relatively high permeability alluvial sands, gravels and cobbles with some intervening silt lenses. The ash/clay layer occurs at depths of 10 feet in the southern portion of the former smelter to 50 feet in the north, and forms a base to the shallow aquifer. The arsenic and selenium plumes are primarily restricted to the shallow aquifer.

### **1.1.2 Groundwater Contaminant Source Areas**

A number of groundwater contaminant source areas have been delineated over the past three decades at the former smelter through various site investigations, including the Comprehensive RI/FS (Hydrometrics, 1990), Current Conditions/ Release Assessment report (Hydrometrics, 1999), and most recently the Phase I and Phase II RCRA Facility Investigations (RFIs) (ACI, 2005; METG, 2011). Various remedial actions have been implemented over the years to address historic groundwater contaminant sources, including mitigation of ongoing process water releases at the Acid Plant and Speiss/Dross handling area in the 1990s, construction of slurry walls in 2006-2007 around highly contaminated soils associated with the Acid Plant and Speiss/Dross Areas, and recent interim measures (IMs) implemented by the Custodial Trust under the CMS program (i.e., the South Plant Hydraulic Control and Tito Park Soils Removal IMs; CH2MHill, 2014). As a result of these actions, groundwater quality beneath the former smelter site has shown significant improvement,



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although groundwater contaminant concentrations remain high on portions of the former smelter (i.e., maximum arsenic concentrations have decreased from over 700 mg/L in the 1980s, to about 35 mg/L today, excluding groundwater contained within the two slurry walls). Despite these significant improvements, current groundwater monitoring data indicates that soils in certain portions of the former smelter continue to leach contaminants to groundwater (Figure 1-1).

The 2014 SAI Work Plan (Hydrometrics, 2014) presents an inventory of identified groundwater contaminant source areas, a summary of current groundwater and soil conditions for each area, and the significance of each area in terms of the downgradient migration of groundwater contaminants (i.e., contribution to the groundwater plumes). The 2014 SAI also identified contaminant source areas as being time-critical or non-time critical in terms of the need to coordinate investigation activities and potential groundwater remedies with other site activities scheduled for 2015-2016 (i.e., realignment of Prickly Pear Creek and capping of the plant site). The source areas are shown in Figure 1-1 and the source inventory results are summarized in Appendix A.

Based on the source area inventory, the 2014 SAI Work Plan recommended investigation of the West Selenium Source Area and North Plant Site Soils Source Area (Figure 1-1) in 2014. The West Selenium Source Area is an area of localized, high selenium concentrations in groundwater (up to nearly 8 mg/L seasonally), and is believed to be a primary contributor to the downgradient selenium plume. The North Plant Site Soils Source Area is located in the north-central portion of the former plant site downgradient of the former Speiss/Dross source area (which was largely enclosed within a slurry wall in 2007). The North Plant Site Area currently exhibits the highest groundwater arsenic concentrations on the former smelter ( $\approx 35$  mg/L) excluding the areas formerly or currently enclosed within slurry walls<sup>2</sup>. These source areas were recommended for inclusion in the 2014 SAI based on the current high contaminant concentrations, their status as significant contributors to the downgradient groundwater plumes, and the need to coordinate potential source control measures in these areas, such as source removal or in-situ treatment, with 2015-2016 remedial activities.

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<sup>2</sup> Prior to 2014, two slurry walls were present on the plant site, one at the Acid Plant Sediment Drying Area and the second in the Speiss/Dross Area, with groundwater arsenic concentrations approaching 100 mg/L within the slurry walls. The Acid Plant Sediment Drying Area slurry wall and associated contaminated soils and groundwater were removed in 2014 as part of the Tito Park Source Removal Interim Measure.

### **1.1.3 Investigation Objectives**

As outlined in the SAI Work Plan (Hydrometrics, 2014), the overall goal of the 2014 SAI was to provide information and environmental data necessary to further characterize specific groundwater contaminant source areas and to evaluate potential groundwater remedial options. Specific objectives of the 2014 SAI include:

1. Provide information necessary to better define physical characteristics of the contaminant source areas including depth, vertical and lateral extent, and contaminant properties, and mechanism(s) of contaminant leaching to and transport within groundwater;
2. Provide information necessary for continued development and refinement of a three-dimensional, numerical groundwater flow and fate and transport model; and
3. Provide information necessary for evaluation of potential contaminant source removal/source control measures as part of the CMS program.

This report summarizes the 2014 field investigation of the West Selenium Source Area and North Plant Site Arsenic Source Area, including a review of investigation procedures, the investigation results, and conclusions based on the source investigation data. Detailed supporting materials are provided as appendices to this report.

## **2.0 INVESTIGATION METHODS**

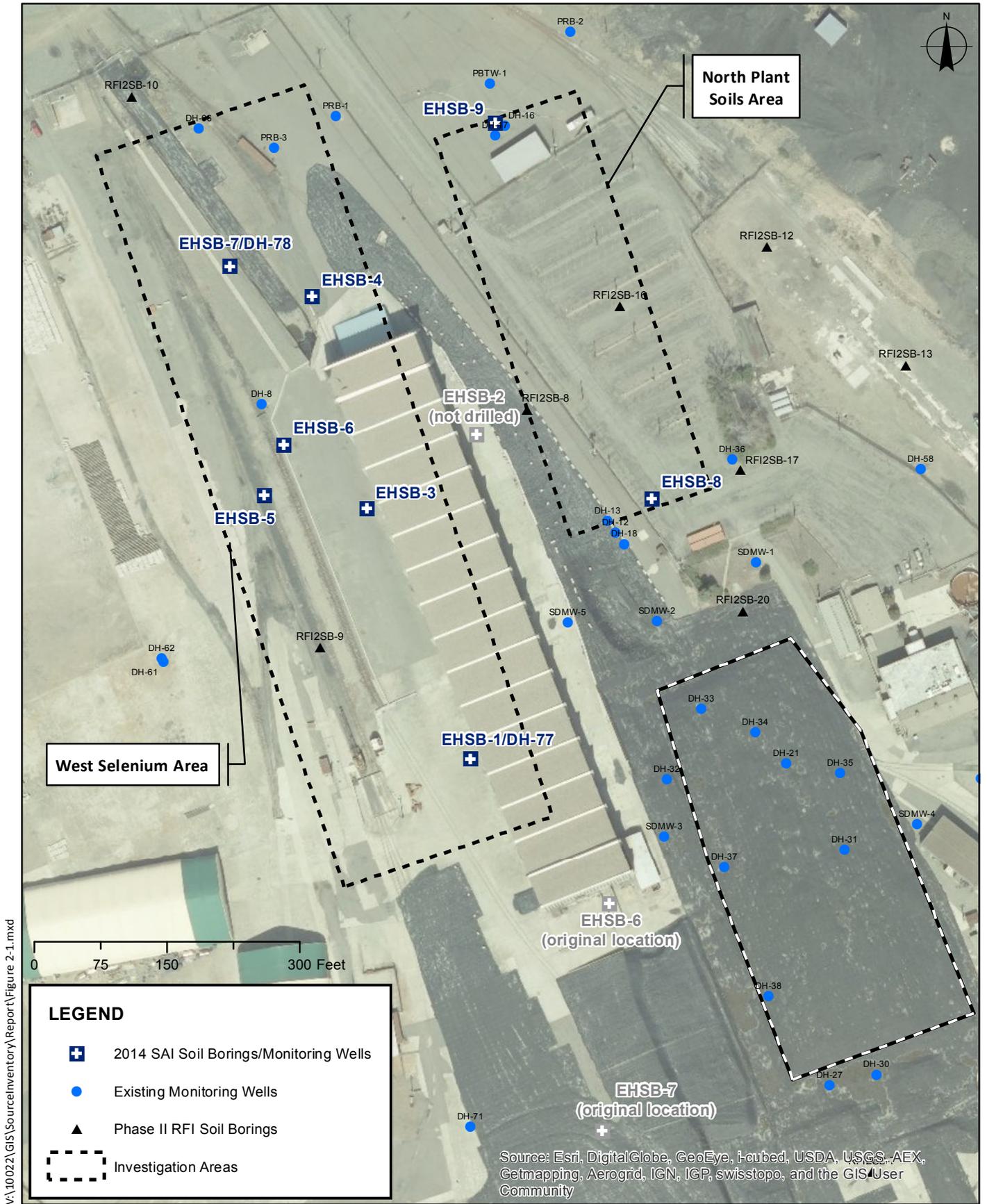
The 2014 SAI methodology and protocol closely followed that outlined in the SAI Work Plan (Hydrometrics, 2014). The SAI included completion of soil borings and soil sampling for geochemical testing and lithologic logging. Following is a brief overview of investigation protocol and methodology, with deviations from the Work Plan noted in Section 2.3. The SAI results are discussed in Section 3.

### **2.1 DRILLING, SOIL SAMPLING, AND MONITORING WELL COMPLETION**

The SAI included completion of eight soil borings with six borings in the West Selenium Area and two in North Plant Site Arsenic Source Area. All drilling was completed using a Mobile tubex air rotary drill rig with all drilling activities observed and supervised by Hydrometrics' personnel. All soil borings were advanced to the top of the ash/clay unit signifying the base of the contaminated shallow aquifer. Soil boring locations are shown in Figure 2-1 and completion details summarized in Table 2-1. Boring logs are included in Appendix B.

Soil samples were collected on five foot intervals using split spoon samplers, with additional grab samples of drill cuttings collected between split spoon intervals to further document lithology and for potential testing. All soil samples were collected, handled, stored, and transported in accordance with the project QAPP (Hydrometrics, 2010b). Field duplicate soil samples were collected and analyzed at a frequency of one per twenty field samples for quality control (QC) purposes. A total of 119 soil samples were collected and either submitted for analyses or archived for potential future use. A complete list of 2014 soil samples is included in Appendix C.

All drilling equipment, including drill rods, bit and casing was decontaminated between boring locations at the Facility truck wash, with decontamination water treated at the Facility water treatment plant. Following drilling, the boreholes were either permanently abandoned or completed as monitoring wells. Borehole abandonment including filling the borehole with bentonite chips or pellets as the drill casing was pulled back (to prevent borehole caving), following procedures outlined in the East Helena Facility Borehole Abandonment Plan (Hydrometrics, 2010a). Boreholes EHSB-1 and EHSB-7 in the West Selenium Area were completed as monitoring wells DH-77 and DH-78, respectively. The monitoring wells were completed in accordance with applicable State regulations (ARM 36.21.800), with construction materials including two-inch diameter flush-threaded schedule 40 PVC, ten feet of factory-slotted PVC screen, silica sand pack and a bentonite annular seal.



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<p>2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER</p>	<p>2014 SOURCE AREA INVESTIGATION SOIL BORING LOCATIONS</p>	<p>FIGURE <b>2-1</b></p>
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**TABLE 2-1. 2014 SOURCE AREA INVESTIGATION SOIL BORING/MONITORING WELL COMPLETION DETAILS**

<b>Boring/ Monitoring Well</b>	<b>Ground Elevation</b>	<b>Total Depth</b>	<b>Screened Interval</b>	<b>Static Water Level at Time of Drilling</b>	<b>Depth to Ash/Clay Layer</b>	<b>Depth of Petroleum</b>
EHSB-1/DH-77	3924.99	52	38-48	42.5	48	34 to 43
EHSB-3	3920.78	52	NA	47.0	48	None
EHSB-4	3916.25	49	NA	43.5	48	None
EHSB-5	3914.46	32	NA	Dry	30.1	None
EHSB-6	3917.11	45.5	NA	43.0	43.5	None
EHSB-7/DH-78	3912.67	47	35-45	40.2	45	None
EHSB-8	3910.18	42	NA	33.7	40.2	23 to 35
EHSB-9	3905.75	49.5	NA	32.0	47.5	26 to 30.3

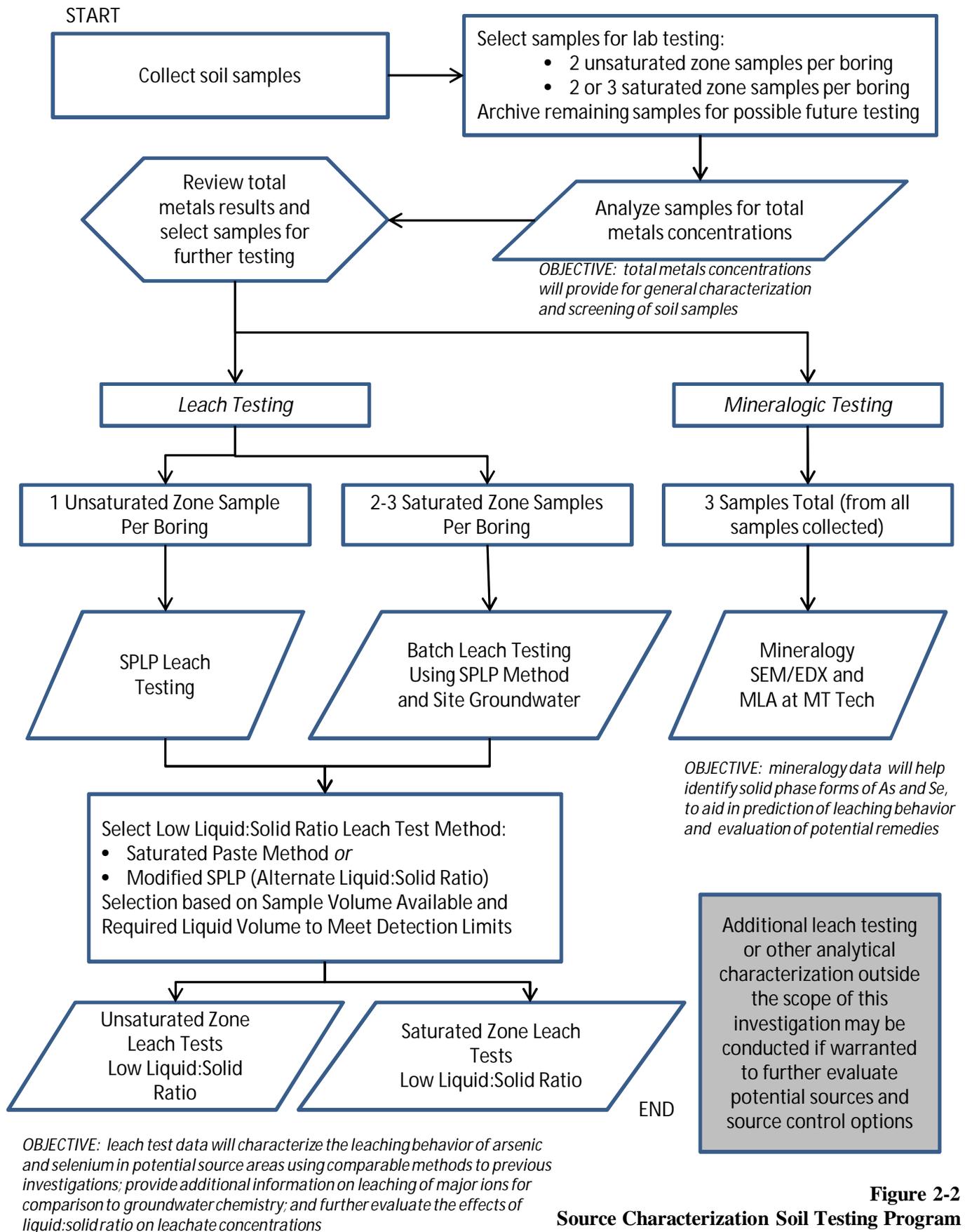
Monitoring wells DH-77 and DH-78 completed with 2" Schedule 40 PVC casing and screen.  
Soil boring and well completion logs are in Appendix B.  
All measurements in feet from ground surface. Elevations relative to mean seal level.

## 2.2 SOIL SAMPLE ANALYSIS

Following completion of each soil boring, soil samples were submitted to an analytical laboratory for analysis of various geochemical properties. In accordance with the SAI Work Plan, soil sample analyses were conducted in three steps or phases, with details of each step based in part on results of the preceding step. The various steps in the sample testing program are outlined in Figure 2-2 and described below.

Step 1 included analysis of selected soils for total metals concentrations and pH to identify areas of potentially significant contaminant loading to groundwater. In general, two samples from the unsaturated zone were selected from each boring; one from the deep vadose zone just above the water table and a second from a shallower depth, with the second sample selected based on visual characteristics. In addition to the unsaturated zone samples, two to three saturated zone soil samples (Figure 2-2) were analyzed for total metals and pH. The analytical parameter list for total metals is included in Table 2-2, and samples selected for total metals analyses are summarized in Table 2-3.

Step 2 of soil testing included further characterization of selected samples by leach testing using EPA Method 1312 (Synthetic Precipitation Leaching Procedure (SPLP)) and saturated paste extraction (USDA, 1954) on separate aliquots of the sample. The dual leach test procedures were used to evaluate the effect of the liquid to soil ratio on leach test results (SPLP uses a 20:1 ratio while saturated paste uses a much lower ratio, averaging about 0.2:1 for this investigation), and to better evaluate actual contaminant leaching processes within



**Figure 2-2**  
**Source Characterization Soil Testing Program**  
**Flow Diagram**

**TABLE 2-2. SOIL SAMPLE ANALYTICAL PARAMETER LIST**

<b>Total Metals Analysis</b>		
<b>Parameter</b>	<b>Analytical Method<sup>(1)</sup></b>	<b>Soil Boring Sample PRDL (mg/kg)</b>
Aluminum (Al)	SW 3050/6010B/6020	5
Arsenic (As)	SW 3050/6010B/6020	5
Cadmium (Cd)	SW 3050/6010B/6020	1
Copper (Cu)	SW 3050/6010B/6020	5
Iron (Fe)	SW 3050/6010B/6020	5
Lead (Pb)	SW 3050/6010B/6020	5
Manganese (Mn)	SW 3050/6010B/6020	5
Selenium (Se)	SW 3050/6010B/6020	0.55
Zinc (Zn)	SW 3050/6010B/6020	5
pH	SW 9045D	0.1 s.u.
<b>Leach Testing Analysis</b>		
<b>Parameter</b>	<b>Analytical Method<sup>(1)</sup></b>	<b>Extractant/Leach Solution PRDL (mg/L)</b>
Arsenic (As)	EPA 200.8/6010/6020	0.005
Selenium (Se)	EPA 200.8/6010/6020	0.005
Calcium	EPA 200.8/6010/6020	1
Magnesium	EPA 200.8/6010/6020	1
Sodium	EPA 200.8/6010/6020	1
Potassium	EPA 200.8/6010/6020	1
Chloride	EPA 300.0	1
Bicarbonate	A 2320B	4
Sulfate	EPA 300.0	1
pH	A 4500-H B	0.1 s.u.

- (1) Analytical methods are from the current version of Standard Methods (SM) for the Examination of Water and Wastewater (available online at <http://www.standardmethods.org/>), or EPA's Methods for Chemical Analysis of Water and Waste (EPA, 1983). Equivalent procedures may be used as long as detection limits are achieved.

Table 2-3. 2014 Supplemental Source Area Investigation Soil Sampling and Analytical Summary Table

Soil Boring	Sample #	Depth (ft bgs)	Total Metals	Leachable Metals	Mineralogy
EHSB-1	AEH-1409-100S	0-5			
	AEH-1409-101S	10-12			
	AEH-1409-102S	15-17			
	AEH-1409-103S	20-21.2			
	AEH-1409-104S	25-26	X		
	AEH-1409-105S	30-30.5			
	AEH-1409-106S	33			
	AEH-1409-107S	34-35			
	AEH-1409-108S	35-35.5			
	AEH-1409-109S	39-39.5			
	AEH-1409-110S	40-41.5	X	X	
	AEH-1409-111S	43-44	X		
	AEH-1409-112S	45-46	X		
	AEH-1409-113S	50-52			
EHSB-3	AEH-1409-132S	5-6.5			
	AEH-1409-133S	9.5	X		
	AEH-1409-134S	10-12			
	AEH-1409-135S	13-15			
	AEH-1409-136S	15-16.3			
	AEH-1409-137S	17-19			
	AEH-1409-138S	20-20.5			
	AEH-1409-139S	23-24			
	AEH-1409-140S	25-25.4			
	AEH-1409-141S	27			
	AEH-1409-142S	30-30.9			
	AEH-1409-143S	33			
	AEH-1409-144S	35-35.5			
	AEH-1409-145S	37	X		
	AEH-1409-146S	40-40.4			
	AEH-1409-147S	44.5	X	X	
	AEH-1409-148S	45-47	X	X	
AEH-1409-149S	48-49	X	X		
AEH-1409-150S	50-52				
EHSB-4	AEH-1409-114S	5-6			
	AEH-1409-115S	6-7			
	AEH-1409-116S	7-10			
	AEH-1409-117S	10-12			
	AEH-1409-118S	15-16.5			
	AEH-1409-119S	20-20.5			
	AEH-1409-120S	25-25.3			
	AEH-1409-121S	29-29.5			
	AEH-1409-122S	30-30.3			
	AEH-1409-123S	33	X		
	AEH-1409-124S	35-36.1			
	AEH-1409-125S	38-40	X		
	AEH-1409-126S	40-41			
	AEH-1409-127S	43-45	X		
	AEH-1409-131S	43-45 Dup	X		
	AEH-1409-128S	45-46	X		
	AEH-1409-129S	47.5-48	X		
AEH-1409-130S	48-49				

Soil Boring	Sample #	Depth (ft bgs)	Total Metals	Leachable Metals	Mineralogy
EHSB-5	AEH-1409-151S	0-5			
	AEH-1409-152S	5-6.8	X		
	AEH-1409-153S	10-11.1			
	AEH-1409-154S	15-18			
	AEH-1409-155S	22-24			
	AEH-1409-156S	25-25.3			
	AEH-1409-157S	27	X		
	AEH-1409-158S	30-32			
EHSB-6	AEH-1409-159s	5-6.4	X		
	AEH-1409-160s	10-11.8	X		
	AEH-1409-161s	10.7-11.4	X		
	AEH-1409-162s	15-15.7	X		
	AEH-1409-163s	20.3-20.9	X	X	X
	AEH-1409-164s	25-25.8	X		
	AEH-1409-165s	30-30.7	X		
	AEH-1409-166s	32-33	X		
	AEH-1409-167s	35-37	X		
	AEH-1409-168s	40-41	X	X	X
AEH-1409-169s	43.5-45.5	X	X		
EHSB-7	AEH-1409-233	5-5.8	X		
	AEH-1409-234	10-11.7			
	AEH-1409-235	15-15.6			
	AEH-1409-236	20-20.2			
	AEH-1409-237	22-23			
	AEH-1409-238	25-25.4			
	AEH-1409-239	29-29.5	X		
	AEH-1409-240	30-30.4			
	AEH-1409-241	31-33			
	AEH-1409-242	34.5-35			
	AEH-1409-243	35-36.7	X		
	AEH-1409-244	38-39	X	X	
	AEH-1409-245	40-41.5	X	X	
	AEH-1409-246	42-43	X	X	
AEH-1409-247	45-47				

Soil Boring	Sample #	Depth (ft bgs)	Total Metals	Leachable Metals	Mineralogy
EHSB-8	AEH-1409-201	5-6.7			
	AEH-1409-202	8.5-9.5			
	AEH-1409-203	10-10.4			
	AEH-1409-204	12-13			
	AEH-1409-205	15-15.7			
	AEH-1409-206	18-19.5	X		
	AEH-1409-207	20-20.4			
	AEH-1409-208	24			
	AEH-1409-209	27-28			
	AEH-1409-210	30-31.3			
	AEH-1409-211	33-34	X	X	
	AEH-1409-214	35-35.2	X		X
	AEH-1409-212	36-37	X	X	
	AEH-1409-213	40-42			
EHSB-9	AEH-1409-215	5-5.8			
	AEH-1409-216	8-8.5			
	AEH-1409-217	10-11.1			
	AEH-1409-218	15-15.8			
	AEH-1409-219	19			
	AEH-1409-220	20-20.4			
	AEH-1409-221	23			
	AEH-1409-222	25-25.5	X		
	AEH-1409-223	26-27			
	AEH-1409-224	30-31.5	X	X	
	AEH-1409-225	33-34			
	AEH-1409-226	35-36.8	X	X	
	AEH-1409-227	37-40			
	AEH-1409-228	40-40.4	X	X	
	AEH-1409-229	43-44.6	X	X	
	AEH-1409-232	45-45.5			
	AEH-1409-230	46-47			
AEH-1409-231	47.5-49.5				

Notes: Blue shading denotes saturated zone sample  
 X = sample analyzed for indicated analysis type  
 All samples archived for potential future testing

the aquifer. Leach testing of unsaturated zone samples was done using the SPLP standard synthetic precipitation leaching solution. Leach testing of saturated zone soils utilized upgradient groundwater to better represent actual aquifer conditions. Groundwater from monitoring well DH-71 was used for leaching the West Selenium Area samples and groundwater from SDMW-4 for North Plant Site Area soils (Figure 2-1). Leach test analytical parameters are shown in Table 2-2, and soil samples selected for leach testing are shown in Table 2-3. Complete details of leach testing conditions (initial soil moisture, mass of soil, volume of leaching solution and chemical composition of groundwater leaching solution) and results are in Appendix C.

Step 3 of soil testing consisted of chemical and mineralogical analysis of soils conducted at the Center for Advanced Mineral and Metallurgical Processing (CAMP) at Montana Tech of the University of Montana. Testing at the CAMP laboratory consisted of reconnaissance level examination of samples with a scanning electron microscope with energy-dispersive x-ray (SEM/EDX) detection of chemical composition. Samples selected for mineralogical testing are shown in Table 2-3.

Analysis of total and leachable metals for all soil samples was conducted by Energy Laboratories in Helena, Montana. Laboratory analytical reports for soil sample analyses are included in Appendix D.

## **2.3 DEVIATIONS FROM SOURCE AREA CHARACTERIZATION WORK PLAN**

Deviations from the Work Plan included the collection and analysis of screening-level groundwater samples; modification of some boring locations from those proposed in the work plan; changes to the number of samples analyzed for total and/or leachable metals concentrations for certain soil borings; and modification of the proposed mineralogic analysis method used by the CAMP laboratory. These work plan deviations were primarily made to better target and characterize source areas. Each of these deviations is briefly discussed below.

### **2.3.1 Screening Level Groundwater Sampling**

Although not proposed in the work plan, limited groundwater sampling and analysis was performed during the source area investigation as a screening tool to provide rapid determination of groundwater contaminant (arsenic, selenium) and major anion (chloride, sulfate) concentrations at each boring. The rapid-turnaround (same- or next-day) results were used to refine subsequent soil boring locations and to select sites for monitoring well completion. Groundwater data from the borings was also used in calculation of net leachate concentrations for saturated zone soils, as described in Section 3. The groundwater samples were collected by lowering a disposal plastic bailer down the inside of the drill casing (after extracting the drill rods and bit) to retrieve the groundwater sample. The sample water was

transferred to appropriate sample containers, with the metals samples first filtered through a disposable 0.45 micron filter and preserved with nitric acid in the field. The samples were transported immediately to a local commercial analytical laboratory (either Energy Laboratories or Alpine Analytical) for rapid-turnaround analysis. Because these groundwater samples were collected as “opportunity” samples and sample collection did not follow procedures outlined in the project QAPP, the screening-level groundwater results were not entered into the East Helena project EnviroData database. Laboratory analytical reports for screening level groundwater samples are included in Appendix E and results are discussed in Section 3.4.

### **2.3.2 Soil Boring Locations**

The source investigation work plan included approximate locations for soil borings and wells, with final locations to be determined based on field conditions and information gained during the drilling program. Based on field observations made during the course of drilling, and results of the screening-level groundwater sampling discussed above, the following modifications were made to the soil boring locations:

- EHSB-2: In the Work Plan, boring EHSB-2 was to be located between the area of highest groundwater selenium concentrations and the former Speiss/Dross Area (Figure 2-1). This boring was eliminated from the program due to the relatively low selenium concentration in a groundwater sample collected at downgradient soil boring EHSB-4, located between the proposed EHSB-2 location and the area of highest groundwater selenium concentrations.
- EHSB-6: In the Work Plan, boring EHSB-6 was to be located south of the former ore storage building, between the West Selenium Area and the former Acid Plant (Figure 2-1). Based on the relatively low groundwater selenium concentration at boring EHSB-1, completion of soil borings further to the south was deemed unnecessary. Instead, EHSB-6 was located south of well DH-8 to better delineate the area of high groundwater selenium concentrations and the steep drop off in the tertiary ash/clay layer which forms the western boundary of the shallow aquifer (Section 3.1). Relocation of EHSB-6 proved valuable in delineating the West Selenium contaminant source area.
- EHSB-7: Similar to EHSB-6, the low groundwater selenium concentration at boring EHSB-1 indicated that completion of additional soil borings to the south, as initially proposed for EHSB-7, was unnecessary for delineation of the selenium source area. Instead, EHSB-7 was completed further north in the central portion of the high concentration groundwater selenium plume to better define groundwater and soil concentrations in this area of prime interest (Figure 2-1).

### 2.3.3 Soil Sample Analyses

In addition to modification of some soil boring locations, for certain soil borings the number of samples analyzed for total or leachable metals varied from that outlined in the work plan based on field observations and screening-level groundwater results. Modifications to soil analyses included:

- EHSB-3: No unsaturated zone leach tests were conducted due to low total selenium (both <0.5 mg/Kg) and arsenic concentrations (49 and 6 mg/Kg) in the two unsaturated zone samples.
- EHSB-4: Leach tests were not conducted on any samples due to relatively low total selenium (all <0.5 mg/Kg) and arsenic (9 to 71 mg/Kg) concentrations in the six soil samples, and relatively low selenium concentrations (0.11 mg/L) in groundwater from this boring.
- EHSB-5: Leach tests were not conducted due to low total selenium (both <0.5 mg/Kg) and arsenic (8 to 22 mg/Kg) concentrations in two soil samples, and the unsaturated conditions encountered down to the tertiary ash/clay layer.
- EHSB-6: Based on the relatively high total selenium concentration in one of the initial unsaturated zone samples (44.7 mg/Kg), total metals analyses were subsequently conducted on all vadose zone samples from this boring. Results of the vertical profiling are discussed in Section 3.2.
- EHSB-7: Two additional unsaturated zone samples were analyzed for total metals to provide more detail on total metals concentrations with depth at this area of localized elevated groundwater selenium concentrations (up to 5 mg/L or more seasonally).
- EHSB-8: Leach testing was not conducted on the unsaturated zone sample due to low total selenium and arsenic concentrations (<0.5 and 5 mg/Kg, respectively). Leach testing was not conducted on one saturated zone sample due to insufficient material for testing.

### 2.3.4 Soil Mineralogic Analyses

The SAI Work Plan also proposed to conduct MLA (mineral liberation analysis) of sediments using SEM/EDX techniques at Montana Tech's CAMP Laboratory. MLA is an automated, computer-based analysis/identification technique that scans a sample with the SEM/EDX collecting a large number of chemical analyses, using software to generate mineral and chemical composition maps of the sample. Based on initial analyses of the two West Selenium Area samples by the SEM/EDX analyst, it was found that selenium concentrations in the samples from EHSB-6 (12.9 to 44.7 mg/kg in the bulk samples based on wet chemistry analyses) were too low to be detected by the SEM/EDX instrument and that further analysis by MLA was unwarranted. For the North Plant Site sample, the analyst had good success identifying the occurrence of arsenic using the SEM/EDX and it was concluded that further analysis by the MLA step likely would not provide additional information; therefore, MLA analysis of samples was not conducted.

## 3.0 RESULTS AND DISCUSSION

### 3.1 STRATIGRAPHY

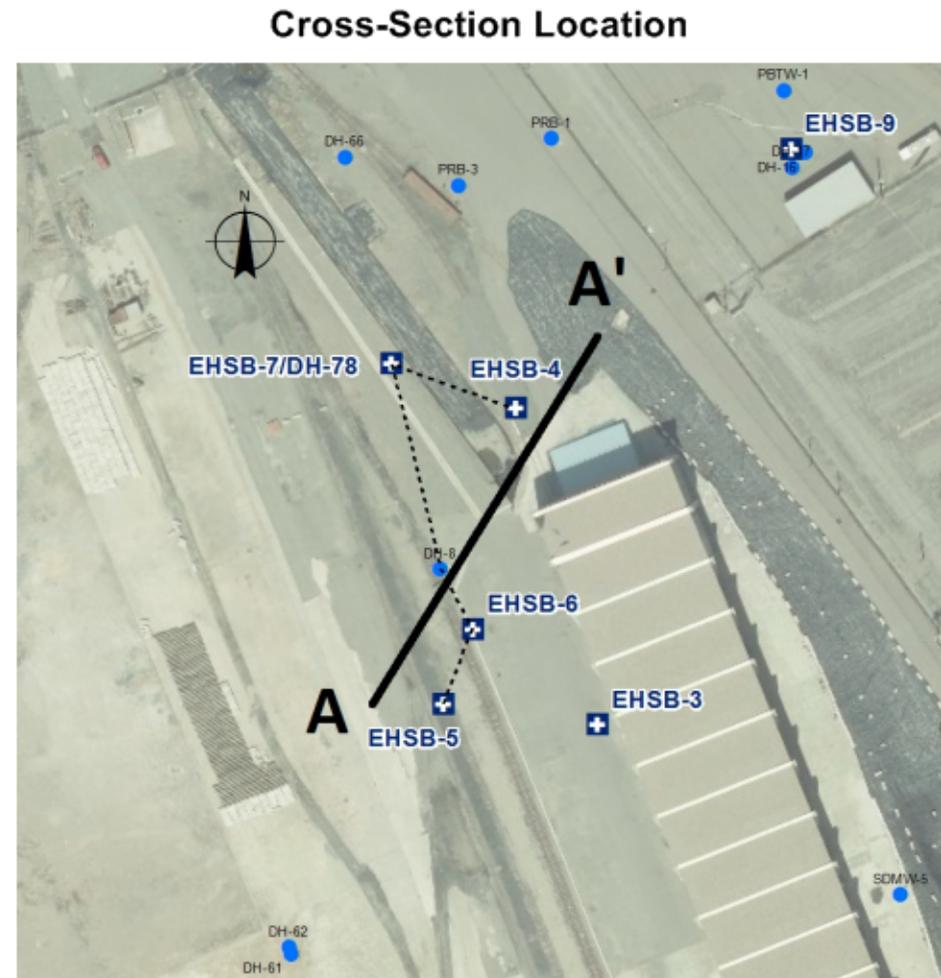
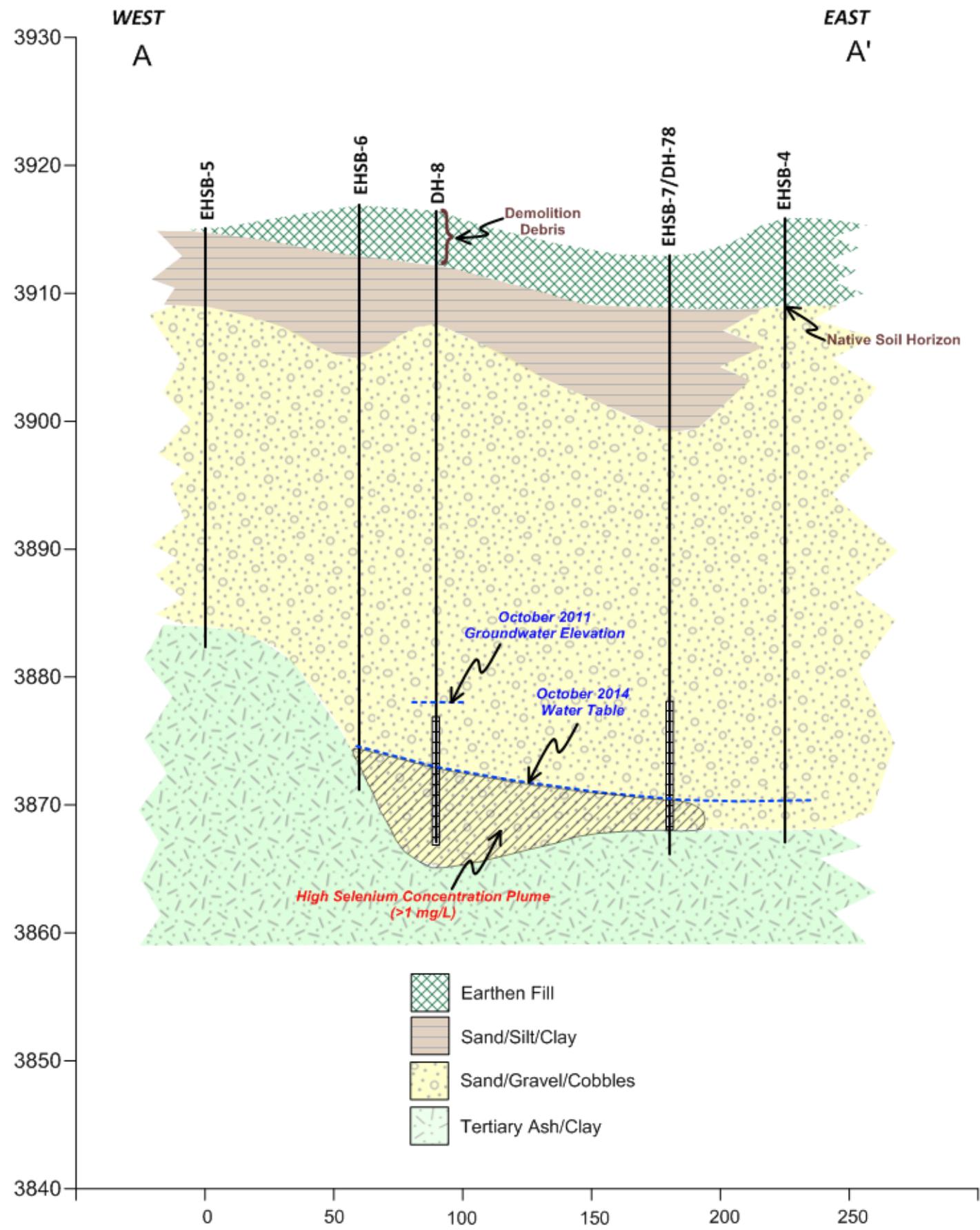
The stratigraphy on the former smelter site has been documented through various investigations since the 1980s with additional detail obtained through the 2014 SAI. Subsurface conditions were recorded at each soil boring through examination of split spoon samples (collected at five-foot intervals) and drill cuttings. Of particular interest is the soil/sediment physical characteristics such as grain size and uniformity (which affect the soil permeability); soil moisture conditions and depth to groundwater; presence of smelter-related debris such as slag, brick or other potential primary contaminant source material; secondary mineralization such as iron-oxide cements which may act as secondary contaminant source material; and hydrocarbon odor or staining (which may affect groundwater redox conditions and contaminant mobility). Stratigraphic logs for the eight source investigation soil borings are included in Appendix B.

The stratigraphy observed through the 2014 drilling program was generally consistent with previous conceptual site models of the stratigraphy in the northern portion of the former smelter. In general, the stratigraphy consisted of a veneer of earthen granular fill overlying varying alluvial/colluvial sediments, in turn overlying the low permeability tertiary-age ash/clay layer at depth. The surficial fill material consists of native earthen material (sand/gravel/silt) with no debris or other nonnative material encountered in any of the 2014 soil borings<sup>3</sup>. As such, visual differentiation of the fill from underlying native in-place soils in the 2014 borings is difficult at best. However, two of the soil borings (EHSB-3 and EHSB-4, Figure 2-1), encountered what appears to be the native soil horizon at depths of nine feet and seven feet, respectively. Since the native soil horizons represent the original (pre-smelter) ground surface, and the smelter was constructed largely on the relatively flat former Prickly Pear Creek floodplain, it is reasonable to assume all material above the native soil horizon, or above approximate elevation 3908 to 3912 in the south and north portions of the investigation area, respectively, represents fill. Differentiation of native in-place soils and sediments from fill material is important since potential source materials such as slag, flue dust or demolition debris, is expected to occur within the fill material only. Contaminant sources within the native material would be limited to secondary sources, such as contaminants adsorbed to soil surfaces or incorporated in secondary mineral precipitates (i.e., iron oxide cements). The native soil/fill contact is shown in Figure 3-1.

Underlying the fill unit are highly variable alluvial/colluvial sediments (Figure 3-1). The majority of this unit consists of coarse-grained gravel and cobble with intervening layers of clean sand. This high permeability material represents alluvial sediments deposited by

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<sup>3</sup> Although no nonnative material was encountered in the 2014 borings, the well log from West Selenium Area well DH-8 (Figure 2-1) identifies ore and brick debris from 0 to 4 feet.



**FIGURE 3-1**  
**SCHEMATIC WEST-EAST CROSS-SECTION**  
**THROUGH WEST SELENIUM AREA**

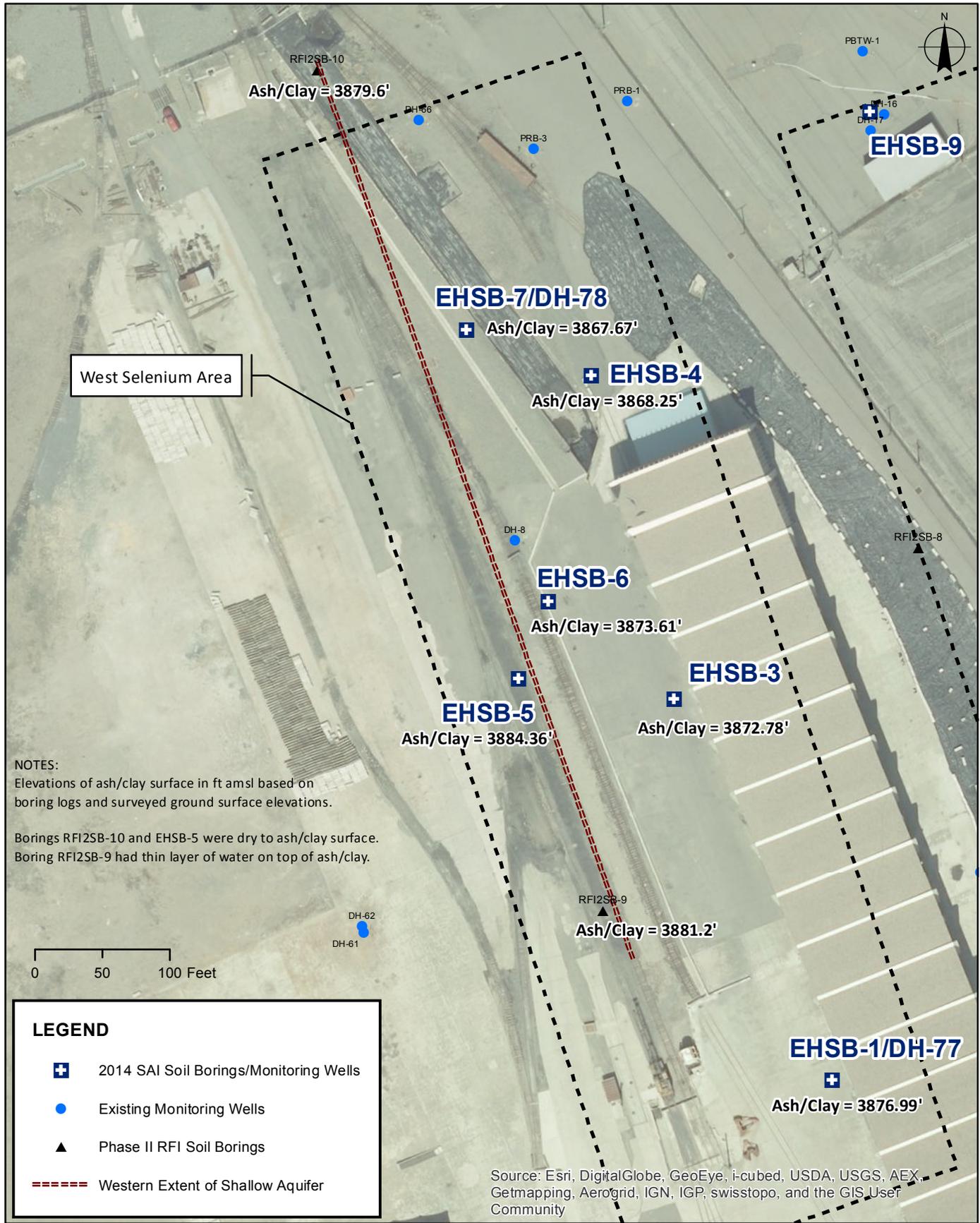
historic Prickly Pear Creek. Along the western margin of the former smelter site (the extreme western portion of the West Selenium source area), the coarse grained alluvium is overlain by sandy/clayey silt. This finer grained unit is believed to be colluvium eroded from the tertiary sediment foothills west of the site. The alluvium/colluvium has a combined thickness ranging from 43 feet at EHSB-1 to 23 feet at EHSB-5.

Underlying the alluvium/colluvium is the low permeability ash/clay unit comprised of altered volcanic ash and fine-grained clastic sediments. The underlying ash/clay layer is an important component of the site hydrostratigraphy as it forms the base of the shallow alluvial aquifer within which the contaminant plumes occur. A steep drop-off in the ash/clay surface occurs along the western margin of the plant site and is most likely an erosional feature associated with historic Prickly Pear Creek. The erosional scarp or ledge is evident in the differing depths to the ash/clay at soil borings EHSB-5 and EHSB-6 (Figure 3-1) and was also documented in Phase II RFI soil borings RFI2SB-9 and RFI2SB-10. As shown in Figures 3-1 and 3-2, this feature represents the western margin of the shallow aquifer on the former smelter site, and the western extent of the high concentration (>1 mg/L) groundwater selenium plume. The pinching out of the shallow aquifer and buttressing effect of the ash/clay ledge has a strong influence on groundwater flow in this area and likely plays a role in the location and narrow configuration of the West Selenium groundwater plume (see Section 3.4).

Petroleum hydrocarbons were detected in soils and groundwater at both North Plant Site Source Area soil borings (EHSB-8 and EHSB-9), and at EHSB-1 located south of the West Selenium Source Area (Figure 2-1). The presence of hydrocarbons in the North Plant Site soils has long been documented, and was initially identified in the Comprehensive RI/FS (Hydrometrics, 1990). Hydrocarbons in this area are part of a larger area of hydrocarbon impacts extending from south to north through the central plant site, and at least partly responsible for lower redox conditions and higher arsenic mobility in this area. The occurrence of petroleum contamination at EHSB-1 was unexpected as hydrocarbons had not previously been encountered on the western portion of the plant site. In both cases, the hydrocarbons appear to be heavy weathered hydrocarbons introduced from historic sources. As noted above, the occurrence of hydrocarbons is of interest since it has the potential to alter groundwater redox conditions, and thus the mobility of both arsenic and selenium.

### **3.2 TOTAL METALS RESULTS**

As described in Section 2.2, total metals analyses were performed on select saturated and unsaturated zone soil samples from each soil boring. A total of 42 soil samples were analyzed for total metals and pH, including 33 samples from the West Selenium Area and 9 samples from the North Plant Site Area. Total metals results are summarized in Table 3-1. Complete metals and pH results are provided in Appendix C, with laboratory reports included in Appendix D.



V:\10022\GIS\SourceInventory\Report\Figure 3-2.mxd

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2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER	<b>WESTERN EXTENT OF SHALLOW AQUIFER IN WEST SELENIUM AREA</b>	<b>FIGURE</b>  <span style="font-size: 2em; font-weight: bold;">3-2</span>
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**TABLE 3-1. SUMMARY OF 2014 SOIL SAMPLE TOTAL METALS ANALYSES**

Parameter	Regional Background <sup>(1)</sup>	West Selenium Area (n = 33)			North Plant Site Area (n = 9)		
		Range	Average	Median	Range	Average	Median
<b>Al</b>	68400	4060-42300	12318	10200	6990-23500	12999	12500
<b>As</b>	43.8	<5-217	38	19	5-323	179	209
<b>Cd</b>	1.2	<1-518	25	<1	<1-59	12	<1
<b>Cu</b>	55.1	8-76	36	33	25-84	39	34
<b>Fe</b>	35300	7650-30800	18177	17300	12800-27400	18722	17000
<b>Pb</b>	53.9	<5-155	19	12	6-20	13	13
<b>Mn</b>	1130	120-2070	500	364	126-406	217	195
<b>Se</b>	0.4	<0.5-44.7	4.2	0.7	<0.5-1.8	0.8	<0.5
<b>Zn</b>	122	20-270	64	46	30-1750	562	463
<b>pH</b>	NC	6.9-9.3	7.9	7.6	6.0-9.1	8.1	8.2

NOTES: n = number of sample results  
 All concentrations in mg/kg except pH (standard units).  
 Values below detection limit replaced with the detection limit for calculation of averages.  
<sup>(1)</sup>Regional background defined here as the 90<sup>th</sup> percentile of concentrations obtained from Lewis and Clark and Jefferson counties during recent statewide sampling of surface soils conducted by Montana DEQ (Hydrometrics, 2013) and USGS (2013).  
 NC = not calculated

### 3.2.1 Lateral and Vertical Distribution of Metals

Comparison of the West Selenium and North Plant Site data shown in Table 3-1 indicates that on average, total manganese and selenium concentrations were higher in the West Selenium Area, averaging 500 mg/kg and 4.2 mg/kg, respectively, compared with 217 mg/kg and 0.8 mg/kg in the North Plant Soils Area. Average total arsenic (179 mg/kg) and zinc (562 mg/kg) concentrations, conversely, were higher in the North Plant Soils Area and lower (38 mg/kg arsenic and 64 mg/kg zinc) in the West Selenium Area. Average concentrations of other metals were reasonably similar between the two areas; the average cadmium concentration for the West Selenium Area (25 mg/kg) was skewed high compared to the North Plant Area (12 mg/kg) by the anomalously high value of 518 mg/kg observed at boring EHSB-1. For individual contaminants, the data in Appendix C show the following:

- The highest concentrations of **arsenic** (up to 241 mg/kg in the unsaturated zone and 323 mg/kg in the saturated zone) and **zinc** (up to 488 mg/kg in the unsaturated zone

and 1750 mg/kg in the saturated zone) were observed in the North Plant Site Area. The unsaturated zone concentrations of 241 mg/kg arsenic and 488 mg/kg zinc occurred in a sample collected from 0.5 to 2.0 feet above the water table, a zone that was saturated, at least seasonally, prior to the November 2011 implementation of the South Plant Hydraulic Control (SPHC) IM (Hydrometrics, 2012).

- The highest concentrations of **selenium** (up to 44.7 mg/kg in the unsaturated zone and 12.9 mg/kg in the saturated zone) and **manganese** (up to 852 mg/kg in the unsaturated zone and 2070 mg/kg in the saturated zone) were observed in the West Selenium Area.
- The highest concentrations of **cadmium** (518 mg/kg) were observed in boring EHSB-1, located upgradient of the West Selenium Area and downgradient of the Acid Plant Area (Figure 2-1). The high cadmium concentration suggests historic influence from the former Acid Plant. The 518 mg/kg cadmium concentration was observed in an unsaturated zone sample collected from just above the current water table, which would have been saturated prior to the fall 2011 implementation of the SPHC IM. Downgradient of boring EHSB-1, saturated zone soils in West Selenium Area soil borings EHSB-6 and EHSB-7 also showed relatively high cadmium concentrations, up to 75 mg/kg at EHSB-6 and 66 mg/kg at EHSB-7. This trend in cadmium concentrations is consistent with a groundwater flowpath from the Acid Plant towards the West Selenium Area.

As noted above, West Selenium Area soil arsenic concentrations are lower than North Plant Soils Area concentrations. Data for individual borings within the West Selenium Area also shows a spatial difference in arsenic concentrations, with an average concentration of 69 mg/kg in borings EHSB-1, EHSB-3 and EHSB-4, located further to the east (closer to the central plant site and the North Plant Soils Area), and an average concentration of 14 mg/kg in borings EHSB-5, EHSB-6 and EHSB-7 further to the west (Figure 2-1).

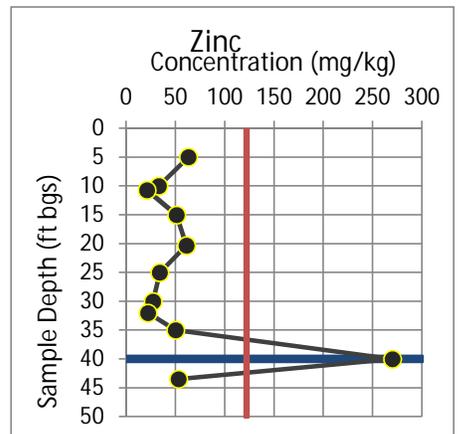
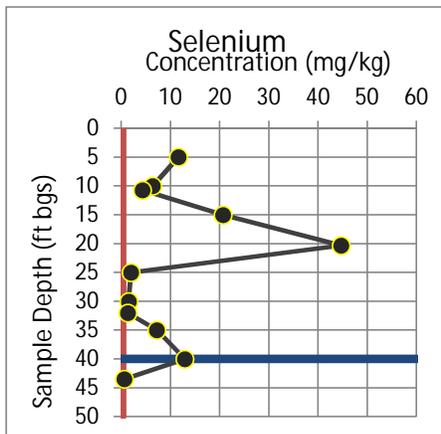
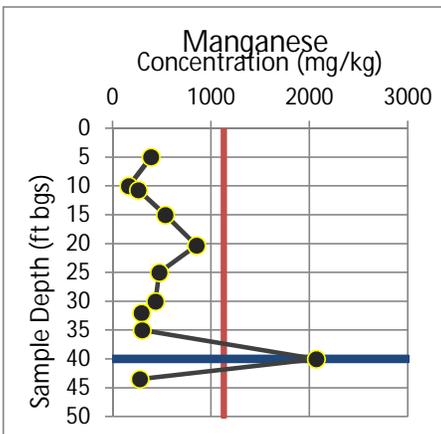
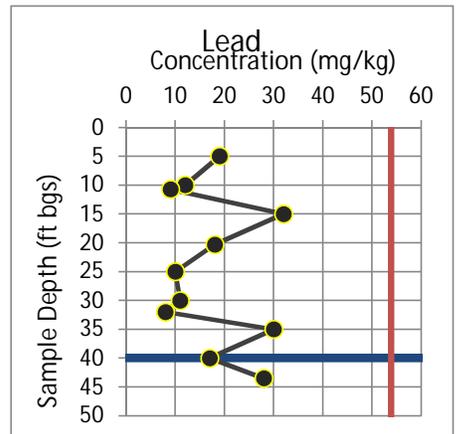
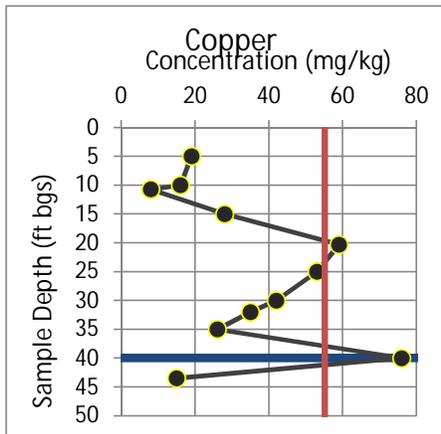
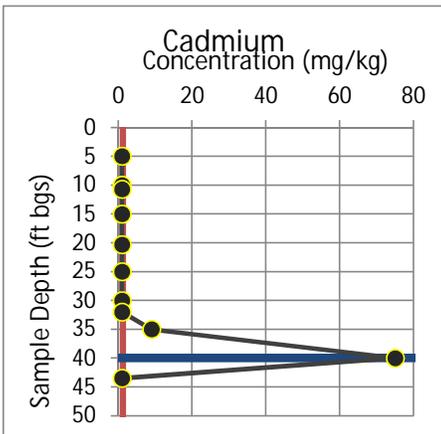
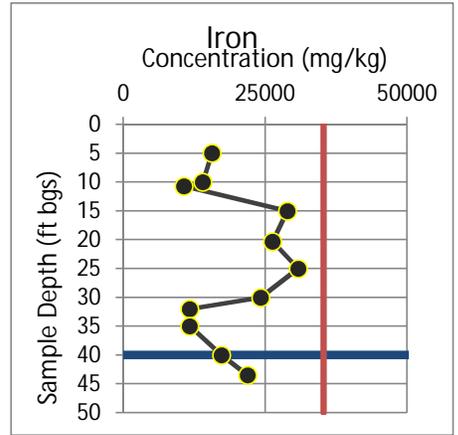
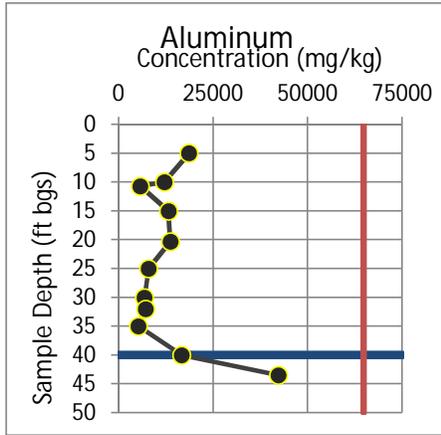
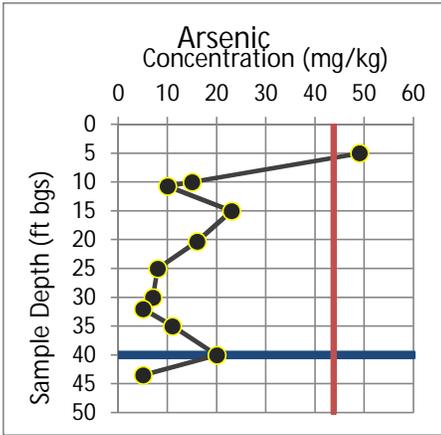
Of particular interest in the 2014 SAI was identification of the source area and materials responsible for the localized, very high (up to 7 mg/L seasonally) groundwater selenium concentrations in the West Selenium Area. The initial total metals analytical results identified soil boring EHSB-6 located near the head of the high concentration selenium plume, as having the highest selenium soil concentrations. Based on these relatively high soils concentrations, and its location near the head of the selenium plume, all soil samples from this boring were analyzed for total metals to provide a complete vertical concentration profile (Figure 3-3). The metals concentration profile at boring EHSB-6 is characterized by moderate metals concentrations in the shallow vadose zone, higher concentrations near 20 feet below ground surface, lower concentrations below 20 feet, and another concentration increase near the current water table at about 40 feet. Most constituents show this general profile pattern, although it is particularly distinct for copper, iron, lead, manganese and



Regional 90th Percentile (mg/kg)



Soil Concentration (mg/kg)



2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER

**TOTAL METALS CONCENTRATION PROFILE FOR SOIL BORING EHSB-6**

FIGURE

**3-3**

selenium. The concentration increase in the 20.3 to 20.9 foot interval corresponds with an interval described in the field logs as moderately cemented with some iron oxide staining. Similarly, the concentration increase in the 40 to 41 foot interval is associated with a sample described as containing cobbles and medium to fine sand with black and orange mottled staining (Appendix B). These observations indicate that higher metals concentrations in soils occur within samples that (visually) contain recognized metal-sorbing phases such as iron and manganese oxides, and act as “secondary” contaminant sources as opposed to potential primary sources such as slag, ore and other smelter debris.

The vertical concentration profile at boring EHSB-6 also is consistent with the conceptual model of historic transport of selenium (and other contaminants) from the surface through the unsaturated zone via infiltration, and eventually down to the saturated zone. Historic surface sources of contaminants in this area likely included ore and other materials stockpiled in uncovered, unpaved areas prior to the 1990 completion of the ore storage building, as well as rail corridor fill material. Transport and deposition of selenium throughout the unsaturated zone and into the saturated zone via repeated cycles of wetting and drying might be expected to lead to the presence of highly leachable forms of selenium in local soils, and subsequently to elevated groundwater concentrations. The leachability of selenium in West Selenium Area soils is further discussed below in Section 3.3.

### **3.2.2 Comparison to Previous Soil Sampling Results**

Total metals concentrations observed in 2014 soil samples were generally consistent with previously observed concentrations at the former smelter site. Numerous site investigations have shown that soil contaminant concentrations across the former smelter are highly variable both laterally and vertically, due to the variety of materials storage and handling processes and process water releases that occurred in different areas throughout the life of the smelter. The average arsenic concentrations shown in Table 3-1 for West Selenium Area samples (38 mg/kg) and North Plant Soils Area samples (179 mg/kg) are lower than averages observed during previous sitewide investigations, including the Phase I RFI (median arsenic concentrations ranging from 197 to 962 mg/kg in surface soils collected from different plant site areas) and the Phase II RFI (average overall arsenic concentration of 370 mg/kg). Note that concentrations of arsenic and other contaminants tend to be higher in slag and in surficial fill that includes smelter waste materials such as brick and flue dust, which often show arsenic concentrations on the order of 1000 mg/kg or greater. The lower overall average arsenic concentrations for the 2014 samples likely reflect the absence of these highly contaminated primary source materials.

Total arsenic concentrations in the two areas investigated in 2014 are consistent with previous investigations when compared with proximal sampling locations. For example, Phase II RFI borings RFI2SB-8, -16, -17, -20 and -21 are located within or near the generally

defined North Plant Soils Area. Data from the Phase II RFI borings showed an overall average arsenic concentration of 120 mg/kg, with an average concentration of 179 mg/kg for saturated zone samples and 92 mg/kg for unsaturated zone samples. The 2014 SAI data for borings EHSB-8 and EHSB-9 in the North Plant Soils Area showed an overall average arsenic concentration of 179 mg/kg, with an average of 226 mg/kg for saturated zone samples and 84 mg/kg for unsaturated zone samples. Phase II RFI boring RFI2SB-16, located approximately midway between borings EHSB-8 and EHSB-9 (Figure 2-1), also showed an average saturated zone arsenic concentration of 226 mg/kg. In the West Selenium Area, total arsenic data from borings EHSB-5, EHSB-6 and EHSB-7 (<5 to 49 mg/kg) is consistent with data previously collected from nearby Phase II RFI borings RFI2SB-9 and RFI2SB-10, which showed arsenic concentrations in non-slag fill soils ranging from <5 to 25 mg/kg.

Boring EHSB-9 was installed in 2014 immediately adjacent to wells DH-16 and DH-17, a well pair drilled in 1986 (Figure 2-1). Comparison of total soil arsenic data for these sampling locations suggests that soil arsenic concentrations may have decreased over time at certain depths, possibly through desorption/dissolution of arsenic from soils and downgradient transport in groundwater. At 30 feet below ground surface, boring EHSB-9 showed a total soil arsenic concentration of 241 mg/kg in 2014, and well DH-17 showed a total arsenic concentration of 266 mg/kg in 1986. Similarly, at 35 feet below ground surface, the concentrations in 1986 (313 mg/kg) and 2014 (323 mg/kg) are comparable. However, deeper in the saturated zone (40-45 feet below ground surface), the concentrations in EHSB-9 (117 to 209 mg/kg) were significantly lower than those measured in 1986 (662 mg/kg), indicating possible net desorption of arsenic from soils in this area over the period from 1986 to 2014. This trend is consistent with the current conceptual model of previously adsorbed and/or coprecipitated arsenic currently being released to the aquifer, thus acting as a secondary contaminant source.

There is less historic data on selenium in soils throughout the former smelter than there is for arsenic since selenium was first identified as a COC in 2007. The Phase II RFI data has shown that the majority of site soils have selenium concentrations <5 mg/kg. Similar to arsenic, elevated selenium concentrations have primarily been observed in slag and in fill containing ore, brick, or other process-related materials, with concentrations up to 325 mg/kg noted in Phase II RFI slag pile samples and up to 662 mg/kg in a Phase II RFI surface fill sample composed of brick and slag. A lower reporting limit (0.5 mg/kg) was utilized for the 2014 SAI in an effort to provide more quantifiable total selenium data for site soils. Overall, the 2014 data confirmed that selenium concentrations in (non-slag) soils are relatively low, ranging from <0.5 to 44.7 mg/kg and showing the lowest average concentrations of any of the constituents tested (Table 3-1). These data are consistent with selenium data for the Phase II RFI North Plant Site and West Selenium Area soil borings, where the majority of

sample concentrations (over 90%) were reported as <5 mg/kg and the few detectable concentrations observed ranged from 0.8 to 17 mg/kg. The maximum concentration observed in the saturated zone in 2014 (12.9 mg/kg at boring EHSB-6) was similar to one of the few detectable saturated zone selenium concentrations observed during the Phase II RFI, at boring RFI2SB-20 (17 mg/kg), located north of the Speiss/Dross slurry wall.

### **3.2.3 Metals Enrichment in Soils**

Metals are naturally present in all soils and sediment, thus identification of metals enrichment or contamination in soils typically involves comparison to ambient or background concentrations. For comparison purposes, a calculated regional background concentration for total metals is shown in Table 3-1, along with the summary of concentrations for the 2014 source area characterization samples. The “regional background” concentration for comparison purposes is the 90<sup>th</sup> percentile of values obtained from recent surface soil sampling studies conducted by the Montana Department of Environmental Quality (Hydrometrics, 2013) and the USGS (2013). To provide a representative regional value for the former smelter site, the calculated 90<sup>th</sup> percentile is based on eleven samples collected from Lewis and Clark County and Jefferson County, since the former smelter is located near the boundary of these two counties.

The distribution of metals concentrations measured in the West Selenium Area and North Plant Site soil samples are shown in probability distribution plots (metal concentration vs. percent exceeding concentration value) in Appendix F, along with median values (50<sup>th</sup> percentile) for the 2014 source area samples and the calculated regional background values for comparison. Overall, the total metals data presented in Table 3-1 and Appendix F suggests the following:

- Aluminum, iron, lead and manganese do not show evidence of widespread enrichment above background, as low percentages of the samples collected (0 to 7% depending on the metal) exceeded the regional background concentration, and median values are significantly below the regional background value (Table 3-1). Copper showed slight enrichment, with 14% of the 2014 soil samples exceeding the regional background level.
- Arsenic, cadmium, selenium and zinc show evidence of enrichment in some samples as a significant percentage of samples collected (26% for zinc, 40% for arsenic and cadmium, and 55% for selenium) exceed the calculated regional background, with some concentrations one or more orders of magnitude greater than the regional background values. Although arsenic, cadmium, selenium and zinc do show evidence of enrichment in some of the samples, the median concentrations of these constituents are still below the regional background concentrations shown in Table 3-1.

### 3.3 LEACH TEST RESULTS

The total metals concentrations described above provide a good overview of soil conditions in the two contaminant source areas investigated, but do not necessarily quantify the availability of metals to partition from the soils to groundwater. Based on the total metals results, select soil samples were leach tested to better assess the leachability of contaminants and their potential to affect groundwater quality (Section 2.2). Complete results of leachable metals and pH analyses conducted on the 2014 SAI samples are presented in Appendix C, and laboratory reports are in Appendix D. Details of leach testing protocols (initial soil moisture, mass of soil, volume of leaching solution, and chemical composition of groundwater leaching solution) are also provided in Appendix C. A total of 4 unsaturated zone samples (3 from the West Selenium Area and 1 from the North Plant Site Area) and 12 saturated zone samples (7 from the West Selenium Area and 5 from the North Plant Site Area) were analyzed using the leach testing protocols (see Section 2.3 for description of sample selection). Leachable metals results for unsaturated zone samples are summarized in Table 3-2, and saturated zone leach test results are summarized in Table 3-3.

**TABLE 3-2. SUMMARY OF UNSATURATED SOIL SAMPLE LEACHING RESULTS**

Parameter	West Selenium Area (n=3)		North Plant Site Area (n=1)	
	SPLP	Saturated Paste	SPLP	Saturated Paste
<b>As</b>	0.005-0.85	<0.005-1.5	1.0	0.58
<b>Se</b>	0.007-1.1	0.13-33	<0.005	<0.005
<b>Ca</b>	3-5	12-160	3	53
<b>Mg</b>	2-9	13-56	2	17
<b>Na</b>	26-45	74-230	32	270
<b>K</b>	2-6	10-15	2	15
<b>HCO3</b>	<1-10	21-200	13	8
<b>SO4</b>	2-14	260-860	11	780
<b>Cl</b>	<1	11-16	<1	5

NOTES: n = number of sample results  
All concentrations in mg/L

**TABLE 3-3. SUMMARY OF SATURATED SOIL SAMPLE LEACHING RESULTS**

<i>Laboratory-Reported Leach Concentrations</i>						
<b>Parameter</b>	<b>West Selenium Area (n=7)</b>			<b>North Plant Site Area (n=5)</b>		
	<b>Initial Leach Solution<sup>(1)</sup></b>	<b>Final SPLP<sup>(1)</sup></b>	<b>Final Saturated Paste<sup>(1)</sup></b>	<b>Initial Leach Solution<sup>(2)</sup></b>	<b>Final SPLP<sup>(2)</sup></b>	<b>Final Saturated Paste<sup>(2)</sup></b>
<b>As</b>	7.5	1.7-2.1	0.017-0.78	0.345	0.69-2.2	3.2-20
<b>Se</b>	0.04	0.036-0.29	0.19-10	0.003	<0.005-0.011	<0.005-0.11
<b>Ca</b>	171	79-110	110-470	53	40-42	8-19
<b>Mg</b>	141	30-37	47-160	15	11-12	3-9
<b>Na</b>	53	47-72	72-300	100	110	180-240
<b>K</b>	72	8-10	10-30	8	6-8	8-14
<b>HCO3</b>	260	260-270	110-180	260	270-280	220-270
<b>SO4</b>	290	300-330	440-1700	190	190-200	150-250
<b>Cl</b>	24	25-31	24-300	11	11	13-17

NOTES: n = number of sample results

All concentrations in mg/L

<sup>(1)</sup>Leach solution for West Selenium Area saturated soils was groundwater from upgradient well DH-71

<sup>(2)</sup>Leach solution for North Plant Site Area saturated soils was groundwater from upgradient well SDMW-4

<i>Corrected Net Leach Concentrations</i>				
<b>Parameter</b>	<b>West Selenium Area (n=7)</b>		<b>North Plant Site Area (n=5)</b>	
	<b>SPLP Net Leached<sup>(1)</sup></b>	<b>Saturated Paste Net Leached<sup>(1)</sup></b>	<b>SPLP Net Leached<sup>(2)</sup></b>	<b>Saturated Paste Net Leached<sup>(2)</sup></b>
<b>As</b>	None	None	0.21-1.8	0-17
<b>Se</b>	0-0.24	0-9.3	0-0.008	0-0.11

NOTES: n = number of sample results

All concentrations in mg/L

Corrected net leach concentrations have been corrected based on initial concentration in leach solution and initial concentration in residual soil moisture (obtained from groundwater samples)

None = no net leaching observed (all samples adsorbed the constituent)

Net leached result of 0 indicates one or more samples showed no net leaching

<sup>(1)</sup>Leach solution for West Selenium Area saturated soils was groundwater from upgradient well DH-71

<sup>(2)</sup>Leach solution for North Plant Site Area saturated soils was groundwater from upgradient well SDMW-4

Leachable concentrations were measured using two different test procedures (SPLP and saturated paste) to simulate conditions of high and low liquid to solid ratios, respectively (Section 2.2). Previous leach testing on site soils has shown that concentrations in soil leachates can vary significantly with liquid to solid ratio; testing at multiple ratios allows for a more robust evaluation of potential impacts to groundwater loading and concentrations. In general, leach test results indicate that the highest leachable mass is observed under the high liquid:solid ratio conditions of the SPLP test, since there is more solvent (water) available to solubilize contaminants. Conversely, the highest leachable concentrations are observed under the low liquid:solid ratio conditions of the saturated paste leach test, since the lower amount of solvent (water) results in less dilution. In general, saturated paste tests may provide a more direct approximation of groundwater concentrations resulting from soil leaching, since the liquid:solid ratio of about 0.2:1 is likely more representative of in situ aquifer conditions.

Leach tests on unsaturated zone soils were conducted with the typical leaching solutions used for the SPLP test (synthetic precipitation). Leach tests on saturated zone samples were conducted using the standard methodology for these two methods, but the typical leach solutions were replaced with upgradient groundwater; monitoring well DH-71 groundwater for the West Selenium Area samples, and SDM-4 groundwater for the North Plant Soils Area samples. Leach testing with area groundwater was intended to provide a more realistic simulation of leaching behavior under actual field conditions. Note that, due to the presence of arsenic and selenium in the groundwater leach solutions and in residual soil moisture within the saturated zone samples, corrected (net) leaching concentrations were calculated for arsenic and selenium in these soils to differentiate between the mass initially present in the leaching solution and the mass actually leached from the soil itself. Corrected net leach concentrations, which are slightly lower than the laboratory-reported concentrations in the leach solution, are included in Table 3-3. For saturated zone soils, the following discussion of leaching results references the corrected net leach concentrations.

### **3.3.1 West Selenium Area Leaching Results**

#### **3.3.1.1 Unsaturated Zone Soils**

Arsenic concentrations observed in unsaturated soil leach tests (SPLP and saturated paste) ranged from <0.005 mg/L up to 1.5 mg/L (Table 3-2). The highest arsenic leach concentration observed was from boring EHSB-1, located upgradient of the main West Selenium Area groundwater plume (Figure 2-1). The groundwater and soil chemistry at boring EHSB-1 indicate that it is outside the main selenium source area, and EHSB-1 is the only west plant site soil boring with hydrocarbon staining on soils. The relatively low leachable arsenic concentrations in other West Selenium Area unsaturated zone samples (<0.005 to 0.11 mg/L) are consistent with the relatively low groundwater arsenic concentrations typical of the West Selenium Area. Based on the calculated mass of arsenic

liberated from soils via leach testing, the unsaturated zone soils in this area (excluding boring EHSB-1) leached a relatively low percentage of total arsenic, ranging from 0.1 to 8 percent, indicating the arsenic mass in the West Selenium Area unsaturated zone is relatively unavailable for partitioning to groundwater.

Selenium concentrations observed in unsaturated soil leach solutions ranged from 0.007 to 1.1 mg/L in SPLP tests and 0.13 to 33 mg/L in saturated paste tests (Table 3-2). The 2014 SPLP results for West Selenium Area unsaturated soils are similar to the range observed in Phase II RFI unsaturated zone samples from this area (0.027 to 0.490 mg/L). The saturated paste results are similar to or higher than actual selenium concentrations in the West Selenium Area groundwater (1 to 8 mg/L). In particular, the 33 mg/L result for an unsaturated zone sample from boring EHSB-6 is the highest leachable selenium concentration observed to date for any soil sample from the former smelter. In contrast to arsenic, larger fractions of the total soil selenium in West Selenium Area unsaturated soil samples were leached (11% to 57%), indicating that selenium is relatively soluble in unsaturated zone soils. Based solely on comparison of leachable concentrations, it appears that leaching of unsaturated soils could theoretically generate the observed selenium (and arsenic) groundwater concentrations in the West Selenium Area. However, if the presence of asphalt ground cover or building footprints is inhibiting infiltration throughout this area the leaching of unsaturated zone soils is not expected to be a significant current source of selenium loading to groundwater in the West Selenium Area.

### **3.3.1.2 Saturated Zone Soils**

The saturated zone leach test results for West Selenium Area soil samples (Table 3-3) show that, for arsenic, final concentrations were lower than initial concentrations, indicating no net leaching; all soils adsorbed or otherwise attenuated arsenic from the leaching solution in both the SPLP and saturated paste leach tests. Net selenium concentrations from the West Selenium Area saturated zone leach tests ranged from 0.00 to 0.24 mg/L for SPLP tests and 0.0 to 9.3 mg/L for saturated paste tests (Table 3-3).

The West Selenium Area saturated zone leaching results indicate that selenium is generally highly “available” for leaching from these saturated soils. The 9.3 mg/L net saturated paste leach concentration (maximum observed) was generated from a sample from boring EHSB-6 with a total selenium concentration of 12.9 mg/kg, while a sample from boring EHSB-7 leached 1.6 mg/L from a total selenium concentration of only 0.9 mg/kg. These values correspond to mass leaching rates of 25% from the EHSB-6 sample and 44% from the EHSB-7 sample, showing that selenium in these saturated zone soils is readily leachable. Several saturated zone soils from this area also leached sulfate, with concentrations in the range of 440-1700 mg/L (Table 3-3), and positive correlations between leached sulfate and selenium concentrations. The “high” leachability of the West Selenium Area saturated soils

and comparability of the leach test results with actual groundwater concentrations indicate that saturated soils within the West Selenium Area are the most likely current source of contaminant loading to local groundwater.

### **3.3.2 North Plant Soils Source Area Leaching Results**

#### **3.3.2.1 Unsaturated Zone Soils**

Moderate arsenic concentrations (0.58 to 1.0 mg/L) and below detect selenium concentrations (<0.005 mg/L) were observed in the unsaturated zone leach tests from North Plant Site soil boring EHSB-9. Given the typical groundwater arsenic concentrations in the North Plant Site of 10 to 30 mg/L and the presence of asphalt ground cover throughout this area, leaching of unsaturated zone soils is unlikely to be a significant current source of arsenic loading to groundwater in the North Plant Soils area.

#### **3.3.2.2 Saturated Zone Soils**

Saturated zone leach test results for the North Plant Site Area are in Table 3-3. Net leach concentrations of arsenic ranged from 0.21 to 1.8 mg/L for SPLP and 0 to 17 mg/L for saturated paste. For comparison, saturated zone samples from the North Plant Site Area tested during the Phase II RFI showed SPLP leach concentrations of 0.31 to 2.8 mg/L arsenic. In addition, a saturated zone sample from Phase II RFI boring RFI2SB-16, located between 2014 borings EHSB-8 and EHSB-9, showed a net release of approximately 4.4 mg/L arsenic during adsorption testing. Further north, Phase II RFI boring RFI2SB-21 showed leachate arsenic concentrations up to 0.31 mg/L. Thus, leach testing results for this area suggest that leaching of saturated zone soils can generate leachate arsenic concentrations that are on the same order as groundwater concentrations in the North Plant Site (10 to 30 mg/L).

Some of the saturated zone soil samples from the North Plant Site Area also showed low but detectable net leach concentrations of selenium, ranging from 0 to 0.008 mg/L under SPLP test conditions and 0 to 0.11 mg/L under saturated paste conditions (Table 3-3). Mass leaching rates for selenium in the North Plant Site Area saturated soils ranged from 0.4% to 16%, generally lower than the leaching rates in the West Selenium Area saturated zone soils (9% to 48%). The lower leachability of selenium in the North Plant Site may be related to the difference in redox conditions, which are reducing in the North Plant Site Area (restricting selenium mobility) and oxidizing in the West Selenium Area (enhancing selenium mobility).

Leach testing for selenium was not conducted for most North Plant Site borings drilled during the Phase II RFI due to below detect (<5 mg/kg) total selenium concentrations; however, one sample from boring RFI2SB-20 near the Speiss/Dross slurry wall, about 150 feet upgradient (south) of boring EHSB-8 (Figure 2-1), showed a total selenium

concentration of 17 mg/kg. This sample was tested for selenium adsorption, and released selenium to the test solution at a concentration of approximately 0.6 mg/L. Sequential extraction testing on the RFI2SB-20 sample also showed that a high percentage of the selenium in the sample (40%) was in the most available phase (exchangeable). Both the total selenium concentration in soil (17 mg/kg) and the leachable selenium concentration (0.6 mg/L) at Phase II RFI boring RFI2SB-20 are higher than any concentrations observed at 2014 North Plant Site Area borings EHSB-8 and EHSB-9.

Despite the relatively low net selenium concentrations in leach solutions, the selenium leaching results for the 2014 North Plant Site saturated zone soils, along with the Phase II RFI results from boring RFI2SB-20 may be significant in terms of potential future groundwater impacts. Currently, groundwater selenium concentrations throughout most of the North Plant Site Area are typically below detection limits (<0.001 mg/L), and both the low selenium concentrations and high arsenic concentrations in this area appear to be related to the effects of petroleum-impacted soils and reducing conditions in the aquifer on contaminant mobility. The North Plant saturated soils selenium leaching concentrations observed as part of the current investigation, while low (0.007 to 0.11 mg/L net leach concentrations using saturated paste), suggest some potential for remobilization of selenium in this area if geochemical conditions are altered, either through remedial actions or through natural reoxidation of groundwater as the effects of the petroleum release are slowly attenuated over time. The potential for selenium remobilization is emphasized by the Phase II RFI results from boring RFI2SB-20 noted above. In addition, several groundwater wells on the periphery of the reduced plume in this area (DH-36 and SDMW-1) have shown recent, albeit slight, increasing trends for selenium in groundwater.

The results from the three North Plant Soils Area borings EHSB-8, EHSB-9 and RFI2SB-20 can be summarized as follows:

<b>Location</b>	<b>Total Se (mg/kg)</b>	<b>Net Leached Se (mg/L)</b>
EHSB-8	0.5 – 1.8	0.067 – 0.11
EHSB-9	<0.5	0 – 0.042
RFI2SB-20	17	0.6

Overall, the North Plant Soils selenium data suggest some potential for selenium release under changing geochemical conditions, particularly in the area closer to the former Speiss/Dross handling and processing area and the current Speiss/Dross slurry wall. While current data are limited and additional investigation would be required to further refine the understanding of the potential for selenium remobilization, based on the available results this potential should be considered as part of any review of groundwater remedies in this area of the former smelter.

### 3.4 SCREENING LEVEL GROUNDWATER

Results of the screening-level groundwater quality samples collected during drilling of the source area investigation soil borings are included in Table 3-4. Overall, the groundwater results obtained from soil borings were consistent with results from area monitoring wells observed during recent sampling events. The North Plant Site Area borings EHSB-8 and EHSB-9 both showed high arsenic concentrations (9.33 and 17.6 mg/L, respectively) and nondetect (<0.001 mg/L) selenium concentrations. The sulfate and chloride concentrations at these two borings were also similar to concentrations at other wells in the main plant site arsenic plume in the North Plant Site Area.

In the West Selenium Area, groundwater results from soil borings allowed refinement of the “higher concentration” (up to 8 mg/L seasonally) selenium plume previously defined by existing wells DH-8 and DH-66 (Figure 3-4). The higher concentration plume is bounded by lower selenium concentrations (about 0.05 to 0.20 mg/L) at well PRB-3 and boring EHSB-4 on the east, boring EHSB-3 on the south, and on the west by the ash/clay ledge that represents the shallow aquifer (and selenium plume) boundary. The selenium concentration at EHSB-7 (4.13 mg/L) was similar to concentrations recently observed at nearby wells DH-8 and DH-66, while EHSB-6, just south of DH-8, showed a slightly lower concentration of 1.36 mg/L. Thus, the high concentration selenium plume appears to originate near EHSB-6 and is laterally constrained by the ash/clay layer to the west and the higher arsenic/lower redox plume to the east (Figure 3-4). The selenium plume corresponds closely with elevated sulfate concentrations in groundwater (Table 3-4). Note that the selenium concentration at well DH-8 reported in Table 3-4 (0.818 mg/L) is anomalously low compared with other groundwater samples collected from this well prior to and following the screening-level sample, which were in the 4 to 5 mg/L range.

As noted above, boring EHSB-1 (completed as monitoring well DH-77) is located south of the elevated groundwater selenium area, and shows an elevated arsenic concentration (2.95 mg/L) and evidence of petroleum impacts. In addition, subsequent groundwater samples have shown a high cadmium concentration at this well (4.95 mg/L in October 2014), consistent with the former Acid Plant impacts suggested by the high soil cadmium concentration also seen at this boring and noted previously (518 mg/kg).

**TABLE 3-4. SCREENING LEVEL GROUNDWATER SAMPLING RESULTS**

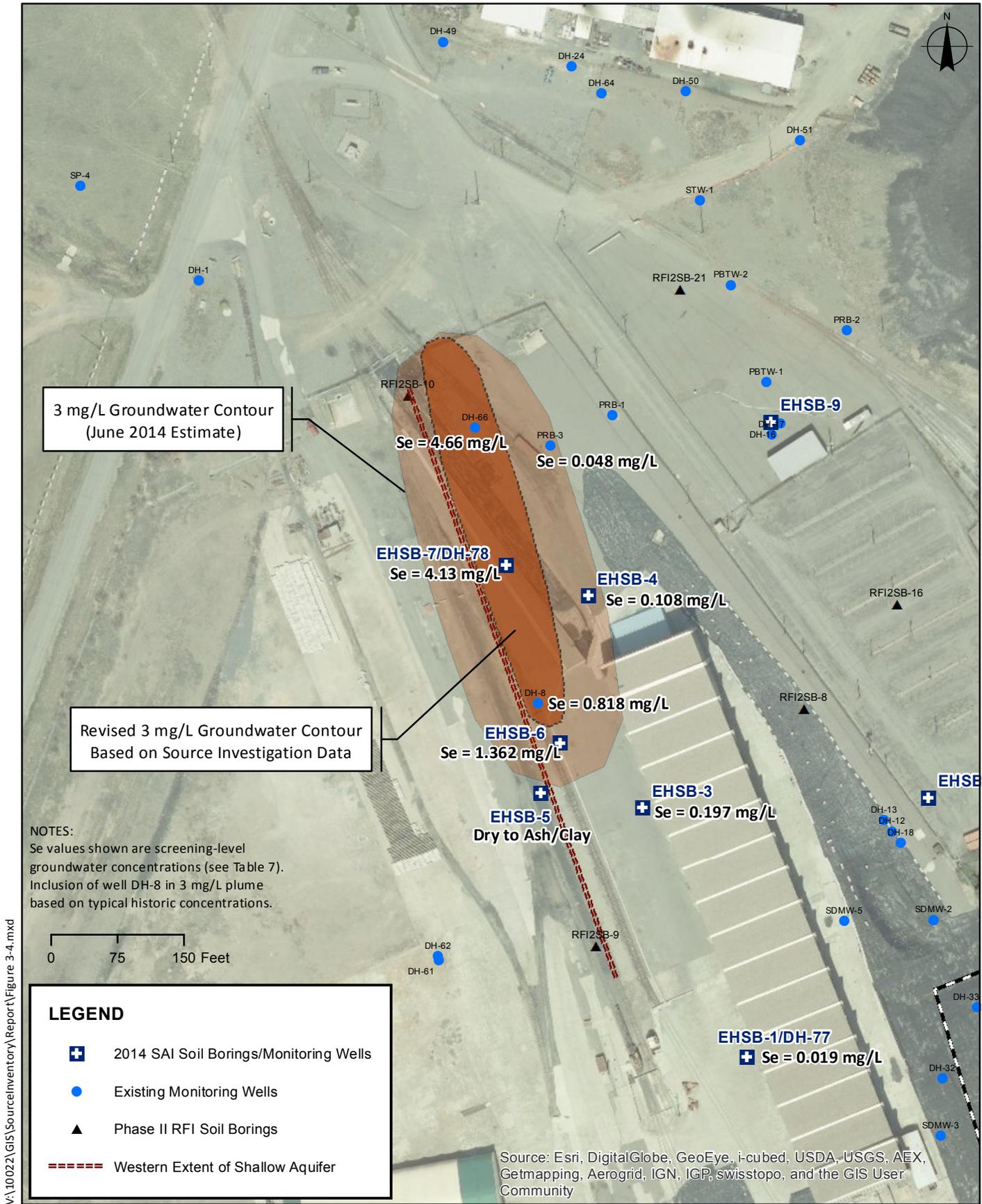
Location	Sample Date	Arsenic	Selenium	Sulfate	Chloride
<b>Soil Borings</b>					
<b>EHSB-1</b>	9/9/14	2.95	0.019	NA	NA
<b>EHSB-3</b>	9/11/14	0.051	0.197	960	210
<b>EHSB-4</b>	9/11/14	1.59	0.108	330	29
<b>EHSB-6</b>	9/15/14	0.091	1.362	1900	430
<b>EHSB-7</b>	9/17/14	0.139	4.13	1300	290
<b>EHSB-8</b>	9/15/14	9.33	<0.001	280	18
<b>EHSB-9</b>	9/16/14	17.6	<0.001	230	13
<b>Existing Monitoring Wells</b>					
<b>PRB-3</b>	9/8/14	2.85	0.048	360	19
<b>DH-8</b>	9/16/14	0.090	0.818*	1800	620
<b>DH-66</b>	9/16/14	0.075	4.66	1200	200

NOTES: All concentrations in mg/L

NA = not analyzed

Shaded cells indicate sample analysis by Alpine Analytical; other samples analyzed by Energy Laboratories

\*Value is anomalously low compared with samples collected prior to and following this sample (concentrations in 4 to 5 mg/L range)



V:\10022\GIS\SourceInventory\Report\Figure 3-4.mxd

**NOTES:**  
 Se values shown are screening-level groundwater concentrations (see Table 7).  
 Inclusion of well DH-8 in 3 mg/L plume based on typical historic concentrations.

0      75      150 Feet

**LEGEND**

- + 2014 SAI Soil Borings/Monitoring Wells
- Existing Monitoring Wells
- ▲ Phase II RFI Soil Borings
- - - - - Western Extent of Shallow Aquifer

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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2014 SUPPLEMENTAL CONTAMINANT SOURCE AREA INVESTIGATION AT THE FORMER EAST HELENA SMELTER	<b>APPROXIMATE EXTENT OF HIGH CONCENTRATION WEST SELENIUM AREA GROUNDWATER PLUME</b>	<b>FIGURE</b>  <span style="font-size: 2em; font-weight: bold;">3-4</span>
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### 3.5 MINERALOGICAL ANALYSIS

Three soil samples were submitted for mineralogical analysis as identified in Table 2-3. A report of findings including scanning electron microscope (SEM) images of sediment samples and identified chemical and mineralogical compositions of sediment samples is provided in Appendix G. A summary of the mineralogical findings is as follows:

#### West Selenium Area–Unsaturated Sample from Boring EHSB-6 (Sample #AEH-1409-163S)

- Sample was collected from 20.3-20.9 ft bgs with total As = 16 mg/kg and total Se = 44.7 mg/kg.
- Iron oxide staining noted in field log.
- SEM/EDX analysis showed various iron and manganese phases present, but the phase or mode of occurrence of selenium and arsenic could not be determined at the low concentrations present.

#### West Selenium Area – Saturated Sample from Boring EHSB-6 (Sample #AEH-1409-163S)

- Sample was collected from 40-41 ft bgs (immediately above ash/clay layer) with total As = 20 mg/kg and total Se = 12.9 mg/kg.
- Black and orange mottled staining noted in field log.
- Manganese oxide coatings were detected on these sediments, but the association of selenium and/or arsenic with the manganese oxide could not be determined at the low concentrations present.
- Barium sulfate (barite) was also observed via SEM/EDX analysis.

#### North Plant Site – Saturated Sample from Boring EHSB-8 (Sample #AEH-1409-214)

- Sample was collected from 35-35.2 ft bgs with total As = 277 mg/kg and total Se = 1.7 mg/kg.
- Iron oxides with associated arsenic up to 2.7 percent (27,000 ppm) were commonly observed throughout the sample.
- Barium sulfate (barite) was also observed via SEM/EDX analysis.

Overall, the mineralogical testing of West Selenium Area soils was inconclusive since the relatively low total selenium concentrations precluded identification of phase associations of selenium in the soils. The presence of barite may exert some control on groundwater sulfate (and potentially selenium) concentrations since barium sulfate is extremely insoluble. Given the sulfate concentrations in the West Selenium Area plume (1500 mg/L), soluble barium concentrations would be expected to be about 0.001 mg/L at equilibrium. Geochemical calculations also show that calcium sulfate (gypsum) is approximately at equilibrium in West Selenium Area groundwater with elevated sulfate concentrations. Both barite and gypsum

have been identified by researchers as possible controlling phases affecting selenium leaching (Dixon, 2007).

Mineralogic testing of the North Plant Soils Area sample showed that arsenic is strongly associated with iron oxide minerals, with iron oxide phases containing up to 2.7% arsenic (presumably bound to the iron oxides through adsorption). Given the arsenic leaching behavior of North Plant Site soils, it is likely that these iron oxide phases represent a reservoir of leachable arsenic and that current groundwater concentrations in the area are to some extent controlled by iron-oxide associated arsenic. This is consistent with the conceptual model of arsenic within the North Plant Site soils having originated from upgradient sources, such as the Speiss/Dross area, and being deposited as secondary iron-arsenic oxide cements on the aquifer matrix when groundwater arsenic concentrations were 500 mg/L or more, and now being released back to groundwater through resolubilization of the secondary minerals since groundwater arsenic concentrations have decreased by an order of magnitude or more.

#### 4.0 SUMMARY AND DISCUSSION

Two current groundwater contaminant source areas were investigated at the former East Helena Smelter in 2014 to provide information necessary for evaluation of potential groundwater remedial options. Based on an inventory of current and historic groundwater contaminant sources, the 2014 SAI focused on the West Selenium Source Area and North Plant Site Arsenic Source Area. The stratigraphy recorded in eight soil borings was consistent with previous drilling results, with earthen fill present at ground surface, alluvial/colluvial sediments underlying the fill, and the low permeability tertiary ash/clay unit encountered at all boring locations. Depths to the ash/clay layer, which forms the base of the contaminated shallow aquifer, range from 31 feet west of the West Selenium Source Area, to 49 feet to the east in the North Plant Site Arsenic Source Area. The 2014 drilling helped refine the location of an abrupt drop-off or ledge in the ash/clay layer surface forming the western margin of the contaminated shallow aquifer. No apparent smelter waste/debris was identified in any of the 2014 soil borings although previous drilling in the area (i.e., monitoring well DH-8), did identify ore, brick and other smelter debris within a few feet of ground surface.

Based on soil sampling and testing, concentrations of arsenic, selenium, cadmium and zinc in subsurface soils are enriched above regional background concentrations. Arsenic and zinc were enriched in the North Plant Site Area and selenium in the West Selenium Area. Cadmium was highly enriched at soil boring EHSB-1, located midway between the Acid Plant and West Selenium Areas, and was also enriched in saturated zone samples from borings EHSB-6 and EHSB-7, downgradient of EHSB-1. Elevated cadmium concentrations are a signature of the former Acid Plant process water circuit, indicating that the west plant site and West Selenium Source Area are recharged by groundwater from the Acid Plant Area. Aluminum, lead, copper and iron did not show significant enrichment.

Total metals concentrations in 2014 SAI samples were generally consistent with concentrations obtained through previous soil sampling programs (ACI, 2005; METG, 2011). The average arsenic concentration in 2014 SAI North Plant Site Area soils was 179 mg/kg (226 mg/kg for saturated zone soils and 84 mg/kg for unsaturated zone soils). For comparison, Phase II RFI data for the North Plant Site Area showed an overall average of 135 mg/kg arsenic (179 mg/kg for saturated zone soils and 92 mg/kg for unsaturated zone soils). For selenium, the 2014 data showed generally low total soil concentrations (with many samples still enriched over typical “background”), consistent with previous sampling results showing the majority of concentrations <5 mg/kg, except in surface fill or slag samples.

Some of the highest unsaturated zone total metals concentrations documented during the 2014 SAI occurred within a couple feet of the current water table, within soils that were saturated prior to the November 2011 implementation of the SPHC IM. Examples include the arsenic (241 mg/kg) and zinc (488 mg/kg) concentrations in the North Plant Site soils unsaturated zone, which were obtained from samples about 0.5 to 2 feet above the current water table. Similarly, the highest cadmium concentration in the unsaturated zone (518 mg/kg upgradient of the West Selenium Area) was obtained from a sample about 1.5 to 2 feet above the current water table. These soils would have been below the water table prior to the Fall 2011 implementation of the SMPC IM, indicating that the SPHC project has segregated some of the higher contaminant concentration soils from groundwater.

#### **4.1 WEST SELENIUM AREA INVESTIGATION FINDINGS**

Prior to 2014, the presence of selenium source material(s) in the West Selenium Area was identified by the high localized groundwater selenium concentrations (historically up to 8 mg/L on a seasonal basis) in the West Selenium Source Area. However, due to the relatively recent (2007) discovery of the selenium plume, the pre-Phase II RFI investigations did not typically include evaluations of selenium concentrations and leaching behavior in site soils. Therefore, a primary goal of the 2014 SAI was to better define the location, extent and properties of the source(s) of elevated selenium concentrations in West Selenium Area groundwater. The results of the 2014 investigation indicate:

- Total selenium concentrations in the West Selenium Area ranged from <0.5 to 44.7 mg/kg; total arsenic concentrations in the West Selenium Area ranged from <5 to 217 mg/kg.
- Both unsaturated zone and saturated zone soils in the West Selenium Area are capable of leaching significant concentrations of selenium in laboratory leach tests. Unsaturated zone soils leached up to 33 mg/L selenium, and saturated zone soils leached up to 9.3 mg/L selenium. Based on these results, local soils appear to be capable of generating the observed high groundwater concentrations in the West Selenium Area (historically up to 8 mg/L seasonally, currently 4 to 7 mg/L). The highest leachable concentrations identified to date are centered on boring EHSB-6, although significant concentrations of leachable selenium are also generated from soils at EHSB-3 and EHSB-7. High concentrations of selenium in leachate are also associated with high sulfate concentrations in leachate.
- The observed concentrations of selenium leachate were generated from soils with total selenium concentrations ranging from <0.5 to 44.7 mg/kg. Selenium in West Selenium Area soils is generally highly leachable; the leach tests solubilized 9% to 57% of the total soil selenium from the samples tested.
- Current selenium loading to groundwater appears to be primarily from saturated zone soils. Although unsaturated zone soils have relatively high total and leachable

selenium concentrations, there does not appear to be a current transport mechanism for this selenium to reach the water table (i.e., limited infiltration). It is possible, based on the total metals profile obtained from boring EHSB-6, that historic vertical transport of selenium through the unsaturated zone did occur prior to completion of the ore storage building in 1990 and paving of the area, and is the ultimate source of the selenium currently present in the saturated zone.

- Screening-level groundwater data and the stratigraphy results discussed above allowed refinement of the higher concentration selenium plume (current maximum concentrations in the 4 to 7 mg/L range). Based on current information, the higher concentration source plume in the West Selenium Area appears to be about 60 to 80 feet in width, originating to the south in the vicinity of boring EHSB-6 and well DH-8.
- Mineralogic testing of West Selenium Area soils was inconclusive in terms of identifying selenium phase associations. Mixed manganese/iron oxides and barite ( $\text{BaSO}_4$ ) were noted in the two samples tested, but no discernable selenium signal was obtained on the EDX spectrum.
- Based on information gained through the 2014 SAI, the selenium source material currently contributing the most contaminant mass to groundwater in the West Selenium Source Area appears to be restricted to the saturated zone due to the lack of a transport mechanism through the unsaturated zone, and is believed to be limited in lateral extent based on the plume geometry. The selenium source material appears to be concentrated in the vicinity of soil boring EHSB-6, with the lateral boundaries between EHSB-6 and EHSB-3 to the south, EHSB-4 to the east and EHSB-7 to the north, and the abrupt rise in the ash/clay unit immediately west of EHSB-6 forming the western margin of the shallow aquifer. Although not fully delineated, current information suggests that the areal extent of source material may range from about 0.25 to 0.75 acres, with a vertical extent of about 3 to 7 feet based on the observed thickness of the saturated zone, although these preliminary dimensions would have to be verified through additional drilling and soil sampling prior to selection of a groundwater remedy. The depth to the West Selenium Area source material ranges from about 40 to 45 feet.

Although groundwater arsenic concentrations are relatively low in the West Selenium Area, one objective of the 2014 SAI was to determine if changes in groundwater geochemical conditions, resulting from remedial activities focusing on the selenium plume or other natural or imposed modifications of the groundwater geochemical system, could cause remobilization of arsenic currently immobilized through adsorption to aquifer matrix material and/or inclusion in secondary mineral assemblages. Results of the 2014 SAI indicate:

- Total arsenic concentrations in the West Selenium Area soil samples are relatively low (mean concentration of 38 mg/kg compared with 179 mg/kg in the North Plant Site, Table 3-1), with total concentrations especially low in the unsaturated zone samples (average 15.7 mg/kg). Leach testing of unsaturated soil samples from borings EHSB-6 and EHSB-7 yielded leachate results of <0.005 to 0.11 mg/L based on saturated paste testing. Conversely, saturated zone soil samples adsorbed arsenic during both SPLP and saturated paste leach testing indicating that saturated zone soils in the West Selenium Area do not leach arsenic under current groundwater conditions.
- Soil boring EHSB-1, located upgradient of the West Selenium Area and downgradient of the former Acid Plant, showed higher arsenic leachability in the unsaturated zone (0.85 to 1.5 mg/L), attributable at least in part to the presence of petroleum contamination and associated enhanced arsenic mobility. EHSB-1 soils also exhibited higher total arsenic concentrations than the downgradient West Selenium Area soil borings. Overall, total arsenic concentrations are higher at borings along the eastern edge of the West Selenium Area closer to the high concentration arsenic plume (EHSB-1, EHSB-3 and EHSB-4), and lower in borings further to the west (EHSB-5, EHSB-6 and EHSB-7).
- Total arsenic concentrations at West Selenium Area borings EHSB-5, EHSB-6 and EHSB-7 and at Phase II RFI borings RFI2SB-9 and RFI2SB-10 are relatively low, ranging from <5 to 49 mg/kg. Based on the low total arsenic concentrations and the lack of observed arsenic leaching from saturated zone soils at these borings, changing redox conditions in groundwater are unlikely to cause significant remobilization of arsenic in the West Selenium Area, particularly relative to the arsenic loading currently occurring in the high arsenic concentration plume in the central plant site.

## 4.2 NORTH PLANT ARSENIC SOURCE AREA FINDINGS

A primary goal of the 2014 SAI was to further evaluate the areal extent and leaching properties of arsenic in the North Plant Site Area saturated zone soils, which have previously been identified as a current source of elevated arsenic concentrations in North Plant Site Area groundwater. The results of the 2014 investigation indicate:

- Total arsenic concentrations in North Plant Site soils ranged from 5 to 323 mg/kg; total selenium in North Plant Site soils ranged from <0.5 to 1.8 mg/kg.
- Unsaturated zone leaching results for North Plant Site soils showed arsenic concentrations ranging from 0.58 to 1.0 mg/L. Given the typical groundwater concentrations in this area of 10 to 30 mg/L, unsaturated zone soils are not likely a current significant source of arsenic loading to groundwater.
- Saturated zone leach test results for arsenic in the North Plant Site Soils Area showed that soils generated 0.2 to 1.8 mg/L in leachate under SPLP conditions and 1.9 to 17 mg/L under saturated paste conditions. The higher concentrations generated under saturated paste conditions were obtained from soils with total concentrations of 117 to 254 mg/kg arsenic, at relatively low mass leaching rates of 0.5% to 2.1%. The North Plant Site arsenic leaching results indicate that saturated zone soils are capable of generating leachate concentrations on the order of local groundwater concentrations (10 to 30 mg/L).
- Total arsenic results from boring EHSB-9 were compared with results from wells DH-16 and DH-17 (installed in 1986), located about 10 feet from EHSB-9. Results show that total arsenic concentrations may have decreased at certain depths over the 1986 to 2014 time period, indicating possible net arsenic desorption from soils and loading to groundwater. This result suggests that arsenic leaching from saturated soils may have been occurring for some time (possibly decades) in this area, but that the effects of this leaching may have been previously masked by significantly higher upgradient groundwater concentrations.
- Screening-level groundwater arsenic results collected from the North Plant Site soils area were consistent with results from area monitoring wells.
- Mineralogy results on a saturated zone sample from boring EHSB-8 showed that iron oxides were common throughout the sample, along with barite. Arsenic associated with the iron oxides was also detected by the EDX method at concentrations of about 2% (20,000 ppm), indicating that iron oxides are likely reservoir for adsorbed and/or coprecipitated arsenic in North Plant Site Area saturated soils.
- The 2014 SAI results, in conjunction with the 2010 Phase II RFI results, indicate that the North Plant Site Soils area (i.e., the area with significant quantities of leachable arsenic in saturated zone soils) is longitudinally extensive in the north-south direction along the arsenic groundwater plume axis. The 2010 and 2014 leach test results indicate that the area of leachable arsenic extends at a minimum from soil boring

EHSB-8 on the south to boring EHSB-9 on the north (about 450 feet). Leachable arsenic from saturated zone soils was also observed at Phase II RFI boring RFI2SB-21, an additional 180 feet north of boring EHSB-9, suggesting that the zone of leachable arsenic extends at least to this location. Based on the current groundwater plume geometry, the width of the arsenic source area may range from 150 to 250 feet. It should be noted that the observed width of the groundwater plume (and thus the inferred width of the source area) may be partly controlled by current aquifer redox conditions, in addition to the spatial distribution of arsenic source material.

Similar to arsenic in the West Selenium Area, groundwater selenium concentrations are low (typically below detection limits) in the North Plant Site Soils Area. As noted above, one objective of the 2014 SAI was to determine if changes in groundwater geochemical conditions, resulting from remedial activities focusing on the arsenic plume or other natural or imposed changes, could cause remobilization of selenium currently immobilized through adsorption to aquifer matrix material, inclusion in secondary mineral assemblages, or precipitation as insoluble elemental selenium due to the current reducing conditions. Results of the 2014 SAI indicate:

- Total selenium concentrations of <0.5 to 1.8 mg/kg were observed in unsaturated and saturated zone soils from the North Plant Site Area soil borings. Unsaturated zone soils from the North Plant Site Area leached no detectable selenium (<0.005 mg/L).
- Saturated zone leach test results showed that North Plant Site soils can generate selenium concentrations from 0.004 to 0.11 mg/L, from soils with total selenium concentrations ranging from <0.5 to 1.8 mg/kg. These total selenium concentrations are similar to concentrations observed in West Selenium Area saturated zone samples. Although groundwater selenium concentrations in North Plant Site wells are typically <0.001 mg/L, selenium mobility in groundwater is likely inhibited by the reducing conditions in this area of the plant site. The combined selenium leaching results from North Plant Site Area borings EHSB-8, EHSB-9 and Phase II RFI boring RFI2SB-20 indicate that selenium remobilization from the North Plant Site Area under changing geochemical conditions (increasing redox state of groundwater) should be considered as possible source control groundwater remedies for this area are evaluated.

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**APPENDIX A**

**FORMER EAST HELENA SMELTER  
GROUNDWATER CONTAMINANT SOURCE INVENTORY**

FORMER EAST HELENA SMELTER GROUNDWATER CONTAMINANT SOURCE INVENTORY

General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	GW Conditions	Recommendations	Time Critical for 2015-2016 IMWP
West Selenium Area	1	Rail Corridor Soils	Se	Rail corridors adjacent to former ore storage building. SPLP leach samples showed 0.027 to 0.490 mg/L selenium. Leachability increased with depth while total concentrations decreased with depth.	Elevated total Se concentrations in near surface soils decrease with depth. Phase II RFI surface soil samples ranged from 569 to 754 mg/kg at RCSS-5 and RCSS-7 (0-6"), decreased to 13 to 96 mg/kg respectively at 2.5-5 ft. Boring RFI2SB-9 surface (slag) samples showed 151 to 281 mg/kg Se, decreased to <5 mg/kg in deeper samples.	Seasonal Se spikes up to 7 mg/L (DH-66), appear to have been mitigated by SPHC. "Baseline" concentrations still 1-2 mg/L range, most recent concentrations 4-6 mg/L (2014). Well DH-66 highly correlated with water table variations and other parameters (SO4, Cl), DH-8 less so (different mechanisms?). Groundwater saturated with respect to gypsum (CaSO4) and calcite (CaCO3). Low arsenic concentrations in this area. Possible secondary mineral cement source.	Although they cannot be ruled out due to high leach concentrations, surface soils seem an unlikely source of seasonal spikes in groundwater. Additional data to be collected as part of 2014 source characterization work. Should be addressed through capping.	Yes
	2	Selenium-Loaded Saturated Soils: Impacted from Speiss-Dross Area Groundwater	Se	Not a former process area. Downgradient of historic source areas (speiss/dross and/or acid plant). Selenium historically loaded onto saturated soils via groundwater transport, possibly precipitated or occluded within minerals former in aquifer matrix during mixing/neutralization of acid plant and speiss dross impacted groundwater. May be released over time, with changing geochemical conditions. Process water in speiss/dross reportedly contained ~40 mg/L selenium, acid plant process water ~6 mg/L selenium. Well DH-21 in speiss/dross area reported about 7 mg/L in 1999 as part of plant water release investigation.	Concentrations and leachability of Se in subsurface soils (both saturated and unsaturated) not well documented. Location estimated based on configuration of west selenium plume.		Possible significant source of current selenium loading to groundwater. Evaluate further for possible mitigation. Additional subsurface data needed.	Yes
	3	Selenium-Loaded Saturated Soils: Impacted from Acid Plant Area Groundwater	Se	Not a former process area. Downgradient of historic source area (speiss/dross) and slurry wall, upgradient of PRB. Arsenic historically loaded onto saturated soils via groundwater transport from upgradient sources; may be released over time with changing geochemical conditions. Also some potential for Se release based on RFI2SB-20 results (leached 0.7 mg/L Se during adsorption tests) and recent gw trends at well DH-36 (As decrease/Se increase).	Concentrations and leachability of Se in subsurface soils (both saturated and unsaturated) not well documented. Location estimated based on configuration of west selenium plume.		Possible significant source of current selenium loading to groundwater. Evaluate further for possible mitigation. Additional subsurface data may be needed.	Yes
North Plant Source Area	4	North Plant Site Saturated Soils	As (Se?)	Not a former process area. Downgradient of historic source area (speiss/dross) and slurry wall, upgradient of PRB. Arsenic historically loaded onto saturated soils via groundwater transport from upgradient sources; may be released over time with changing geochemical conditions. Also some potential for Se release based on RFI2SB-20 results (leached 0.7 mg/L Se during adsorption tests) and recent gw trends at well DH-36 (As decrease/Se increase).	Organic contamination at water table common in wells and soil borings. Deep (saturated) soil As concentrations highest at DH-13 (300-1400 mg/kg), DH-17 (300-700 mg/kg). More recent data somewhat lower: Phase II RFI borings in area range from 25-432 mg/kg; lower on As plume periphery. As adsorption observed at RFI2SB-8 and -21. As leaching at RFI2SB-16 (40-42'), adsorption at 25-32'.	Downgradient of slurry wall, gw concentrations are 3-12 mg/L range (SDMW-1, -2, -5, DH-13). 450' downgradient at DH-17 concentrations are 35 mg/L. DH-17 concentrations stable since 2002 but have recently decreased to minimum seen since 2002 (from 45 mg/L down to 31.5 mg/L). As(III) predominant at DH-17, continuing downgradient to DH-64, alters to As (V) as plume crosses Hwy 12.	Possible primary current source of arsenic loading to downgradient groundwater. Potential future source of selenium loading to groundwater if geochemical conditions change. Evaluate further for possible mitigation. Additional subsurface data needed.	Yes
Slag Pile	5	Younger Unfumed Slag	As/Se	Slag not processed through zinc plant during periods prior to zinc plant construction (1930s) and following cessation of zinc plant operation (1982). Generally south end and "upper lift" of slag pile.	Unfumed slag shows higher total metals concentrations than fumed slag. Phase II RFI samples from well DH-74 showed 97 to 209 mg/kg Se and 814 to 1840 mg/kg As from 0-42 ft; deeper samples showed <5 to 17 mg/kg Se and 9 to 194 mg/kg As. Slag leach concentrations from Phase II RFI (SPLP) showed 0.009 to 0.130 mg/L As, 0.036 to 0.400 mg/L Se. RI/FS era slag leach and test basin samples showed 0.353 to 0.620 mg/L As in test basins and 0.31 mg/L As in bottle roll for unfumed slag. Fumed slag showed lower concentrations (0.0283 to 0.054 mg/L in test basins and 0.19 mg/L in bottle roll). Test basin K results were 54 to 74 mg/L for fumed slag, 1540 to 2650 mg/L for unfumed slag. Bottle roll K results were 3.9 mg/L for fumed and 22 mg/L for unfumed slag.	Selenium and arsenic concentrations in area currently highest near north and northwest portion of slag pile. Highest Se concentrations at well DH-56. Some Se (IV) contribution in this area. Very high K concentrations at DH-56 (400 mg/L). As about 1-2 mg/L and Se 0.4 to 1.0 mg/L in select wells, some wells lower. South of well DH-55 Se is below detect, As about 0.3 mg/L. Groundwater beneath south portion of pile appears more reducing due to influence of marsh sediments. Alluvial aquifer beneath slag pile shows downward vertical gradient and decreasing concentrations with depth; possible indication of loading from above (slag). Although lower concentration, selenium originating from slag pile area a significant source of downgradient selenium loading due to greater groundwater flux.	Large area and not well defined as a whole. Review of slag pile history (available analytical data, aerial photo and map review to determine placement of slag over time, field reconnaissance) recommended to evaluate potential areas of contaminant loading from slag; possible more detailed evaluation in future if warranted. Not a time critical source area relative to near-term remedial activities.	No

FORMER EAST HELENA SMELTER GROUNDWATER CONTAMINANT SOURCE INVENTORY

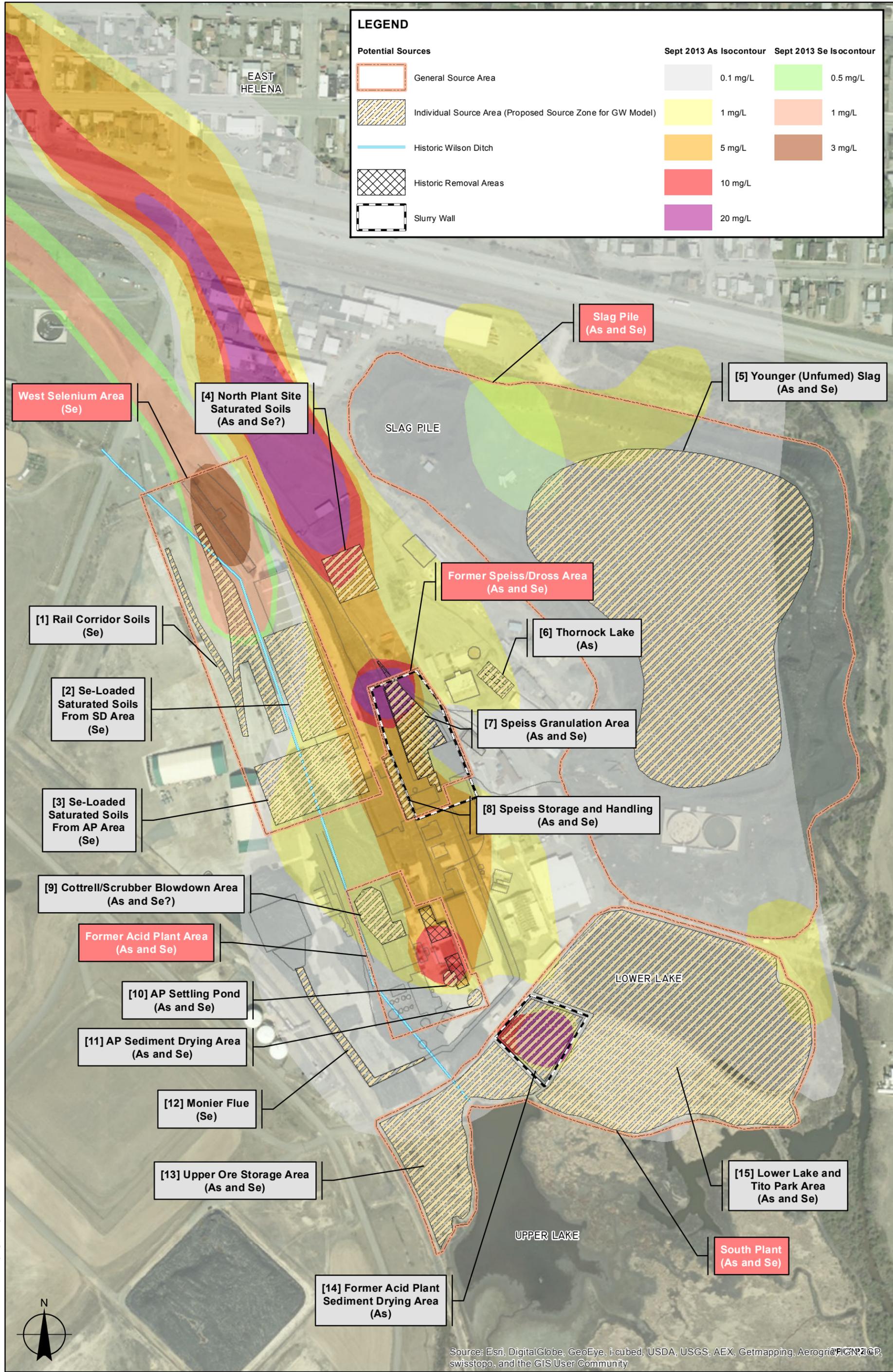
General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	GW Conditions	Recommendations	Time Critical for 2015-2016 IMWP
Former Thornock Lake	6	Former Thornock Lake Area Soils	As	Former process pond. Pond replaced with tank in 1986. Soils excavated in 1986-1987 and 1991.	Pre-remediation total As in soils as high as 120,000 mg/kg but quite variable. Post-excavation samples in 1991 showed total As 513 to 3055 mg/kg. SPLP As 0.22 to 3.8 mg/L. SPLP Se all <0.1 mg/L. Phase I RFI soil borings RFISB-1 and RFISB-2 showed relatively low total arsenic concentrations (<10 to 231 mg/kg, average of 32 mg/kg).	Groundwater at wells DH-57 in DH-58 in Thornock Lake area recently 1-2 mg/L arsenic, 0.01 to 0.05 mg/L selenium. Generally decreasing trends since plant shutdown.	Not associated with highest GW concentrations although some leachable arsenic probably remains in soils. Further consideration not warranted at this time given the other areas with much higher impacts to groundwater. May warrant further evaluation some time in the future depending on water quality trends and project developments.	Yes
Former Speiss/Dross Area	7	Speiss Granulation Area	As/Se	Very high historic process water concentrations for both arsenic (3,000+ mg/L) and selenium (40+ mg/L). Historic area of highest groundwater impacts due to use of ponds, process water releases. Elevated groundwater pH (11-13). Encapsulated in slurry wall in 2007; slurry wall appears effective at limiting downgradient migration of contaminants (As at SDMW-2 decrease of 50+mg/L to 10 mg/L since 2007).	Variable due to historic soil removal actions. Likely still some areas of elevated soil arsenic concentrations, particularly within saturated zone. Selenium concentrations unknown within wall. Phase I RFI soil borings RFISB-3 and RFISB-4 showed moderate arsenic soil concentrations (<10 to 777 mg/kg, average of 243 mg/kg). Phase II boring north of wall (RFI2SB-20) leached up to 0.7 mg/L Se from sample with total Se of 17 mg/kg.	Groundwater arsenic as high as 750 mg/L in the past, selenium as high as 7 mg/L but very limited data (well DH-21). Current arsenic concentrations within slurry wall 80 to 100 mg/L. Groundwater yield within wall appears to be decreasing over time.	Groundwater quality generally improving in area. May warrant further evaluation in future depending on water quality trends within and outside of slurry wall, and long-term integrity of wall. Potential source areas outside of slurry wall should be evaluated as potential source to West Selenium Area groundwater plume. Not a time critical source.	No
	8	Speiss Storage and Handling Area	As/Se	Outside storage bins and material handling area for speiss. Likely impacts from material spillage and water application. Partially encapsulated in slurry wall in 2007; slurry wall appears effective at limiting downgradient migration of contaminants. Portion outside (west) of slurry wall.	Limited soil data in this area. Well DH-38 soil samples showed 72 to 1906 mg/kg total arsenic. Concentrations increased from about 170 mg/kg just above water table to 700 mg/kg just below water table.	Arsenic concentrations up to 250 mg/L historically in groundwater at well DH-38. No recent water quality data from area.	Area outside slurry wall warrants further evaluation as potential source to West Selenium Plume area. Majority of high concentration soils within slurry wall, and limited downgradient migration of arsenic currently indicated. Long-term integrity of slurry wall should be evaluated.	Yes
Former Acid Plant Area	9	Cottrell/Scrubber Blowdown Area	As/Se	Area of significant process water leaks during plant operations; very high process water concentrations (1,800 mg/L As; 5 mg/L Se; 200 mg/L Cd). Extensive remediation conducted in Acid Plant Area in late 1980s/early 90s. Contaminated soils remain at depth at location of former acid plant settling pond and possibly other areas.	Soils highly impacted by historic process water releases; highest concentration soils excavated in 1990s. Current concentrations up to 12,000 mg/Kg arsenic at former settling pond area. Highest concentration soils recently desaturated by SPHC IM. High concentration soils are localized and located under HDS building.	DH-19 up to 416 mg/L arsenic in groundwater in 1991. Arsenic concentrations have decreased from about 11.5 to 9 mg/L since 2011. Selenium decrease recently from 60 to 25 ppb. Recent improvements attributed to SPHC.	Historically significant source of arsenic loading to groundwater, but groundwater quality improving due to past remedial activities and recent SPHC IM. Localized high arsenic concentration soils at former Acid Plant Settling Pond may warrant removal or other source control after HDS demolition and before capping in late 2016. Monitor groundwater level and quality trends though 2015 to determine full response to SPHC, and select course of action for 2016.	Yes
	10	Acid Plant Settling Pond	As/Se					
	11	Original AP Sediment Drying Area	As/Se					
Monier Flue	12	Monier Flue Area Soils	Se	Soils beneath former Monier Flue, which was removed in 2008, are largely unsaturated. Potential contaminant mechanism was periodic washing out of flue with water and letting water infiltrate into ground. Soils sampled during demolition and during Phase II RFI.	Demolition soil samples up to 1,350 mg/Kg selenium; highest document soil concentration. Phase II boring RFISB-6 up to 106 mg/kg at 2 to 5 feet; leached 0.28 mg/L. Very high cadmium (75,000 mg/kg), lead (53,000 mg/kg), copper (17,000 mg/kg). All concentrations decreased significantly below 5 feet bgs.	No data; aquifer very thin (2 to 0 feet thick).	Underlying soils dry down to clay layer in most areas; elevated selenium soils will be addressed through capping. No need to evaluate further.	No

FORMER EAST HELENA SMELTER GROUNDWATER CONTAMINANT SOURCE INVENTORY

General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	GW Conditions	Recommendations	Time Critical for 2015-2016 IMWP
South Plant	13	Upper Ore Storage Area	As/Se	Area used for storage of ore and other materials historically.	NA -- draining of Lower Lake and removal of soils to 3910 feet amsl in Tito Park/APSD/UOS areas conducted as part of TPA Source Removal/SPHC IM projects. Post-SPHC conditions to be determined.		To be addressed through TPA Source Removal and SPHC IMs.	No
	14	Former AP Sediment Drying Area	As	Former acid plant sediment drying area associated with elevated groundwater arsenic and metals concentrations, along with elevated soil concentrations. Encapsulated in APSD slurry wall in 2006.				
	15	Lower Lake/Tito Park	As/Se	Lower Lake historically used as process pond, more recently as water treatment plant MPDES discharge point. Contaminated sediments dredged from lake in mid-1990s. Tito Park used as storage area for various materials throughout plant history. Materials removed to CAMU in early 2000s.				

Source Numbers, Names and General Areas shown on Figure A-1.  
 SD - Speiss/Dross Area  
 AP - Acid Plant Area

	Recommended for additional evaluation
	Not recommended for additional evaluation



FIGURE

**CURRENT AND/OR HISTORIC SUSPECTED ARSENIC AND SELENIUM SOURCE AREAS EAST HELENA FACILITY**

**A-1**

Path: V:\10022\GIS\SourceInventory\Figures\Figure 2-2.mxd

**APPENDIX B**

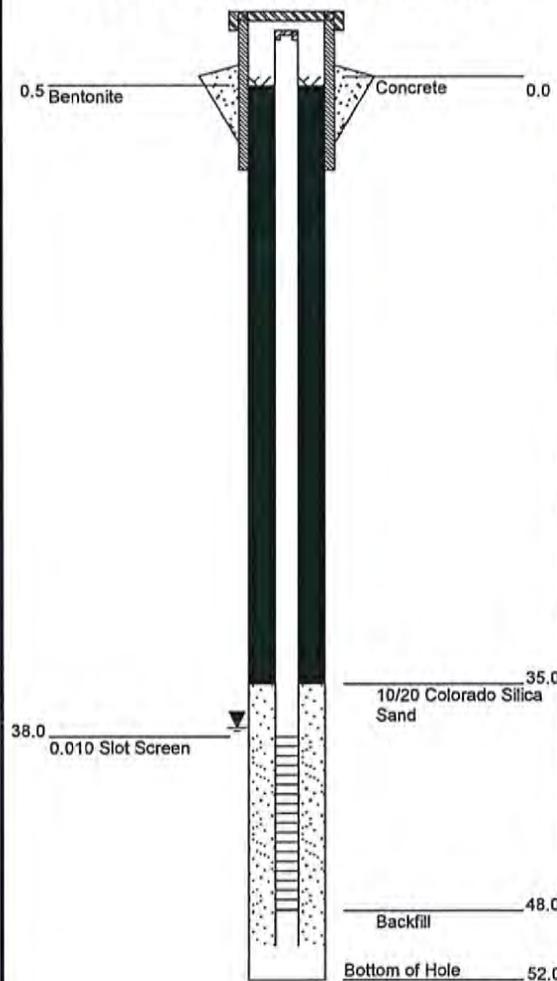
**SOIL BORING AND MONITORING  
WELL COMPLETION LOGS**

Client: Montana Environmental Trust Group  
 Project: East Helena Facility  
 County: Lewis & Clark State: Montana  
 Property Owner: MT Environmental Custodial Trust  
 Legal Description: T10N, R3W, Sec 36  
 Location Description: South End of Former Ore Storage Bldg  
 Recorded By: Scott Mason  
 Drilling Company: Boland Drilling  
 Driller: Chris Tigard  
 Drilling Method: Air Rotary  
 Drilling Fluids Used: Air/Water  
 Purpose of Hole: Soil Sampling and Monitor Well  
 Target Aquifer: Shallow  
 Hole Diameter (in): 5.5  
 Total Depth Drilled (ft): 52

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	
Surface Casing Used?	Y	6" Steel	-2 to +5
Screen/Perforations?	Y	0.010-inch slot, Sch 40, PVC	38 - 48
Sand Pack?	Y	10/20 Colorado Silica Sand	35 - 48
Annular Seal?	Y	Bentonite	0.5 - 35
Surface Seal?	Y	Concrete	0 - 0.5
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Pumping	
Water Samples Taken?	Y	Grab Sample	
Boring Samples Taken?	Y	Split Spoon and Grab	
Northing: 860292.48		Easting: 1359639.25	
Static Water Level Below MP: 42.5		Surface Casing Height (ft): 5.5	
Date: 9/9/2014		Riser Height (ft): 5	
MP Description: Top of PVC		Ground Surface Elevation (ft): 3924.99	
MP Height Above or Below Ground (ft): 5		MP Elevation (ft): 3930.04	

Remarks: Located immediately west of former ore storage building. Split spoon samples collected at 5-foot intervals. Ground surface asphalt. Petro odor and staining at 35 feet. Borehole completed as monitoring well. First water at 43 feet.

## WELL CONSTRUCTION



## GRAPHICS

## GEOLOGICAL DESCRIPTION

0.0 - 5.0'	<b>Granular Fill</b> Slightly moist, brown, medium-coarse sand (75%) with gravel. Split spoon sample 5 - 7 feet (AEH-1409-100s).
5.0 - 12.0'	<b>Sandy, Cobbly GRAVEL</b> Slightly moist, moist gravel with cobbles and minor medium to coarse sand, brown, rounded. Split spoon sample 10 - 12 feet (AEH-1409-101s).
12.0 - 15.0'	<b>Cobbly, Sandy GRAVEL</b> As above with increasing sand.
15.0 - 25.0'	<b>Alternating Gravelly Sand with Cobbles to Sandy Gravel with Cobbles</b> Alternating layered cobbly gravelly sand (70%), gray to brown, slightly moist, rounded, occasional charcoal (17 feet) to sandy (20%) cobbly (30%) gravel, some carbonate cement. Split spoon sample 15 - 17 feet (AEH-1409-102s); split spoon sample 20 - 21.2 feet (AEH-1409-103s).
25.0 - 34.0'	<b>Sandy GRAVEL</b> Hard, dry to slightly moist, partially cemented, iron stained, sand (10 to 40%) and gravel (60 to 90%) with occasional cobble. Moist zone at 27.5 feet, large gray dolomite cobble/boulder 27 - 28 feet, charcoal 30 - 30.5 feet. Split spoon samples 25 - 26 feet (AEH-1409-104s); 30 - 30.5 feet (AEH-1409-105s).
34.0 - 40.5'	<b>Sandy GRAVEL with Petroleum Staining</b> As above, slightly moist with strong petroleum staining (gray to black) and petroleum odors (diesel?). Grab sample 33 feet (AEH-1409-106s) and 34 - 35 feet (AEH-1409-107s); spoon 35 - 35.5 feet (AEH-1409-108s); grab sample 39 - 39.5 feet (AEH-1409-109s).
40.5 - 43.0'	<b>Coarse Sand and Gravel - Moist with Petroleum Staining</b> Moist, gray-black stained gravel with sand (25%) grading downward to moist, tan-brown gravelly sand. Split spoon sample 40 - 41.5 feet (AEH-1409-110s).
43.0 - 48.0'	<b>Coarse Sand and Gravel - Wet</b> Tan-brown coarse sand and gravel with occasional cobbles. Grab sample 43 - 44 feet (AEH-1409-111s); split spoon 45 - 46 feet (AEH-1409-112s).
48.0 - 49.5'	<b>Clayey Silt (Weathered Ash)</b> Wet, clayey silt with occasional ash particles.
49.5 - 52.0'	<b>Ash/Clay</b> Moist, white/gray/green volcanic ash with occasional red-brown stained layers. Split spoon 50 - 52 feet (AEH-1409-113s).

Client: Montana Environmental Trust Group  
Project: East Helena Facility  
County: Lewis & Clark State: Montana  
Property Owner: MT Environmental Custodial Trust  
Legal Description: T10N, R3W, Sec 36  
Location Description: North End of Former Ore Storage Bldg  
Northing: 860575.1 Easting: 1359523  
Elevation: 3920.78

Drilling Company: Boland Drilling  
Driller: Chris Tigard  
Drilling Method: Air Rotary  
Drilling Fluids Used: Air  
Purpose of Hole: Soil Sampling  
Hole Diameter (in): 5.5"  
Total Depth Drilled (ft): 52  
Recorded By: Scott Mason

Remarks: West of former ore storage building. Split spoon samples collected at 5-foot intervals. Ground surface asphalt. No petro odor or staining. First water at 47 feet.

DEPTH	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DATE/TIME	NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION
5	AEH-1409-132s	SS	9/11/2014	Sample 5 feet to 6.5 feet.		0.0 - 9.5' <b>Granular Fill</b> Dry to slightly moist, moderately hard to loose, gravelly (30%) sand to sandy (30%) gravel with cobbles, brown, subround to round.
10	AEH-1409-133s AEH-1409-134s	GRAB SS	9/11/2014 9/11/2014	Sample 9.5 feet to 10 feet. Sample 10 feet to 12 feet.		9.5 - 10.0' <b>Topsoil - Loamy Soil</b> Dark brown, slightly moist to moist, loamy soil.
15	AEH-1409-135s	GRAB	9/11/2014	Sample 13 feet to 15 feet.		10.0 - 20.0' <b>Silty Sand</b> Dark brown grading down to tan-brown, slightly moist, fine-medium sand with silt and occasional gravel.
20	AEH-1409-136s AEH-1409-137s	SS SS	9/11/2014 9/11/2014	Sample 15 feet to 16.3 feet. Sample 17 feet to 19 feet.		20.0 - 44.5' <b>Gravel and Sand</b> Dry to slightly moist, alternating sand and gravel with occasional cobbles.
25	AEH-1409-138s AEH-1409-139s	SS GRAB	9/11/2014 9/11/2014	Sample 20 feet to 20.5 feet. Sample 23 feet to 24 feet.		
30	AEH-1409-140s AEH-1409-142s	SS SS	9/11/2014 9/11/2014	Sample 25 feet to 25.4 feet. Sample 30 feet to 30.9 feet.		
35	AEH-1409-143s AEH-1409-144s	GRAB SS	9/11/2014 9/11/2014	Sample 33 feet to 34 feet. Sample 35 feet to 35.5 feet.		
40	AEH-1409-145s AEH-1409-146s	GRAB SS	9/11/2014 9/11/2014	Sample 37 feet to 38 feet. Sample 40 feet to 40.4 feet.		
45	AEH-1409-147s AEH-1409-148s	GRAB GRAB	9/11/2014 9/11/2014	Sample 44.5 feet to 45 feet. Sample 45 feet to 47 feet.		44.5 - 48.0' <b>Sand</b> Slightly moist to wet, brown to dark red brown, fine to medium sand.
50	AEH-1409-149s AEH-1409-150s	GRAB SS	9/11/2014 9/11/2014	Sample 48 feet to 49 feet. Sample 50 feet to 52 feet.		48.0 - 52.0' <b>Volcanic Ash/Clay</b> Moist, tan sandy clay (weathered ash and sand) grading downward to moist white-gray volcanic ash.
55						

SOIL\_BORE\_REV2 K:\GINT\PROJECTS\10022.GPJ HYDHLN2.GDT 12/15/14

Client: Montana Environmental Trust Group

Drilling Company: Boland Drilling

Project: East Helena Facility

Driller: Chris Tigard

County: Lewis & Clark State: Montana

Drilling Method: Air Rotary

Property Owner: MT Environmental Custodial Trust

Drilling Fluids Used: Water at 47 to 50 ft.

Legal Description: T10N, R3W, Sec 36

Purpose of Hole: Soil Sampling

Location Description: North End of Former Ore Storage Bldg

Hole Diameter (in): 5.5"

Northing: 860815.1

Easting: 1359461

Total Depth Drilled (ft): 49

Elevation: 3916.25

Recorded By: Scott Mason

Remarks: Immediately southeast of former Thawhouse. Split spoon samples collected at 5-foot intervals. Ground surface gravel. No petro odor or staining. First water at 43.5 feet.

DEPTH	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DATE/TIME	NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION
						0.0 - 1.0' <b>Granular Fill</b> Dry, crushed limestone/dolomite. Road mix.
						1.0 - 6.7' <b>Granular Fill</b> Dry to slightly moist sand (30%) and cobbles.
5	AEH-1409-114s	SS	9/10/2014	Sample 5 feet to 6 feet.		
	AEH-1409-115s	SS	9/10/2014	Sample 6 feet to 7 feet.		
	AEH-1409-116s	GRAB	9/10/2014	Sample 7 feet to 10 feet.		
10	AEH-1409-117s	SS	9/10/2014	Sample 10 feet to 12 feet.		6.7 - 7.0' <b>Topsoil - Silty Sandy Loam</b> Black, organic-rich, slightly moist, silty sandy loam topsoil.
						7.0 - 15.7' <b>Silty Gravelly SAND</b> Dry to slightly moist, soft, tan, well graded, very fine to coarse sand (70 - 90%) with gravel (10 - 30%) and occasional cobbles.
15	AEH-1409-118s	SS	9/10/2014	Sample 15 feet to 16.5 feet.		
20	AEH-1409-119s	SS	9/10/2014	Sample 20 feet to 20.5 feet.		15.7 - 29.0' <b>Sandy GRAVEL</b> Hard, dry, gravel and cobbles with sand (10 - 30%).
25	AEH-1409-120s	SS	9/10/2014	Sample 25 feet to 25.3 feet.		
30	AEH-1409-121s	GRAB	9/11/2014	Sample 29 feet to 29.5 feet.		29.0 - 33.0' <b>Sand and Gravel</b> Dry to slightly moist, brown, well graded sand (30 - 90%) and gravel (10 - 70%).
	AEH-1409-122s	SS	9/11/2014	Sample 30 feet to 30.3 feet.		
35	AEH-1409-123s	GRAB	9/11/2014	Sample 33 feet to 34 feet.		33.0 - 35.5' <b>Gravelly SAND</b> Moist to very moist, red-brown coarse sand (80%) with gravel.
						35.5 - 38.0' <b>Gravelly SAND</b> As above, dry and hard. Adding water to drill.
40						38.0 - 40.5' <b>Gravelly SAND</b> Moist, brown sand (80%) with 1/4 to 1/2 inch gravel. Adding water to drill.
45						40.5 - 48.0' <b>Sand and Gravel with Cobbles</b> Moist to wet, sand (20 - 40%) and gravel with cobbles (10 - 30%). Static water level at 43.5 feet.
50	AEH-1409-130s	SS	9/11/2014	Sample 48 feet to 49 feet.		48.0 - 49.0' <b>Ash/Clay</b> Moist, soft, various mottled colors white-gray-brown-green.

SOIL\_BORE\_REV2 K:\GINT\PROJECTS\10022.GPJ HYDHLN2.GDT 12/15/14

Client: Montana Environmental Trust Group  
 Project: East Helena Facility  
 County: Lewis & Clark State: Montana  
 Property Owner: MT Environmental Custodial Trust  
 Legal Description: T10N, R3W, Sec 36  
 Location Description: West of Former Ore Storage Bldg.  
 Northing: 860590.6 Easting: 1359407  
 Elevation: 3914.46

Drilling Company: Boland Drilling  
 Driller: Chris Tigard  
 Drilling Method: Air Rotary  
 Drilling Fluids Used: Air  
 Purpose of Hole: Soil Sampling  
 Hole Diameter (in): 5.5"  
 Total Depth Drilled (ft): 32  
 Recorded By: Scott Mason

Remarks: Located west of rail corridor in Lower Ore Storage Area. Split spoon samples collected at 5-foot intervals. Ground surface dirt. No petro odor or staining. Unsaturated to total depth.

DEPTH	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DATE/TIME	NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION
5	AEH-1409-151s	GRAB	9/12/2014	Sample 0.5 feet to 5 feet.		0.0 - 0.5' Silt - FILL Dark brown silt.
5	AEH-1409-152s	SS	9/12/2014	Sample 5 feet to 6.8 feet.		0.5 - 5.8' Clayey Silty Sand - FILL Slightly moist, moderately plastic, brown, fine sand with silt and clay and occasional pebbles.
10	AEH-1409-153s	SS	9/12/2014	Sample 10 feet to 11.1 feet.		5.8 - 27.0' Sand Gravel Dry to slightly moist, brown to red-brown, subround to round, alternating sandy gravel and gravelly sand with occasional silt layers.
15	AEH-1409-154s	GRAB	9/12/2014	Sample 15 feet to 18 feet.		
20	AEH-1409-155s	GRAB	9/12/2014	Sample 22 feet to 24 feet.		
25	AEH-1409-156s	SS	9/12/2014	Sample 25 feet to 25.3 feet.		
25	AEH-1409-157s	GRAB	9/12/2014	Sample 27 feet to 28 feet.		
30	AEH-1409-158s	SS	9/12/2014	Sample 30 feet to 32 feet.		27.0 - 28.0' SAND Moist, soft, red brown sand. 28.0 - 30.1' Sandy GRAVEL Dry, gravel with sand.
35						30.1 - 32.0' Ash/Clay Slightly moist to moist, white-pink-green volcanic ash.

Client: Montana Environmental Trust Group  
 Project: East Helena Facility  
 County: Lewis & Clark State: Montana  
 Property Owner: MT Environmental Custodial Trust  
 Legal Description: T10N, R3W, Sec 36  
 Location Description: West of North End of Former Ore Storage  
 Northing: 860647.7 Easting: 1359429  
 Elevation: 3917.11

Drilling Company: Boland Drilling  
 Driller: Chris Tigard  
 Drilling Method: Air Rotary  
 Drilling Fluids Used: Air  
 Purpose of Hole: Soil Sampling  
 Hole Diameter (in): 5.5"  
 Total Depth Drilled (ft): 45.5  
 Recorded By: Bob Anderson

Remarks: Soil boring drilled approximately 50 feet south of well DH-8 to delineate potential selenium source area. Split spoon samples collected at 5-foot intervals. Ground surface asphalt. No petro odor or staining. First water at 43 feet.

DEPTH	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DATE/TIME	NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION
						0.0 - 3.0' <b>Granular Fill</b> Sand and gravel.
5	AEH-1409-159s	SS	9/12/2014	Sample 5 feet to 6.4 feet.		3.0 - 6.4' <b>Clay Fill</b> Dark brown, plastic clay, damp, no odor.
						6.4 - 10.7' <b>Silty CLAY</b> Light to medium brown, silty clay, minor fine sand, damp, no odor.
10	AEH-1409-160s	SS	9/12/2014	Sample 10 feet to 11.8 feet.		6.4 - 10.7' <b>Silty CLAY</b> Light to medium brown, silty clay, minor fine sand, damp, no odor.
	AEH-1409-161s	SS	9/12/2014	Subsample of 160S, 10.7 feet to 11.4 feet.		
15	AEH-1409-162s	SS	9/12/2014	Sample 15 feet to 15.7 feet.		10.7 - 11.4' <b>SAND</b> Medium brown, fine to medium sand with minor fine gravel, damp.
						11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
20	AEH-1409-163s	SS	9/12/2014	Sample 20 feet to 20.3 feet.		11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
25	AEH-1409-164s	SS	9/12/2014	Sample 25 feet to 25.8 feet.		11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
30	AEH-1409-165s	SS	9/12/2014	Sample 30 feet to 30.7 feet.		11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
						11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
35	AEH-1409-167s	SS	9/12/2014	Sample 35 feet to 37 feet.		11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
						11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
40	AEH-1409-168s	SS	9/12/2014	Sample 40 feet to 41 feet.		11.4 - 32.0' <b>Cobbly, Sandy GRAVEL</b> Sand, gravel and cobbles in varying proportions, harder drilling, dry (dusty drilling).
45	AEH-1409-169s	SS	9/12/2014	Sample 43.5 feet to 45.5 feet.		43.5 - 45.5' <b>Silty Clay and Ash/Clay</b> Light tan, slightly greenish silty clay and Volcanic Ash, moist to wet.

Client: Montana Environmental Trust Group  
Project: East Helena Facility  
County: Lewis & Clark State: Montana  
Property Owner: MT Environmental Custodial Trust  
Legal Description: T10N, R3W, Sec 36  
Location Description: West of Thawhouse

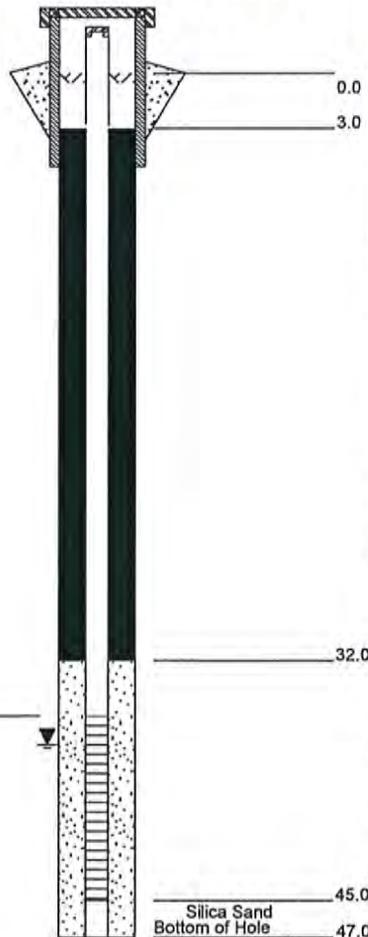
WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch, flush threaded, Sch 40, PVC	
Surface Casing Used?	Y	6" Steel	-3 to +4
Screen/Perforations?	Y	0.010-inch slot, Sch 40, PVC	35-45
Sand Pack?	Y	10/20 Colorado Silica Sand	32-45
Annular Seal?	Y	Bentonite Chips	0.5-32
Surface Seal?	Y	Concrete	0-0.5

Recorded By: Scott Mason  
Drilling Company: Boland Drilling  
Driller: Jason Hoffman  
Drilling Method: Air Rotary  
Drilling Fluids Used: Air  
Purpose of Hole: Soil Sampling and Monitor Well  
Target Aquifer: Shallow  
Hole Diameter (in): 5.5"  
Total Depth Drilled (ft): 47

DEVELOPMENT/SAMPLING			
Well Developed?	N		
Water Samples Taken?	Y	Raw and filtered HNO3	45' from drill casing
Boring Samples Taken?	Y	See geologic log.	
Northing: 860849		Easting: 1359368.35	
Static Water Level Below MP:	40.25	Surface Casing Height (ft):	4.0
Date:	9/17/2014	Riser Height (ft):	3.7
MP Description:	Top of PVC	Ground Surface Elevation (ft):	3912.67
MP Height Above or Below Ground (ft):	3.7	MP Elevation (ft):	3916.39

Remarks: Located west of Thawhouse. Split spoon sampling collected at 5-foot intervals. Ground surface dirt/gravel. No petro odor/staining. Borehole completed as monitoring well. First water approximately 40 feet.

## WELL CONSTRUCTION



GRAPHICS

## GEOLOGICAL DESCRIPTION

0.0 - 0.5'	<b>Granular Fill</b> Gravel and cobbles.
0.5 - 4.0'	<b>Clayey Silt - FILL</b> Black clayey silt.
4.0 - 14.0'	<b>Clayey Silt and Sand with Gravel</b> Slightly moist, tan clayey gravelly silt and fine sand with gravel. Split spoon sample 5 - 5.8' (AEH-1409-233), 10 - 11.7' (AEH-1409-234).
14.0 - 40.0'	<b>Sand and Gravel</b> Alternating dry to slightly moist, brown, sand and gravel with occasional iron oxide (red) and manganese (black) staining and cement noted at 25 to 40 feet.  Grab samples: 22 - 23' (AEH-1409-237), 29 - 29.5' (AEH-1409-239), 31 - 33' (AEH-1409-241), 34.5 - 35' (AEH-1409-242), 38 - 39' (AEH-1409-244). Spoon samples: 15 - 15.6' (AEH-1409-235), 20 - 20.2' (AEH-1409-236), 25 - 25.4' (AEH-1409-238), 30 - 30.4' (AEH-1409-240), 35 - 36.6' (AEH-1409-243).
40.0 - 45.0'	<b>Clayey Sand with Gravel</b> Moist to wet, mottled yellow-brown, brown to gray, clayey sandy gravel with iron staining.  Spoon sample: 40 - 41.5' (AEH-1409-245). Grab sample: 42 - 43' (AEH-1409-246).
45.0 - 47.0'	<b>Ash/Clay</b> Moist, varicolored (tan-gray-green-white) volcanic ash with few gravel clasts at top. Color grades downward from tan to white gray-green.  Spoon sample: 45 - 47' (AEH-1409-247).

Client: Montana Environmental Trust Group  
Project: East Helena Facility  
County: Lewis & Clark State: Montana  
Property Owner: MT Environmental Custodial Trust  
Legal Description: T10N, R3W, Sec 36  
Location Description: North Parking Lot Area  
Northing: 860586.48 Easting: 1359845.55  
Elevation: 3910.18

Drilling Company: Boland Drilling  
Driller: Chris Tigard  
Drilling Method: Air Rotary  
Drilling Fluids Used: Air  
Purpose of Hole: Soil Sampling  
Hole Diameter (in): 5.5"  
Total Depth Drilled (ft): 42  
Recorded By: Scott Mason

Remarks: West side of parking lot. Split spoon samples collected at 5-foot intervals. Ground surface asphalt. Petro odor and staining. First water approximately 38 feet.

DEPTH	SAMPLE NUMBER	SAMPLE TYPE	SAMPLE DATE/TIME	NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION
						0.0 - 2.5' <b>Granular Fill</b> Gravel with black staining from asphalt.
						2.5 - 5.0' <b>Silty Sand</b> Moist, buff, clayey silty sand.
5						5.0 - 18.0' <b>Silty Sand with Gravel</b> Dry to slightly moist, soft, tan, well graded, very fine to coarse sand (70 - 90%) with gravel (10 - 30%) and occasional cobbles.
	AEH-1409-116s	GRAB	9/15/2014	Sample 7 feet to 10 feet.		
10						18.0 - 22.0' <b>Sand and Gravelly Sand</b> Moist, loose, brown medium sand with 5 to 50% gravel.
	AEH-1409-117s	SS	9/15/2014	Sample 10 feet to 12 feet.		
						22.0 - 23.0' <b>Gravel and Cobbles</b> Dry, gravel and cobbles.
15						23.0 - 36.0' <b>Sand and Gravelly Sand with Petroleum Odors and Staining</b> Dark gray to black stained medium-coarse sand with gravel.
	AEH-1409-118s	SS	9/15/2014	Sample 15 feet to 16.5 feet.		
	AEH-1409-206	GRAB	9/15/2014	Sample 18 feet to 19.5 feet.		
20						36.0 - 40.0' <b>Sand with Silt</b> Loose, moist to wet, brown sand with silt, occasional gravel and minor clay.
	AEH-1409-207	SS	9/15/2014	Sample 20 feet to 20.4 feet.		
25						40.0 - 40.2' <b>Gravel</b> Wet, clasts to 1.5 inches. Adding water to drill.
	AEH-1409-208	GRAB	9/15/2014	Sample 24 feet to 24.5 feet.		
						40.2 - 42.0' <b>Ash/Clay</b> Moist, green-gray-tan ash with iron-stained layer at 41.7 feet.
30						
	AEH-1409-209	GRAB	9/15/2014	Sample 27 feet to 28 feet.		
35						
	AEH-1409-210	SS	9/15/2014	Sample 30 feet to 31.3 feet.		
40						
	AEH-1409-211	GRAB	9/15/2014	Sample 33 feet to 34 feet.		
45						
	AEH-1409-212	SS	9/15/2014	Sample 36 feet to 37 feet.		
	AEH-1409-213	SS	9/15/2014	Sample 40 feet to 42 feet.		



**APPENDIX C**

**2014 SOURCE AREA INVESTIGATION  
SOIL SAMPLING AND ANALYSIS SUMMARY**

EHSB-1

East of Former CSHB, about 460 feet southeast of well DH-8; completed as well DH-77

Sample #	Depth	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-100S	0-5	Grab										
AEH-1409-101S	10-12	Split Spoon										
AEH-1409-102S	15-17	Split Spoon										
AEH-1409-103S	20-21.2	Split Spoon										
AEH-1409-104S	25-26	Split Spoon	10100	217	<1	55	20900	18	547	<0.5	55	7.9
AEH-1409-105S	30-30.5	Split Spoon										
AEH-1409-106S	33	Grab										
AEH-1409-107S	34-35	Grab										
AEH-1409-108S	35-35.5	Split Spoon										
AEH-1409-109S	39-39.5	Grab										
AEH-1409-110S	40-41.5	Split Spoon	7330	72	518	25	10700	<5	132	5	137	7.1
AEH-1409-111S	43-44	Grab	8930	148	48	36	19000	9	187	<0.5	103	6.9
AEH-1409-112S	45-46	Split Spoon	10200	103	38	25	16000	6	240	<0.5	88	7.0
AEH-1409-113S	50-52	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture
AEH-1409-110S	40-41.5	Total (mg/kg)	72	5	7.1	--	--	--	--	--	--	--			
		SPLP Precip Leach (mg/L)	0.85	0.007	10.2	3	2	26	2	10	3	<1	100.29	2000	7.6%
		Sat Paste Precip Leach (mg/L)	1.5	0.13	6.9	41	21	74	10	21	260	11	795	152	7.6%

Sample #	Depth (ft)	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-132S	5-6.5	Split Spoon										
AEH-1409-133S	9.5	Grab	18300	49	2	40	16000	155	389	<0.5	119	7.5
AEH-1409-134S	10-12	Split Spoon										
AEH-1409-135S	13-15	Grab										
AEH-1409-136S	15-16.3	Split Spoon										
AEH-1409-137S	17-19	Grab										
AEH-1409-138S	20-20.5	Split Spoon										
AEH-1409-139S	23-24	Grab										
AEH-1409-140S	25-25.4	Split Spoon										
AEH-1409-141S	27	Grab										
AEH-1409-142S	30-30.9	Split Spoon										
AEH-1409-143S	33	Grab										
AEH-1409-144S	35-35.5	Split Spoon										
AEH-1409-145S	37	Grab	6880	6	<1	33	28900	8	278	<0.5	26	7.5
AEH-1409-146S	40-40.4	Split Spoon										
AEH-1409-147S	44.5	Grab	10100	49	<1	33	19500	15	354	<0.5	42	7.4
AEH-1409-148S	45-47	Grab	9790	113	2	56	21800	9	1560	1.2	37	7.4
AEH-1409-149S	48-49	Grab	27700	34	<1	25	18100	38	600	0.7	46	7.5
AEH-1409-150S	50-52	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth (ft)	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture initial
AEH-1409-147S	44.5	Total (mg/kg)	49	<0.5	7.4	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	1.8	0.036	8.4	90	35	54	10	270	300	25	100.37	2000	4.9%
		Net Leached SPLP (mg/L)	None	None											
		Sat Paste DH-71 Leach (mg/L)	0.19	0.19	8.1	110	47	110	12	180	440	61	119.74	35	4.9%
		Net Leached Sat Paste (mg/L)	None	0.13											
AEH-1409-148S	45-47	Total (mg/kg)	113	1.2	7.4	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	2	0.066	8.4	79	30	47	8	270	300	25	100.05	2000	7.2%
		Net Leached SPLP (mg/L)	None	0.025											
		Sat Paste DH-71 Leach (mg/L)	0.78	2	7.9	120	47	130	14	140	540	60	333.8	75	7.2%
		Net Leached Sat Paste (mg/L)	None	1.92											
AEH-1409-149S	48-49	Total (mg/kg)	34	0.7	7.5	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	1.8	0.049	8.4	100	33	66	7	270	310	27	100.67	2000	29.9%
		Net Leached SPLP (mg/L)	None	0.007											
		Sat Paste DH-71 Leach (mg/L)	0.12	0.58	7.90	210	58	72	10	120	660	110	461.97	150	29.9%
		Net Leached Sat Paste (mg/L)	None	0.46											

Blue shading denotes saturated zone samples. Net Leached values are leach concentrations corrected for concentrations in residual soil moisture and groundwater leach solution. "None" indicates negative net leached values (soil removed constituent from initial leaching solution).

DH-71 Leach Solution Initial Concentrations (mg/L)	As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl
Before Leach Testing	7.5	0.04	7.6	171	141	53	72	260	290	24
After Leach Testing	7.11	0.04	7.7	175	138	54	70	260	300	25

Sample #	Depth	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-114S	5-6	Split Spoon										
AEH-1409-115S	6-7	Split Spoon										
AEH-1409-116S	7-10	Grab										
AEH-1409-117S	10-12	Split Spoon										
AEH-1409-118S	15-16.5	Split Spoon										
AEH-1409-119S	20-20.5	Split Spoon										
AEH-1409-120S	25-25.3	Split Spoon										
AEH-1409-121S	29-29.5	Grab										
AEH-1409-122S	30-30.3	Split Spoon										
AEH-1409-123S	33	Grab	8150	9	<1	44	10800	14	153	<0.5	32	7.5
AEH-1409-124S	35-36.1	Split Spoon										
AEH-1409-125S	38-40	Grab	10900	19	<1	41	17300	10	476	<0.5	35	7.5
AEH-1409-126S	40-41	Split Spoon										
AEH-1409-127S	43-45	Grab	9210	71	4	33	17400	16	342	<0.5	44	7.6
<i>AEH-1409-131S</i>	<i>43-45 Dup</i>	<i>Grab</i>	<i>9640</i>	<i>48</i>	<i>3</i>	<i>26</i>	<i>14700</i>	<i>11</i>	<i>322</i>	<i>&lt;0.5</i>	<i>37</i>	<i>7.8</i>
AEH-1409-128S	45-46	Split Spoon	9160	47	4	26	14700	7	364	<0.5	25	7.5
AEH-1409-129S	47.5-48	Split Spoon	16300	34	4	29	19900	<5	710	<0.5	50	8.0
AEH-1409-130S	48-49	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-151S	0-5	Grab										
AEH-1409-152S	5-6.8	Split Spoon	12500	22	<1	23	17300	25	362	<0.5	67	9.1
AEH-1409-153S	10-11.1	Split Spoon										
AEH-1409-154S	15-18	Grab										
AEH-1409-155S	22-24	Grab										
AEH-1409-156S	25-25.3	Split Spoon										
AEH-1409-157S	27	Grab	10700	8	<1	59	21000	18	662	<0.5	54	7.6
AEH-1409-158S	30-32	Split Spoon										

Sample #	Depth (ft)	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-159s	5-6.4	Split Spoon	18600	49	<1	19	15600	19	390	11.6	63	8.1
AEH-1409-160s	10-11.8	Split Spoon	12100	15	<1	16	14000	12	164	6.4	33	9.1
AEH-1409-161s	10.7-11.4	Split Spoon	5770	10	<1	8	10700	9	261	4.3	21	9.3
AEH-1409-162s	15-15.7	Split Spoon	13200	23	<1	28	28900	32	536	20.7	51	9.1
AEH-1409-163s	20.3-20.9	Split Spoon	13700	16	<1	59	26300	18	852	44.7	61	9.0
AEH-1409-164s	25-25.8	Split Spoon	7970	8	<1	53	30800	10	474	2.0	34	7.9
AEH-1409-165s	30-30.7	Split Spoon	6830	7	<1	42	24200	11	434	1.5	27	8.0
AEH-1409-166s	32-33	Grab	7140	<5	<1	35	11700	8	292	1.3	22	8.1
AEH-1409-167s	35-37	Split Spoon	5240	11	9	26	11700	30	299	7.2	50	8.4
AEH-1409-168s	40-41	Split Spoon	16700	20	75	76	17300	17	2070	12.9	270	7.4
AEH-1409-169s	43.5-45.5	Split Spoon	42300	<5	<1	15	21900	28	277	0.6	53	7.4

Blue shading denotes saturated zone samples

Sample #	Depth (ft)	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture initial
AEH-1409-163s	20.3-20.9	Total (mg/kg)	16	44.7	9.0	--	--	--	--	--	--	--			
		SPLP Precip Leach (mg/L)	0.065	1.1	10.5	8	9	31	6	<1	2	<1	100.68	2000	7.8%
		Sat Paste Precip Leach (mg/L)	0.11	33	8.3	12	13	230	10	200	270	16	465.4	70	7.8%
AEH-1409-168s	40-41	Total (mg/kg)	20	12.9	7.4	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	1.7	0.29	8.5	92	37	72	8	270	320	25	100.67	2000	17.5%
		Net Leached SPLP (mg/L)	None	0.238											
		Sat Paste DH-71 Leach (mg/L)	0.066	10.0	7.60	290	110	300	14	110	1700	24	683.31	120.00	17.5%
		Net Leached Sat Paste (mg/L)	None	9.30											
AEH-1409-169s	43.5-45.5	Total (mg/kg)	<5	0.6	7.4	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	2.1	0.044	8.5	110	31	71	8	260	330	31	100.09	2000	39.3%
		Net Leached SPLP (mg/L)	None	None											
		Sat Paste DH-71 Leach (mg/L)	0.017	0.53	7.70	470	100	190	19	130	1500	300	322.80	40.00	39.3%
		Net Leached Sat Paste (mg/L)	None	None											

Blue shading denotes saturated zone samples. Net Leached values are leach concentrations corrected for concentrations in residual soil moisture and groundwater leach solution. "None" indicates negative net leached values (soil removed constituent from initial leaching solution).

DH-71 Leach Solution Initial Concentrations (mg/L)	As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl
Before Leach Testing	7.5	0.04	7.6	171	141	53	72	260	290	24
After Leach Testing	7.11	0.04	7.7	175	138	54	70	260	300	25

Sample #	Depth (ft)	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-233	5-5.8	Split Spoon	13300	26	<1	15	15500	12	255	9.2	37	8.8
AEH-1409-234	10-11.7	Split Spoon										
AEH-1409-235	15-15.6	Split Spoon										
AEH-1409-236	20-20.2	Split Spoon										
AEH-1409-237	22-23	Grab										
AEH-1409-238	25-25.4	Split Spoon										
AEH-1409-239	29-29.5	Grab	9040	6	<1	40	14400	10	193	0.6	29	7.8
AEH-1409-240	30-30.4	Split Spoon										
AEH-1409-241	31-33	Grab										
AEH-1409-242	34.5-35	Grab										
AEH-1409-243	35-36.7	Split Spoon	4060	<5	4	20	7650	<5	120	<0.5	20	7.4
AEH-1409-248	35-36.7 Dup	Split Spoon	4850	<5	2	25	9390	6	141	<0.5	29	7.4
AEH-1409-244	38-39	Grab	13700	<5	<1	38	15100	14	474	0.8	43	7.6
AEH-1409-245	40-41.5	Split Spoon	14300	18	66	73	23000	19	1410	0.9	212	7.4
AEH-1409-246	42-43	Grab	16300	9	31	48	21800	12	630	0.7	123	7.5
AEH-1409-247	45-47	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth (ft)	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture initial
AEH-1409-244	38-39	Total (mg/kg)	<5	0.8	7.6	--	--	--	--	--	--	--			
		SPLP Precip Leach (mg/L)	0.005	0.023	10.4	5	4	45	2	<4	14	<1	100.88	2000	0.101
		Sat Paste Precip Leach (mg/L)	<0.005	1.3	7.6	160	56	160	15	48	860	15	393	100	0.101
AEH-1409-245	40-41.5	Total (mg/kg)	18	0.9	7.4	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	2	0.051	8.6	97	34	66	8	260	300	26	100.66	2000	0.118
		Net Leached SPLP (mg/L)	None	None											
		Sat Paste DH-71 Leach (mg/L)	0.068	3.60	7.80	590.00	160.00	230.00	30.00	120.00	940.00	160.00	770.00	100.00	0.12
		Net Leached Sat Paste (mg/L)	None	1.61											
AEH-1409-246	42-43	Total (mg/kg)	9	0.7	7.5	--	--	--	--	--	--	--			
		SPLP DH-71 Leach (mg/L)	1.8	0.047	8.5	96	34	55	10	270	310	26	100.54	2000	0.083
		Net Leached SPLP (mg/L)	None	None											
		Sat Paste DH-71 Leach (mg/L)	0.02	0.96	7.90	250.00	73.00	110.00	17.00	140.00	810.00	140.00	352.38	80.00	0.08
		Net Leached Sat Paste (mg/L)	None	None											

Blue shading denotes saturated zone samples. Net Leached values are leach concentrations corrected for concentrations in residual soil moisture and groundwater leach solution. "None" indicates negative net leached values (soil removed constituent from initial leaching solution).

DH-71 Leach Solution Initial Concentrations (mg/L)	As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl
Before Leach Testing	7.5	0.04	7.6	171	141	53	72	260	290	24
After Leach Testing	7.11	0.04	7.7	175	138	54	70	260	300	25

Sample #	Depth	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-201	5-6.7	Split Spoon										
AEH-1409-202	8.5-9.5	Grab										
AEH-1409-203	10-10.4	Split Spoon										
AEH-1409-204	12-13	Grab										
AEH-1409-205	15-15.7	Split Spoon										
AEH-1409-206	18-19.5	Grab	8520	5	<1	34	20100	9	217	<0.5	30	8.1
AEH-1409-207	20-20.4	Split Spoon										
AEH-1409-208	24	Grab										
AEH-1409-209	27-28	Grab										
AEH-1409-210	30-31.3	Split Spoon										
AEH-1409-211	33-34	Grab	14600	168	25	32	21100	10	311	1.8	712	9.0
AEH-1409-214	35-35.2	Split Spoon	18800	277	59	46	27400	13	406	1.7	1080	9.1
AEH-1409-212	36-37	Grab	7810	264	18	25	12800	8	126	0.5	463	8.9
AEH-1409-213	40-42	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture initial
AEH-1409-211	33-34	Total (mg/kg)	168	1.8	9.0	--	--	--	--	--	--	--			
		SPLP SDMW-4 Leach (mg/L)	1.0	0.011	8.5	40	12	110	8	280	190	11	100.3	2000.0	6.2%
		Net Leached SPLP (mg/L)	0.627	0.008											
		Sat Paste SDMW-4 Leach (mg/L)	6.1	0.11	8.4	12	6	180	12	260	150	13	198.2	80.0	6.2%
		Net Leached Sat Paste (mg/L)	4.56	0.107											
AEH-1409-212	36-37	Total (mg/kg)	264	0.5	8.9	--	--	--	--	--	--	--			
		SPLP SDMW-4 Leach (mg/L)	2.2	0.007	8.5	41	11	110	7	280	200	11	100.7	2000.0	9.6%
		Net Leached SPLP (mg/L)	1.81	0.004											
		Sat Paste SDMW-4 Leach (mg/L)	20	0.069	8.4	11	5	220	12	270	200	17	356.2	80.0	9.6%
		Net Leached Sat Paste (mg/L)	17.0	0.067											

Blue shading denotes saturated zone samples. Net Leached values are leach concentrations corrected for concentrations in residual soil moisture and groundwater leach solution.

SDMW-4 Leach Solution Initial Concentrations (mg/L)	As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl
Before Leach Testing	0.345	0.003	7.4	53	15	100	8	260	190	11
After Leach Testing	0.343	0.003	7.6	53	15	99	8	250	200	11

Sample #	Depth	Description	Total Metals (mg/kg)									pH
			Al	As	Cd	Cu	Fe	Pb	Mn	Se	Zn	
AEH-1409-215	5-5.8	Split Spoon										
AEH-1409-216	8-8.5	Grab										
AEH-1409-217	10-11.1	Split Spoon										
AEH-1409-218	15-15.8	Split Spoon										
AEH-1409-219	19	Grab										
AEH-1409-220	20-20.4	Split Spoon										
AEH-1409-221	23	Grab										
AEH-1409-222	25-25.5	Split Spoon	16000	7	<1	43	23700	13	222	1	51	7.2
AEH-1409-223	26-27	Grab										
AEH-1409-224	30-31.5	Split Spoon	12500	241	<1	37	16900	20	193	<0.5	488	6.0
AEH-1409-225	33-34	Grab										
AEH-1409-226	35-36.8	Split Spoon	23500	323	3	84	17000	18	144	<0.5	1750	8.2
AEH-1409-227	37-40	Grab										
AEH-1409-228	40-40.4	Split Spoon	6990	209	<1	26	15200	19	141	<0.5	269	8.1
AEH-1409-229	43-44.6	Grab	8270	117	<1	28	14300	6	195	<0.5	216	8.5
AEH-1409-232	45-45.5	Split Spoon										
AEH-1409-230	46-47	Grab										
AEH-1409-231	47.5-49.5	Split Spoon										

Blue shading denotes saturated zone samples

Sample #	Depth	Analysis	Leach Test Results										Leach Prep Data		
			As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl	g soil	mL fluid	wt % moisture initial
AEH-1409-224	30-31.5	Total (mg/kg)	241	<0.5	6.0	--	--	--	--	--	--	--			
		SPLP Precip Leach (mg/L)	1.0	<0.005	10.2	3	2	32	2	13	11	<1	100.35	2000	10.2%
		Sat Paste Precip Leach (mg/L)	0.58	<0.005	5.9	53	17	270	15	8	780	5	810.39	180	10.2%
AEH-1409-226	35-36.8	Total (mg/kg)	323	<0.5	8.2	--	--	--	--	--	--	--			
		SPLP SDMW-4 Leach (mg/L)	0.69	<0.005	8.5	42	11	110	6	270	200	11	100.37	2000	15.8%
		Net Leached SPLP (mg/L)	0.209	NC											
		Sat Paste SDMW-4 Leach (mg/L)	3.20	0.043	8.30	19.00	9.00	240.00	14.00	240.00	250.00	15.00	951	120	15.8%
		Net Leached Sat Paste (mg/L)	None	0.042											
AEH-1409-228	40-40.4	Total (mg/kg)	209	<0.5	8.1	--	--	--	--	--	--	--			
		SPLP SDMW-4 Leach (mg/L)	0.83	<0.005	8.3	42	11	110	6	280	190	11	100.00	2000	19.0%
		Net Leached SPLP (mg/L)	0.323	NC											
		Sat Paste SDMW-4 Leach (mg/L)	15	<0.005	8.2	8	3	200	8	220	220	16	629.88	70	19.0%
		Net Leached Sat Paste (mg/L)	3.77	NC											
AEH-1409-229	43-44.6	Total (mg/kg)	117	<0.5	8.5	--	--	--	--	--	--	--			
		SPLP SDMW-4 Leach (mg/L)	0.83	<0.005	8.3	40	11	110	7	280	190	11	100.07	2000	5.7%
		Net Leached SPLP (mg/L)	0.436	NC											
		Sat Paste SDMW-4 Leach (mg/L)	5.8	0.009	8.4	8	4	210	8	230	200	17	315.22	70	5.7%
		Net Leached Sat Paste (mg/L)	1.93	0.007											

Blue shading denotes saturated zone samples. Net Leached values are leach concentrations corrected for concentrations in residual soil moisture and groundwater leach solution. "None" indicates negative net leached values (soil removed constituent from initial leaching solution). NC = not calculated due to below detect values for total and leachate.

SDMW-4 Leach Solution Initial Concentrations (mg/L)	As	Se	pH	Ca	Mg	Na	K	HCO3	SO4	Cl
Before Leach Testing	0.345	0.003	7.4	53	15	100	8	260	190	11
After Leach Testing	0.343	0.003	7.6	53	15	99	8	250	200	11

**APPENDIX D**

**SOIL SAMPLE LABORATORY  
ANALYTICAL REPORTS**

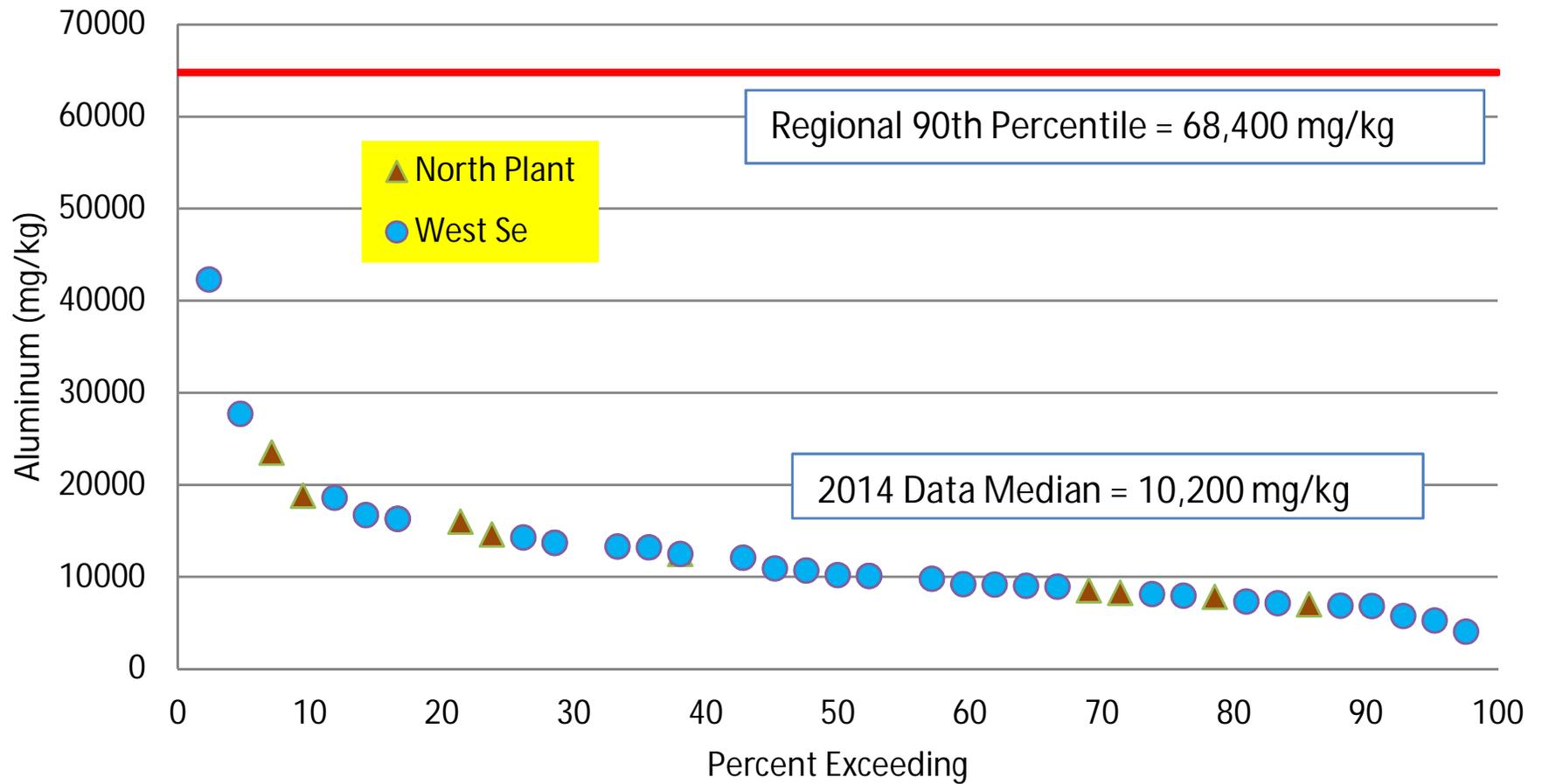
**APPENDIX E**

**GROUNDWATER SAMPLE LABORATORY  
ANALYTICAL REPORTS**

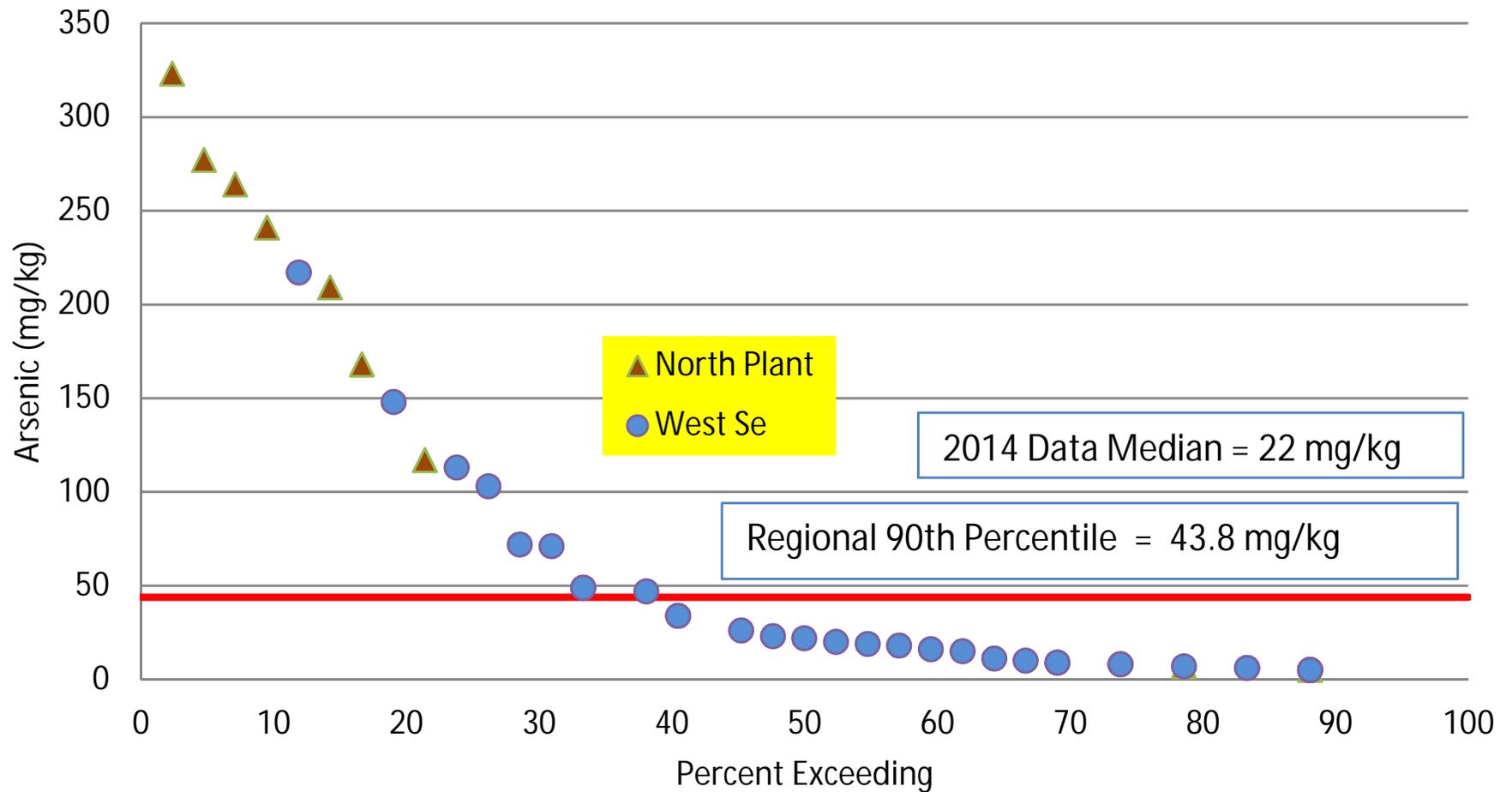
**APPENDIX F**

**TOTAL METALS DISTRIBUTION PLOTS  
AND BACKGROUND THRESHOLD VALUE COMPARISONS**

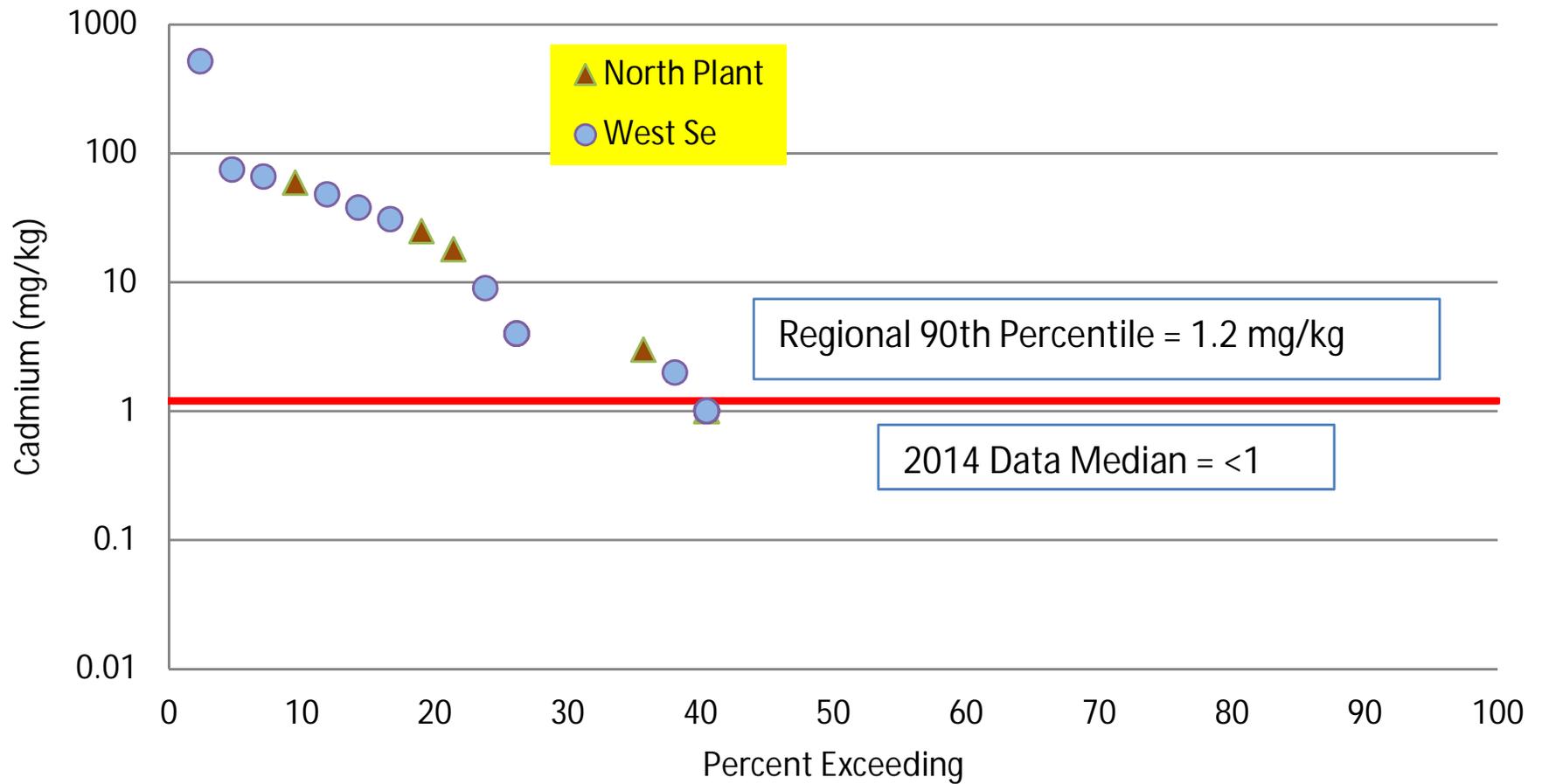
# Source Area Inventory Borings



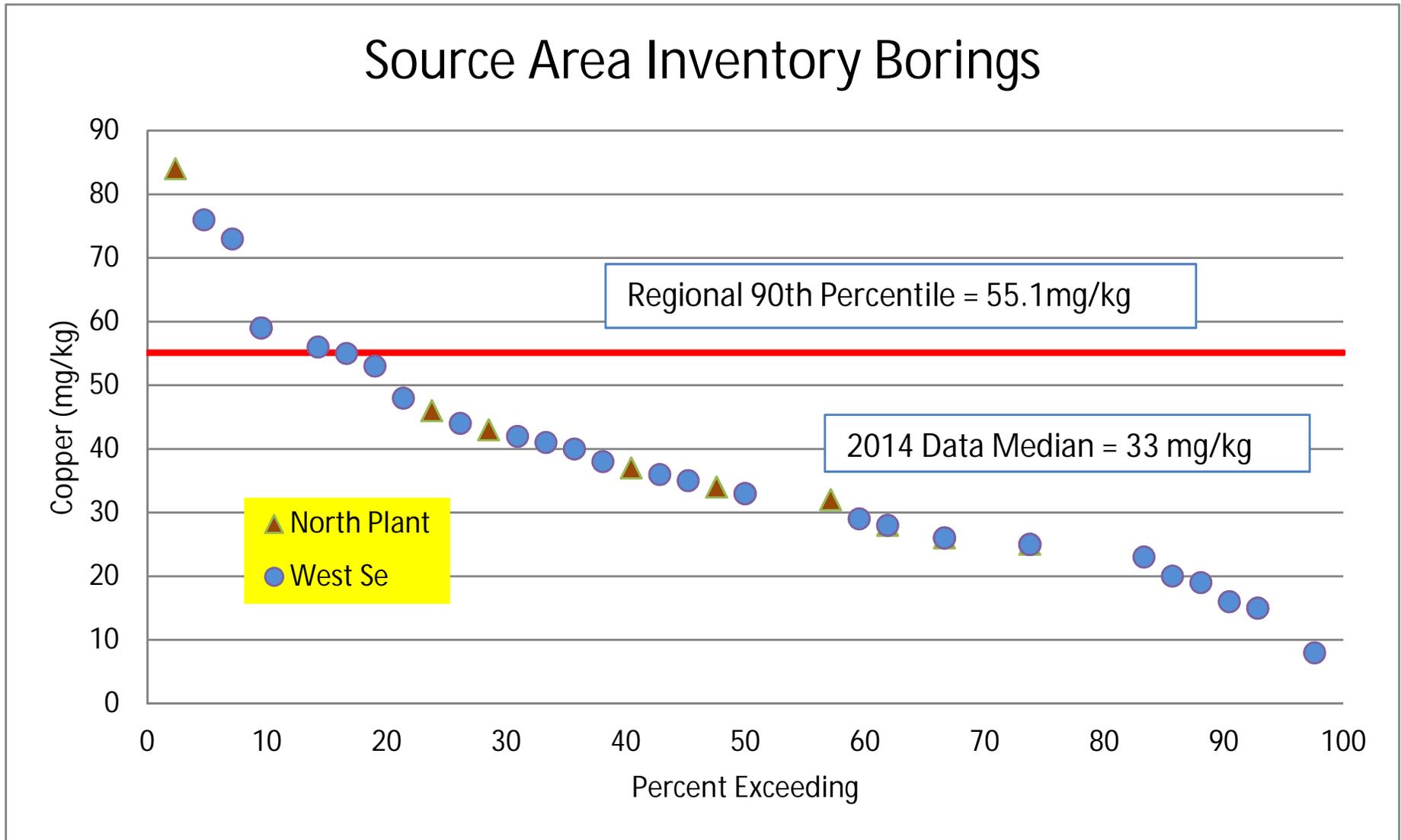
# Source Area Inventory Borings



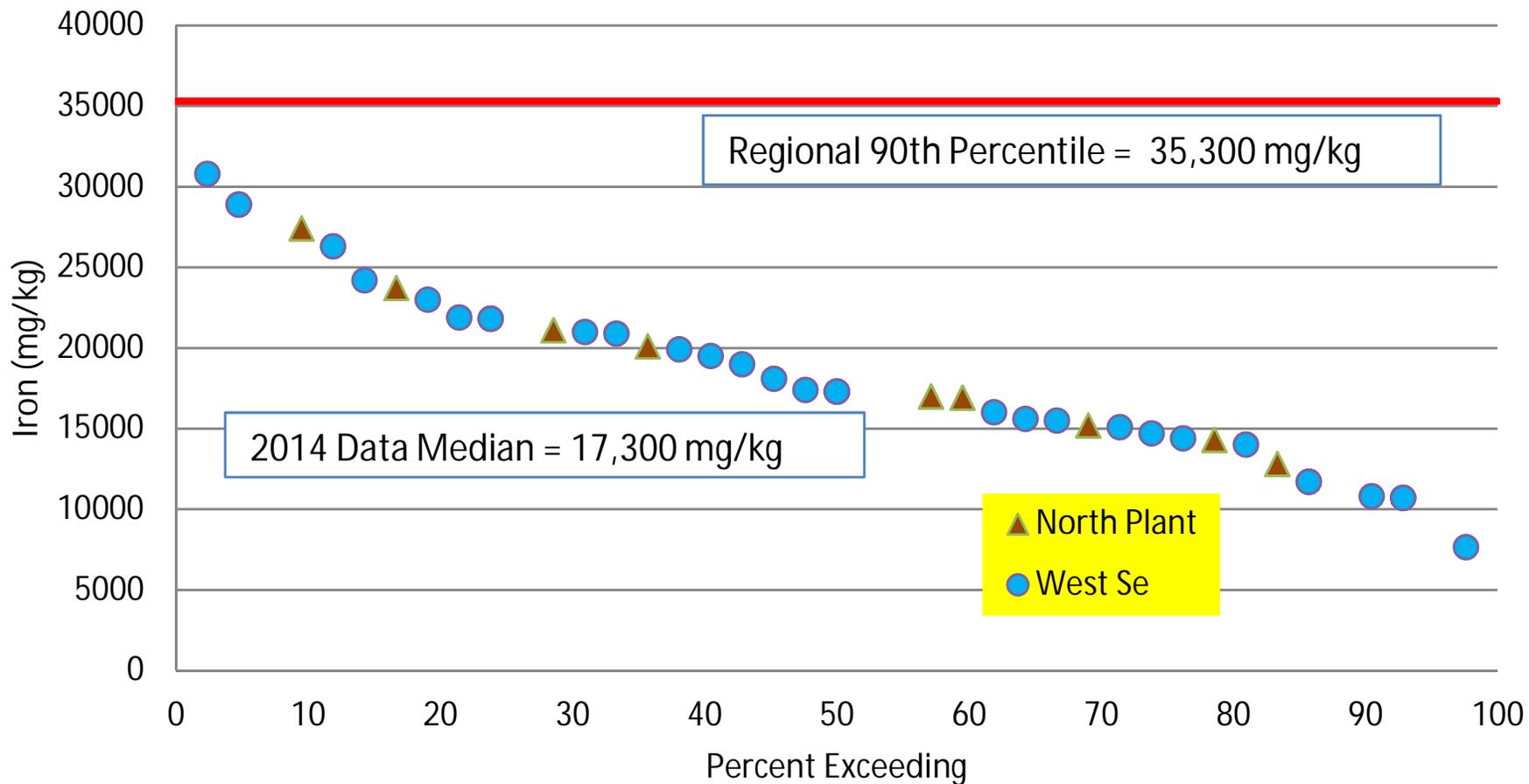
# Source Area Inventory Borings



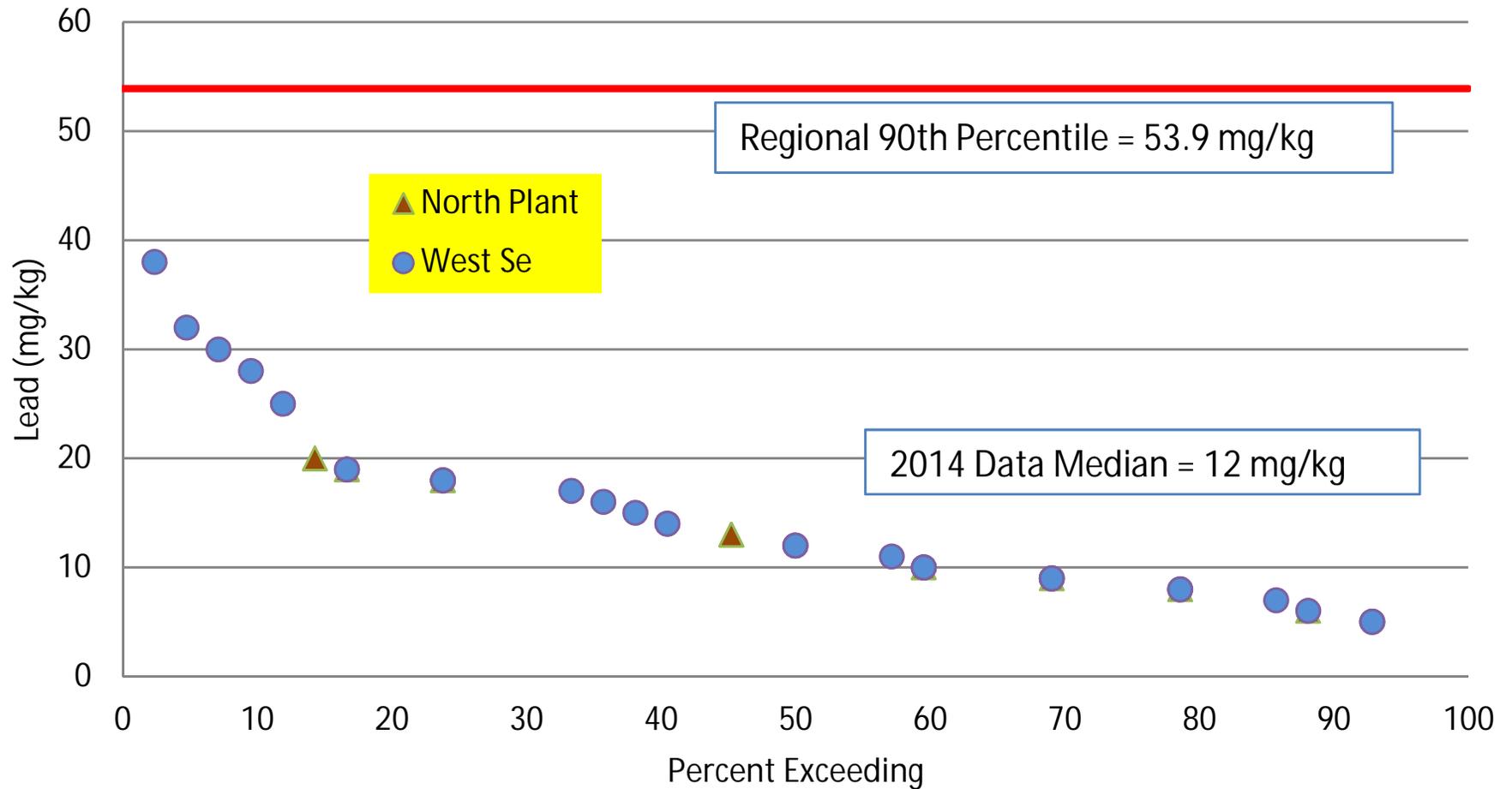
# Source Area Inventory Borings



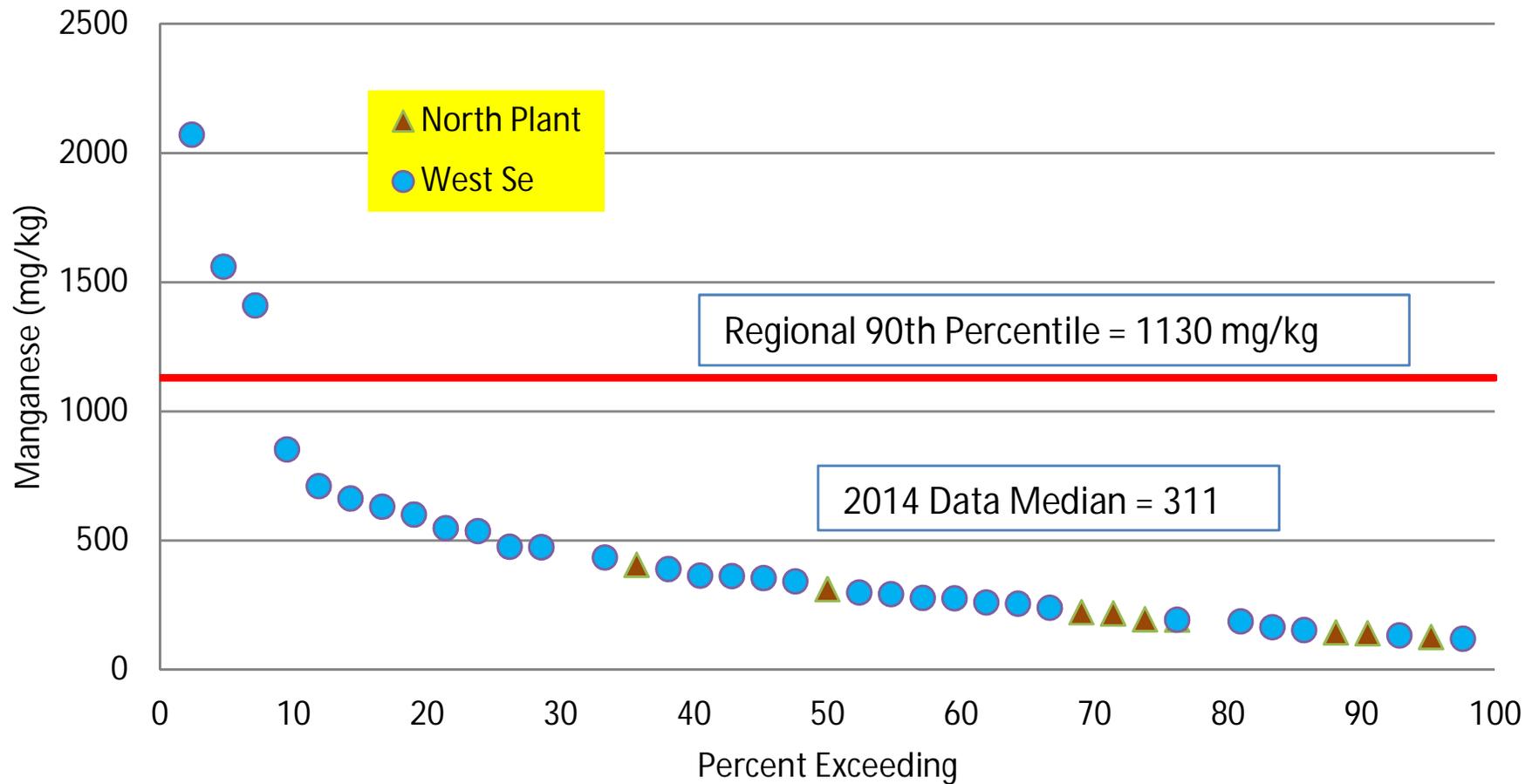
# Source Area Inventory Borings



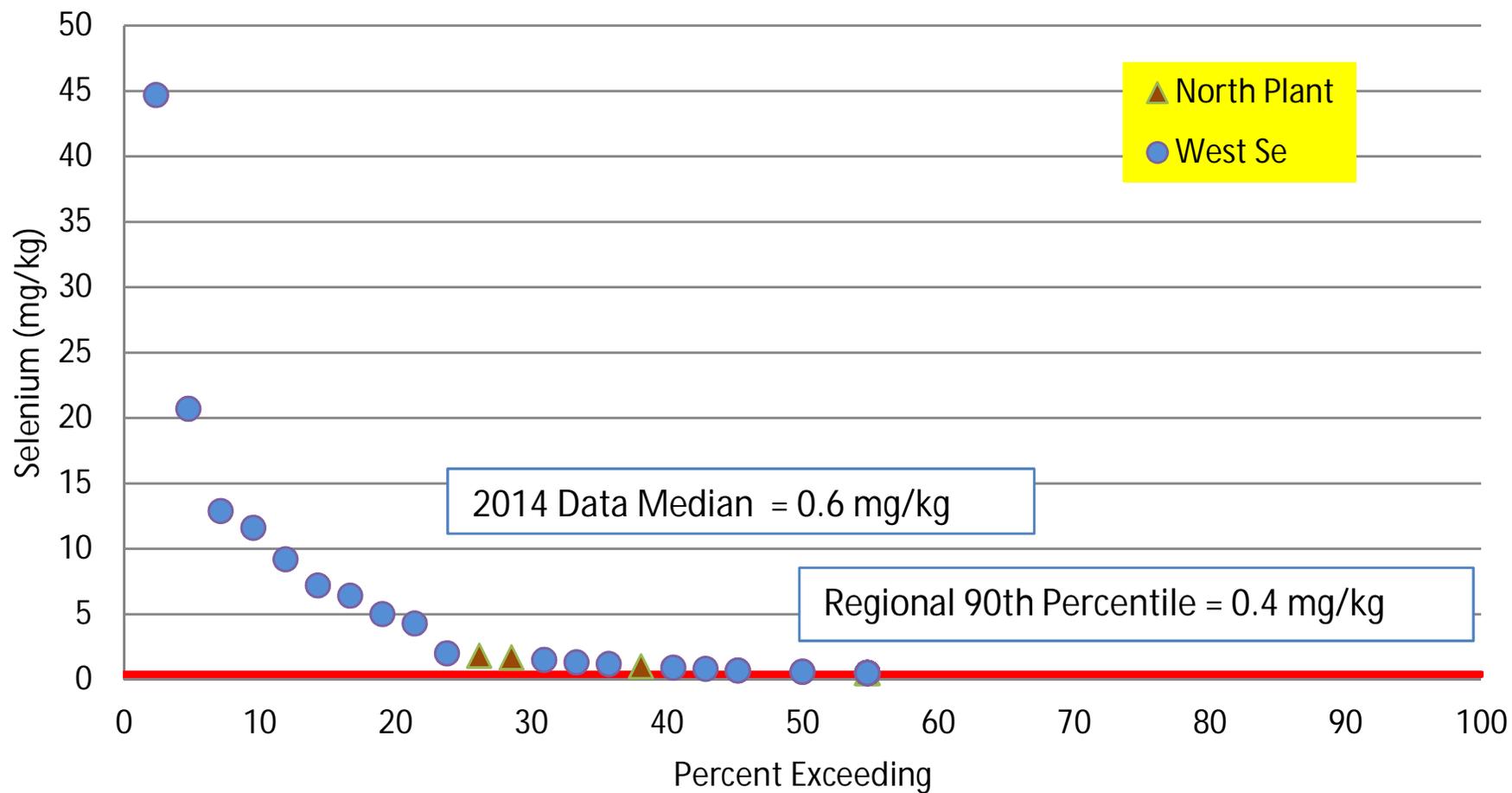
# Source Area Inventory Borings



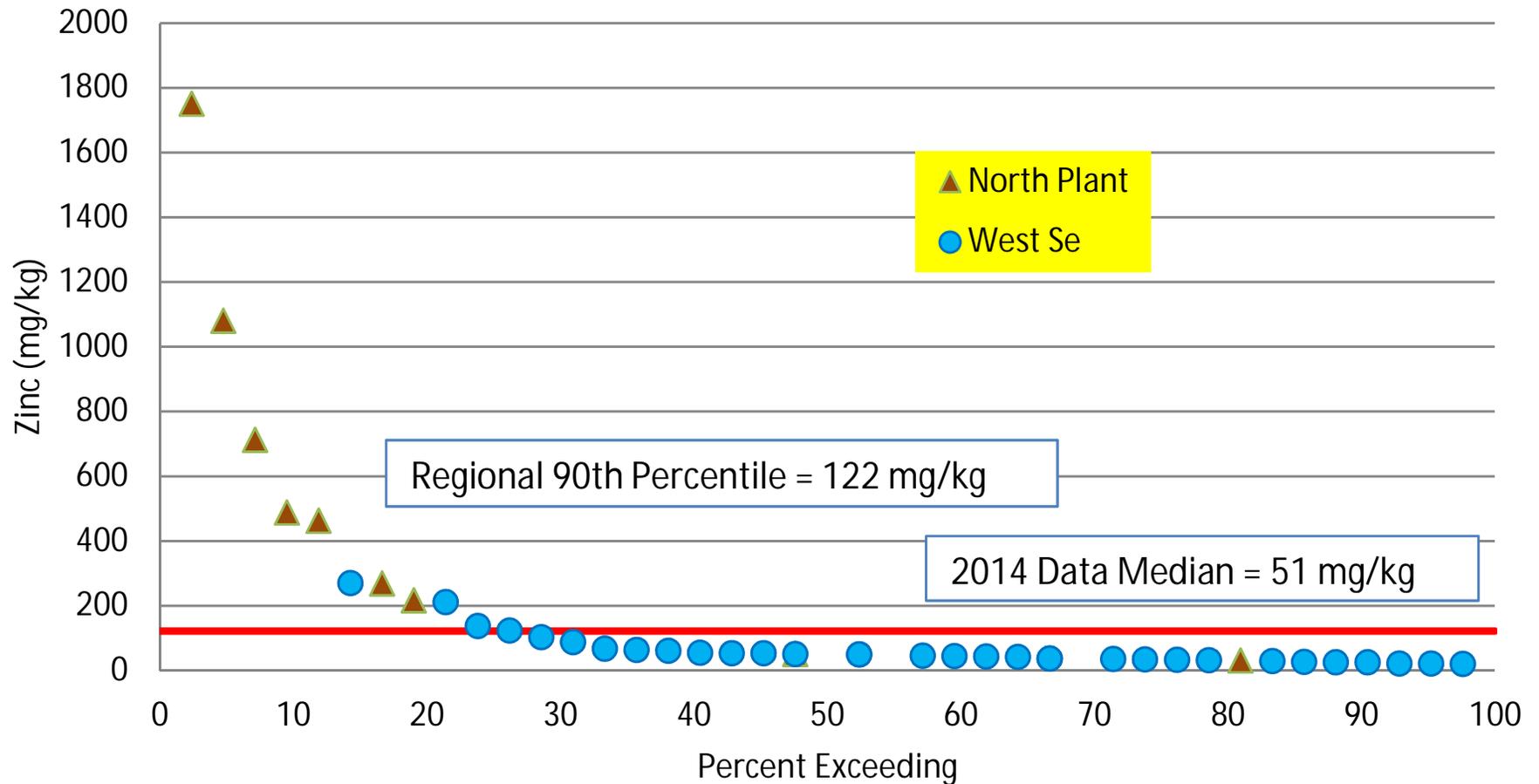
# Source Area Inventory Borings



# Source Area Inventory Borings



# Source Area Inventory Borings



**APPENDIX G**

**MONTANA TECH CAMP SEM/EDX REPORT**

**SEM-EDS Analysis of Mesh Coatings**

**Prepared for**

**Hydrometrics, Inc.**



**THE CENTER FOR ADVANCED  
MINERAL & METALLURGICAL PROCESSING  
Montana Tech of the University of Montana  
Butte, Montana**

**December 9, 2014**

**SEM-EDS Analysis of Mesh Coatings**

**Prepared for**

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**December 9, 2014**

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## EXECUTIVE SUMMARY

The Center for Advanced Mineral and Metallurgical Processing (CAMP) received seven (7) samples delivered on November 7, 2014. Three samples were selected for manual examination by scanning electron microscope coupled with energy dispersive X-ray microanalysis (SEM-EDS) to determine if certain discernable phases were accumulating selenium and arsenic. The samples selected for examination were:

- AEH-1409-163s (163S) for selenium,
- AEH-1409-168s (168S) for selenium, and
- AEH-1409-214 (214) for arsenic.

The specimens were imaged with a scanning electron microscope (SEM) using the back scattered electron (BSE) detector, with elemental data collected using energy dispersive X-ray (EDS) analysis.

Chip specimens from samples 163S and 168S were examined, with emphasis on analysis of the black material. The black material in these samples was composed of primarily manganese oxides; however, no discernable selenium was found (i.e., no peaks in the EDS spectra at lines characteristic of selenium). The iron oxide phase was examined in 163S and no selenium was found with it.

Identification of arsenic was the focus during examination of the rusty, iron oxide phases in specimens from sample 214. Arsenic was present in two of the three specimens investigated. Arsenic was present at approximately 1 to 2.7% in the spots analyzed by EDS with the exception of the specimen that contained a euhedral grain of iron oxide that was somewhat chemically “pure”. Aluminosilicates were present in the iron oxides that had trace amounts of arsenic.

In summary, no selenium was found associated with the manganese oxides in samples 163S and 168S, but arsenic was found with iron oxides in sample 214. Analysis by a more sensitive method than SEM-EDS, such as electron microprobe analysis could be used to reveal selenium in the manganese oxides.



**Gary F. Wyss**  
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**December 9, 2014**

***Qualifying Statement***

*This confidential report was prepared for the Hydrometrics, Inc. and is based on information available at the time of the report preparation. It is believed the information, estimates, conclusions and recommendations contained herein are reliable under the conditions and subject to the qualifications set forth. Furthermore, the information, estimates, conclusions and recommendations are based on the experience of CAMP and data supplied by others, but the actual result of the work is dependent, in part, on factors over which CAMP has no control.*

## Overview, Experimental Work and Results

Samples 163S and 168S were selected for selenium analysis and sample 214 was selected for arsenic enrichment. Chemical data indicated an apparent correlation between manganese and selenium, while arsenic appeared to be related to iron oxide. Chips were taken from the black regions of samples 163S and 168S which were believed to be elevated in manganese and examined for detectable selenium. Sample 214 was examined for arsenic with particular attention given to the reddish, iron-stained, material.

The selected rock chip specimens were carbon coated and grounded using carbon tape to prevent charging for SEM-EDS “spot” analysis. The SEM used in the examination was a LEO 1430 VP outfitted with a backscattered electron (BSE) detector for imaging and Ametek Apollo 40 silicon drift detectors for EDS X-ray analysis. The SEM was operated at an accelerating voltage of 25.0 kV with a working distance of between 16 and 18 mm, a spot size of approximately 600. Photographs of the specimens analyzed are shown below in Figure 1.

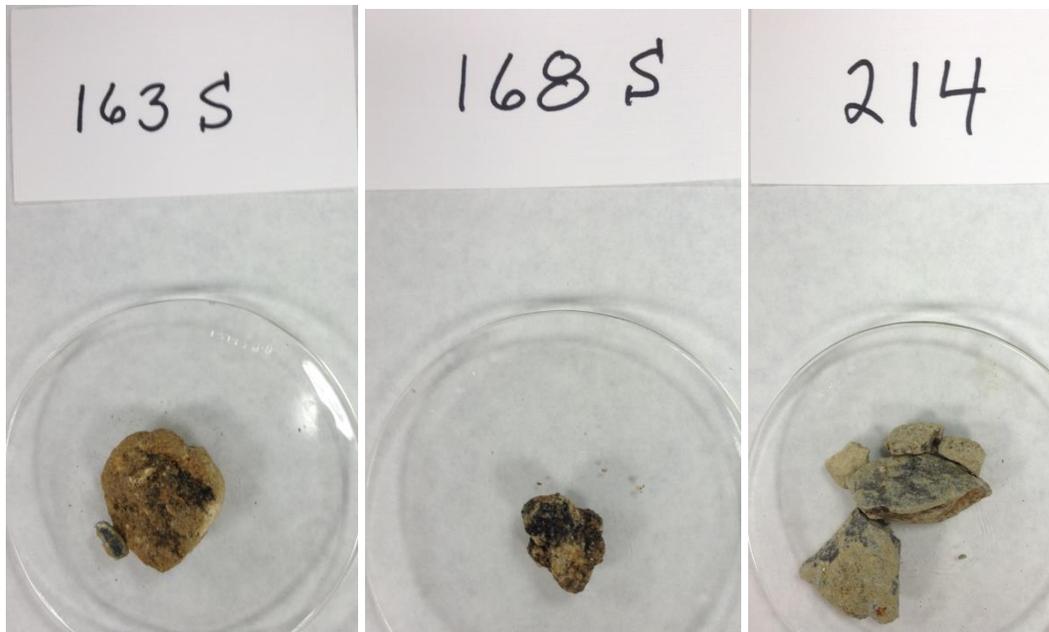


Figure 1. Photographs of the rock chip specimens examined by SEM-EDS.

## SEM-EDS Analysis

### AEH-1409-163s (163S)

The backscattered electron (BSE) image obtained at 1000X magnification and associated EDS analysis is shown in Figure 2. The approximate location of EDS data acquisition is marked with a blue “X” in the BSE image. The EDS spectrum shows a strong peak for manganese and oxygen with minor peaks for iron and silicon. The EDS X-ray spectrum and associated elemental standardless analysis is a result of multiple phases due to the relatively large interaction volume with respect to the size of the phases being examined. No visible selenium peaks were observed and the chemical analysis was at 0.56% Se. No formal detection limit has been established for selenium but results of less than 1% should be considered non-detectable for selenium.

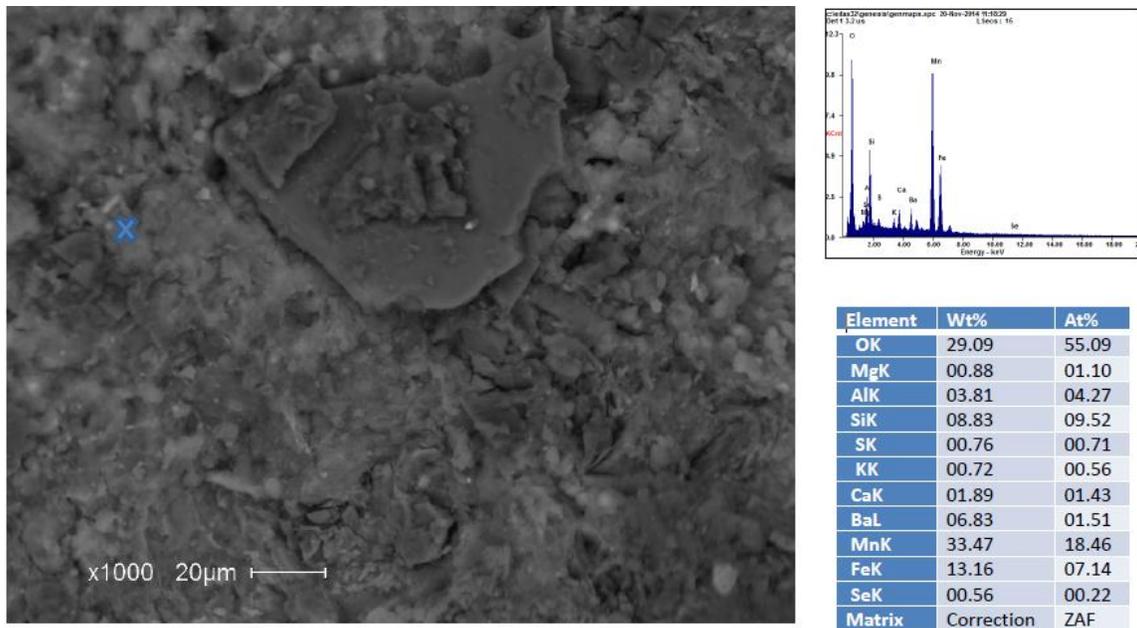


Figure 2. SEM photomicrograph and EDS analysis from image 1 of specimen 163S.

A second spot analyzed from region 1 of specimen 163S is shown in Figure 3. The spectrum acquired from the flake-like grain appears to be of a biotite, with no indication of selenium.

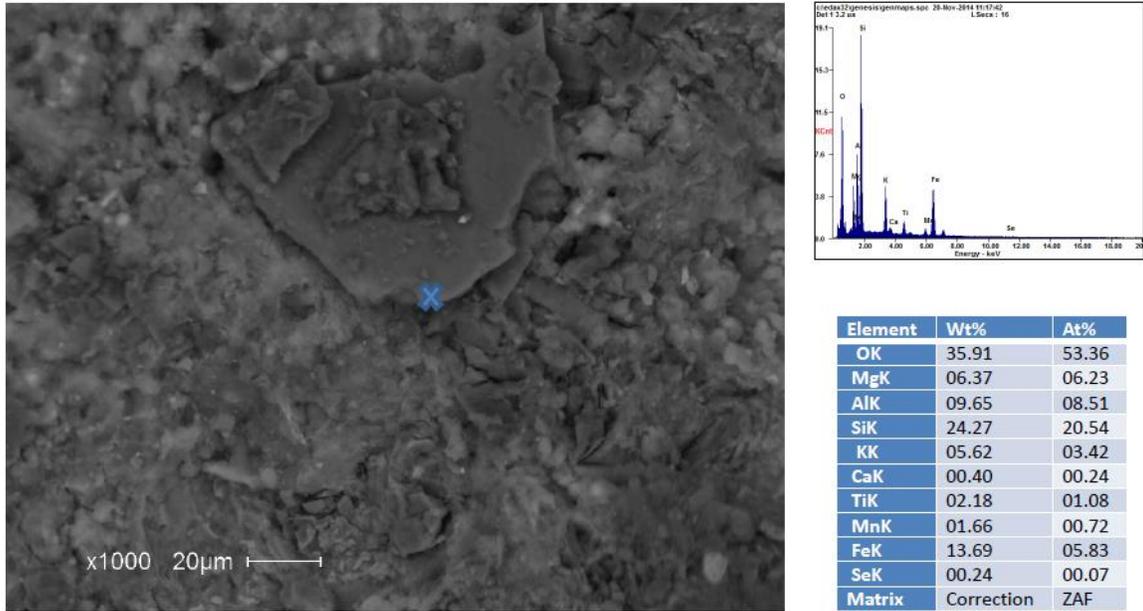


Figure 3. BSE image and EDS analysis from spot #2 from image 1 of specimen 163S.

The bright spot on the flake-like grain was examined in this acquisition Figure 4. The EDS spectrum indicates the bright phase is zircon, with no selenium.

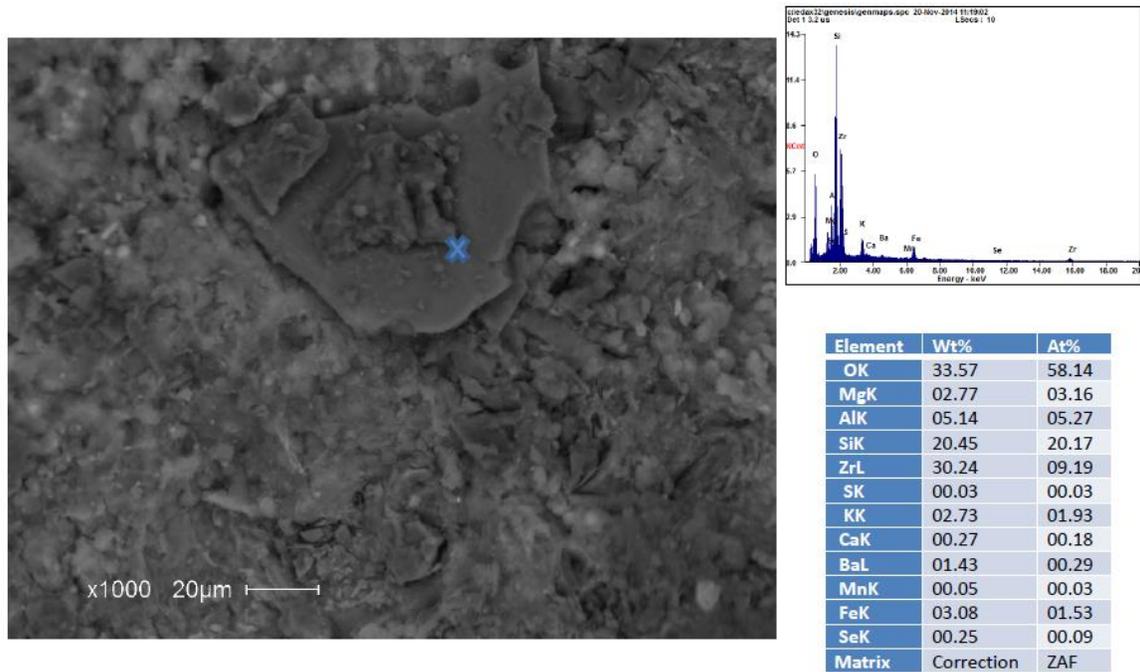


Figure 4. BSE image and EDS analysis from spot #3 from image 1 of specimen 163S.

Manganese oxide predominates in the location examined in Figure 5. No discernable selenium peak appears, but the calculated weight percent was higher than observed in previous analysis at 0.95% Se.

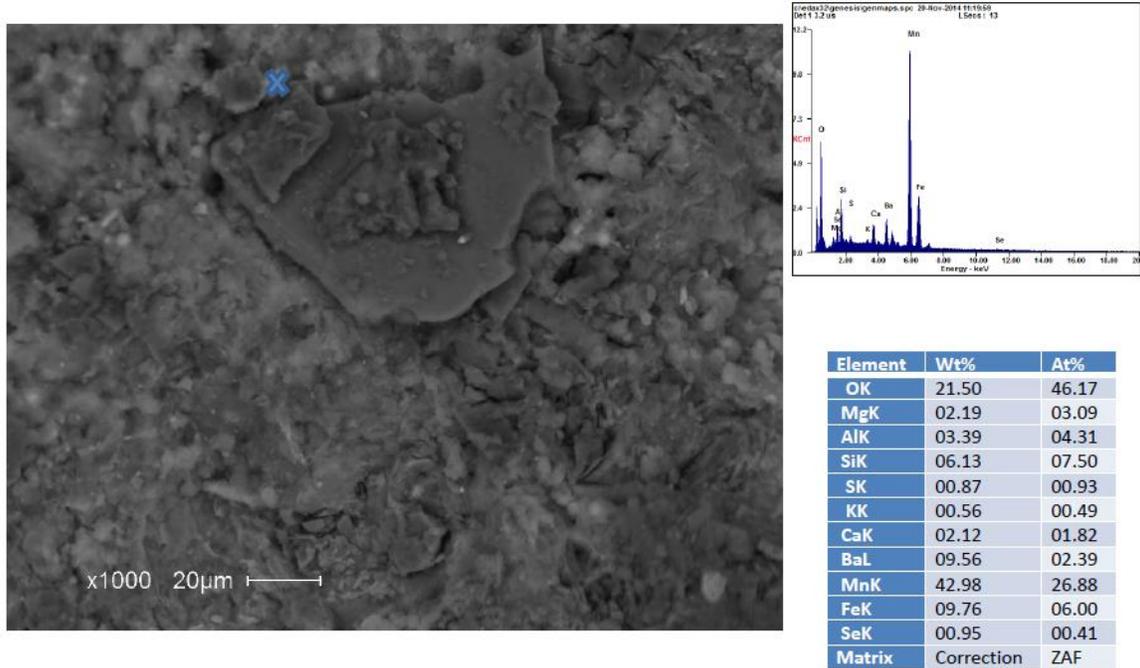


Figure 5. BSE image and EDS analysis from spot #4 from image 1 of specimen 163S.

The iron, manganese, and silicon oxides at the location Figure 6 showed no selenium.

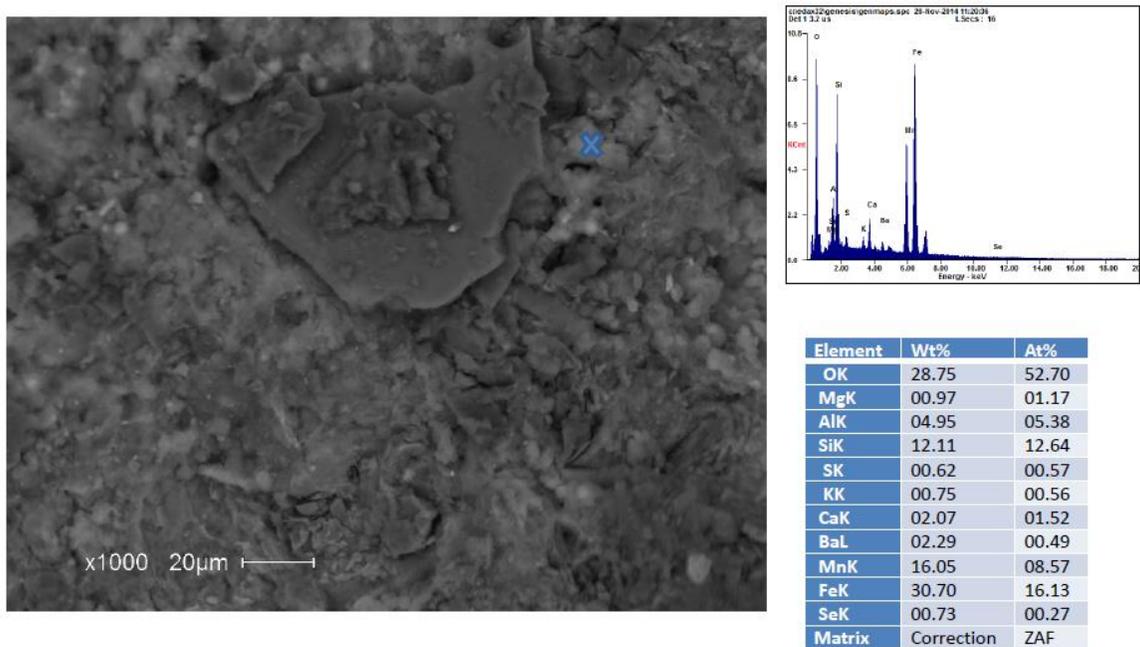


Figure 6. BSE image and EDS analysis from spot #5 from image 1 of specimen 163S.

Iron sulfide, possibly pyrite, was the bright phase analyzed in Figure 7. It appears to be on a phyllosilicate, maybe biotite or muscovite, judging by the EDS spectrum. No selenium was detected.

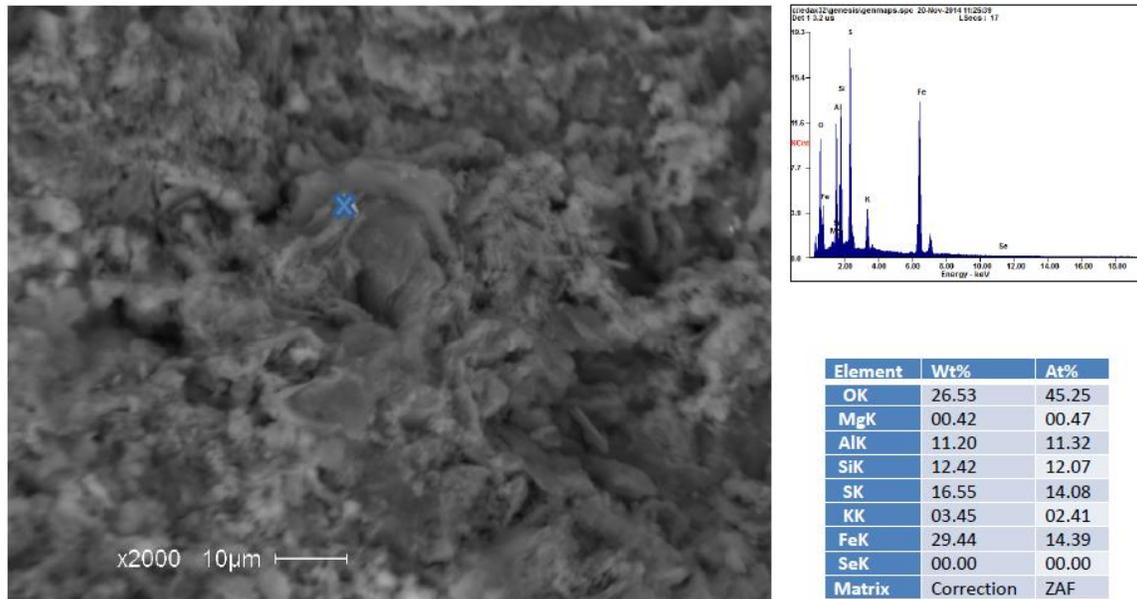


Figure 7. BSE image and EDS analysis from spot #1 from image 2 of specimen 163S.

Analysis of the “matrix” mineral in indicates that it is likely biotite according to the EDS spectrum in Figure 8.

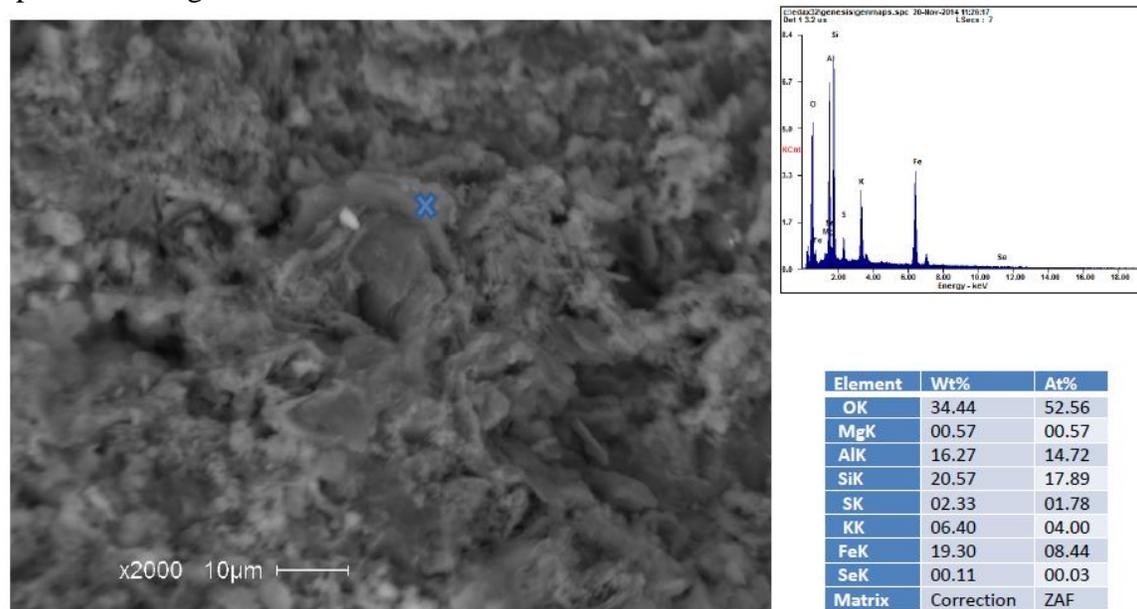


Figure 8. BSE image and EDS analysis from spot #2 from image 2 of specimen 163S.

Examination of the finer grained material shows that it is iron oxide with no selenium (Figure 9).

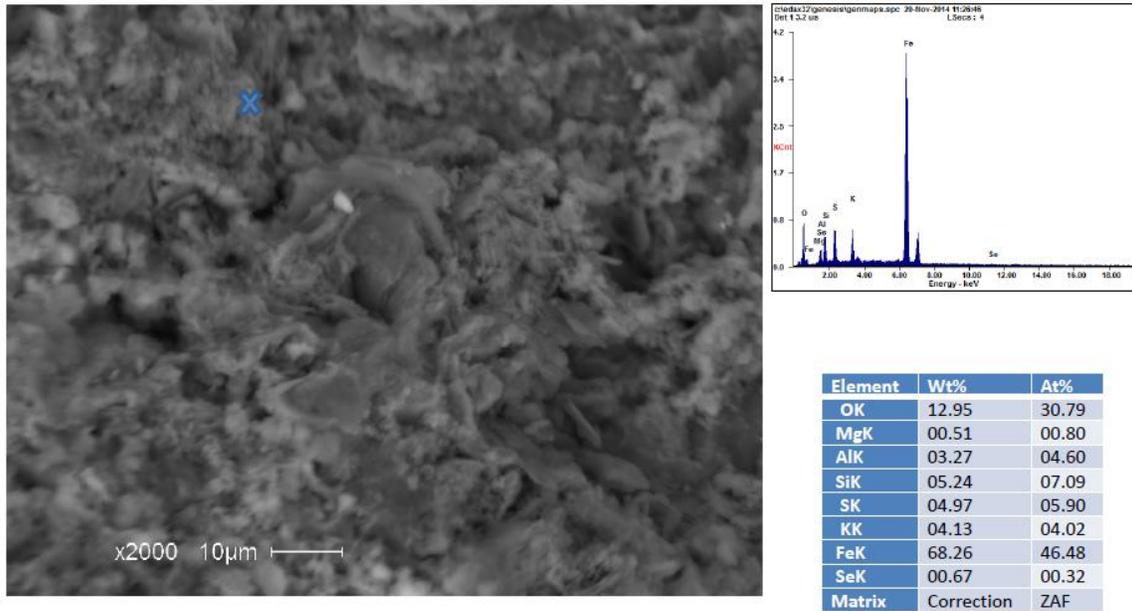


Figure 9. BSE image and EDS analysis from spot #3 from image 2 of specimen 163S.

Examination of a nearby point shows little change in composition from the previous location (Figure 10).

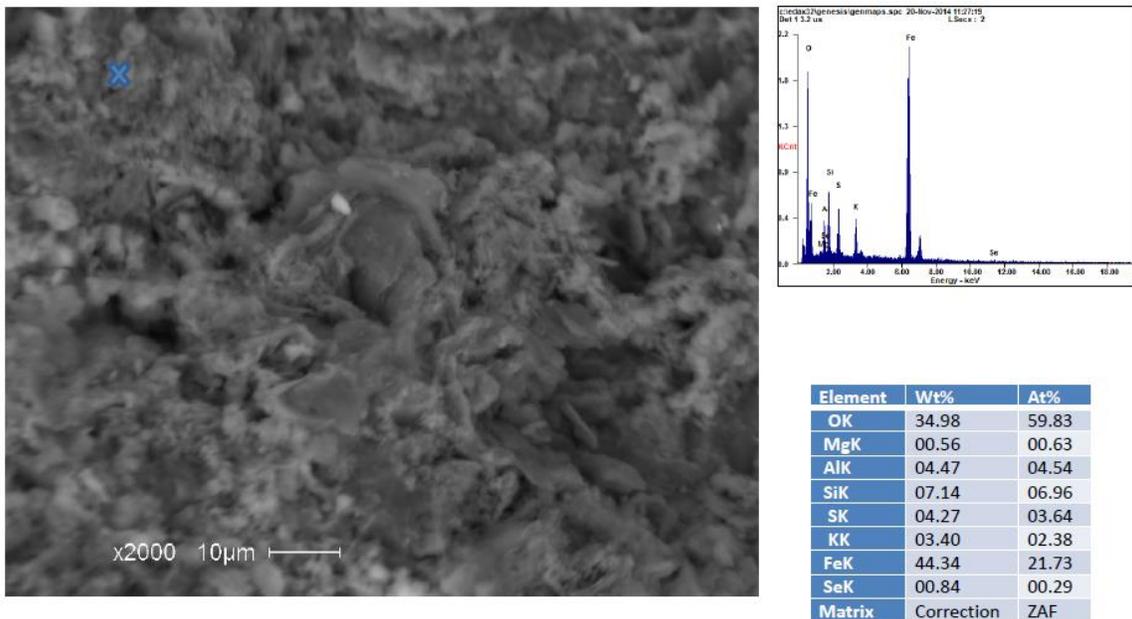


Figure 10. BSE image and EDS analysis from spot #4 from image 2 of specimen 163S.

The bright area in the third image from 163S was primarily manganese oxide. The EDS spectrum in Figure 11 shows no discernable selenium.

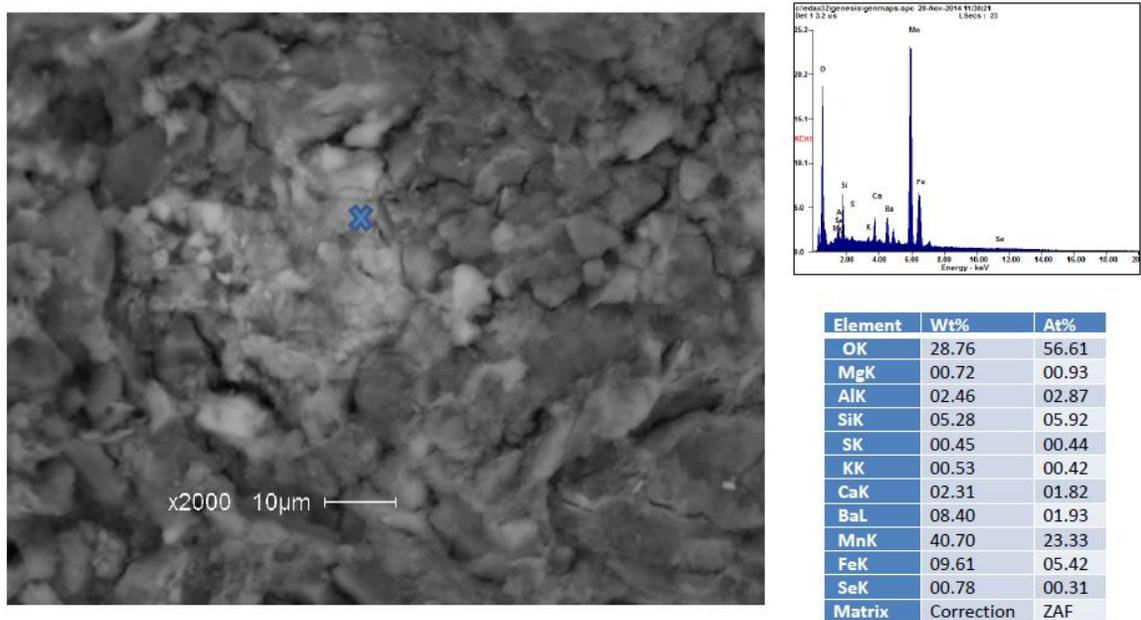


Figure 11. BSE image and EDS analysis from spot #1 from image 3 of specimen 163S.

The ferro-manganese silicon oxide contains traces of aluminum, potassium, calcium, and barium, but no selenium (Figure 12).

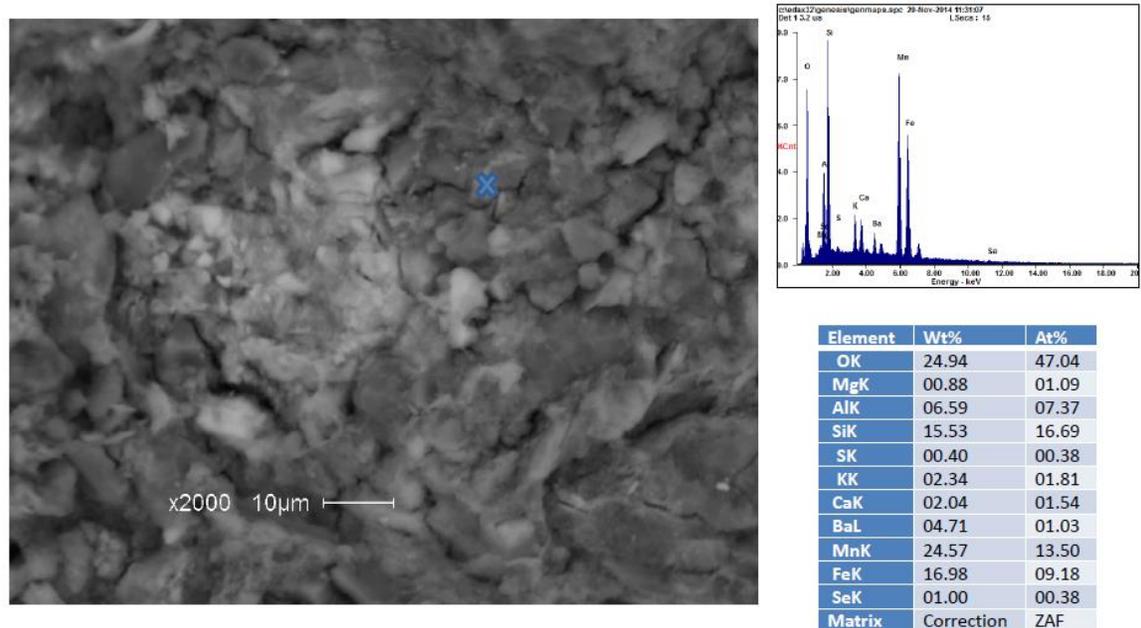


Figure 12. BSE image and EDS analysis at spot #2 from image 3 of specimen 163S.

The aluminosilicate at this spot is likely muscovite according to the EDS spectrum in (Figure 12).

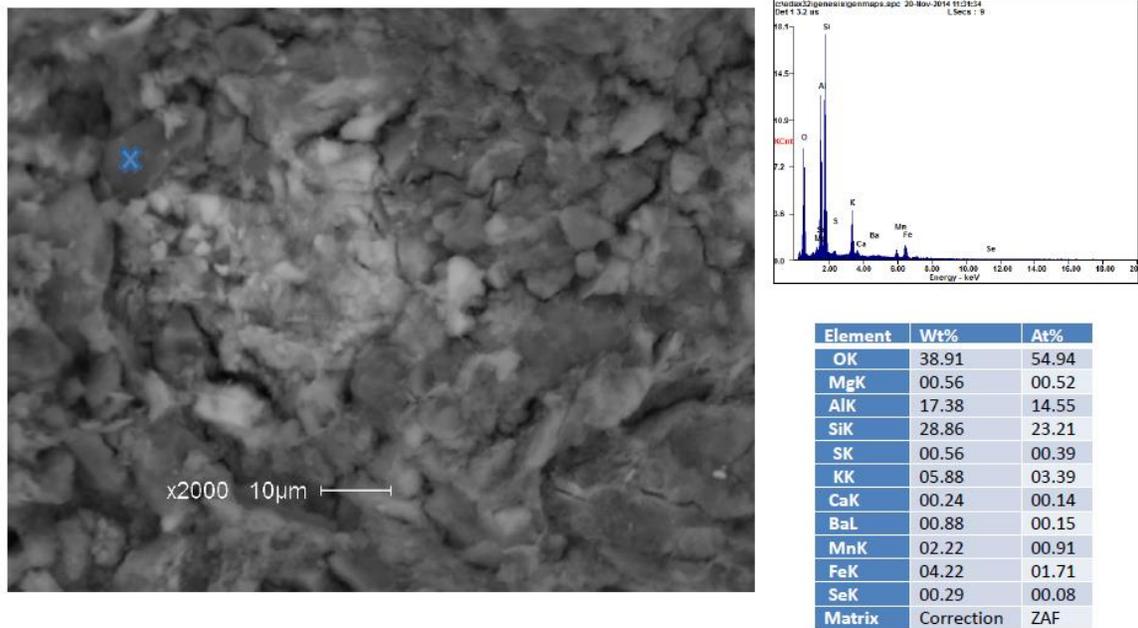


Figure 13. BSE image and EDS analysis at spot #3 from image 3 of specimen 163S.

The dark phase at this spot is quartz according to the EDS spectrum in (Figure 14).

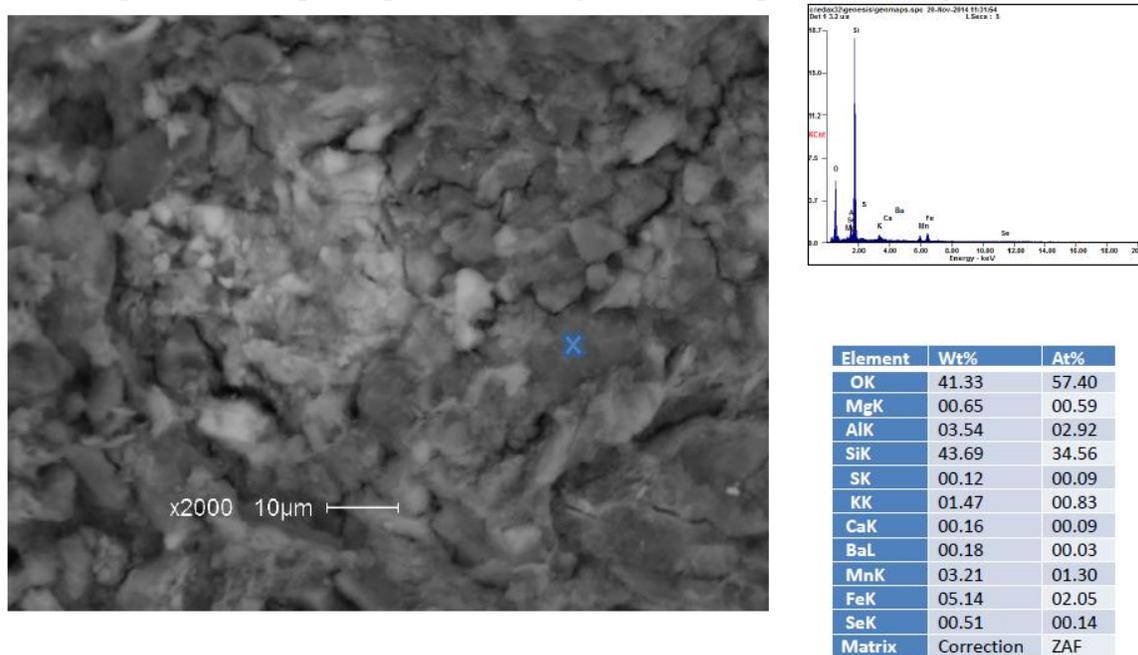


Figure 14. BSE image and EDS analysis at spot #4 from image 3 of specimen 163S.

**AEH-1409-168s (168S)**

The bright phase spotted in the BSE image in Figure 15 is barite with an aluminosilicate. No selenium was found with the barite.

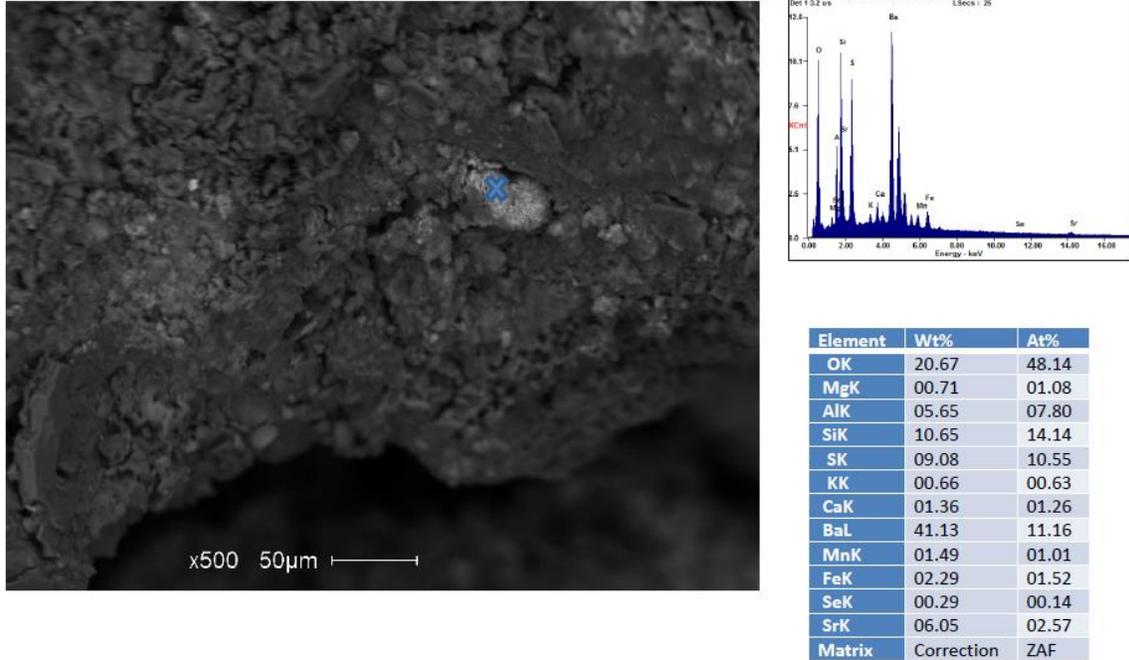


Figure 15. BSE image and EDS analysis from spot #1 from image 1 of specimen 168S.

The dark, matrix phase, is an aluminosilicate, with no selenium as seen in Figure 16 and Figure 17.

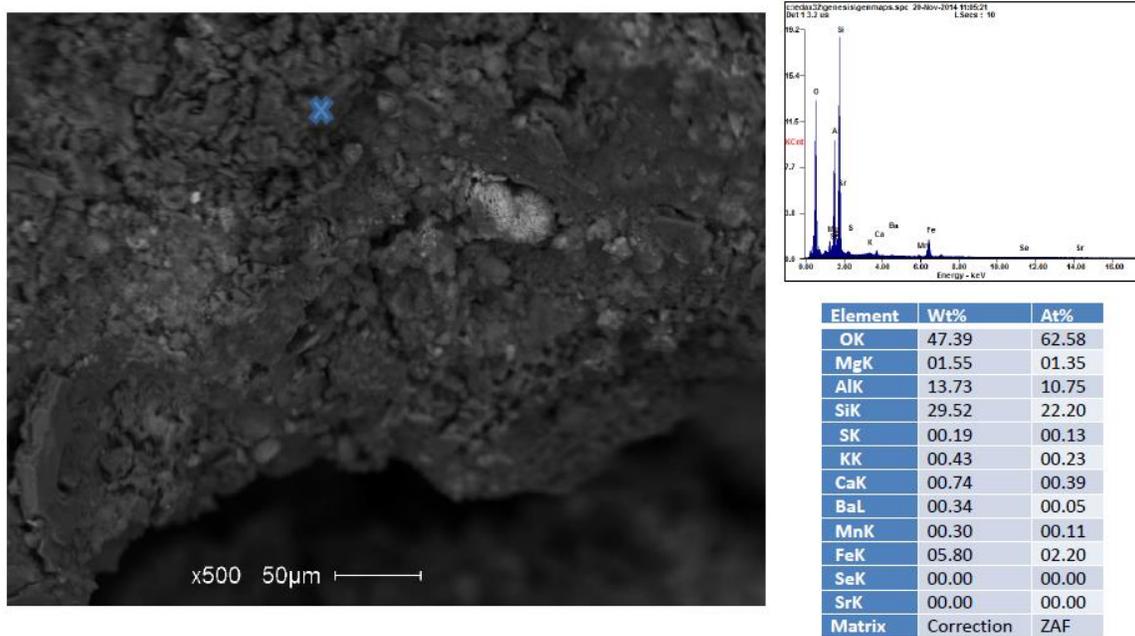


Figure 16. BSE image and EDS analysis from spot #2 from image 1 of specimen 168S.

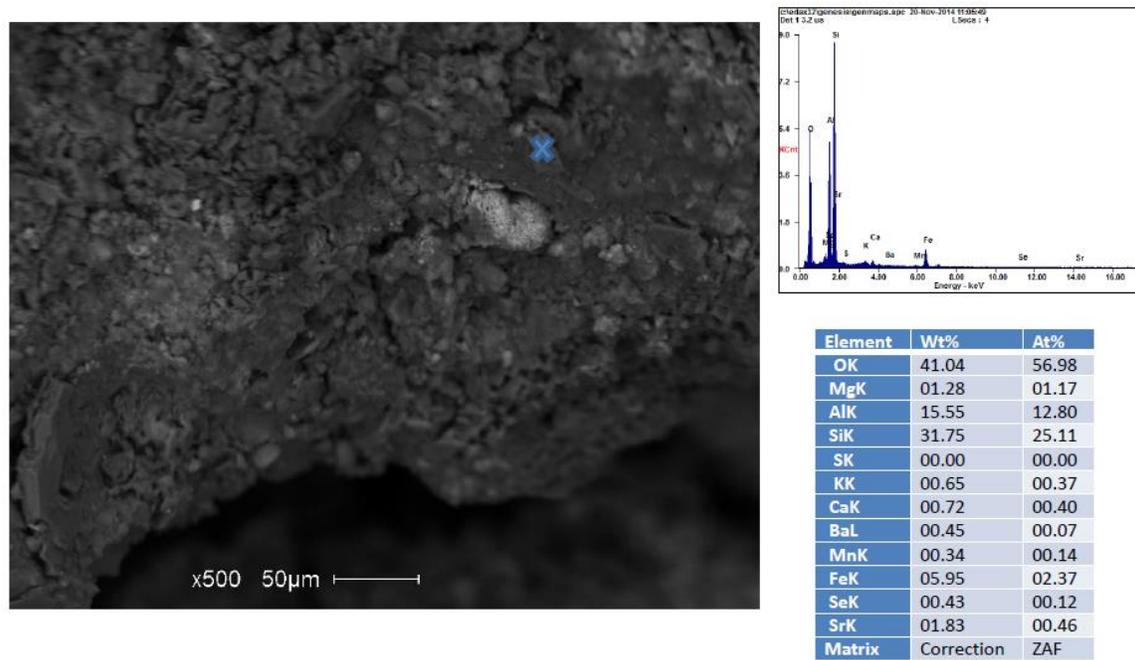


Figure 17. BSE image and EDS analysis from spot #3 from image 1 of specimen 168S.

The brighter, colloform-like phase that appears to be coating the substrate appears to be a manganese oxide on an aluminosilicate in Figure 18. No elevated selenium was associated with this spot.

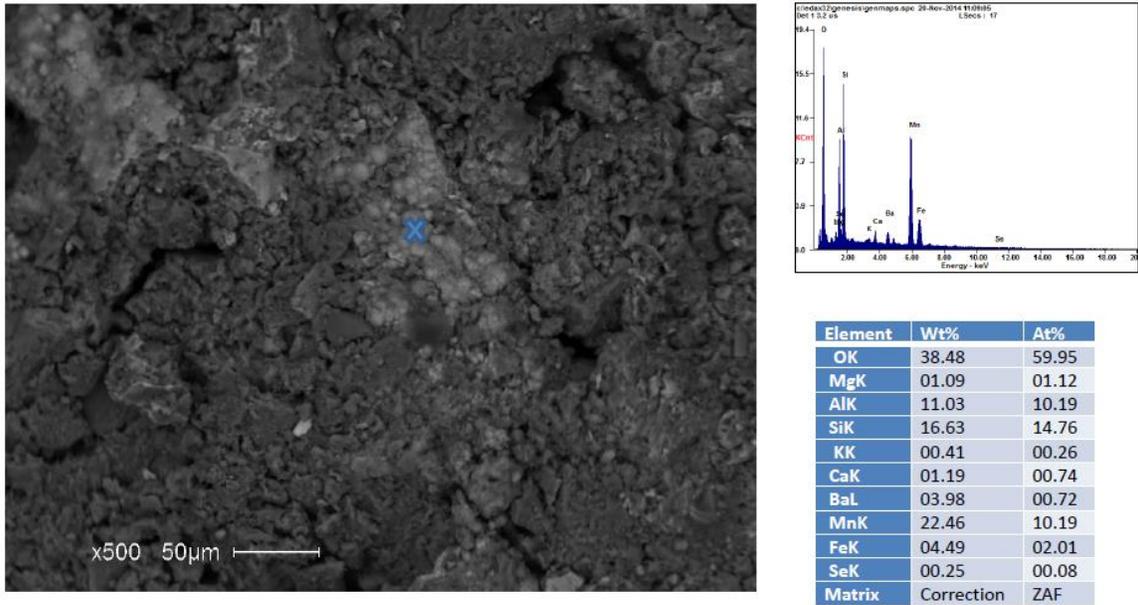


Figure 18. BSE image and EDS analysis from spot #1 from image 2 of specimen 168S.

Analysis of the darker phase shows that it is indeed an aluminosilicate, possible muscovite containing no selenium (Figure 19).

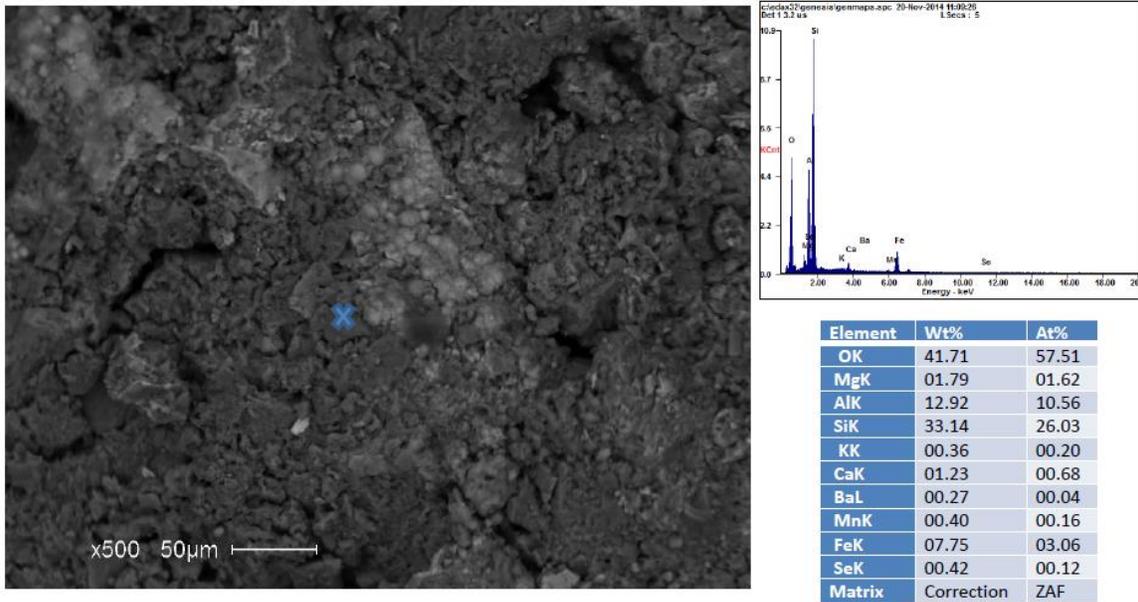


Figure 19. BSE image and EDS analysis from spot #2 from image 2 of specimen 168S.

Analysis of the edge of the bright colloform material shows again that it is manganese oxide, with a small amount of barium (Figure 20).

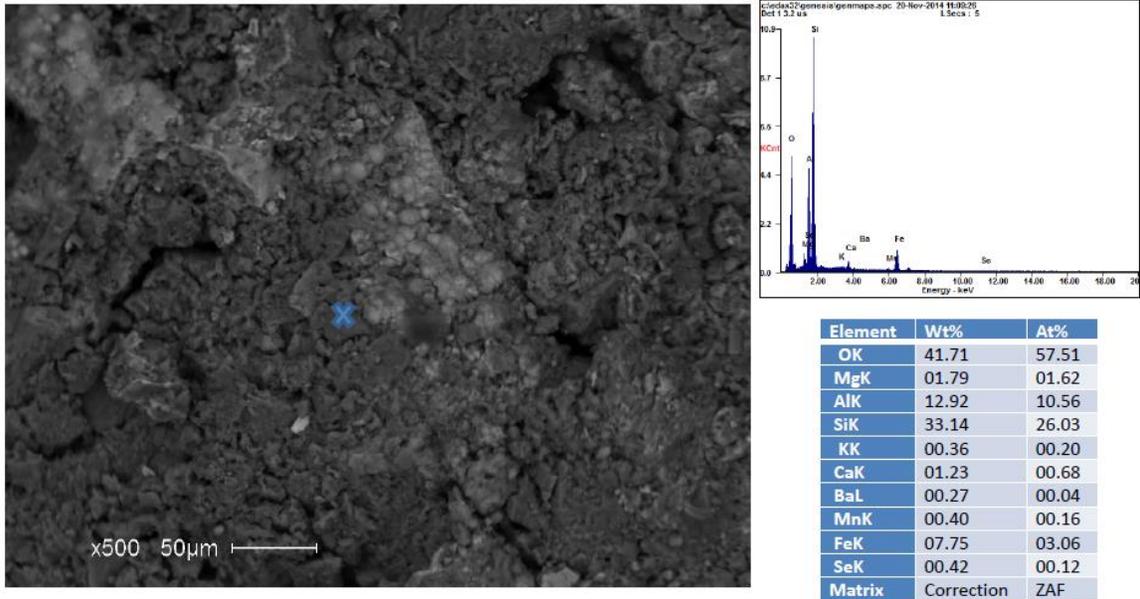


Figure 20. BSE image and EDS analysis from spot #3 from image 2 of specimen 168S.

The bright grain is barite (Figure 21).

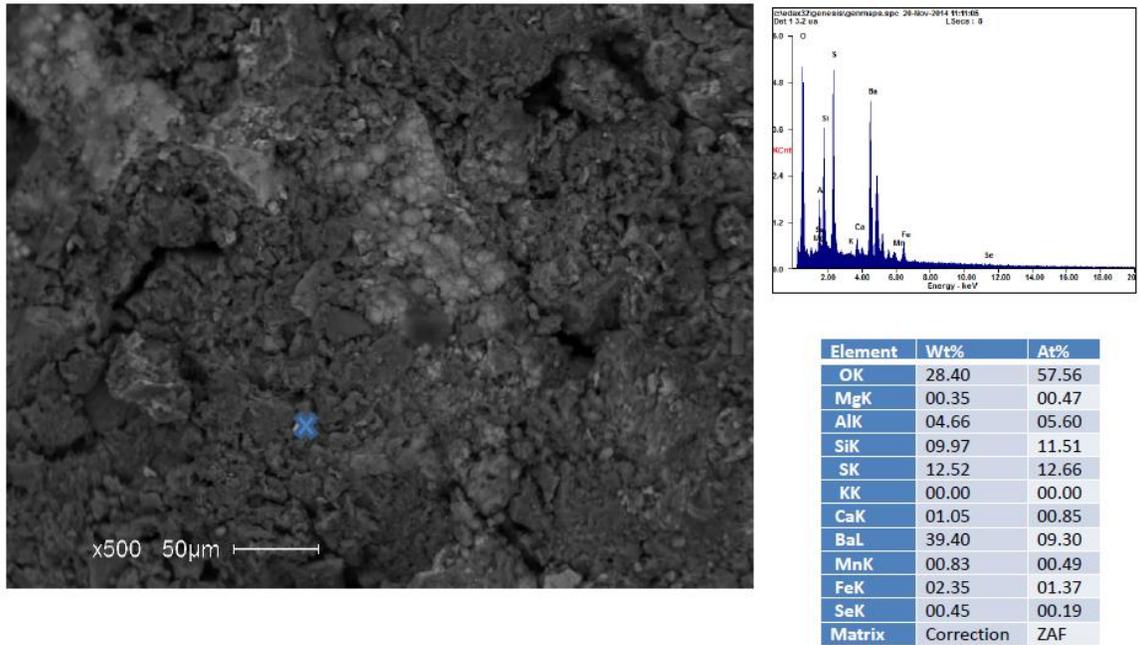


Figure 21. BSE image and EDS analysis from spot #4 from image 2 of specimen 168S.

**AEH-1409-214 (214)**

The bright phase spotted in the BSE image in Figure 22 is barite.

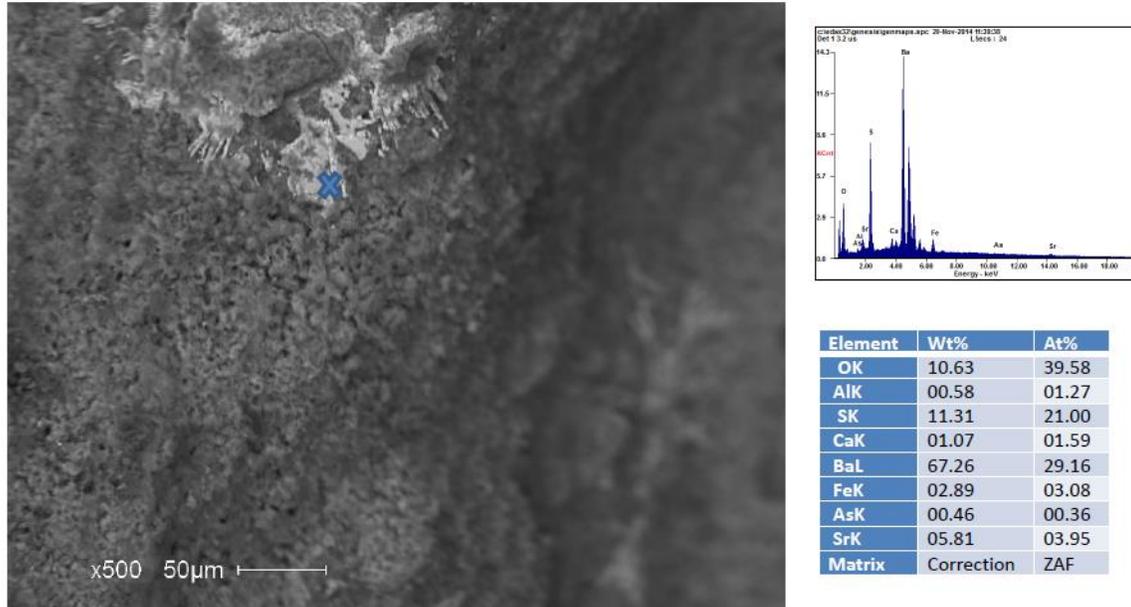


Figure 22. BSE image and EDS analysis from spot #1 from image 1 of specimen 214.

The phase less bright than barite is primarily iron oxide as shown in Figure 23. Small peaks observed in the X-ray spectrum were at characteristic energies for arsenic. The standardless EDS analysis determined 1.6% As.

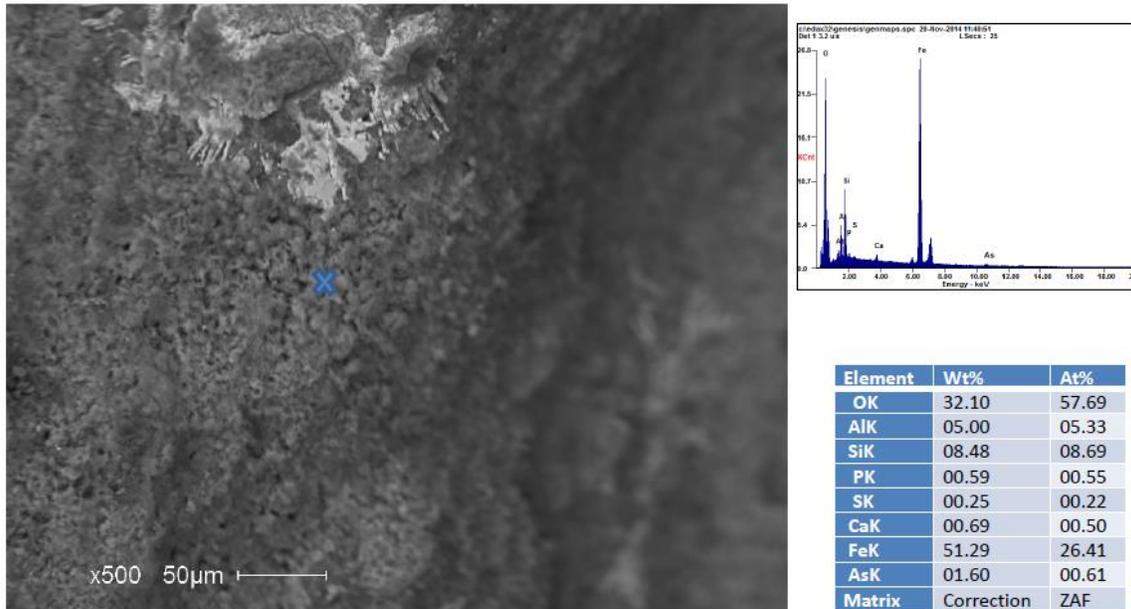


Figure 23. BSE image and EDS analysis from spot #2 from image 1 of specimen 214.

Analysis of the iron oxide at a second spot indicated 2.02% arsenic by EDS (Figure 24).

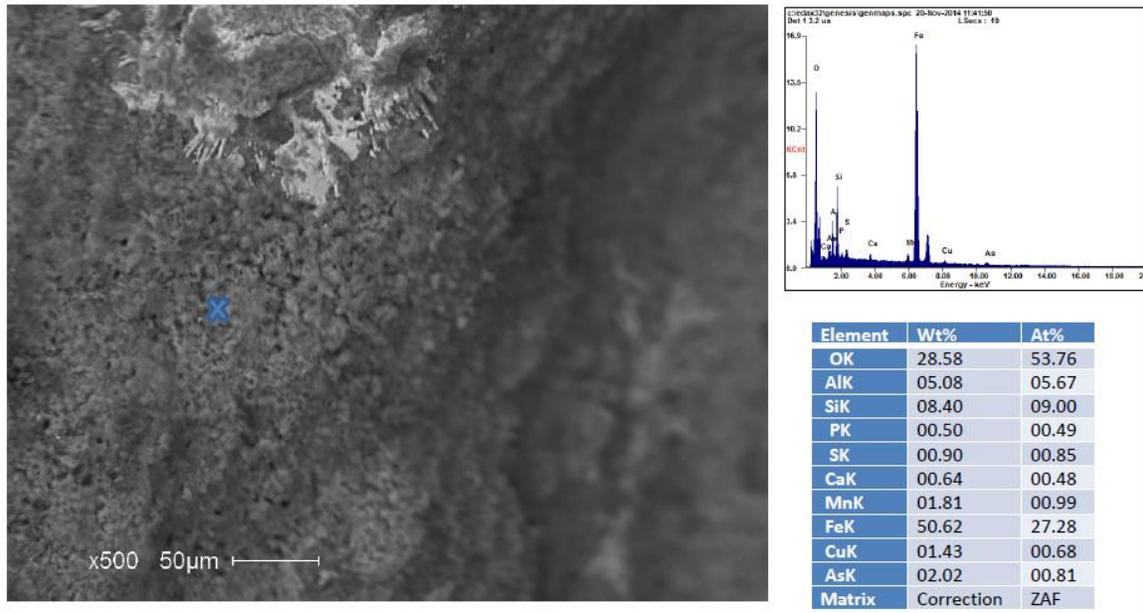


Figure 24. BSE image and EDS analysis from spot #3 from image 1 of specimen 214.

EDS analysis of the iron oxide at the boundary of the barite showed the presence of arsenic at 1.11% (Figure 25).

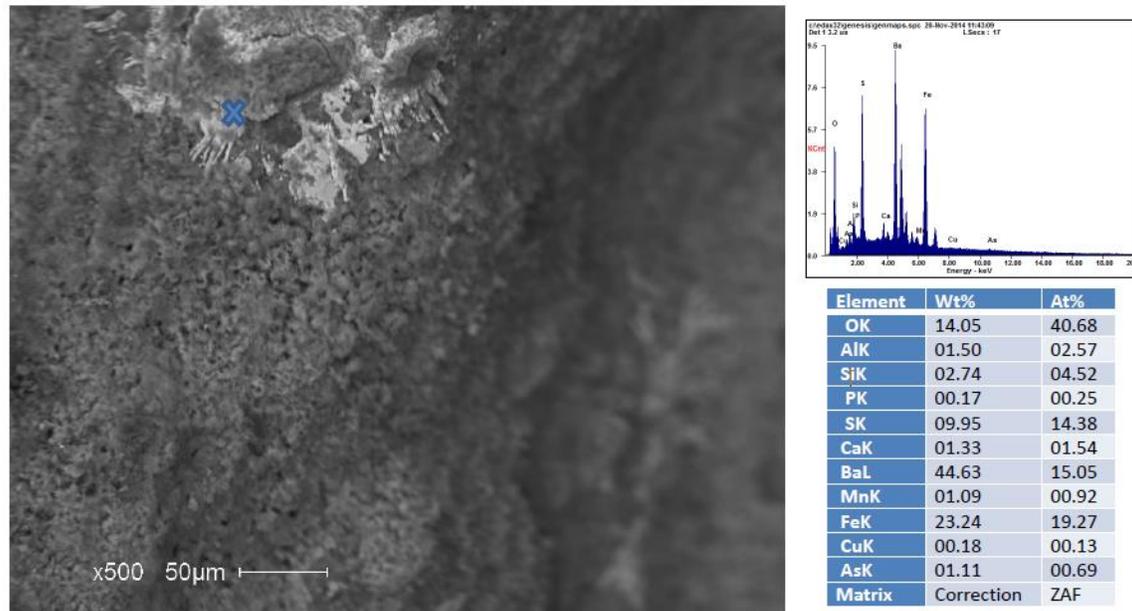


Figure 25. BSE image and EDS analysis from spot #4 from image 1 of specimen 214.

A bright grain is a relatively pure iron oxide as shown in Figure 26. There appeared to be no arsenic in this phase.

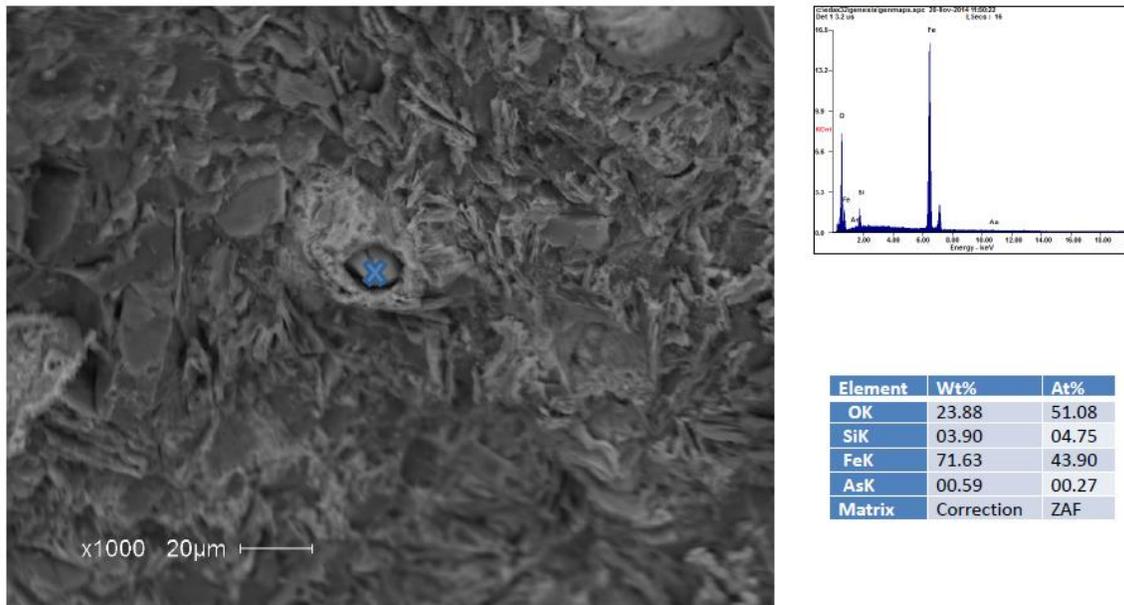


Figure 26. BSE image and EDS analysis from spot #1 from image 2 of specimen 214.

Also, the iron oxide surrounding this grain did not contain arsenic (Figure 27).

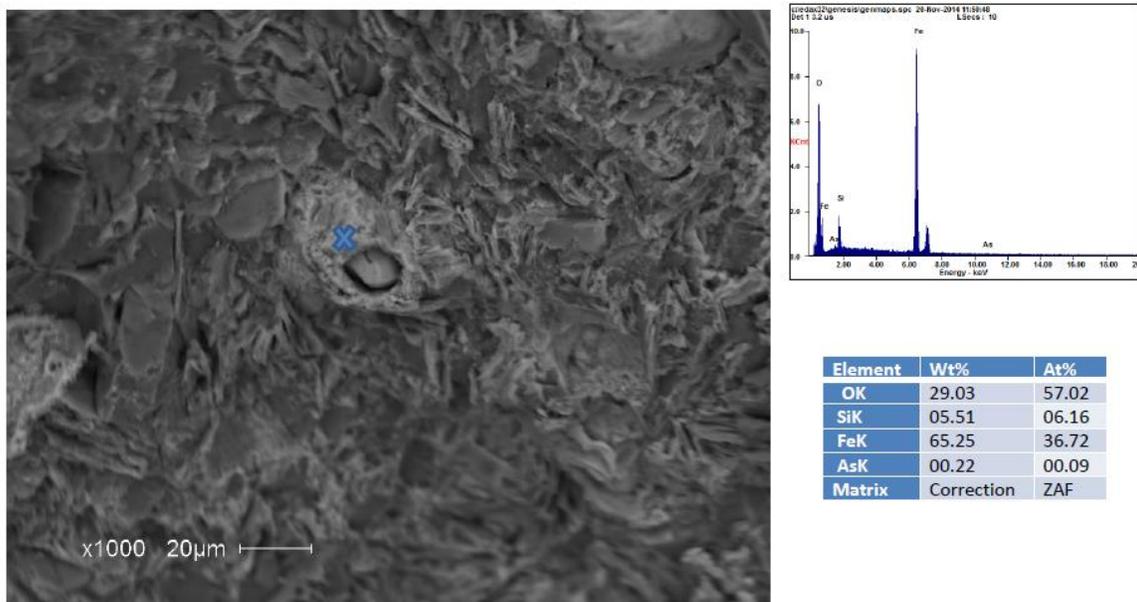


Figure 27. BSE image and EDS analysis from spot #2 from image 2 of specimen 214.

The flake-like grain adjacent to the iron oxide appears to be biotite according to the EDS spectrum in Figure 28.

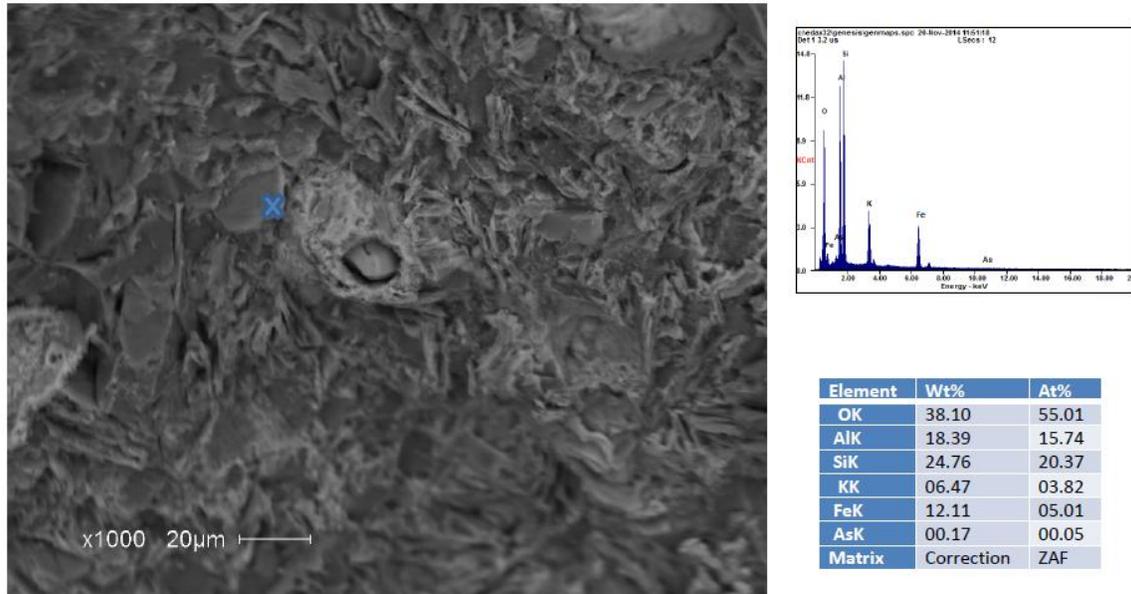


Figure 28. BSE image and EDS analysis from spot #1 from image 2 of specimen 214.

Other regions of iron oxide in this image did not contain arsenic (Figure 29 & Figure 30).

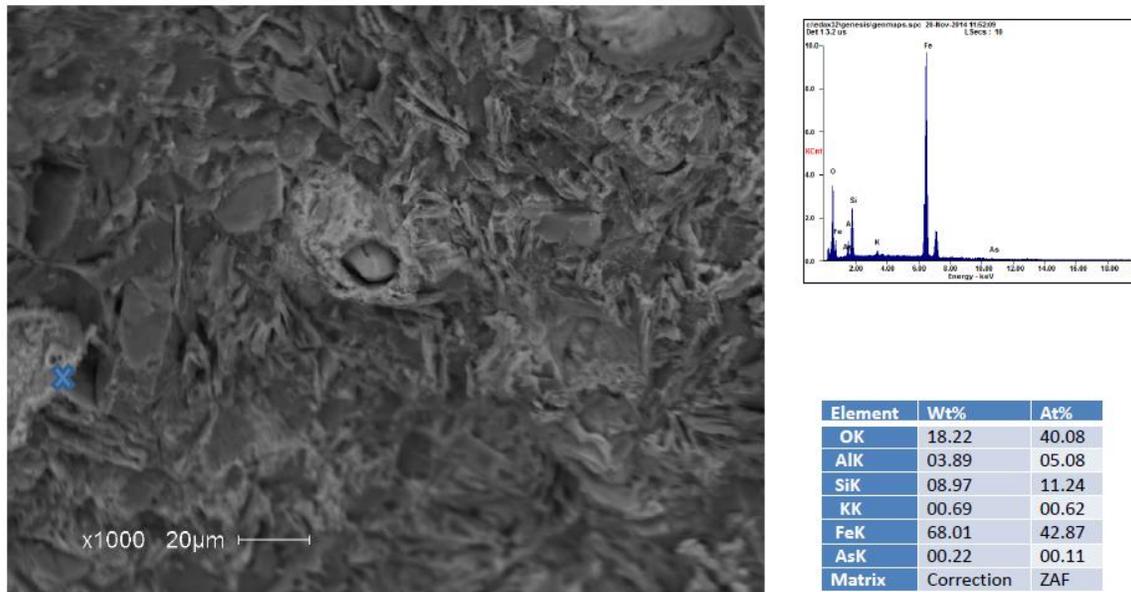


Figure 29. BSE image and EDS analysis from spot #2 from image 2 of specimen 214.

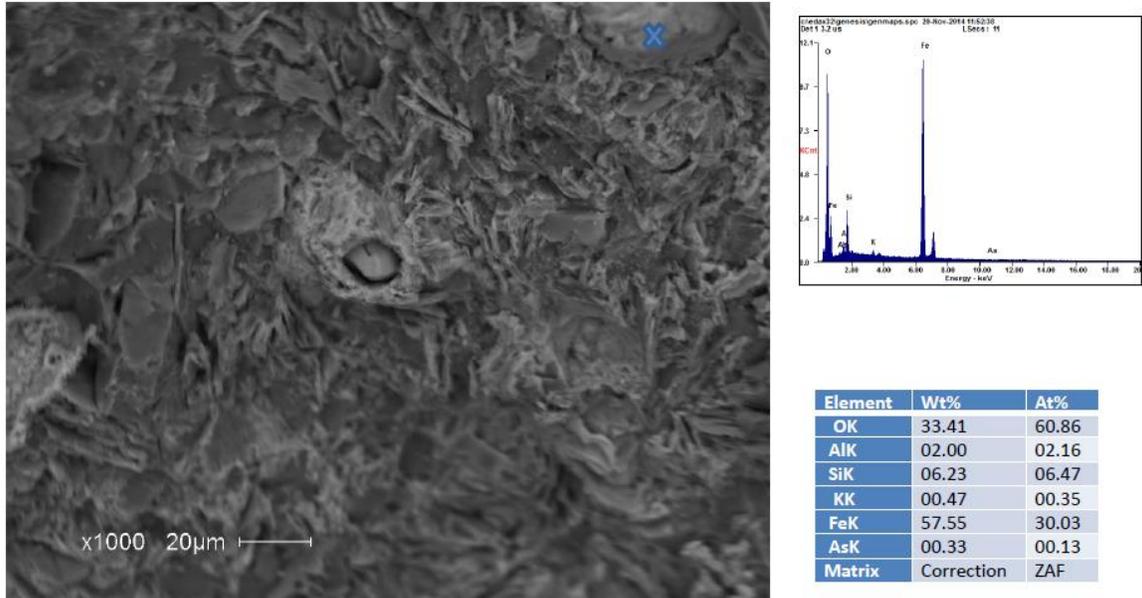


Figure 30. BSE image and EDS analysis from spot #3 from image 2 of specimen 214.

In the BSE image from sample 214 shown in Figure 31, the bright phase is barite, as has been typical in this sample set. No arsenic was observed with the barite.

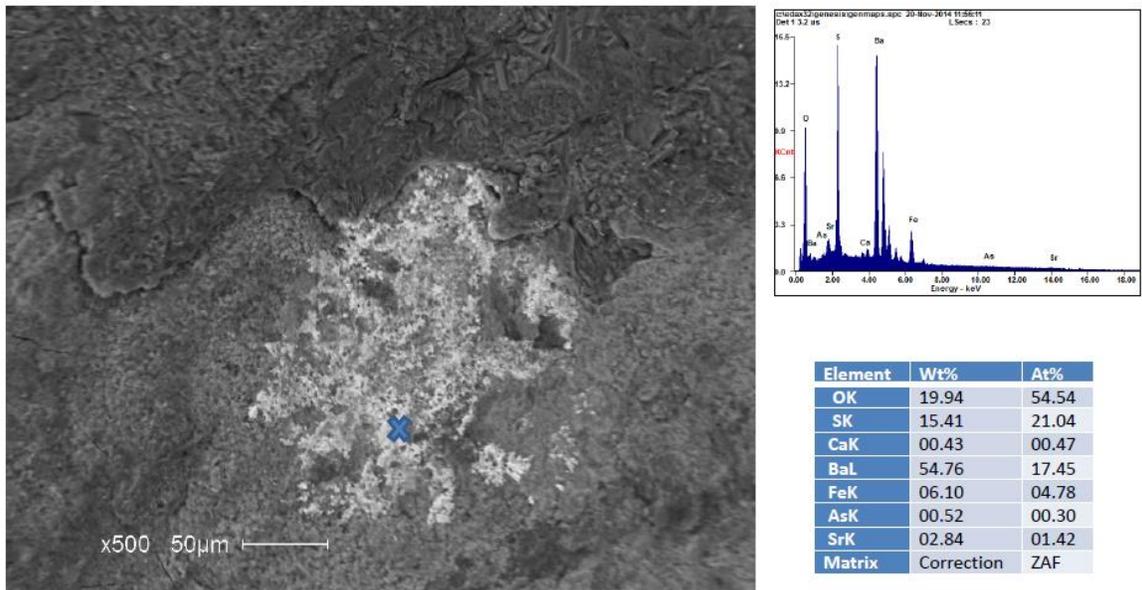


Figure 31. BSE image and EDS analysis from spot #1 from image 3 of specimen 214.

The darker material amongst the barite was spotted in the analysis in Figure 32 and Figure 33. This phase contained more iron oxide and showed trace arsenic at 1.39% and 1.69%, respectively, by EDS.

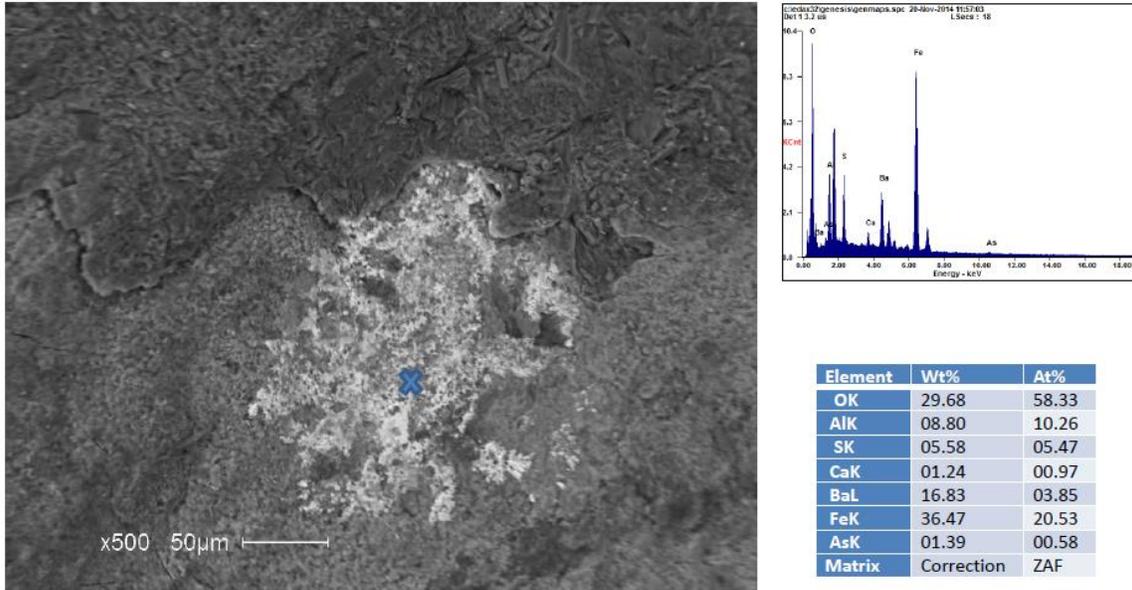


Figure 32. BSE image and EDS analysis from spot #2 from image 3 of specimen 214.

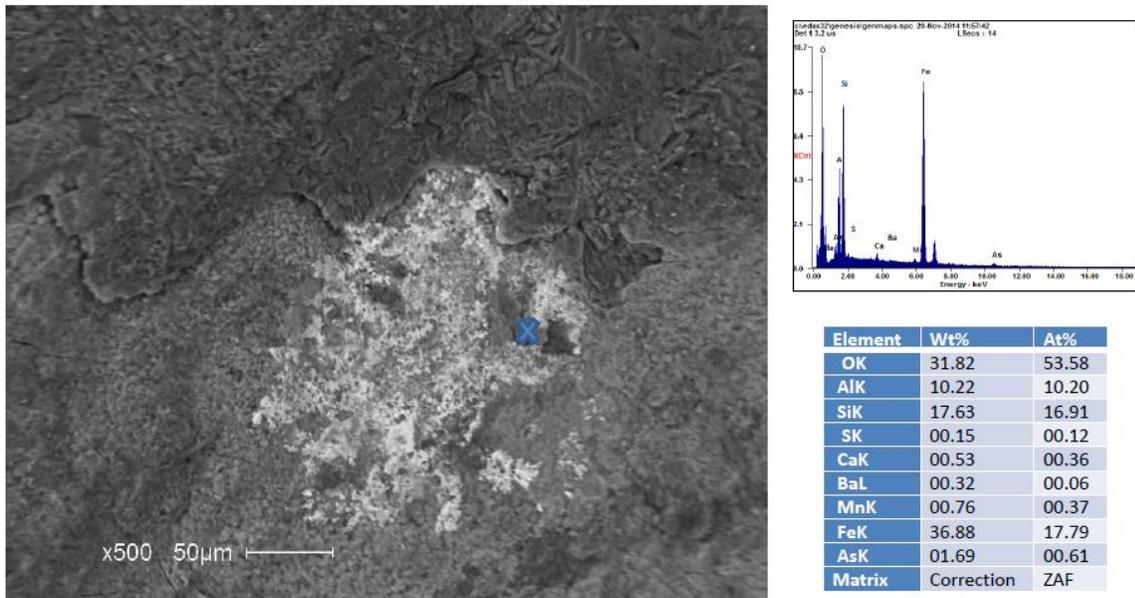


Figure 33. BSE image and EDS analysis from spot #3 from image 3 of specimen 214.

Several of the following images (Figure 34 through Figure 38) are included to show the range of arsenic found in the iron oxide phase. Arsenic was found at 1.46 to 2.69% in these acquisitions of the iron oxide.

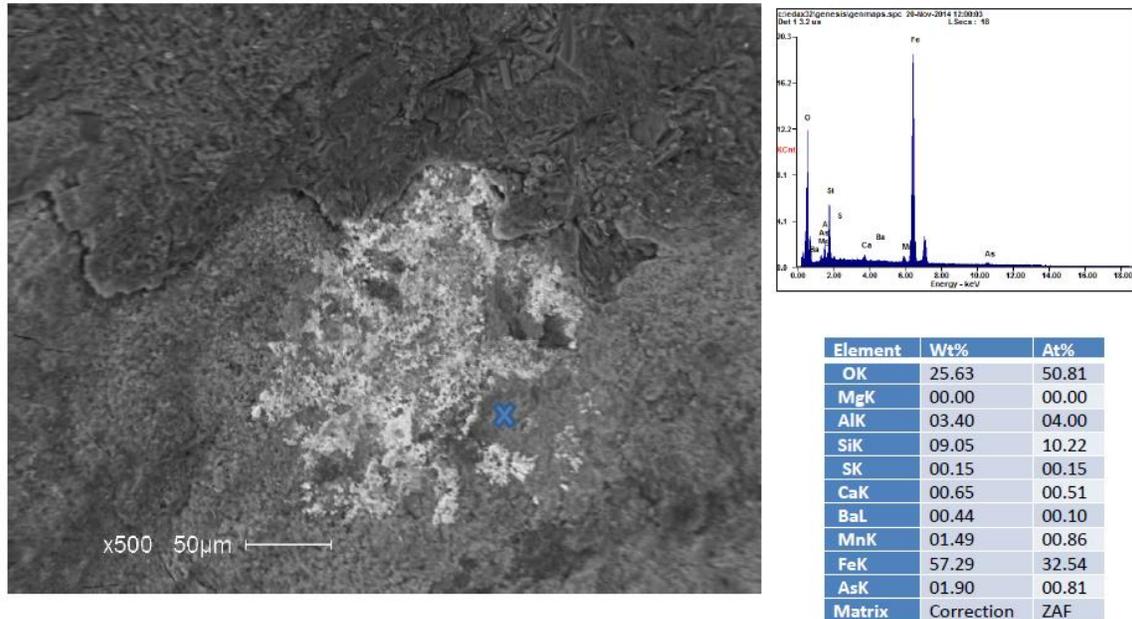


Figure 34. BSE image and EDS analysis from spot #4 from image 3 of specimen 214.

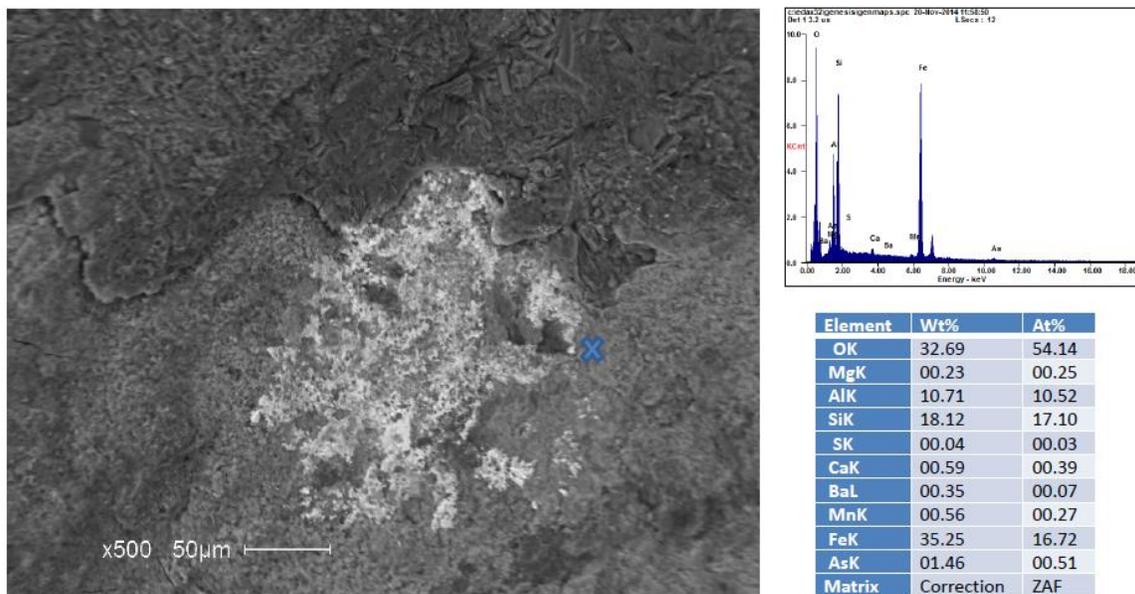


Figure 35. BSE image and EDS analysis from spot #5 from image 3 of specimen 214.

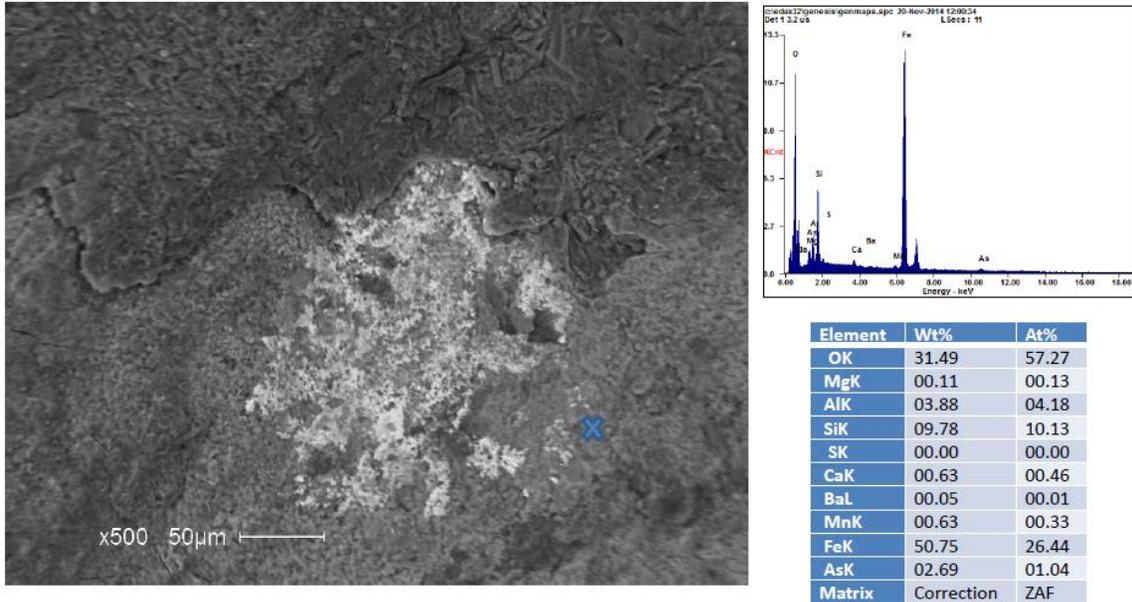


Figure 36. BSE image and EDS analysis from spot #6 from image 3 of specimen 214.

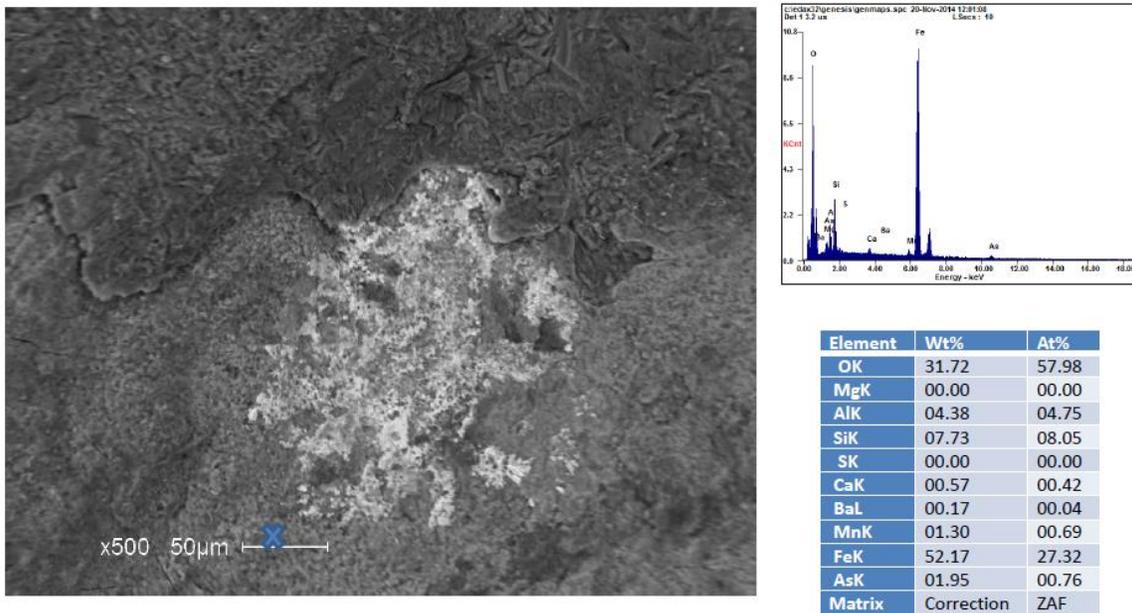


Figure 37. BSE image and EDS analysis from spot #7 from image 3 of specimen 214.

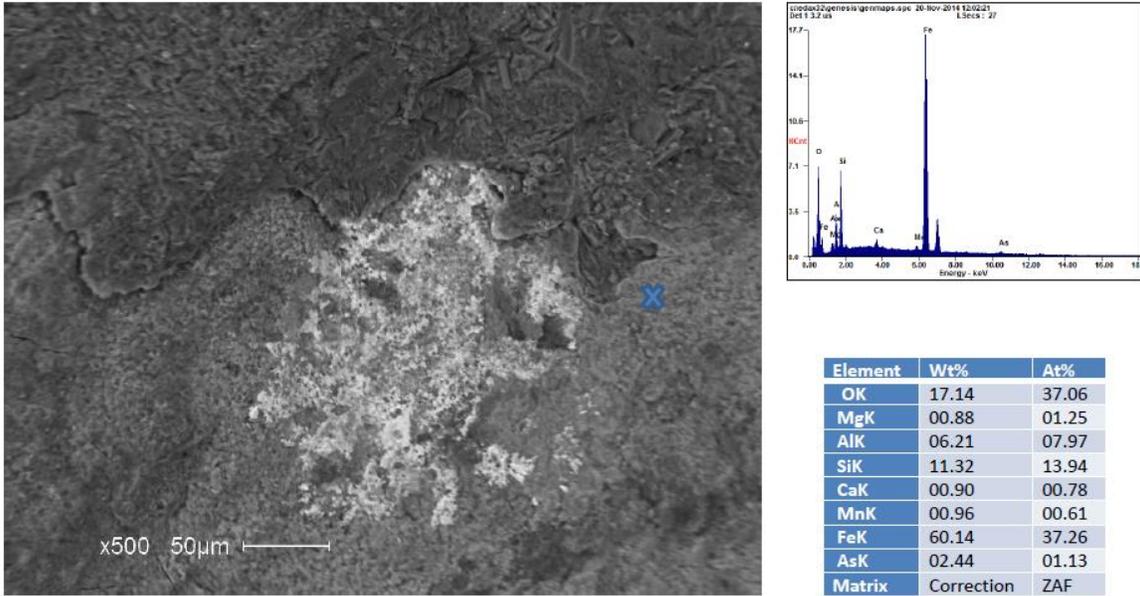


Figure 38. BSE image and EDS analysis from spot #8 from image 3 of specimen 214.

The dark phase in this image appeared to be titanite (Figure 39).

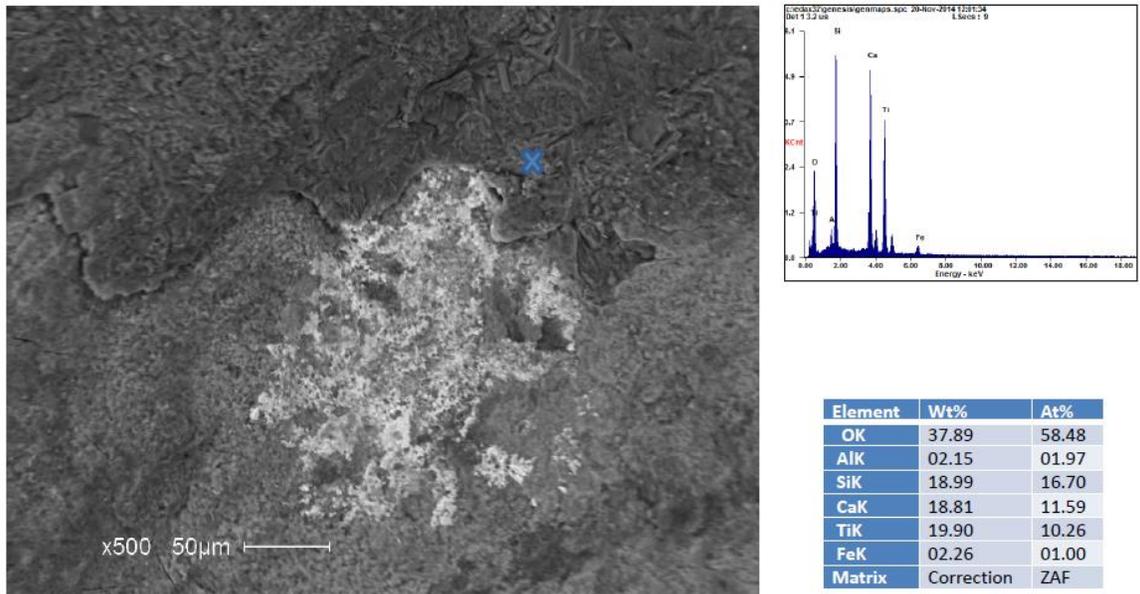


Figure 39. BSE image and EDS analysis from spot #9 from image 3 of specimen 214.