Atlantic Richfield Company

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February 24, 2016

Mr. Charlie Coleman
U.S. EPA, Region VIII
Federal Building, 10 West 15th Street
Suite 3200
Helena, Montana 59626-0096

RE: ACM Smelter and Refinery Site Operable Unit 1 RI/FS – Transmittal of Two CDs with Final Baseline Human Health Risk Report

Dear Charlie:

In accordance with your approval letter dated February 5, 2016, we have prepared the enclosed CDs containing the Final Baseline Human Health Risk Assessment (HHRA) Report for the Anaconda Copper Mining Company (ACM) Smelter and Refinery Site, Operable Unit 1 (OU1) for your files.

If you have any questions or comments, please contact me at (406) 723-1832.

Sincerely,

Luke Pokorny
Project Manager

W/enclosures (2)

File: MiningSharePoint@bp.com

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8, MONTANA OFFICE
FEDERAL BUILDING, 10 W. 15th STREET, SUITE 3200
HELENA, MONTANA 59626

Ref: 8MO

February 05, 2016

Mr. Luke Pokorny
Atlantic Richfield Company
317 Anaconda Road
Butte, Montana 59701

Dear Luke:

EPA, in consultation with DEQ, approves Atlantic Richfield's *Final Baseline Human Health Risk Assessment (HHRA) Report for the ACM Smelter and Refinery Site, Operable Unit 1 - Community Soils Areas of Interest (CSAOI) and Outlying Areas, dated January 2016.* Please provide EPA two complete copies of the Final HHRA on CD for our files.

If you have any questions, please give me a call.

Sincerely,

Charles Coleman
ACM Project Manager

cc: Andy Lensink, 8ENF-L (email)
Charles Partridge, 8EPR-PS (email)
Dick Sloan, DEQ (email)
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Atlantic Richfield Company
Butte, Montana

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BASELINE HUMAN HEALTH RISK ASSESSMENT

ACM SMELTER AND REFINERY SITE OPERABLE UNIT 1

RAMBOLL ENVIRON

BASELINE HUMAN HEALTH RISK ASSESSMENT
ACM SMELTER AND REFINERY SITE OPERABLE UNIT 1

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ACRONYMS AND ABBREVIATIONS

95UCLM:	95 percent upper confidence limit of the arithmetic mean
ACM:	Anaconda Copper Mining Company
ADD:	average daily dose
ALM:	Adult Lead Methodology
ATV:	all-terrain vehicle
CDC:	Center for Disease Control and Prevention
COI:	chemical of interest
COPC:	chemical of potential concern
CSAOI:	Community Soils Areas of Interest
CSM:	conceptual site model
CTE:	central tendency exposure
ECDR:	Electric City Dirt Riders
EPC:	exposure point concentration
FS:	feasibility study
GI:	gastrointestinal
HHRA:	human health risk assessment
HI:	hazard index
HQ:	hazard quotient
IEUBK:	Integrated Exposure, Uptake, and Biokinetic
IVBA:	in vitro bioaccessibility data
LADD:	lifetime average daily dose
MDEQ:	Montana Department of Environmental Quality
MSD:	mass soil-to-dust transfer factor
NHANES:	National Health and Nutrition Examination Survey
NOAEL:	no-observable-adverse-effect-level
OU1:	Operable Unit 1
PEF:	particulate emission factor
PRG:	preliminary remediation goal
RBA:	relative bioavailability
RfD:	reference dose
RI:	remedial investigation
RME:	reasonable maximum exposure
SF:	slope factor
SOW:	Statement of Work
USEPA:	US Environmental Protection Agency

UNITS OF MEASURE

cm^2:	square centimeters
cm/hr:	centimeters per hour
g/day:	grams per day
kg/m^3:	kilograms per cubic meter
L/day:	liters per day
m^3/day:	cubic meters per day
mg/kg:	milligrams per kilogram
mg/kg-day:	milligrams per kilogram per day
$(mg/kg\text{-}day)^{-1}$:	per milligram per kilogram per day
mg/L:	milligrams per liter
mL/hr:	milliliters per hour
µg/day:	micrograms per day
µg/dL:	micrograms per deciliter
µg/g:	micrograms per gram
$µg/m^3$:	micrograms per cubic meter
$(µg/m^3)^{-1}$:	per microgram per cubic meter

1. INTRODUCTION

Atlantic Richfield Company and ARCO Environmental Remediation, LLC (collectively "Atlantic Richfield") are implementing a Remedial Investigation/Feasibility Study (RI/FS) at Operable Unit 1 (OU1) of the Anaconda Copper Mining Company (ACM) Smelter and Refinery Site (the ACM Site) pursuant to the Administrative Settlement Agreement and Order on Consent (Settlement Agreement/CO) between Atlantic Richfield and the US Environmental Protection Agency (USEPA) dated September 8, 2011 (USEPA 2011a) and its attached Statement of Work (SOW). USEPA is the lead agency for the OU1 RI/FS, and the Montana Department of Environmental Quality (MDEQ) is participating as a support agency. The SOW specifies that USEPA will conduct the baseline human health risk assessment (HHRA) component of the OU1 RI and that assessment of ecological risks for OU1 will be deferred to the future RI/FS for the former smelter and refinery property and the Missouri River. In May 2014, USEPA requested that Atlantic Richfield conduct the baseline HHRA.

USEPA recently approved the RI report (Formation 2015) and baseline HHRA work plan (ENVIRON 2015b) for OU1. The approved HHRA work plan is included as Appendix A to this report. This baseline HHRA report and the approved RI report will be used by USEPA to support risk management decisions for OU1. The scope of the HHRA and its findings are not intended to supersede USEPA's consideration of ecological risks for OU1 that has been deferred for evaluation in conjunction with other ACM Site operable units.

1.1 Focus of the HHRA

The baseline HHRA focuses on people living, working, and recreating within OU1 and their potential exposures to lead and arsenic in OU1 soil, dust, air, sediment, and surface water. As defined by USEPA (2011a) in the Settlement Agreement/CO and described in the RI report, OU1 includes the Community Soils Areas of Interest (CSAOI) and Outlying Areas as shown on Figure 1-1. USEPA has also designated a portion of the railroad beds within Black Eagle as OU1; RI/FS activities within the "Railroad Corridor" are being conducted under USEPA's Unilateral Administrative Order issued to BNSF Railway Company (USEPA 2011b). The former smelter and refinery property and the Missouri River are not included in OU1.

Baseline risks are risks that might exist if no remediation or institutional controls were applied at a site. As is typical of HHRAs conducted prior to the feasibility study, this HHRA presents estimates of typical and upper end risks present on average in different areas within OU1. The CSAOI includes Black Eagle in the southern portion and residential and undeveloped lots in the northern portion. The Outlying Areas include the northern portion of Great Falls (south of the Missouri River) and unincorporated areas of Cascade County that surround the CSAOI. The Outlying Areas include areas developed for residential, commercial, industrial, agricultural, and recreational uses, as well as undeveloped land areas, though not all land uses are currently present in all portions of the Outlying Areas. While future land use of individual parcels may change, as stated in the approved HHRA work plan, future land use within and surrounding OU1 is not expected to differ substantially from current land uses; therefore, land use assumptions included in the baseline HHRA apply to both current and future land uses.

1.2 Document Organization

In addition to the introduction, this document consists of the following sections:

- Section 2 – Conceptual Site Model Summary
- Section 3 – Exposure Assessment

- Section 4 – Toxicity Assessment
- Section 5 – Arsenic Risk Characterization
- Section 6 – Lead Risk Characterization
- Section 7 – Uncertainty Assessment
- Section 8 – Conclusions
- Section 9 – Range of Preliminary Remediation Goals
- Section 10 – References

All tables and figures are located at the end of the document. Detailed information and analyses supporting selection or derivation of exposure inputs used in this baseline HHRA were previously documented in the approved HHRA work plan, which is included as Appendix A to this report. Reference to specific sections of the work plan is provided in this report in lieu of representing the information herein. New analyses and updated assumptions not included in the work plan are detailed in this report.

2. CONCEPTUAL SITE MODEL SUMMARY

As detailed in the approved baseline HHRA work plan (Appendix A), the conceptual site model (CSM) for OU1 integrates information on the physical setting and potentially exposed populations within OU1 with identification of potential pathways for exposure of people to chemicals originating from the site. The CSM considers chemical sources, release mechanisms, transport pathways, and potential routes of human exposure and forms the basis for specific exposure scenarios evaluated in the baseline HHRA. Early in the RI process, a preliminary CSM was used to guide the evaluation of site media; this CSM continued to be updated throughout the RI process based on consideration of new information provided by the RI. The CSM was again updated upon completion of the RI, resulting in the current CSM (Figure 2-1), which summarizes the potentially complete exposure pathways for lead and arsenic that are evaluated in this baseline HHRA. Details of the data and approaches used to screen OU1 media of potential concern and to characterize pathways of lead and arsenic exposure of people living, working, and recreating within OU1 is documented in the approved baseline HHRA work plan and briefly summarized below.

2.1 Chemicals and Media of Potential Concern

The approved HHRA work plan describes analytical data for residential and non-residential (e.g., commercial, agricultural, recreational, and vacant land) soil samples from the CSAOI and Outlying Areas, groundwater from water supply wells, surface water in two natural drainages and storm water culverts, sediment in natural drainages and storm water culverts, indoor dust samples from homes in the CSAOI, and exterior paint tests for lead on homes in the CSAOI. Two chemicals of potential concern (COPCs), lead and arsenic, were identified as the focus of the baseline HHRA based on a health-protective screening process for chemicals of interest (COIs) in soil, groundwater, surface water and sediment. Based on additional medium-specific screening for lead and arsenic, the following chemicals and media of potential concern are the focus of exposures evaluated in this baseline HHRA:

- lead and arsenic in residential and non-residential soil from the CSAOI and Outlying Areas;
- lead and arsenic in fugitive dusts originating from soil[1] from the CSAOI and Outlying Areas;
- arsenic[2] in surface water from the Black Eagle stream drainages within the CSAOI;
- arsenic[3] in sediment deposited in the Black Eagle stream drainage in the CSAOI and in the Electric City Dirt Riders (ECDR) drainage[4] in the Outlying Areas;
- lead and arsenic in soil from unpaved roads and alleys from the CSAOI; and
- lead and arsenic in indoor (living space) dusts and attic dusts from residential properties within the CSAOI.

[1] Arsenic in ECDR sediment is treated as soil for evaluation of fugitive dust exposures within the ECDR; see Section 3.1.1.2 of Appendix A.

[2] As discussed in Section 2.3 of the approved work plan (Appendix A), the process for selecting chemicals of potential concern for evaluation in the baseline HHRA included screening maximum concentrations of all COIs in OU1 surface water samples against USEPA risk-based screening levels (RSLs) for tap water. However, as none of the surface water bodies sampled in OU1 is accessed by people for drinking water, use of tap water RSLs for screening may be overly conservative. For the Black Eagle stream drainage, arsenic was the only COI to exceed the tap water RSL, therefore, lead was eliminated from further evaluation in surface water from the Black Eagle stream drainages within the CSAOI.

[3] As discussed in Section 2.4 of the approved work plan (Appendix A), maximum sediment concentrations of each of the OU1 COIs were screened against USEPA RSLs for residential exposure to soil as a surrogate for sediment. Arsenic was the only COI to exceed the soil RSL, therefore lead in sediment was eliminated from further evaluation in the baseline HHRA.

[4] As noted in Appendix A, Section 4.2.5, ingestion of arsenic from ECDR sediment is evaluated as part of ECDR soils.

2.2 OU1 Populations and Potentially Complete Exposure Pathways

Based on consideration of current and likely future uses of OU1, the approved HHRA work plan identified people living, working, or recreating within OU1 as the populations with the greatest potential for exposure to lead and arsenic in site media. Specifically, the CSM (Figure 2-1) includes both a CSAOI resident and a southern Outlying Area (i.e., Great Falls) resident, an ATV/dirt bike rider, and three types of workers (a general outdoor worker, a utility worker, and an indoor worker).

For all populations identified, exposure to arsenic and lead is most likely to occur by contact with soil and/or dusts originating from soil. The primary intake route for arsenic and lead in soil and dust is expected to result from incidentally ingesting soil particles adhered to skin via hand-to-mouth activities. Direct absorption of soil arsenic and lead through skin is expected to be minimal and is not evaluated in the baseline HHRA.

Incidental ingestion of arsenic and lead in surface soil and indoor dust are potentially complete exposure pathways for OU1 residents. Incidental ingestion of surface soil is a potentially complete exposure pathway for outdoor workers, while indoor dust is a potentially complete exposure pathway for indoor workers. Utility workers and ATV/dirt bike riders may be exposed to both surface and subsurface soil via incidental ingestion. Inhalation of airborne soil particulate by residents, outdoor and utility workers, and ATV/dirt bike riders is also considered a potentially complete exposure pathway.

Contact with surface water and sediment containing arsenic[5] is expected to be less than contact with soil, but also represents a potentially complete arsenic exposure pathway for CSAOI residents in addition to soil/dust. Residents may be exposed to arsenic in surface water and sediment during recreational activities in which incidental ingestion of water and/or sediment occurs. As with soil, direct absorption of arsenic in sediment through skin is expected to be minimal and is not evaluated in the baseline HHRA. Dermal contact with arsenic in surface water is evaluated.

Residents may also incidentally ingest lead and arsenic in attic dust when accessing attics used for storage. Such exposures are likely to occur infrequently and be of short duration. Direct absorption of arsenic and lead through skin is expected to be minimal and is not evaluated in the baseline HHRA. As shown in Figure 2-1, the source of lead and arsenic in soil is assumed to be the same as for attic dust, but soil is not assumed to contribute to attic dust.

Given these populations and media of potential concern, this baseline HHRA includes quantitative evaluation of the following receptors and exposure scenarios:

- A resident (child and adult) within the CSAOI who periodically visits the Black Eagle drainage area. Exposure pathways for the resident receptors are assumed to include arsenic and lead from residential soils (0 to 6 inch depth interval[6]), indoor dust originating from residential surface soils (0 to 2 inch depth interval), and airborne particulate from resuspended community-wide surface soils (0 to 2 inch depth interval). The resident is also assumed to be exposed to arsenic in surface

[5] Please see additional discussion provided in footnotes 2 and 3.

[6] Although direct contact by residents with soil on their properties is most likely to occur at the surface, some residential activities, such as gardening and child play increase the potential that direct contact could also occur with shallow soils beneath the surface. Additionally, based on information presented in the RI report, concentrations of arsenic in OU1 residential soil were generally found to increase with depth, while lead was generally highest at the surface (Formation 2015). Thus, defining residential surface soil as the 0 to 6 inch depth interval addresses potential differences in the distributions of arsenic and lead in shallow soils and potential activity-based considerations that are specific to OU1 residents. While it is possible that a resident may also contact deeper soils (i.e., 6 to 18 inch depths), the frequency of such contact on residential properties is expected to be very low.

water and sediment from the Black Eagle stream drainage (all sampled depth intervals). The CSAOI resident adult is also assumed to be exposed to arsenic and lead in attic dust.[7]

- A resident (child and adult) within the southern portion of the Outlying Areas (Great Falls[8]) who is assumed to be exposed to arsenic and lead in residential surface soils (0 to 6 inch depth interval), indoor dust originating from residential soils (0 to 2 inch depth interval), and airborne particulate from resuspended community-wide surface soils (0 to 2 inch depth interval).
- An adult outdoor worker within the CSAOI and the northern portion of the Outlying Areas (excluding the ECDR area and associated soils) who is assumed to be exposed to arsenic and lead primarily in non-residential surface soils[9] and surface soil-derived airborne particulate (0 to 2 inch depth interval for both media).
- An adult utility worker within the CSAOI and the northern portion of the Outlying Areas (excluding the ECDR area and associated soils) exposed to arsenic and lead in non-residential surface and subsurface soils (all sampled depth intervals) through incidental ingestion of soil and inhalation of soil-derived airborne particulate.
- An adult indoor worker within the CSAOI and in the northern Outlying Areas who is assumed to be exposed to arsenic and lead in indoor dust within a commercial building that originates from non-residential surface soil (0 to 2 inch depth interval).
- An ATV/dirt bike rider (older teen/young adult[10]) who regularly rides at the ECDR track with assumed exposures to arsenic and lead in ECDR surface and subsurface soils (all sampled depth intervals) as well as in airborne particulate originating from these soils. The rider is also assumed to be exposed to arsenic in sediment and in sediment-derived airborne particulate from the ECDR drainage while engaged in track use.

Inputs used to quantitatively evaluate each of these exposure scenarios are summarized in the following sections.

[7] Attic dust samples were only collected in the southern CSAOI but will be used to evaluate risks to both southern and northern CSAOI residents.

[8] Throughout the remainder of this report the southern portion of the Outlying Areas is referred to as the Great Falls area.

[9] Based on information presented in the RI report, concentrations of metals in undisturbed non-residential soil were generally higher at the surface (Formation 2015).

[10] As discussed in Section 3.1.1.2 of the approved HHRA work plan, track users under the age of 14 years must be accompanied by an adult when using the track. Therefore, this individual is assumed to be older than 14 years old. For the purposes of the baseline HHRA, exposure assumptions (e.g., body weight, contact rates, exposure duration, skin surface area, etc.) are assumed to be the same as for an adult.

3. EXPOSURE ASSESSMENT

The approved HHRA work plan (Appendix A) summarizes the assessment of available RI data adequacy for use in the baseline HHRA and details the approaches used to estimate exposures to people living, working, and recreating within OU1. As noted in the work plan, USEPA risk assessment guidance specifies different approaches to assess risks from exposure to lead versus non-lead chemicals, such as arsenic. Exposure input parameters used to assess risks from arsenic exposure also differ from those used to model lead risks. This section of the baseline HHRA summarizes the exposure input parameters for each. For arsenic, a summary of estimated intakes for each exposure scenario is also provided. These intakes are combined with toxicity data in Section 4 to characterize arsenic risks presented in Section 5. For lead, input values for the child and adult risk models are summarized. Lead risk modeling results are presented in Section 6. Uncertainties associated with exposure parameter inputs are summarized in Section 7.

Details regarding the rationale for selection of most exposure inputs are provided in Appendix A, the approved HHRA work plan. Exposure point concentrations (EPCs) calculated for residential and non-residential exposures to arsenic are detailed below. EPCs selected for estimating risks represent the lower of the 95 percent upper confidence limit of the arithmetic mean (95UCLM) or maximum concentration for each dataset.

The arsenic relative bioavailability (RBA) input has been updated since completion of the approved HHRA work plan based on a recently published study by Bradham et al. (2015), which used mouse data to develop a new regression equation relating arsenic in vitro bioaccessibility data (IVBA) to arsenic RBA values. Applying the Bradham et al. (2015) regression to arsenic IVBA data summarized in ENVIRON (2015a) results in a mean arsenic RBA of 29 percent for all samples (n = 35). An update to ENVIRON (2015a), which documents the updates to the site-specific arsenic RBA based on use of the Bradham et al. (2015) regression is provided as Appendix B to this report.

3.1 Arsenic – Residential Exposure Scenarios

Residential exposure scenarios for the northern and southern CSAOIs and the Great Falls area are evaluated in the baseline HHRA. The primary exposure unit for the OU1 residents is assumed to be the residential property where a young child is likely to spend the most time at play in contact with yard soil. Residents are also expected to have contact with dusts originating from yard soil that is tracked in or blown into residential interiors and to be exposed to soil-derived particulate in air from residential and non-residential soils within each residential area. Additional, periodic exposures to attic dust (adults only), surface water, and sediment are assumed to occur for residents of the CSAOIs. Residential EPCs are summarized in Table 1. Table 2 provides a summary of all other input parameters used in the baseline HHRA to assess exposures to OU1 residents. Appendix C provides all of the equations and assumptions used to estimate soil-derived air particulate emission factors.

3.1.1 Soil EPCs

Residential soil EPCs assume direct contact with arsenic in surface soil to a depth of 6 inches below ground surface. Residential soil samples collected for the RI included multiple soil components and depth intervals for each residential lot/property. Property-specific COPC concentrations in surface soil are based on the average of all sample components for a given residential property after depth-weighting average[11] sample results for the 0 to 2 inch and 2 to 6 inch depth intervals. For estimating

[11] Depth-weighted averaging was applied on a sample location-specific basis. For example, if the concentrations of arsenic in the 0 to 2 inch and 2 to 6 inch depth intervals at sample location X were 10 ppm and 20 ppm respectively, the depth-weighted average concentration for

exposures, residential soil EPCs for arsenic are based on the 95UCLM of property-specific average concentrations for all residential properties within each residential area evaluated. As shown in Table 1, the soil EPCs for the southern CSAOI and Great Falls are 29.8 mg/kg and 26.2 mg/kg, respectively. The soil EPC for the northern CSAOI resident (95.6 mg/kg) is more than two times higher than the soil EPCs for the other two residential areas.

3.1.2 Indoor Dust EPCs

Residential indoor dust EPCs are based on the average of measured and estimated indoor dust concentrations that are assumed to originate from outdoor soil. Measured indoor dust data was collected from 30 residential properties within the CSAOIs during the RI. As described in the approved HHRA work plan, concentrations measured in indoor dust and surface soils (0 to 2 inch depth interval) from the same residential properties were used to estimate a site-specific mass soil-to-dust transfer factor (MSD). The MSD for arsenic is 0.39 (Table 2). This MSD was multiplied by the concentration of arsenic in surface soil samples (0 to 2 inch depth interval) for each property where a measured indoor dust sample result was not available to estimate arsenic concentrations in indoor dust for that property. The indoor dust EPCs for arsenic are based on the 95UCLM of estimated and measured property-specific concentrations for all residential properties within each residential area evaluated. As with the residential soil EPCs, the indoor dust EPC for the northern CSAOI (21.4 mg/kg) is more than two times the EPC for the southern CSAOI (9.45 mg/kg) or Great Falls (7.76 mg/kg).

3.1.3 Airborne Particulate EPCs

As detailed in the approved HHRA work plan, exposures to site-related arsenic concentrations in air are estimated using a simple model that applies wind-driven particulate emission factors (PEFs) to surface soil (0 to 2 inch depth interval) arsenic concentrations. For each of the three residential areas evaluated in the baseline HHRA, PEFs were applied to 95UCLM soil concentrations from all surface soils within each area. All concentrations are reported as micrograms arsenic per cubic meter of air ($\mu g/m^3$). As shown in Table 3, surface soil arsenic concentrations from unpaved roads and alleys samples and from the portion of the northern Outlying Areas that is between the railroad corridor and the river were also included in the 95UCLM soil concentration for the southern CSAOI. This 95UCLM was modified by the wind-driven PEF for the area. Fugitive dust emissions to air from vehicle traffic on the unpaved roads and alleys were also calculated using a separate vehicle-generated PEF. The estimated air concentration from wind was then added to the estimated air concentration from vehicle traffic. Arsenic concentrations in air resulting from these estimates of fugitive dust emitted from surface soil are highest in the southern CSAOI ($2.1x10^{-3}$ $\mu g/m^3$), followed by the northern CSAOI ($7.2x10^{-4}\mu g/m^3$) and then Great Falls ($3.4x10^{-4}$ $\mu g/m^3$).

3.1.4 Attic Dust EPCs

Adult residents within the northern and southern CSAOIs are also assumed to have intermittent contact with residential attic dust that contains arsenic. The EPC for attic dust (191 mg/kg) is based on 95UCLM arsenic concentrations for attic dust samples collected from a subset of residential properties (n = 18) during the RI (Table 1).

3.1.5 Surface Water and Sediment EPCs for Arsenic

Children and adults living within the northern or southern CSAOI are assumed to periodically visit the Black Eagle drainage area where they may come into contact with arsenic in surface water and

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the 0 to 6 inch depth interval at location X was calculated as: ((10 x 2) + (20 x 4))/6 = 16.7 ppm. The resulting depth-weighted sample concentration estimates were then input to ProUCL to generate the residential soil EPCs summarized in Table 1.

sediment. EPCs for these environmental media are based on 95UCLM arsenic concentrations for all samples of each type collected from the Black Eagle drainage as part of the RI (Table 1).

3.2 Arsenic - Non-Residential Exposure Scenarios

Three worker exposure scenarios (an outdoor worker, an indoor worker, and a utility worker) are evaluated in the baseline HHRA for the northern and southern CSAOIs and northern portion of the Outlying Areas (excluding the ECDR area and associated soils). The outdoor worker is assumed to be exposed to arsenic primarily in non-residential surface soils (0 to 2 inch depth interval) through incidental ingestion of soil and inhalation of surface soil-derived airborne particulate. The indoor worker is assumed to be exposed via incidental ingestion to arsenic in indoor dust within a commercial building that originates from non-residential surface soil (0 to 2 inch depth interval). The utility worker is assumed to be exposed to arsenic in non-residential surface and subsurface soils (all sampled depth intervals) through incidental ingestion of soil and inhalation of soil-derived airborne particulate. For the utility worker scenario, exposures to arsenic in unpaved roads and alleys are evaluated in addition to exposures to other non-residential soils from the northern and southern CSAOIs and the northern portion of the Outlying Areas.

A recreational exposure scenario (ATV/dirt bike rider) is evaluated for exposures occurring within the ECDR non-residential area. This older teen/young adult is assumed to ride at the ECDR track on a regular basis where contact with arsenic in ECDR surface and subsurface soils (all sampled depth intervals) occurs, along with inhalation of airborne particulate originating from these soils.

Soil and indoor dust EPCs calculated for the four non-residential exposure scenarios are discussed below and summarized in Table 4. Estimated air concentrations for each area evaluated are summarized in Table 3. Table 5 provides a summary of all other input parameters used in the baseline HHRA to assess exposures to people working or recreating within OU1. Appendix C provides all of the equations and assumptions used to estimate soil-derived air particulate emission factors.

3.2.1 Soil EPCs

Soil EPCs for the outdoor worker and utility worker scenarios are based on the 95UCLM arsenic concentration in soil; the sample depths included in each estimate vary depending on the type of worker. Indoor workers are not exposed directly to soil; therefore, soil EPCs for the indoor worker were not calculated. For the outdoor worker, surface soil concentrations are based on the 0 to 2 inch depth interval samples[12]. For the utility worker, arsenic EPCs for each area are based on a depth-weighted average[13] that assumes the worker has equal contact with arsenic in soil from all depths sampled[14] (0 to 18 inch depth horizon). As shown in Table 4, the soil EPC for the outdoor worker in the northern CSAOI (188 mg/kg) is more than three times higher than in the southern CSAOI (56.3 mg/kg). For the outdoor worker in the northern outlying area, the EPC (108 mg/kg) is almost twice the EPC for the southern CSAOI. Utility worker soil EPCs vary less across the different exposure areas, ranging from 51.5 mg/kg to 60.3 mg/kg.

[12] This depth interval was selected based on USEPA's request on April 8, 2015 via email from Charles Partridge (see Appendix A, response to comments attachments).

[13] Depth-weighted averaging was applied on a sample location-specific basis. The resulting depth-weighted sample concentration estimates were then input to ProUCL to generate the utility worker soil EPCs summarized in Table 4.

[14] This depth horizon was selected based on USEPA's request on April 8, 2015 via email from Charles Partridge (see Appendix A, response to comments attachments).

For the ECDR rider, arsenic sediment data are incorporated into the EPC for soil. The EPC (95ULCM value) based on ECDR soils/sediment incorporates depth-weighted averaging[15] that assumes the rider has equal contact with arsenic in soil from all soil depths sampled[16] (Table 4). The ECDR soil EPC (195 mg/kg) is higher than soil EPCs for any of the residential or worker exposure scenarios, but similar to the northern CSAOI outdoor worker soil EPC.

3.2.2 Indoor Dust EPCs

For the indoor worker, indoor dust concentrations within commercial properties were not sampled as part of the RI. Instead, indoor dust concentrations are estimated values based on application of the site-specific MSD for arsenic in residential soils (0.39) to non-residential surface soils (0 to 2 inch depth interval) within each exposure area evaluated. Indoor dust EPCs for each exposure area evaluated are based on the 95UCLM of estimated indoor dust arsenic concentrations (Table 4).

3.2.3 Airborne Particulate EPCs

Arsenic airborne particulate EPCs for three nonresidential scenarios (the outdoor worker, utility worker, and ATV/dirt bike rider) were derived using the same approaches used for estimating arsenic air concentrations for residential scenarios (Section 3.1.3). Estimated air concentrations for the outdoor worker are based on wind-driven PEFs applied to all surface soils (0 to 2 inch depth interval) within each of the three areas evaluated in the baseline HHRA. For the outdoor worker, estimated arsenic concentrations in air are highest in the southern CSAOI ($2.1x10^{-3}$ µg/m^3), followed by the northern outlying area ($1.7x10^{-3}$ µg/m^3), and then the northern CSAOI ($7.2x10^{-4}$ µg/m^3). For the utility worker, assumptions from USEPA's Soil Screening Guidance (2002b) for workers exposed to fugitive dust emissions during construction were modified to address exposures by a utility worker who is engaged in digging for 10 days over a localized area. USEPA's construction worker guidance considers worker exposures to particulates emitted from construction vehicle traffic on temporary unpaved roads in addition to fugitive dusts generated from other construction activities such as excavation, soil dumping, dozing, grading, and tilling as well as from wind erosion of soil surfaces. The ambient air dispersion of the vehicle versus other generated emissions is different with vehicle emissions occurring in proximity to the road and the others assumed to occur at the center of the emission source. However, the utility worker scenario is not assumed to be associated with a construction site as envisioned by the USEPA guidance and the digging may or may not be along a road. For these reasons, we determined that the most analogous scenario would be the excavation scenario where the worker is exposed to fugitive dusts from excavation activities and from wind-dispersed particulate. Utility worker PEFs estimated from both localized particulate emissions generated from wind and excavation of soil are applied to non-residential soils (0 to 18 inch depth interval) for each of the three utility worker areas evaluated. Discussion of uncertainties associated with not considering vehicle traffic on a road next to an excavation area is provided in Section 7.1.2. For the utility worker, estimated arsenic air concentrations are highest in the unpaved roads and alleys ($6.5x10^{-2}$ µg/m^3) and lowest in the northern outlying area ($5.5x10^{-2}$ µg/m^3).

ATV/dirt bike rider exposures to airborne particulate account for soil particles emitted to air from wind and vehicle actions on soil resulting in the PEFs shown in Table 3. Estimated air concentrations used in the baseline HHRA are based on the 95UCLM ECDR soil concentration from all depths sampled (0 to 18 inch depth horizon). USEPA guidance for modeling dust emissions from a dirt bike riding scenario is not available. Instead, modeling of this scenario was adapted using USEPA (2002b) guidance for an

[15] Depth-weighted averaging was applied on a sample location-specific basis. The resulting depth-weighted sample concentration estimates were then input to ProUCL to generate the ECDR rider soil EPC summarized in Table 4.

[16] Based on the nature of activities conducted at the ECDR track, both with regard to track riders and track maintenance/contouring, a high degree of mixing is assumed to occur throughout the sampled soil horizon (0 to 18 inches).

off-site resident impacted by construction-related traffic across unpaved roads at a construction site. The guidance for this receptor assumes the resident is located on the perimeter of the site and in the prevailing downwind direction of particulate emitted from the site. Applying this scenario to the ECDR track user, the vehicle-driven PEF was calculated to estimate the concentration of airborne dust generated from 10 dirt bike riders using the ECDR track, each traveling at a speed of 24 kilometers per hour (Tetra Tech 1996) for a three-hour period during each day the rider is assumed to use the track. Based on these assumptions, each rider is assumed to travel 72 kilometers of track during the three hour exposure period, generating airborne particulate during the whole time. Conservatively, the ATV/dirt bike rider is assumed to be located on the perimeter of the area being used by the 10 track riders and always downwind of the dust generated from the track use.[17] The vehicle-driven PEF (6.1×10^{-7} kg/m^3) is 40 times greater than the wind-driven PEF for the ECDR area (Table 3). Vehicle-generated and windblown air concentration estimates are added together for the ECDR resulting in a combined arsenic air concentration estimate of 0.12 µg/m^3, one to three orders of magnitude higher than the estimates for any other area evaluated in OU1.

3.3 Arsenic Exposure Intakes

For ingestion and dermal exposure pathways, EPCs (Table 1 and Table 4) are combined with exposure assumptions from Table 2 and Table 5 to calculate quantitative exposure estimates (intakes) for each exposure scenario evaluated in the baseline HHRA. For non-cancer endpoints, these intakes are estimated as an average daily dose (ADD). For the cancer endpoint, the intakes are estimated as a lifetime average daily dose (LADD). Separate intakes are calculated to represent central tendency exposure (CTE) and reasonable maximum exposure (RME) estimates. The CTE estimates represent average or typical exposures for people living, working, recreating at the site while RME estimates are intended to represent exposures that are well-above average, but still plausibly within the range of possible exposures for the site. CTE and RME intakes developed for this baseline HHRA incorporate different input values for resident and worker ingestion rates and ATV/dirt bike rider exposure frequency. Input assumptions for all other variables are the same for both the CTE and RME estimates. Intake estimates for arsenic are summarized in Tables 6 and Table 7 for residential exposure scenarios and Table 8 for non-residential exposure scenarios.

Per USEPA HHRA guidance, exposures to arsenic in air are evaluated by comparison of air exposure concentrations to the arsenic inhalation reference concentration (non-cancer) or unit air risk (cancer); daily inhalation intakes are not calculated. The estimated air concentrations (Table 3) are modified by the exposure parameters (time, frequency, duration) and divided by the appropriate averaging time to derive inhaled air exposure concentrations for comparison to the inhalation reference concentration and the unit air risk.

Section 7 provides an evaluation of uncertainty associated with the arsenic exposure intake estimates.

3.4 Summary of Lead Risk Model Inputs

The baseline HHRA utilizes two lead risk models. USEPA's Integrated Exposure, Uptake, and Biokinetic (IEUBK) model is used to evaluate lead risks for children. Adult lead exposures are evaluated using USEPA's Adult Lead Methodology (ALM). For residential exposures, USEPA guidance specifies assessing risks based on exposures to children, the most sensitive population to the effects of lead at a

[17] See Appendix C for assumptions and equations pertaining to the ATV/dirt bike rider PEF. Because the rider is assumed to cease exposure to soil particles in air after three hours of riding, the exposure duration term in the offsite resident equation is modified to reflect the rider's total contact time (i.e., 52 days/year x 3 hours/day). The PEF resulting from this estimation approach is consistent with an activity-based PEF for release of soil particles into air due to ATV riding (1.18×10^{-6} kg/m^3), which was derived using empirical data collected at a smelter site in California and incorporated into a USEPA Region 8 baseline HHRA (SRC 2009).

residence. For non-residential exposures, the ALM is used to assess risks based on adult exposures to lead. A summary of model inputs for each scenario evaluated is provided in Table 9 and Table 10 for the child and adult exposure scenarios, respectively. Details regarding the basis for each input are provided in Appendix A, the approved HHRA work plan with the exception of updates to the maternal blood lead level and modeling of the adult resident with periodic access to their attic, which are discussed below.

For both the IEUBK and ALM models, USEPA currently assumes a geometric mean baseline maternal blood lead level of 1.0 microgram per deciliter (µg/dL) based on analysis of 1999-2004 National Health and Nutrition Examination Survey (NHANES) blood lead data for the national population of non-institutionalized women ages 17 to 45 years. However, analysis of more recent NHANES data for the same population collected from 2005-2012 supports reduction of the current model assumption by 0.2 µg/dL, resulting in a mean value of 0.8 µg/dL for the national population. This value was selected for use in the baseline HHRA.

While children are the primary population of concern at residences, as noted in Section 2.2, the CSAOI resident adult is also assumed to be exposed to lead in attic dust during entry into the attic one time per week throughout the year. Periodic exposure of the adult resident to attic dust is evaluated using the ALM model. For this scenario, it is assumed that the attic dust intake rate is equal to half of the adult resident's indoor dust intake rate on the days when this individual accesses his or her attic (Table 10).

Site-specific soil and indoor dust concentrations used in the models are summarized in Table 11. USEPA lead risk models specify central tendency values for outdoor soil lead concentration inputs to the models. For the IEUBK model, the concentration of lead in indoor dust is assumed to be related to the concentration in outdoor soil and is accounted for in the model by the MSD input (0.39). For the indoor worker who is not exposed directly to soil, but is exposed to indoor dust assumed to derive from site-related soil, the concentration input to the ALM represents the indoor dust lead concentration rather than the soil lead concentration. This indoor dust concentration was derived based on application of the MSD (0.39) to outdoor soil concentrations (0 to 2 inch depth interval) using the same approaches described for estimating indoor dust concentrations for arsenic (Section 3.2). The basis for each scenario-specific soil lead concentration utilized in the models is detailed in below for each exposed population. IEUBK model input screenshots are provided as Appendix D.

Section 7 provides an evaluation of uncertainty associated with inputs to the lead risk models.

3.4.1 Child Resident

Residential soil lead concentrations used to evaluate lead exposures to child residents of the northern and southern CSAOIs, and Great Falls assume direct contact with lead in surface soil to a depth of 6 inches below ground surface. Residential soil samples collected for the RI included multiple soil components and depth intervals for each residential lot/property. Property-specific lead concentrations are based on the average of all sample components for a given residential property after depth-weighting average[18] sample results for the 0 to 2 inch and 2 to 6 inch depth intervals. As shown in Table 11, the mean lead in soil is 92.7 mg/kg for the northern CSAOI, which is the lowest of the three child exposure areas. Mean soil lead in Great Falls is comparable at 103 mg/kg and twice as high in the southern CSAOI (203 mg/kg).

[18] Depth-weighted averaging was applied on a sample location-specific basis. The resulting depth-weighted sample concentration estimates were then input to ProUCL to generate the soil concentration inputs summarized in Table 11.

3.4.2 Adult Workers

Non-residential soil lead concentrations from the 0 to 2 inch depth interval were used in the adult lead model for outdoor workers contacting soil and to estimate indoor dust concentrations derived from soil for the indoor worker exposure scenario. Separate soil lead concentrations were estimated for workers in the northern CSAOI, southern CSAOI, and the northern outlying areas. For the outdoor worker, average lead concentrations were highest in the northern CSAOI (226 mg/kg) and lowest in the northern outlying area (67.9 mg/kg), as shown in Table 11. For the indoor worker, estimated average indoor dust concentrations ranged from 26.5 mg/kg in the northern Outlying Area to 88.2 mg/kg in the northern CSAOI (Table 11). Exposures to lead by the utility worker was not quantified given that the exposure duration assumed for this potentially exposed population does not meet the minimum ALM model assumptions of one day per week for three months[19].

3.4.3 ATV/Dirt Bike Rider

The soil lead concentration used to model lead risks for the ATV/dirt bike rider are based on measured lead concentrations in soil[20] samples collected from all depth intervals within the ECDR area. Concentrations at each sampled location were depth-weighted[21] prior to calculating the average for all ECDR locations. Mean lead from the ECDR is higher than soil lead inputs for all other areas evaluated (Table 11).

[19] Exposure assumptions for the utility worker were selected based on USEPA's request on April 8, 2015 via email from Charles Partridge (see Appendix A, response to comments attachments).

[20] Lead in sediment was eliminated for further consideration during screening conducted in the HHRA work plan phase (see Appendix A).

[21] As described in the RI report (Formation 2015), the depth distribution of metals in ECDR soils was generally distinct from that observed in soils sampled from other OU1 locations. Given that a high degree of mixing is assumed to occur throughout the sampled soil horizon (0 to 18 inches) during track use by riders and as a result of track maintenance and re-contouring, it is reasonable to assume track riders may be exposed to soils from all depths when riding at the track. Therefore, depth-weighted averaging was applied on a sample location-specific basis. The resulting depth-weighted sample concentration estimates were then input to ProUCL to generate the ECDR rider soil EPC summarized in Table 11.

4. TOXICITY ASSESSMENT

Consistent with USEPA risk assessment guidance for Superfund (USEPA 1989), the purpose of the toxicity assessment is to characterize the nature of potential toxic effects and provide an estimate of the dose-response relationship for relevant effects that can be used to characterize risks for exposed individuals. The dose-response relationship is estimated based on evaluation of the strength of available data that support the potential for a chemical to cause adverse health effects in individuals at a given exposure level, by a particular route of exposure, and over a specific period of time. The toxicity assessment considers both non-cancer and cancer effects for the chemicals evaluated.

For the baseline HHRA, the toxicity assessment was limited to lead and arsenic. The toxicity of both arsenic and lead has been well-studied resulting in abundant quantitative and qualitative information that has been reviewed by USEPA and other organizations. The reviews have considered animal and human data along with other supporting types of information, such as pharmacokinetic studies and biomonitoring studies, as appropriate.

Sensitive subpopulations were considered. For instance, young children (i.e., less than 6 years old) are the population of greatest concern for residential exposures to lead because they are expected to have higher lead absorption rates and higher exposure per unit body weight than adults. Because lead is a neurotoxicant, young children are also more susceptible to the effects of lead given the high rate of neurodevelopment occurring in the first few years of life.

Consideration also was given to the forms of arsenic and lead that are most relevant to OU1 exposure media. For instance, arsenic is a natural element that is widely distributed in the environment, including in soil, groundwater, and surface water, and in plants and animals. In soil and water, most arsenic is present as inorganic arsenic, but in some plants and animals organic forms of arsenic are present. Because arsenic occurs naturally in the environment, all humans are exposed to low doses. For most populations, the primary source of exposure to inorganic arsenic is the diet. In addition, human activities have caused widespread increases in concentrations of inorganic arsenic in soil and water. Inorganic arsenic is the most toxic form and is most relevant to OU1 exposure media; therefore, inorganic arsenic was the focus of the arsenic risk characterization in the baseline HHRA. A summary of the arsenic and lead toxicity assessment was provided in the approved HHRA work plan and is represented below.

4.1 Arsenic Toxicity Values

Toxicological benchmarks (i.e., reference doses and cancer slope factors) for arsenic relevant to OU1 media are summarized below. Potential uncertainty associated with the arsenic toxicity values used in this baseline HHRA are summarized in Section 7.

4.1.1 Cancer Effects

Arsenic is classified by the USEPA as a human carcinogen. Skin and internal organ cancers have been increased in populations exposed to high levels of arsenic in drinking water. Cancer risks are described by using the slope of the dose-response curve at low doses, known as the slope factor (SF). The units of the SF are dimensions of risk of cancer per unit dose. The oral SF for arsenic is 1.5 $(mg/kg\text{-}day)^{-1}$ (USEPA 1998).

USEPA has determined that sufficient data exist to show that lung cancer mortality has been increased with arsenic inhalation. The inhalation unit risk factor for arsenic is 0.0043 $(\mu g/m^3)^{-1}$, based on lung cancer in humans occupationally exposed.

4.1.2 Non-Cancer Effects

Early epidemiology studies identified skin as the most sensitive non-cancer endpoint of long-term oral arsenic exposure. Hyperkeratinization of the skin, formation of multiple hyperkeratinized corns or warts, and hyperpigmentation of the skin with interspersed spots of hypopigmentation are the most common types of lesions associated with oral arsenic exposure (ATSDR 2007). More recent studies in humans have also reported cardiovascular effects following oral exposures to arsenic. Cardiac effects include altered myocardial depolarization, cardiac arrhythmias, and ischemic heart disease. Chronic exposure to arsenic has been shown to lead to effects on the vascular system (ATSDR 2007). USEPA is currently reviewing a wide range of other toxic endpoints potentially associated with arsenic exposure, including effects on the endocrine system such as diabetes mellitus.

The non-cancer oral reference dose (RfD) for arsenic is 0.0003 mg/kg-day. This value was derived from a no-observable-adverse-effect-level (NOAEL) for a critical effect based on human chronic oral exposure resulting in hyperpigmentation and keratosis (Tseng 1977; Tseng et al. 1968). The NOAEL was divided by an uncertainty factor of three, due to a lack of reproductive toxicity data and uncertainty in whether the NOAEL is protective of all sensitive individuals. This value is applied to all ingestion-based exposure scenarios evaluated in the baseline HHRA except the utility worker. The short exposure frequency and duration for the utility worker necessitates use of a subchronic oral SF for arsenic. USEPA does not provide an RfD for subchronic exposure. Tsuji et al. (2004) developed a reference level of 0.005 mg/kg-day for subchronic exposures (e.g., 14 days to 6 years). The reference level was established by reviewing health effects in children exposed to arsenic for subchronic durations. A study of children aged 0 to 9 years showing skin effects during exposure to arsenic via drinking water provided the basis for the reference level. Similar to the USEPA's RfD, the subchronic reference level is based on the most sensitive endpoint established for arsenic, changes to the skin.

The USEPA does not provide a reference concentration for inhalation exposures. However, the California USEPA Office of Environmental Health Hazard Assessment provides a value of 0.015 µg/m^3. This value is applied to all inhalation-based exposure scenarios evaluated in the HHRA.

4.1.3 Dermal Toxicity Values

Application of an oral reference dose or slope factor based on intake may not be protective of dermal exposures (which are calculated in terms of uptake or absorbed dose) when oral absorption of a chemical is low. Thus, when considering dermal risks, USEPA guidance indicates the oral RfD or SF should be adjusted to an absorbed dose whenever oral absorption is 50 percent or less. For arsenic, this adjustment is not necessary as more than 80 percent of inorganic arsenic dissolved in water is absorbed by the gastrointestinal (GI) tract. The chronic oral RfD and SF without adjustment were used for assessing dermal toxicity to arsenic in water.

4.2 Lead Toxicity Assessment

Lead exposures result in a wide range of adverse effects, including effects on the nervous system, cardiovascular system, immune function, heme synthesis and red blood cell function, and reproductive and developmental function. A no effect level has not been established for lead exposures (ACCLP 2012; CDC 2012; NTP 2012; USEPA 2013b).

Young children are the population of greatest concern for residential exposures because they are expected to have higher lead absorption rates and higher exposure per unit body weight than adults. Children are also more susceptible to the effects of lead (USEPA 2006; NTP 2012). From a population of adults, women of child-bearing age are of greatest interest given the potential for adverse effects on the fetus resulting from elevated maternal blood lead.

USEPA does not have standard toxicity values for lead because a no-effect dose has not been identified. Instead, USEPA has identified a target blood lead level (10 µg/dL) to use in risk management.

5. ARSENIC RISK CHARACTERIZATION

As detailed in the approved HHRA work plan, quantitative estimates of arsenic exposure and toxicity were combined to yield numerical estimates of potential health risk for noncarcinogenic and carcinogenic effects. Noncarcinogenic health risks due to arsenic are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of exposure to arsenic from OU1 media of concern. Non-cancer arsenic risks are evaluated based on comparison of estimated arsenic exposure to an arsenic reference dose or air reference concentration. Estimated arsenic exposures via oral and dermal pathways are expressed as ADDs. For the inhalation pathway, arsenic exposure is estimated as an inhalation exposure concentration. The ratio of estimated exposure to reference exposure is referred to as the "hazard quotient" (HQ). HQs were calculated for each resident for exposure to arsenic in soil/indoor dust, fugitive dust in air, attic dust, sediment, and surface water. Medium-specific HQs for each exposed population are summed to generate a hazard index (HI). An HI that is equal to or less than one indicates that no adverse health effects are expected (USEPA 1989). An HI greater than one does not mean that adverse health effects will occur, but rather that further evaluation is needed.

Arsenic cancer risk estimates are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to arsenic in OU1 media. The term "incremental" reflects the fact that the calculated risk associated with exposure to OU1 media is in addition to the background risk of cancer experienced by all individuals in the course of daily life. Cancer risk due to oral or dermal arsenic exposure is calculated as the product of the arsenic LADD and the arsenic slope factor. Arsenic cancer risk due to inhalation exposure is calculated as the product of the estimated arsenic exposure and the arsenic unit air risk. Cancer risks were calculated for each resident for exposure to arsenic in soil/indoor dust, fugitive dust in air, attic dust, sediment, and surface water. For the residents, child and adult exposures to each medium are combined to estimate lifetime cancer risk. Medium-specific risks are also summed for each exposed population. Risk estimates are characterized in the context of the target lifetime excess cancer risk range of 1 in 1 million (1×10^{-6}) to 1 in 10,000 (1×10^{-4}), within which USEPA generally strives to manage risks as part of a Superfund cleanup (USEPA 1991).

Non-cancer and cancer risk results for each OU1 population evaluated in this baseline HHRA are summarized below and in Table 12 through Table 15. Section 7 provides an evaluation of uncertainty associated with the arsenic risk characterization approaches used in this baseline HHRA.

5.1 Resident (Child and Adult)

Non-cancer risks for children and adults for all residential exposure scenarios are very low (Table 12). The highest HI (0.5) corresponds to the RME child living within the northern CSAOI. None of the HIs are above one indicating that adverse noncarcinogenic effects due exposure to arsenic in residential media within OU1 are not expected.

Cancer risk estimates for residents living within the CSAOIs and Great Falls areas of OU1 are all within USEPA's (1991) target risk range of 1 in 1 million to 1 in 10,000 (Table 13). The highest total cancer risk (3 in 100,000) is estimated for the RME resident assumed to live within the northern CSAOI for 26 years (including 6 years as a young child). CTE total cancer risk for this same combined child and adult exposure scenario is 1 in 100,000. Total cancer risk estimates for the combined child and adult for the southern CSAOI are 1 in 100,000 and 0.7 in 100,000 for RME and CTE, respectively. For Great Falls residents, combined child and adult estimates are 0.7 in 100,000 and 0.4 in 100,000 for RME and CTE, respectively. Soil and indoor dust exposure pathways contributed most to total cancer risks for

the combined child and adult risk estimates. None of the risk estimates for attic dust, sediment, and surface water exposure pathways were higher than 1 in 1 million, the low end of USEPA's target risk range, and did not contribute significantly to total cancer risk estimates for the combined child and adult resident. Within the southern CSAOI, estimated airborne soil particulate concentrations resulting from vehicle use on unpaved roads and alleys were found to increase risks contributed by inhalation of windblown soil particulate by about 3 times compared to the other residential exposure areas; however, soil/dust ingestion remained the primary risk driver for all residential exposure areas.

5.2 Workers (Adult)

Non-cancer risks for all worker exposure scenarios are very low (Table 14). The highest HI (0.1) corresponds to the RME outdoor worker within the northern CSAOI. None of the HIs are above one indicating that adverse noncarcinogenic effects due to worker exposure to arsenic in non-residential soil within OU1 are not expected.

For all worker scenarios, risk estimates are highest within the northern CSAOI area (2 in 100,000; Table 15). The highest indoor worker cancer risk estimates is 3 in 1 million. Outdoor worker cancer risk estimates range from 3 to 8 in 1 million for CTE scenarios and 0.5 to 2 in 100,000 for RME scenarios. Utility worker risk estimates are all well below 1 in 1 million, the low end of USEPA's (1991) target risk range. Total cancer risks for outdoor workers are driven by soil/dust ingestion with lesser contribution from inhalation of soil/dust. For the utility worker, soil/dust ingestion and inhalation contribute similarly to the total cancer risk.

5.3 ATV/Dirt Bike Rider (Adult)

Non-cancer risk estimates for the ATV/dirt bike rider at the ECDR (HI = 0.2 for RME) are not expected to result in adverse noncarcinogenic effects (Table 14). Cancer risk estimates are lower than 1 in 10,000, the upper end of the target risk range within which USEPA generally strives to manage risks as part of a Superfund cleanup (USEPA 1991). The RME risk estimate for the ATV/dirt bike rider is 1 in 100,000, while the CTE estimate is 0.5 in 100,000 (Table 15). Risks are primarily contributed by the ingestion pathways, with inhalation pathways represented less than half the ingestion risks.

6. LEAD RISK CHARACTERIZATION

As described in the approved HHRA work plan, lead risks are characterized by use of two mathematical models to estimate the distribution of blood lead values in a population of people exposed to lead under a specified set of conditions. The IEUBK model was used to predict the risk, as a probability, that a typical young child (0 to 6 years old) will have a blood lead level greater than 10 µg/dL when exposed to a combination of specified media concentrations of lead (USEPA 2002a). The ALM model was used to estimate blood lead concentrations for the outdoor worker, indoor worker, utility worker, and ATV/dirt bike rider. USEPA (2013a) assumes "the most sensitive receptor is the fetus of a worker who develops a body burden as a result of non-residential exposure to lead. This body burden is available to transfer to the fetus for several years after exposure ends." The ALM predicts the fetal geometric mean blood lead level based on assumed proportionality between fetal and adult blood lead levels. The central tendency adult blood lead level is estimated as the sum of an expected starting (i.e., baseline) blood lead in the absence of site exposure and an expected site-related increase (USEPA 2003).

As described in Section 3, the baseline HHRA utilized a combination of model default and site-specific data to model lead risks. The basis for each of the site-specific/alternate model assumptions is described in the approved HHRA work plan (Appendix A) or in Section 3.5 of this report. For the child resident, IEUBK model results are summarized using both default and alternative soil ingestion rates. A discussion of uncertainties associated with results based on each set of soil ingestion rates is provided in Section 7.

Risk results for each OU1 population evaluated in this baseline HHRA are summarized below. Child lead risks are also shown in Table 16 and Figure 6-1 through 6-6 while adult lead risks are summarized in Table 17.

As noted in Section 4.2, USEPA uses a target blood lead level (10 µg/dL) for evaluating risk management decisions. This target is based on the Centers for Disease Control and Prevention (CDC) recommendation of 10 µg/dL as a blood lead "level of concern" when based on a confirmed venous blood draw. Based on the CDC level of concern, USEPA specifies a risk management goal that the probability that any exposed child or pregnant female will have a blood lead level above 10 µg/dL should not be greater than 5 percent. In accord with this approach, HHRA health risks from lead were judged to be acceptable if the probability of a blood lead value exceeding the target blood lead level (10 µg/dL) did not exceed 5 percent based on the IEUBK model or the ALM. These probability estimates are based on all sources of the potentially exposed population's lead exposure, including both site related exposures and baseline (non-site related) exposures.

CDC (2012) no longer uses the blood lead "level of concern" concept for lead and has derived a population reference level of 5 µg/dL, stating that "This new level is based on the US population of children ages 1-5 years who are in the highest 2.5 percent of children when tested for lead in their blood." Conceptually, the 2012 CDC reference level is not the same as the target blood lead level on which USEPA currently bases evaluation of lead risks and USEPA has not yet determined if or how the 2012 CDC reference level may be used in risk management for lead sites in the future. USEPA is reviewing its approach to addressing lead-contaminated soil at Superfund sites in light of more recent scientific information, including the CDC's 2012 recommendation for blood lead levels in children which cut in half the concentration of lead in blood at which referral to a health professional for medical monitoring is recommended (from 10 µg/dL to 5 µg/dL). The CDC recommendation pertains to a child's exposure to all lead sources (e.g., paint, consumer products, soil, etc.) and serves as a national

goal. USEPA is focused on limiting site related lead exposure, taking into consideration CDC's recommendation and other information. While the 2012 CDC reference level will help to inform the identification of a protective level to support cleanups, USEPA is also considering other scientific information. Superfund remediation of the most highly lead-contaminated soil, combined with activities to address other lead sources, has proven to be an effective part of an overall strategy for reducing blood-lead levels in children.

6.1 Child Resident

As shown in Figures 6-1 through 6-6, there is a very low probability that a resident child's blood lead level would exceed USEPA's target blood lead level (10 µg/dL). Based on IEUBK model runs using the default soil ingestion rates, the probabilities for exceeding the target blood lead level ranged from 0.005 to 0.1 percent for the three residential exposure areas. Using the alternate soil ingestion rates[22], the probabilities range from 0.001 to 0.02 percent. Probabilities were highest for the southern CSAOI area where predicted geometric mean blood lead levels were 2.5 µg/dL using the default soil intake rates and 1.9 µg/dL using the alternate values.

6.2 Adult Resident Accessing Attic

Intermittent access by adult residents of their attics is not expected to significantly increase exposures to site-related lead. As shown in Table 17, the probability that attic exposures will increase fetal blood lead above 10 µg/dL is very low at 0.0008 percent.

6.3 Adult Outdoor and Indoor Worker

Based on the results of the ALM modeling for outdoor workers and indoor workers, there is a very low probability (0.0005 to 0.009 percent) that site-related exposures to lead in soil or soil-derived dust would result in fetal blood lead levels that exceed USEPA's level of concern (Table 17).

6.4 Adult ATV/Dirt Bike Rider

There is a 0.005 percent probability that USEPA's blood lead level of concern would be exceeded due to ATV/dirt bike riding within the ECDR (Table 17).

[22] The basis for alternate soil ingestion rates is provided in the approved HHRA work plan (see Appendix A).

7. UNCERTAINTY ASSESSMENT

USEPA (1989) risk assessment guidance for Superfund specifies:

> *…the Superfund human health evaluation needs to focus on providing information necessary to justify action at a site and to select the best remedy for the site. This should include characterizing the contaminants, the potential exposures, and the potentially exposed population sufficiently to determine what risks need to be reduced or eliminated and what exposures need to prevented. It is important to recognize that information should be developed only to help EPA determine what actions are necessary to reduce risks, and not to fully characterize site risks or eliminate all uncertainty from the analysis.*

Use of standardized risk assessment approaches yield estimates of theoretical risks to hypothetical individuals exposed to site-related chemicals, which are not without uncertainties. Incorporation of parameter inputs based on site-specific data, modeled estimates, and other sources of information used in the HHRA all represent sources of uncertainty. The goal of the uncertainty evaluation is to provide context to the HHRA results by considering the potential impact of the specific approaches and inputs used to generate the results. An evaluation of uncertainty related to the exposure evaluation, toxicity evaluation, and risk characterization components of this HHRA is provided below.

7.1 Uncertainty Related to Exposure Evaluation

The baseline HHRA was conducted using a deterministic approach to characterize site-specific exposures to arsenic within OU1. With a deterministic approach, the value of each input parameter represents a point estimate selected from a range of possible values for that parameter. For RME estimates, value selection is intended to result in a combination of values that yields an estimate of exposure that is as high as can be reasonably expected to occur by individuals within a given population exposed via one or more exposure pathways. For CTE estimates, value selection results in an exposure estimate more reflective of average or typical exposures. For lead, exposure estimates are based on CTE assumptions input to a model that yields a distribution of values, from which RME is identified. For both types of estimates, best professional judgment is applied in selection of specific input values, which represents a source of uncertainty surrounding the exposure estimates. Potential variability in measured or estimated site data, as well as other factors and assumptions considered in selecting parameter inputs, all contribute to uncertainty related to the exposure evaluation.

Table 18 summarizes different sources of uncertainty to the OU1 exposure assessment. For each source of uncertainty, the expected direction (e.g., overestimated vs. underestimated) and potential magnitude (e.g., low, moderate, high) of impact on exposure estimates is noted. The low, moderate, and high categories of potential magnitude are assessed qualitatively based on consideration of how the input variable or approach is likely to affect the overall exposure estimate. A discussion of each category of uncertainty in Table 18 is provided below.

7.1.1 Environmental Sampling Data

Three primary potential sources of uncertainty to the OU1 exposure assessment relate to the environmental sampling data used. First, for the purposes of the HHRA, it was assumed that arsenic and lead measured in all environmental samples collected during the OU1 RI originates from sources related to the former ACM smelter and refinery facility and processes. Natural and anthropogenic background sources of arsenic and lead are likely to have contributed to the presence of these COPCs within OU1 over the history of the site. Thus, this assumption is expected to overestimate exposures

due to site-related arsenic and lead alone. The magnitude of the effect on exposure estimates for arsenic is expected to be low given the low likelihood that widespread sources of arsenic were historically present, other than from the former site processes and related activities. For lead, the age of the housing stock, particularly within the CSAOIs, is more likely to be associated with sources of lead that are not related to the former facility resulting in overestimates of site-related lead concentrations in some environmental data used in the HHRA. The impact of this uncertainty on lead exposures may be moderate.

Second, while the RI sampling efforts yielded an extensive database of lead and arsenic concentrations in OU1 soil, sampling data for indoor (living space) dust, attic dust, and Black Eagle drainage surface water and sediment were based on collection of a limited number of samples. EPCs developed for the HHRA are intended to represent estimates of the average concentration in each medium that an individual is reasonably expected to contact over time. For EPCs based on limited data (e.g., surface water, sediment, and attic dust), increased variability in estimated averages is expected. For arsenic, where the 95UCLM is selected as the EPC, such variability can result in an estimated 95UCLM that is higher than the maximum concentration (e.g., Black Eagle surface water). In the case of residential indoor dust EPCs, the 95UCLM was calculated based on a combination of measured and estimated indoor dust values representing each of the 422 residential properties. Estimated indoor dust concentrations were based on analysis of the relationship between arsenic measured in indoor dust samples and the average concentration of arsenic in 0 to 2 inch depth yard soil samples collected from a subset of 30 properties. The size of this measured dataset may increase uncertainty in the predictive value of the relationship between soil and indoor dust; however, selection of specific properties for sampling indoor dust was generally biased toward properties with higher arsenic soil concentrations in sampled yard components. Assuming transfer of soil particles to indoor dust was occurring, we would expect indoor dust concentrations of arsenic to be higher at properties with higher soil arsenic. Thus, development of a transfer factor based on these biased data would be likely to result in a dataset that overestimates indoor dust arsenic at most properties. However, as detailed in the approved work plan (Appendix A), the correlation between dust arsenic and soil arsenic for the 30 properties was not strong (Pearson correlation coefficient, R = 0.3), suggesting little relationship between surface soil and interior dust arsenic concentrations at the properties selected, despite bias in the selection approach. Concentrations at the 30 residential properties ranged from 2.58 to 25.5 mg/kg for arsenic and 12.7 to 321 mg/kg for lead. Concentrations estimated for the 392 residential properties without indoor dust data encompassed the measured values ranging from 2.45 to 35.2 mg/kg arsenic and 5.70 to 882 mg/kg lead.

For attic dust, the EPC is based on sample results for 18 of the 30 properties selected for indoor dust sampling. This small sample represents a large range of concentrations (8.52 to 695 mg/kg arsenic and 91.6 to 2,800 mg/kg lead), with maximum concentrations more than twice as high as soil concentrations from the 0 to 6 inch depth interval used for estimating risks for soil pathways (provided in Table 1 or Table 11). It is uncertain whether the EPC based on 18 properties adequately represents the remaining 404 residential attics in OU1; however, the property selection criteria applied to identify properties for sampling sought to include properties that were considered representative of the community's ages of homes and types of home construction, resident demographics, arsenic and lead concentrations in residential yards, and locations relative to historical emissions sources associated with the former smelter/refinery.

While limited data may under- or overestimate exposure estimates due to increased variability, the overall effect of this source of uncertainty on the risk estimates is expected to be low given that the

primary source of exposures to OU1 populations is arsenic and lead in soil and soil-derived secondary media.

Third, a subset of soil samples were selected for analysis of arsenic and lead bioaccessibility (i.e., IVBA analyses) in order to estimate site-specific soil RBA values for input in the arsenic exposure estimates and lead risk models. For both COPCs, USEPA specifies use of linear regression models to estimate RBA based on correlations between in vitro and in vivo testing. The regression models are based on data from studies that may or may not be similar to OU1 with regard to sources of lead and arsenic and specific soil characteristics. This represents a potential source of uncertainty that may over- or underestimate actual RBA for the site. The RBA input can have a large impact on exposure estimates, therefore, the potential magnitude of effect associated with this uncertainty may be high. Given that the default RBA for lead is very close to the site-specific RBA estimate, the magnitude of potential effect of RBA uncertainty on the lead risk model is expected to be low. For arsenic, the site-specific RBA estimate is lower than the default assumption, but based on a recent regression model developed based on mouse data and consistent with other recent models proposed, thus uncertainty is also expected to be low to moderate.

7.1.2 Fate and Transport Modeling

Fate and transport models relating indoor dust and particulate in air to soil were incorporated into the OU1 HHRA and represent additional sources of uncertainty surrounding risk estimates. For indoor dust, the MSD variable was estimated based on statistical evaluation of the relationship between measured COPC concentrations in surface soil (0 to 2 inch depth interval) and indoor dust from a subset of residential properties. This relationship assumed that measured lead and arsenic in indoor dust at these properties originated exclusively from lead and arsenic in yard soils sampled from the 0 to 2 inch depth interval at the same residential property. If some of the lead and arsenic measured in the indoor dust samples had originated from interior sources and not yard soil, the mass of lead and arsenic in soil that is transferred to indoor dust (i.e., the MSD variable) would be overestimated. The MSD variable was used to predict indoor dust concentrations for residential and commercial/industrial properties without measured indoor dust data and/or to apportion the contribution of soil vs. indoor dust to total soil intake. Thus, if the site-specific MSD is overestimated, the contribution of indoor dust to total soil/dust exposures would also be overestimated. Given that soil/dust ingestion intakes contributed significantly to total exposures for all scenarios, the potential magnitude of this uncertainty is considered moderate.

An additional source of uncertainty related to the MSD is the assumption that the value estimated based on residential data is applicable to commercial/industrial properties and accurately predicts indoor dust concentrations originating from nonresidential soils to which workers are exposed. A variety of paved, landscaped, bare soil conditions might be expected at different commercial/industrial properties which either limit or promote transfer of soil particulate to the indoor environment. Similarly, commercial/industrial properties are likely to vary with regard to the frequency and extent of routine cleaning of interiors that might also influence the presence of transferred soil particulate. None of the data used to derive the relationship between soil and indoor dust was based on samples collected from commercial/industrial properties, therefore, some uncertainty surrounds the assumption that exposure to indoor dust by the indoor worker can be estimated from nonresidential soil using the MSD for residential properties. This uncertainty may over- or underestimate exposure estimates for this worker. The magnitude of effect is expected to be high as indoor dust is the only medium to which this receptor is assumed to be potentially exposed.

Air monitoring samples were not collected as part of the RI. For adult lead exposures, a model input for air is not included, so air exposure data were not needed. For evaluating child lead risk using the IEUBK model, the model default air concentration (0.1 µg/m^3) was assumed to be constant for all child ages. The current national ambient air quality standard for lead is 0.15 µg/m^3; thus, this default is expected to be reasonably conservative for the HHRA. Actual lead concentrations in air may be over- or underestimated by this default assumption; however, the magnitude of impact is expected to be low within the range of possible concentration values for which uncertainty exists.

For arsenic, air concentrations were estimated based on the concentration of arsenic in soils that were assumed likely to be disturbed by wind and/or vehicle[23] forces causing emission of arsenic-containing soil particulate to air. For each exposure scenario evaluated, PEFs were developed to estimate the relationship between the soil concentration of arsenic and the concentration of arsenic in air as a consequence of particle suspension. Several sources of uncertainty surround these air estimates. The PEF approach assumes that all soils within the specified area of the site are contributing equally to the release of particles to air and that the forces acting on the soils are constant over time such that the potentially exposed population is breathing in this concentration throughout their entire exposure duration. The concentration of arsenic in soil that contributes to air is based on the 95UCLM concentration for all soils within the 0 to 2 inch depth interval for residential and outdoor worker scenarios and for all depths for the utility worker and ECDR track user. The 95UCLM was used given uncertainty associated with estimates of mean soil concentrations due to variability across each area; however, it is unlikely that a single individual would be constantly exposed to this concentration throughout his or her assumed exposure duration.

Additionally, the proportion of the source area that is covered by vegetation is assumed based on gross estimation, but does not necessarily account for other non-vegetative barriers to soil that would limit erosion, such as paved areas and buildings. Thus, the assumed percentages of vegetative cover are likely to overestimate the actual area of exposed soil surfaces within each source area.

For residential and outdoor worker scenarios, wind eroded soils are assumed to contribute to air based on a mean annual wind speed assumption and the concentration in air that would be assumed to result at the center of a box corresponding to the area of source soils. Vehicle-generated soil particulate is assumed to represent the mean 1-hour concentration along a straight road bisecting the source area. Assumptions regarding the number of days with at least 0.01 inch rainfall at the site and the weights and number of vehicles traveling along the road are also incorporated. For the southern CSAOI, the concentration of arsenic estimated to be emitted from travel along an average unpaved road segment was added to the concentration from wind-generated actions on soil over the entire source area. Similar combinations of wind- and vehicle-generated soil particulate are estimated for the southern CSAOI outdoor worker and ECDR track user scenarios. For the utility worker, the decision to exclude vehicle-generated fugitive dusts is not expected to impact risk conclusions. As shown in Table 3, the estimated air concentration from vehicles driving year-round on permanent unpaved roads and alleys is 1.8 x 10^{-3} µg/m^3. Given the way the vehicle-driven PEF is calculated, the estimated air concentration from vehicle passes over a 10 day duration would be lower than 1.8 x 10^{-3} µg/m^3 because there would be fewer vehicles traveling the road over the period of exposure. Further, since the air concentrations for wind and excavation dispersed particulate that were applied to the utility worker are an order of magnitude higher (5.5 x 10^{-2} to 6.5 x 10^{-2} µg/m^3) than the long-term vehicle-generated air concentration applied to the CSAOI resident and outdoor worker scenarios, the contribution from vehicles to air would have a negligible effect on the air concentration from wind and

[23] For residential and outdoor worker scenarios, standard vehicle traffic was considered. For the utility worker, non-standard vehicle forces from excavation equipment was considered. For the ATV/dirt bike rider, the vehicle assumptions were based dirt bike type vehicles.

excavation and no effect on the air pathway risks for this receptor. Values for all inputs to the PEFs were selected to be conservative resulting in air concentration estimates that are likely to represent overly conservative, high-end values. The effect of these uncertainties is expected to overestimate air concentrations to which OU1 populations are exposed with a high magnitude of impact on exposure estimates contributed by air.

7.1.3 Exposure Parameter Inputs

Exposure parameter inputs used in the HHRA are associated with uncertainty as described below.

USEPA (2014a) default exposure assumptions regarding exposure duration, exposure time, body weight, and life expectancy may not be representative of any actual exposure situation due to variability of different individuals potentially exposed to COPCs while residing, working, and recreating within OU1. Overall, the default values for these inputs are expected to overestimate exposures, although the effect on the exposure estimates is expected to be low.

Exposure estimates are sensitive to assumptions regarding the potentially exposed population's rate of contact with different site media. Medium-specific contact rates used in the exposure assessment are assumed to be constant and representative of the exposed population. Actual contact with site media is expected to vary over time and space. Uncertainty associated with the contact rate assumptions is likely to overestimate exposure intakes. The effect of this uncertainty may be high, particularly for RME estimates which combine upper bound contact rate assumptions with other high end exposure assumptions to estimate exposure. As discussed in the approved HHRA work plan (see Section 5.1.3 of Appendix A), based on consideration of more recent studies and reanalysis, current IEUBK default age-dependent soil intake rates likely overestimate child soil/dust ingestion. Incorporating more up to date soil ingestion rate information, child lead risks were estimated using alternate age-dependent soil intake rates in addition to default rates (see Table 9). Comparison of the results for each set of rates (Table 16) shows that the default rates increase mean blood lead estimates by 0.3 to 0.6 µg/dL. Considering the relatively low blood lead estimates predicted for OU1 exposures, the effect of this uncertainty is high.

As detailed in Section 4.2.9 of the approved HHRA work plan, the exposure assessment adjusted USEPA default exposure frequencies based on average climate data for Great Falls and anecdotal information provided by the community. Climate assumptions factored into the adjustments were based on historical averages, while annual exposure frequency is expected to vary over time along with shorter-term climate fluctuations that may be much more mild or extreme. Activity-based adjustments to the exposure frequencies used in the exposure assessment were intended to represent reasonable upper-end frequencies. Actual exposure frequencies will vary by individual and the specific nature of activities in which he or she engages. Thus, uncertainty surrounding the exposure frequencies may lead to over- or underestimates of individual exposures, with overestimates being more likely. Within the range of possible uncertainty, a moderate effect on exposure estimates is expected.

The EPCs calculated for estimating intakes assumed different populations would be exposed to different soil depth intervals. For example, the resident is assumed to have regular contact with arsenic and lead in soils sampled to a depth of 6 inches, while the outdoor worker is assumed to have regular contact with soils in the top 2 inches only. While these assumptions were made in consideration of agency guidance and recommendations, actual contact by potentially exposed populations is likely to vary with regard to specific depths, leading to some uncertainty surrounding these inputs. This uncertainty may over- or underestimate exposure intakes. Given the importance of

the concentration term in influencing exposure, the potential magnitude of impact is expected to be moderate to high.

7.2 Uncertainty Related to Toxicity Assessment

For characterization of risks due to site-related arsenic exposures, the baseline HHRA employs an oral slope factor for arsenic which is derived from a dose response model that assumes that there is no threshold for cancer induction. This assumption may result in higher risk estimates when the actual risks may be as low as zero.

Since USEPA derived the arsenic oral cancer slope factor and reference dose, hundreds of additional studies have been published examining a variety of toxicity endpoints and mechanisms of action. USEPA is in the process of updating arsenic toxicity values. The outcome of the reanalysis is unknown at this time, and could cause the values to increase or decrease.

For evaluation of non-cancer effects due to inhalation of arsenic, the HHRA utilizes an inhalation reference concentration that is based on long-term exposure to arsenic. This value may overestimate risks due to subchronic exposure of the utility worker to arsenic in air.

7.3 Uncertainty Related to Risk Characterization

For each potentially exposed population, arsenic risk estimates were calculated for individual exposure pathways and risks from all pathways were summed to estimate that population's total risk. For pathway-specific risks based on conservative RME inputs, this approach implies that the same individual within the given population is experiencing RME to arsenic in multiple media from the same area over the same time period. In reality, it is more likely that one individual within the population may experience RME via soil arsenic, while another experiences RME via surface water and sediment exposures. Thus, summing RME risk estimates for individual exposure pathways is likely to overestimate total risk estimates for potentially exposed populations.

While risks to residents, workers, and ECDR riders were evaluated separately in the baseline HHRA, it is also possible that an individual who resides within OU1 may also work within OU1 and use the ECDR track. Risks to such individuals from exposure to arsenic, for example, cannot be determined simply by summing total cancer risks for each exposure scenario. Doing so would result in an estimate of risk that is not reasonably plausible based on the combination of exposure inputs used to derive risks for each exposure scenario. For example, the adult resident is assumed to be exposed to soils from the residential yard for 24 hours per day over a period of 225 days, while the outdoor worker is exposed to non-residential soils 8 hours per day over a period of 150 days and the ECDR track user is exposed to ECDR soils 3 hours per day over a period of 26 to 52 days per year. At a most basic level, combining exposure frequencies for these three populations, 401 to 427 days per year, is not plausible. Such an approach is also inconsistent with USEPA risk assessment guidance for Superfund sites which defines RME as "the highest exposure that is reasonably expected to occur at a site" and further states: "RMEs are estimated for individual pathways. If a population is exposed via more than one pathway, the combination of exposures across pathways also must represent an RME." Thus, reasonable estimates of cumulative risks for multiple exposure scenarios would first require reduction in assumed values for individual exposure parameters (e.g., exposure frequency, exposure time, etc.) for each scenario to ensure the combined exposure could reasonably be expected to occur at the site. As noted above, each scenario evaluated in the baseline HHRA for the RME case already represents a conservatively high estimate of potential risk to that population. Even if one assumed that combining cancer risks across different exposed populations was reasonable, the sum of the highest RME risks for the adult resident, worker, and ECDR track user is 3 in 100,000, which is similar to the highest risk result (lifetime cancer risk estimated for the northern CSAOI resident) and still within USEPA's target

risk range. Thus, it is unlikely that evaluation of a cumulative exposure scenario in the baseline HHRA would have yielded a range of risk estimates that exceed those reported for any of the potentially exposed populations evaluated.

As discussed in Section 6, USEPA has not yet determined if or how the CDC (2012) blood lead reference level may be used in risk management for lead sites. The new CDC reference level (5 µg/dL) differs from the blood lead level of concern (10 µg/dL) used in USEPA's lead risk models not just in terms of value, but also in terms of how one may conceptually interpret the probability of exceeding a population-based reference value vs. an effect-based level, particularly in the context of setting soil-based cleanup levels in communities where both site- and non-site sources of lead influence exposure, such as communities where older housing and other demographic factors (e.g., poverty) may influence blood lead levels. The highest predicted geometric mean blood lead level (2.5 µg/dL; for the southern CSAOI child) is half the 2012 CDC reference value. However, because the USEPA's lead risk models used in this HHRA have been validated using the 10 µg/dL blood lead target, those models may not support development of soil lead PRGs that correspond to no more than a 5 percent probability of blood lead levels exceeding a target blood lead level that is based on the 2012 CDC reference value. The EPA is currently examining the model's predictive ability at 5 µg/dL as part of the overall examination of an updated lead policy.

8. CONCLUSIONS

For arsenic, the risk estimates for current and future exposures of OU1 populations to arsenic are all below a 1 in 10,000 total cancer risk level (Tables 13 and 15) and below a non-cancer HI of one (Tables 12 and 14), which are the typical upper end risk levels below which USEPA strives to manage risks for non-lead chemicals. For lead, USEPA uses a target blood lead level (10 µg/dL) for evaluating risk management decisions with a goal that the probability that any exposed child or pregnant female will have a blood lead level above 10 µg/dL should not be greater than 5 percent. Using USEPA's lead risk models, this HHRA demonstrates that there is a very low probability (i.e., no greater than 0.1 percent) that any of the potentially exposed OU1 populations evaluated will have a blood lead level above 10 µg/dL (Tables 16 and 17, and Figures 6-1 through 6-6). Uncertainties surrounding the arsenic and lead results produced by this HHRA are also more likely to overestimate, than underestimate the results. While the level of confidence is high that the risk estimates presented in the HHRA will not underestimate risks to a hypothetical person who lives, works, or recreates with each of the OU1 subareas evaluated, these estimates do not consider the distribution of lead and arsenic risks associated with individual residential and commercial properties within OU1, which may be higher or lower than the average risk estimated for OU1 subareas. To the extent that USEPA determines remedial action is necessary for any OU1 media, the scope of such actions and areas to be addressed will be identified and evaluated during the feasibility study phase of the RI/FS. Preliminary remediation goals described in the next section will support the feasibility study.

9. RANGE OF PRELIMINARY REMEDIATION GOALS

Based on the findings of the baseline HHRA, a range of preliminary remediation goals (PRGs) for arsenic and lead in residential and non-residential soil were developed. PRGs are calculated using typical "backward" risk methodologies based on exposure assumptions employed in development of the baseline HHRA to generate a range of plausible PRGs for consideration by USEPA in risk management decision-making for OU1. For arsenic, PRGs are calculated for different risk levels within USEPA's target risk range for the cancer endpoint (1 in 1,000,000 to 1 in 10,000) and also based on an HI of one. For lead, both model default and alternate soil intake rate assumptions were used.

Given that all arsenic cancer risk estimates corresponding to attic dust, sediment, and surface water exposures did not exceed 1 in 1 million, the low end of USEPA's target risk range, PRGs were not developed for those media. A summary of arsenic and lead PRGs is provided below.

9.1 Arsenic PRGs

Exhibit 1 provides the equation for calculating residential PRGs for arsenic. Residential soil PRGs for arsenic account for a resident's contact with soil and soil-derived indoor dust, but not attic dust, which is not derived from residential soil. The PEF used to estimate risks for the Great Falls is incorporated into these PRGs to account for exposure to wind-generated surface soil particulate in air. As shown in Table 3windblown soil PEFs varied little across the three residential exposure scenarios evaluated; however, the PEF for the Great Falls residential area is slightly higher (i.e., more conservative) than the PEFs for the CSAOIs.

Non-residential soil arsenic PRGs also account for soil-derived pathways. For the outdoor worker, utility worker, and ATV/dirt bike rider these include incidental ingestion of soil and inhalation of resuspended soil particulate in air. For the indoor worker, the PRGs account only for soil-derived indoor dust exposures. Exhibit 3 provides the equation for calculating non-residential PRGs for arsenic. As with the residential PRG, a single PRG range was developed for each outdoor worker and utility worker exposure scenario based on the most conservative PEF for the exposure areas evaluated. For the ATV/dirt bike rider, the combined windblown and vehicle-generated air concentration estimate from Table 3 was used to back-calculate a single PEF for use in the PRG equation.

Arsenic PRGs for residential and non-residential soil are summarized in Table 19. Comparing these PRGs to the maximum property-specific arsenic concentrations in Tables 1 and 4 reveals that some of the residential properties exceed the PRG based on a 1 in 100,000 risk level (36 mg/kg) and/or a hazard quotient of 1 (175 mg/kg), but none of the properties exceed the PRG of 360 ppm (corresponding to the 1 in 10,000 risk level). Some of the location-specific depth-weighted average concentrations for arsenic at the ECDR exceed the ATV/dirt bike rider PRGs based on a 1 in 100,000 risk level (200 mg/kg); but the PRGs based on a 1 in 10,000 risk level and a hazard quotient of 1 are not exceeded. For outdoor workers, some of the location-specific arsenic concentrations exceed the PRG based on a 1 in 100,000 risk level (120 mg/kg), but all results are well-below the PRG based on a 1 in 10,000 risk level (1,204 mg/kg) and the PRG based on a hazard quotient of 1 (1,566 mg/kg). Some location-specific soil concentrations contributing to indoor dust exposures by the indoor worker exceed the 1 in 1 million risk level PRG (58 mg/kg), but are below all other PRGs. For utility workers, all of the location-specific arsenic concentrations in soil are well-below the lowest PRG (767 mg/kg), which corresponds to a 1 in 1 million risk level.

9.2 Lead PRGs

Relying on the same model assumptions used to estimate blood lead levels (e.g., soil ingestion rate, soil to dust transfer coefficient, site-specific bioavailability) for the HHRA, the IEUBK model was run to derive residential soil lead PRGs that are protective of children contacting soil and soil-derived indoor dust. Residential soil lead PRGs are based on the probability that no more than 5 percent of exposed children will have a blood lead level that exceeds 10 µg/dL. PRGs were developed using the current IEUBK model default inputs for soil intake as well as alternate soil ingestion rates used in the baseline HHRA.

For adult exposures to residential attic dust and non-residential soil exposure scenarios, PRGs were developed using the same ALM inputs and assumptions used to estimate lead risks in the baseline HHRA. These PRGs are based on the probability that no more than 5 percent of exposed pregnant female adults and their fetuses will have a blood lead level that exceeds 10 µg/dL. Lead PRGs for soil are summarized in Table 20. Comparing these PRGs to the maximum property-specific lead concentrations in Table 11 reveals that some of the residential properties in the southern CSAOI will exceed the PRGs based on the default and alternate soil ingestion rates (500 mg/kg and 768 mg/kg, respectively), but none of the property-specific average lead concentrations for the northern CSAOI or Great Falls area will exceed the residential PRGs. The maximum location-specific lead concentration corresponding to the ATV/dirt bike rider, the outdoor worker, and the indoor worker are all lower than the corresponding PRGs.

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TABLES

Table 1: Arsenic EPCs for residents

Exposure Area	N	Minimum	Mean	95UCLM	Maximum	EPC[1]
Soil[2] (mg/kg)						
Northern CSAOI	11	29.8	62.4	95.6	200	95.6
Southern CSAOI	380	7.5	28.5	29.8	178	29.8
Great Falls	31	10.27	22.5	26.2	61.4	26.2
Dust (mg/kg)						
Northern CSAOI[3]	11	2.58	15.9	21.4	35.2	21.4
Southern CSAOI[3]	380	2.46	9.09	9.45	29.6	9.45
CSAOI Attic User[4]	18	8.52	111	191	695	191
Great Falls[3]	31	3.72	6.90	7.76	18.5	7.76
Sediment[5] (mg/kg)						
Northern CSAOI	4	11	12.1	13.4	13.6	13.4
Southern CSAOI						
Surface Water[5] (mg/L)						
Northern CSAOI	8	0.0015	0.0055	0.0155	0.014	0.014
Southern CSAOI						

Notes:
N = number of properties for soil and dust or number of samples for sediment and surface water
95UCLM = 95 percent upper confidence limit of the arithmetic mean
EPC = exposure point concentration
mg/kg = milligrams per kilograms
mg/L = milligrams per liter
CSAOI = Community Soils Areas of Interest

[1] EPC is the lower of the UCLM and the maximum concentration.
[2] Soil concentrations are based on the 0 to 6 inch depth interval. Location-specific sample results for the 0 to 2 inch and 2 to 6 inch depth intervals were depth-weight averaged prior to calculation of summary statistics.
[3] Indoor dust concentrations for residents of this area are based on the average of measured and estimated indoor dust concentrations. Estimated values are based on the application of an empirically-derived relationship between arsenic in residential soils (0 to 2 inch depth interval) and residential indoor dust to residential surface soils (0 to 2 inch depth interval) at properties where indoor dust was not sampled.
[4] Attic dust concentrations are based on samples collected from a subset of residential properties during the RI.
[5] Surface water and sediment concentrations are based on samples collected from the Black Eagle stream drainage.

Table 2: Arsenic exposure parameters for residents

Parameter	Units	Child Resident		Adult Resident	
		CTE	RME	CTE	RME
Duration of Exposure	years	6 (a)		20 (a)	
Body Weight	kg	15 (a)		80 (a)	
Averaging Time for Cancer	days	25550 (a)		25550 (a)	
Averaging Time for Non-Cancer	days	2190 (b)		7300 (b)	
Soil / Indoor Dust / Fugitive Dust					
Soil/Dust Inhalation Exposure Time	hours/day	24 (a)		24 (a)	
Soil/Dust Exposure Frequency	days/year	225 (a,c)		225 (a,c)	
Soil/Dust Ingestion Rate	mg/day	100 (d)	200 (a)	50 (d)	100 (a)
Fraction of Ingested Intake as Soil	unitless	0.45 (e)		0.45 (e)	
Soil/Dust Relative Oral Bioavailability	unitless	0.29 (f)		0.29 (f)	
Attic Dust					
Attic Dust Exposure Frequency	days/year	N/A		52 (g)	
Attic Dust Ingestion Rate	mg/day	N/A		50 (h)	100 (h)
Attic Dust Relative Oral Bioavailability	unitless	N/A		0.29 (f)	
Sediment					
Sediment Exposure Time	hours/event	1 (i)		1 (i)	
Sediment Exposure Frequency	days/year	24 (i)		12 (i)	
Sediment Ingestion Rate	mg/day	45 (d, j)	90 (a, j)	22.5 (d, j)	45 (a, j)
Surface Water					
Surface Water Exposure Time	hours/event	1 (i)		1 (i)	
Surface Water Exposure Frequency	events/year	24 (i)		12 (i)	
Incidental Surface Water Ingestion Rate	mL/hour	50 (k)		10 (k)	
Skin Surface Area (Hands and Feet)	cm^2	813 (l)		2300 (l)	
Arsenic Dermal Permeability Coefficient	cm/hour	0.001 (l)		0.001 (l)	

Notes:
CTE = central tendency exposure
RME = reasonable maximum exposure
kg = kilogram
mg/day = milligrams per day
mL/hour = milliliters per hour
cm = centimeter

References:
a. USEPA 2014a
b. USEPA 1989
c. Adjusted for local climate; see Appendix A for details.
d. USEPA 2011c
e. IEUBK model assumption.
f. Bradham et al. 2015
g. URS 2003
h. Assumed equal to soil/dust ingestion rate values for adult resident.
i. Best professional judgment; see Appendix A for details.
j. Assumes sediment intake is equivalent to the fraction of ingested soil/dust intake that is due to soil.
k. USEPA 2014b
l. USEPA 2004

Table 3: Estimated arsenic air concentrations

Area			Vegetative Cover[1] (%)	Site Area[2] (acres)	PEF (kg/m^3)	Arsenic Soil 95UCLM[3] (mg/kg)	Estimated Arsenic Air Concentration[4] (µg/m^3)	
0-2 inch Soils	Northern CSAOI		50	80	8.1E-09	89	7.2E-04	
	Southern CSAOI[5]	All properties, including unpaved roads and alleys and outlying area near railroad corridor	50	165	8.9E-09	26	2.3E-04	2.1E-03
		Unpaved roads only, assessed for vehicle-driven emissions	0	0.5	9.7E-08	19	1.8E-03	
	Northern Outlying Area		25	500	1.6E-08	108	1.7E-03	
	Southern Outlying Area (Great Falls)		50	500	1.0E-08	33	3.4E-04	
0-18 inch Soils	All CSAOI[6]		0	0.5	1.1E-06	53	5.7E-02	
	Unpaved Roads[6]		0	0.5	1.1E-06	60	6.5E-02	
	Northern Outlying Area[6]		0	0.5	1.1E-06	52	5.5E-02	
	ECDR	Windblown Dust	0	51	1.5E-08	195	3.0E-03	1.2E-01
		Vehicle-Generated	0	51	6.1E-07	195	1.2E-01	

Notes:
kg/m^3 = kilograms per cubic meter
95UCLM = 95 percent upper confidence limit of the arithmetic mean
mg/kg = milligrams per kilogram
µg/m^3 = micrograms per cubic meter
CSAOI = Community Soils Areas of Interest
ECDR = Electric City Dirt Riders

[1] Based on aerial photography and professional judgement.
[2] Based on geospatial analysis of area boundaries.
[3] 95UCLM calculated in ProUCL from soils in the depth interval as specified in the left column of the table. For the 0-18 inch soils, depth-weigh averaging was performed for each sample location. No other property averaging was performed before calculation of 95UCLM.
[4] Calculated as PEF x Soil 95UCLM x 1000.
[5] The southern CSAOI area includes unpaved roads and alleys. For this area, the air concentration was generated by adding the air concentration from windblown dust from all properties (including the unpaved roads) to the air concentration generated by vehicles on the unpaved roads.
[6] Estimated air concentration applies to the utility worker and is based on wind-driven and excavation-generated soil particles emitted to air.
[7] Estimated air concentrations from windblown dust across the ECDR were added to an estimate of the concentration in air that a rider would be exposed to from 10 dirt bikes simultaneously traversing the ECDR track during each three-hour exposure event.

Table 4: Arsenic EPCs for non-residential scenarios

Non-Resident	N	Minimum	Mean	95UCLM	Maximum	EPC[1]
Soil (mg/kg)						
Outdoor Worker – Northern CSAOI[2]	29	23.9	142	188	440	188
Outdoor Worker – Southern CSAOI[2]	22	11.4	42.4	56.3	212	56.3
Outdoor Worker – Northern Outlying Area[2]	83	0.150	78.3	108	390	108
Utility Worker – CSAOI[3]	51	9.4	46.6	53.3	109	53.3
Utility Worker – Unpaved Roads[3]	28	7.92	45.9	60.3	403	60.3
Utility Worker – Northern Outlying Area[3]	83	7.0	45.5	51.5	156.8	51.5
ATV/Dirt Bike Rider[3]	17	18.0	140	195	498	195
Indoor Dust[4] (mg/kg)						
Indoor Worker – Northern CSAOI	29	9.32	55.3	73.2	172	73.2
Indoor Worker – Southern CSAOI	22	4.45	16.5	22.0	82.7	22.0
Indoor Worker – Northern Outlying Area	83	0.0585	30.5	42.0	152	42.0

Notes:
N = number of sample locations
95UCLM = 95 percent upper confidence limit of the arithmetic mean
EPC = exposure point concentration
mg/kg = milligrams per kilograms
CSAOI = Community Soils Areas of Interest
ATV = all-terrain vehicle

[1] EPC is the lower of the UCLM and the maximum concentration.
[2] Outdoor worker soil concentrations are based on the 0 to 2 inch depth interval.
[3] Soil concentrations are based on the 0 to 18 inch depth interval. Location-specific sample results for the 0 to 2 inch, 2 to 6 inch, 6 to 12 inch, and 12 to 18 inch depth intervals were depth-weight averaged prior to calculation of summary statistics.
[4] Indoor dust concentration data used to calculate summary statistics are estimated values based application of an empirically-derived relationship between arsenic in residential soils and residential indoor dust to non-residential surface soils (0 to 2 inch depth interval) within each exposure area evaluated.

Table 5: Arsenic exposure parameters for non-residential scenarios

Parameter	Units	Adult ATV / Dirt Bike Rider		Outdoor Worker		Indoor Worker		Utility Worker	
		CTE	RME	CTE	RME	CTE	RME	CTE	RME
Duration of Exposure	years	20 (a,b)		25 (a)		25 (a)		1 (d)	
Body Weight	kg	80 (a)		80 (a)		80 (a)		80 (a)	
Averaging Time for Cancer	days	25550 (a)		25550 (a)		25550 (a)		25550 (a)	
Averaging Time for Non-Cancer	days	7300 (c)		9125 (c)		9125 (c)		365 (c)	
Soil Ingestion Rate	mg/day	165 (d,e)		50 (a,f)	100 (a)	25 (a,f)	50 (a)	330 (d)	
Fraction of Intake as Soil	unitless	1 (f)		1 (f)		0 (f)		1 (f)	
Relative Oral Bioavailability	unitless	0.29 (g)		0.29 (g)		0.29 (g)		0.29 (g)	
Soil Inhalation Exposure Time	hours/day	3 (f)		8 (a)		8 (a)		8 (a)	
Soil Exposure Frequency	days/year	26 (f)	52 (f)	150 (a,h)		167 (a,h)		10 (f)	

Notes:
ATV = all-terrain vehicle
CTE = central tendency exposure
RME = reasonable maximum exposure
kg = kilogram
mg = milligram

References:
a. USEPA 2014a
b. Assumed equal to an adult resident exposure duration.
c. USEPA 1989
d. USEPA 2002b
e. Tetra Tech 1996
f. Best professional judgment; see Appendix A for details.
g. Bradham et al. 2015
h. Adjusted for local climate; see Appendix A for details.

Table 6: Estimated arsenic intakes for residents (non-cancer)

Resident		Soil/Dust Ingestion (mg/kg-day)	Attic Dust Ingestion (mg/kg-day)	Soil Particulate Inhalation ($\mu g/m^3$)	Sediment Ingestion (mg/kg-day)	Surface Water Ingestion (mg/kg-day)	Surface Water Dermal (mg/kg-day)
Northern CSAOI - Child	CTE	7E-05	--	4E-04	3E-06	3E-06	5E-08
	RME	1E-04	--	4E-04	5E-06	3E-06	5E-08
Northern CSAOI - Adult	CTE	6E-06	1E-06	4E-04	1E-07	6E-08	1E-08
	RME	1E-05	3E-06	4E-04	2E-07	6E-08	1E-08
Southern CSAOI - Child	CTE	2E-05	--	1E-03	Same as Northern CSAOI resident child and adult		
	RME	4E-05	--	1E-03			
Southern CSAOI - Adult	CTE	2E-06	1E-06	1E-03			
	RME	4E-06	3E-06	1E-03			
Great Falls - Child	CTE	2E-05	--	2E-04	--	--	--
	RME	4E-05	--	2E-04	--	--	--
Great Falls - Adult	CTE	2E-06	--	2E-04	--	--	--
	RME	4E-06	--	2E-04	--	--	--

Notes:
mg/kg-day = milligrams arsenic per kilogram bodyweight per day
$\mu g/m^3$ = micrograms arsenic per cubic meter of air
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable

Table 7: Estimated arsenic intakes for residents (cancer)

Resident		Soil/Dust Ingestion (mg/kg-day)	Attic Dust Ingestion (mg/kg-day)	Soil Particulate Inhalation (µg/m^3)	Sediment Ingestion (mg/kg-day)	Surface Water Ingestion (mg/kg-day)	Surface Water Dermal (mg/kg-day)
Northern CSAOI - Child	CTE	6E-06	--	4E-05	2E-07	3E-07	4E-09
	RME	1E-05	--	4E-05	5E-07	3E-07	4E-09
Northern CSAOI - Adult	CTE	2E-06	4E-07	1E-04	4E-08	2E-08	4E-09
	RME	3E-06	8E-07	1E-04	7E-08	2E-08	4E-09
Northern CSAOI - Child + Adult	CTE	7E-06	4E-07	2E-04	3E-07	3E-07	8E-09
	RME	1E-05	8E-07	2E-04	5E-07	3E-07	8E-09
Southern CSAOI - Child	CTE	2E-06	--	1E-04	Same as Northern CSAOI resident child and adult		
	RME	4E-06	--	1E-04			
Southern CSAOI - Adult	CTE	6E-07	4E-07	4E-04			
	RME	1E-06	8E-07	4E-04			
Southern CSAOI - Child + Adult	CTE	2E-06	4E-07	5E-04			
	RME	5E-06	8E-07	5E-04			
Great Falls - Child	CTE	2E-06	--	2E-05	--	--	--
	RME	3E-06	--	2E-05	--	--	--
Great Falls - Adult	CTE	5E-07	--	6E-05	--	--	--
	RME	1E-06	--	6E-05	--	--	--
Great Falls - Child + Adult	CTE	2E-06	--	8E-05	--	--	--
	RME	4E-06	--	8E-05	--	--	--

Notes:
mg/kg-day = milligrams arsenic per kilogram bodyweight per day
µg/m^3 = micrograms arsenic per cubic meter of air
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable

Table 8: Estimated arsenic intakes for non-residential scenarios (non-cancer and cancer)

Non-Resident		Soil/Dust Ingestion (mg/kg-day)		Soil Particulate Inhalation (µg/m^3)	
		ADD	LADD	ADD	LADD
Northern CSAOI - Outdoor Worker	CTE	1E-05	5E-06	1E-04	4E-05
	RME	3E-05	1E-05	1E-04	4E-05
Southern CSAOI – Outdoor Worker	CTE	4E-06	1E-06	3E-04	1E-04
	RME	8E-06	3E-06	3E-04	1E-04
Northern Outlying Area - Outdoor Worker	CTE	8E-06	3E-06	2E-04	8E-05
	RME	2E-05	6E-06	2E-04	8E-05
Northern CSAOI - Indoor Worker	CTE	3E-06	1E-06	--	--
	RME	6E-06	2E-06	--	--
Southern CSAOI - Indoor Worker	CTE	9E-07	3E-07	--	--
	RME	2E-06	7E-07	--	--
Northern Outlying Area - Indoor Worker	CTE	2E-06	6E-07	--	--
	RME	3E-06	1E-06	--	--
CSAOI - Utility Worker		2E-06	2E-08	5E-04	7E-06
Unpaved Roads/Alleys - Utility Worker		2E-06	3E-08	6E-04	8E-06
Northern Outlying Area - Utility Worker		2E-06	2E-08	5E-04	7E-06
ATV/Dirt Bike Rider	CTE	8E-06	2E-06	1E-03	3E-04
	RME	2E-05	5E-06	2E-03	6E-04

Notes:
mg/kg-day = milligrams arsenic per kilogram bodyweight per day
µg/m^3 = micrograms arsenic per cubic meter of air
ADD = average daily dose (non-cancer)
LADD = lifetime average daily dose (cancer)
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable
ATV = all-terrain vehicle

Table 9: IEUBK model input values selected for use in the baseline HHRA

IEUBK Model Parameter	Input Value	Source
Outdoor Soil Lead (µg/g)	Site-Specific	Mean lead from OU1 RI Data (see Table 11)[1]
Maternal Blood Lead (µg/dL)	0.8	USEPA (2003) default, updated with more recent NHANES data (see Section 3.4)
Soil-Dust Relationship (MSD)	0.39	Site-specific
Air Concentration (µg/m^3)	0.1	IEUBK model default
Soil/Dust Absorption	29.5%	Site-specific
Drinking Water Concentration (µg/L)	4	IEUBK model default

Age-Dependent Default Parameters [2]

Age (years)	Vent. Rate (m^3/day)	Diet (µg/day)	Water (L/day)	Soil[3] (g/day)
0-1	2	2.26	0.2	0.085 (0.086)
1-2	3	1.96	0.5	0.135 (0.094)
2-3	5	2.13	0.52	0.135 (0.067)
3-4	5	2.04	0.53	0.135 (0.063)
4-5	5	1.95	0.55	0.100 (0.067)
5-6	7	2.05	0.58	0.090 (0.052)
6-7	7	2.22	0.59	0.085 (0.055)

Notes:
µg/g = micrograms per gram
µg/dL = micrograms per deciliter
NHANES = National Health and Nutrition Examination Survey
MSD = mass fraction of soil in indoor dust
µg/m^3 = micrograms per cubic meter
µg/L = micrograms per liter
m^3/day = cubic meters per day
µg/day = micrograms per day
L/day = liters per day
g/day = grams per day

[1] Concentrations in Table 11 are reported in terms of mg/kg, which is equal to units of µg/g.
[2] IEUBK win v1.1 build 11
[3] IEUBK model default (Alternate input; see Appendix A)

Table 10: Summary of ALM input values

Parameter	Units	Resident in Attic	Indoor Worker	Outdoor Worker	ATV/Dirt Bike Rider	Source/Basis
Fetal/Maternal Blood Lead Ratio	unitless	0.9	0.9	0.9	0.9	USEPA (2003) default
Baseline Blood Lead	µg/dL	0.8	0.8	0.8	0.8	USEPA (2003) default, updated with more recent NHANES data (see Section 3.4)
Soil Lead Concentration	µg/g	Site-specific	Site-specific	Site-specific	Site-specific	Mean lead from OU1 RI Data
Biokinetic Slope Factor	µg/dL per µg/day	0.4	0.4	0.4	0.4	USEPA (2003) default
Soil Ingestion Rate (including soil-derived indoor dust)	grams/day	0.0138	0.050	0.100	0.165	Resident see Appendix A; Indoor Worker: USEPA (2003) default; Outdoor Worker: USEPA (2013d) recommendation for contact-intense worker; ATV/Dirt Bike Rider: one-half the value assumed for a construction worker involved in excavation activities (USEPA 2002b; Tetra Tech 1996).
Absorption Fraction (same for soil and dust)	unitless	0.118	0.118	0.118	0.118	USEPA (2003) default adjusted for 59 percent site-specific RBA
Exposure Frequency (same for soil and dust)	days/year	52	167	150	52	Resident: professional judgment Workers and ATV/Dirt Bike Rider: site-specific (see Appendix A)
Averaging Time (same for soil and dust)	days/year	365	365	365	365	USEPA (2003) default
Geometric Standard Deviation Blood Lead	unitless	1.8	1.8	1.8	1.8	USEPA 2009

Notes:
ATV = all-terrain vehicle
µg/dL = micrograms per deciliter
NHANES = National Health and Nutrition Examination Survey
µg/g = micrograms per gram
µg/day = micrograms per day
RBA = relative bioavailability

Table 11: Soil/dust concentration inputs to lead models

Exposure Scenario	N	Minimum (mg/kg)	Mean (mg/kg)	Maximum (mg/kg)
Soil (mg/kg)				
Resident (Child + Adult) - Northern CSAOI[1]	11	38.5	92.7	197
Resident (Child + Adult) - Southern CSAOI[1]	380	14.9	203	1181
Resident (Child + Adult) - Great Falls[1]	31	33.3	103	250
ATV/Dirt Bike Rider - ECDR[2]	17	21.3	300	1161
Outdoor Worker - Northern CSAOI[3]	29	30.5	226	644
Outdoor Worker - Southern CSAOI[3]	22	18.4	167	455
Outdoor Worker - Northern Outlying Area[3]	83	0.0305	67.9	390
Dust (mg/kg)				
Resident Adult in Attic - CSAOI	18	91.6	887	2800
Indoor Worker - Northern CSAOI[4]	29	11.9	88.2	251
Indoor Worker - Southern CSAOI[4]	22	7.18	65.1	178
Indoor Worker - Northern Outlying Area[4]	83	0.0119	26.5	152

Notes:
N = number of properties for resident scenarios or number of sample locations for non-resident scenarios
mg/kg = milligrams per kilograms
CSAOI = Community Soils Areas of Interest
ATV = all-terrain vehicle

[1] Soil concentrations are based on the 0 to 6 inch depth interval. Location-specific sample results for the 0 to 2 inch and 2 to 6 inch depth intervals were depth-weight averaged prior to calculation of summary statistics.
[2] Soil concentrations are based on the 0 to 18 inch depth interval. Location-specific sample results for the 0 to 2 inch, 2 to 6 inch, 6 to 12 inch, and 12 to 18 inch depth intervals were depth-weight averaged prior to calculation of summary statistics.
[3] Soil concentrations are based on the 0 to 2 inch depth interval.
[4] Attic dust concentrations are based on samples collected from a subset of residential properties during the RI.
[5] Indoor dust concentration data used to calculate summary statistics are estimated values based application of an empirically-derived relationship between arsenic in residential soils and residential indoor dust to non-residential surface soils (0 to 2 inch depth interval) within each exposure area evaluated.

Table 12: Arsenic non-cancer hazard quotients and hazard indices for residents

Resident		Soil & Dust Ingestion	Attic Dust Ingestion	Soil Particulate Inhalation	Sediment Ingestion	Surface Water Ingestion	Surface Water Dermal	Hazard Index
Northern CSAOI - Child	CTE	0.2	--	0.03	0.009	0.01	0.0002	**0.3**
	RME	0.4	--	0.03	0.02	0.01	0.0002	**0.5**
Northern CSAOI - Adult	CTE	0.02	0.005	0.03	0.0004	0.0002	0.00004	**0.06**
	RME	0.04	0.009	0.03	0.0008	0.0002	0.00004	**0.1**
Southern CSAOI - Child	CTE	0.07	--	0.08	0.009	0.01	0.0002	**0.2**
	RME	0.1	--	0.08	0.02	0.01	0.0002	**0.3**
Southern CSAOI - Adult	CTE	0.007	0.005	0.08	0.0004	0.0002	0.00004	**0.1**
	RME	0.01	0.009	0.08	0.0008	0.0002	0.00004	**0.1**
Great Falls - Child	CTE	0.06	--	0.01	--	--	--	**0.08**
	RME	0.1	--	0.01	--	--	--	**0.1**
Great Falls - Adult	CTE	0.006	--	0.01	--	--	--	**0.02**
	RME	0.01	--	0.01	--	--	--	**0.03**

Notes:
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable

Table 13: Arsenic cancer risk estimates for residents

Resident		Soil & Dust Ingestion	Attic Dust Ingestion	Soil Particulate Inhalation	Sediment Ingestion	Surface Water Ingestion	Surface Water Dermal	Total Cancer Risk
Northern CSAOI - Child	CTE	8E-06	--	2E-07	3E-07	4E-07	6E-09	**9E-06**
	RME	2E-05	--	2E-07	7E-07	4E-07	6E-09	**2E-05**
Northern CSAOI - Adult	CTE	3E-06	6E-07	5E-07	5E-08	2E-08	6E-09	**4E-06**
	RME	5E-06	1E-06	5E-07	1E-07	2E-08	6E-09	**7E-06**
Northern CSAOI - Child + Adult	CTE	1E-05	6E-07	7E-07	4E-07	4E-07	1E-08	**1E-05**
	RME	2E-05	1E-06	7E-07	8E-07	4E-07	1E-08	**3E-05**
Southern CSAOI - Child	CTE	3E-06	--	5E-07	3E-07	4E-07	6E-09	**4E-06**
	RME	6E-06	--	5E-07	7E-07	4E-07	6E-09	**7E-06**
Southern CSAOI - Adult	CTE	9E-07	6E-07	2E-06	5E-08	2E-08	6E-09	**3E-06**
	RME	2E-06	1E-06	2E-06	1E-07	2E-08	6E-09	**5E-06**
Southern CSAOI - Child + Adult	CTE	4E-06	6E-07	2E-06	4E-07	4E-07	1E-08	**7E-06**
	RME	7E-06	1E-06	2E-06	8E-07	4E-07	1E-08	**1E-05**
Great Falls - Child	CTE	2E-06	--	8E-08	--	--	--	**3E-06**
	RME	5E-06	--	8E-08	--	--	--	**5E-06**
Great Falls - Adult	CTE	8E-07	--	3E-07	--	--	--	**1E-06**
	RME	2E-06	--	3E-07	--	--	--	**2E-06**
Great Falls - Child + Adult	CTE	3E-06	--	3E-07	--	--	--	**4E-06**
	RME	6E-06	--	3E-07	--	--	--	**7E-06**

Notes:
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable

Table 14: Arsenic non-cancer hazard quotients and hazard indices for non-residents

Non-Resident		Soil & Dust Ingestion	Soil Particulate Inhalation	Hazard Index
Northern CSAOI - Outdoor Worker	CTE	0.05	0.007	**0.05**
	RME	0.09	0.007	**0.1**
Southern CSAOI – Outdoor Worker	CTE	0.01	0.02	**0.03**
	RME	0.03	0.02	**0.05**
Northern Outlying Area - Outdoor Worker	CTE	0.03	0.02	**0.04**
	RME	0.05	0.02	**0.07**
Northern CSAOI - Indoor Worker	CTE	0.01	--	**0.01**
	RME	0.02	--	**0.02**
Southern CSAOI - Indoor Worker	CTE	0.003	--	**0.003**
	RME	0.006	--	**0.006**
Northern Outlying Area - Indoor Worker	CTE	0.006	--	**0.006**
	RME	0.01	--	**0.01**
CSAOI - Utility Worker		0.0003	0.03	**0.04**
Unpaved Roads/Alleys - Utility Worker		0.0004	0.04	**0.04**
Northern Outlying Area - Utility Worker		0.0003	0.03	**0.03**
ATV/Dirt Bike Rider	CTE	0.03	0.1	**0.1**
	RME	0.06	0.1	**0.2**

Notes:
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable
ATV = all-terrain vehicle

Table 15: Arsenic cancer risk estimates for non-residents

Non-Resident		Soil & Dust Ingestion	Soil Particulate Inhalation	Total Cancer Risk
Northern CSAOI - Outdoor Worker	CTE	7E-06	2E-07	**8E-06**
	RME	1E-05	2E-07	**2E-05**
Southern CSAOI – Outdoor Worker	CTE	2E-06	4E-07	**3E-06**
	RME	4E-06	4E-07	**5E-06**
Northern Outlying Area - Outdoor Worker	CTE	4E-06	4E-07	**5E-06**
	RME	9E-06	4E-07	**9E-06**
Northern CSAOI - Indoor Worker	CTE	2E-06	--	**2E-06**
	RME	3E-06	--	**3E-06**
Southern CSAOI - Indoor Worker	CTE	5E-07	--	**5E-07**
	RME	1E-06	--	**1E-06**
Northern Outlying Area - Indoor Worker	CTE	9E-07	--	**9E-07**
	RME	2E-06	--	**2E-06**
CSAOI - Utility Worker		4E-08	3E-08	**7E-08**
Unpaved Roads/Alleys - Utility Worker		4E-08	4E-08	**8E-08**
Northern Outlying Area - Utility Worker		4E-08	3E-08	**7E-08**
ATV/Dirt Bike Rider	CTE	4E-06	1E-06	**5E-06**
	RME	7E-06	3E-06	**1E-05**

Notes:
CSAOI = Community Soils Areas of Interest
CTE = central tendency exposure
RME = reasonable maximum exposure
-- = pathway not applicable
ATV = all-terrain vehicle

Table 16: IEUBK model results

Child Resident Exposure Area	Soil Intake Rate Basis	Geometric Mean Blood Lead (µg/dL)	Probability Child Blood Lead > 10 µg/dL
Northern CSAOI	Default	1.598	0.005%
	Alternate	1.325	0.001%
Southern CSAOI	Default	2.460	0.1%
	Alternate	1.905	0.02%
Great Falls	Default	1.681	0.007%
	Alternate	1.380	0.001%

Notes:
CSAOI = Community Soils Areas of Interest
µg/dL = micrograms per deciliter

Table 17: Adult lead model results

Exposure Scenario	Geometric Mean Blood Lead (µg/dL)	95th Percentile Fetal Blood Lead (µg/dL)	Probability Fetal Blood Lead > 10 µg/dL
Baseline	0.80	1.9	0.0004%
Attic User - CSAOI	0.88	2.1	0.0008%
Outdoor Worker - Northern CSAOI	1.2	2.9	0.009%
Outdoor Worker - Southern CSAOI	1.1	2.7	0.005%
Outdoor Worker - Northern Outlying Area	0.93	2.2	0.001%
Indoor Worker - Northern CSAOI	0.90	2.1	0.0009%
Indoor Worker - Southern CSAOI	0.87	2.1	0.0007%
Indoor Worker - Northern Outlying Area	0.83	2.0	0.0005%
ATV/Dirt Bike Rider	1.1	2.7	0.005%

Notes:
CSAOI = Community Soils Areas of Interest
µg/dL = micrograms per deciliter
ATV = all-terrain vehicle

Table 18: Key uncertainties associated with the exposure assessment

Source of uncertainty	Potential Effect on Exposure Estimates	Potential Magnitude of Effect
Environmental Sampling Data		
Source of lead and arsenic detected in samples may or may not have originated from the former ACM smelter and refinery site.	Overestimate	Low to moderate
Number of samples collected for some exposure media or areas are limited.	Over- or underestimate	Low
Extrapolation of IVBA data to RBA estimates.	Over- or underestimate	Low to moderate
Fate and Transport Modeling		
Concentrations of indoor (living space) dust in residential homes are assumed to be due solely to transport of soil particulate from the home's yard.	Overestimate	Moderate
The relationship between yard soil concentration and indoor dust concentration at residential properties is assumed the same as the relationship at commercial/industrial properties.	Over- or underestimate	High
Default lead air concentration used in the IEUBK model.	Over- or underestimate	Low
Use of PEFs to estimate of the relationship between soil concentration of arsenic and the concentration of arsenic in air as a consequence of particle suspension.	Overestimate	High
Exposure Parameter Estimation		
USEPA (2014a) default exposure assumptions regarding exposure duration, exposure time, body weight, and life expectancy may not be representative of any actual exposure situation.	Overestimate	Low
Medium-specific contact rates are assumed to be constant and representative of the exposed population.	Overestimate	High
Adjustment of exposure frequencies based on average climate data for Great Falls and anecdotal information provided by the community.	Over- or underestimate	Moderate
Assumption of specific sample depths to which exposures of different populations may occur.	Over- or underestimate	Moderate to high

Table 19: Arsenic soil preliminary remediation goals (PRGs)

Exposure Scenario	Arsenic PRG Concentration (mg/kg)			
	Risk = 1E-06	Risk = 1E-05	Risk = 1E-04	HQ = 1
Resident - OU1 Soil	4	36	360	175
Outdoor Worker – OU1 Soil	12	120	1,204	1,566
Utility Worker – OU1 Soil	767	7,670	76,697	1,312
Indoor Worker – OU1 Soil	58	577	5,772	9,276
ATV/Dirt Bike Rider – ECDR Soil	20	200	1,996	979

Notes:
mg/kg = milligram arsenic per kilogram soil
HQ = hazard quotient
ATV = all-terrain vehicle
ECDR = Electric City Dirt Riders

Table 20: Lead soil preliminary remediation goals (PRGs)

Exposure Scenario	Lead PRG Concentration (mg/kg)
Child Resident - OU1 Soil (alternate soil intake rates)	768
Child Resident - OU1 Soil (default soil intake rates)	500
Outdoor Workers - OU1 Soil	1,766
Indoor Workers - OU1 Soil	3,172
ATV/Dirt Bike Rider – ECDR Soil	3,087
Notes: mg/kg = milligram lead per kilogram soil ATV = all-terrain vehicle ECDR = Electric City Dirt Riders	

FIGURES

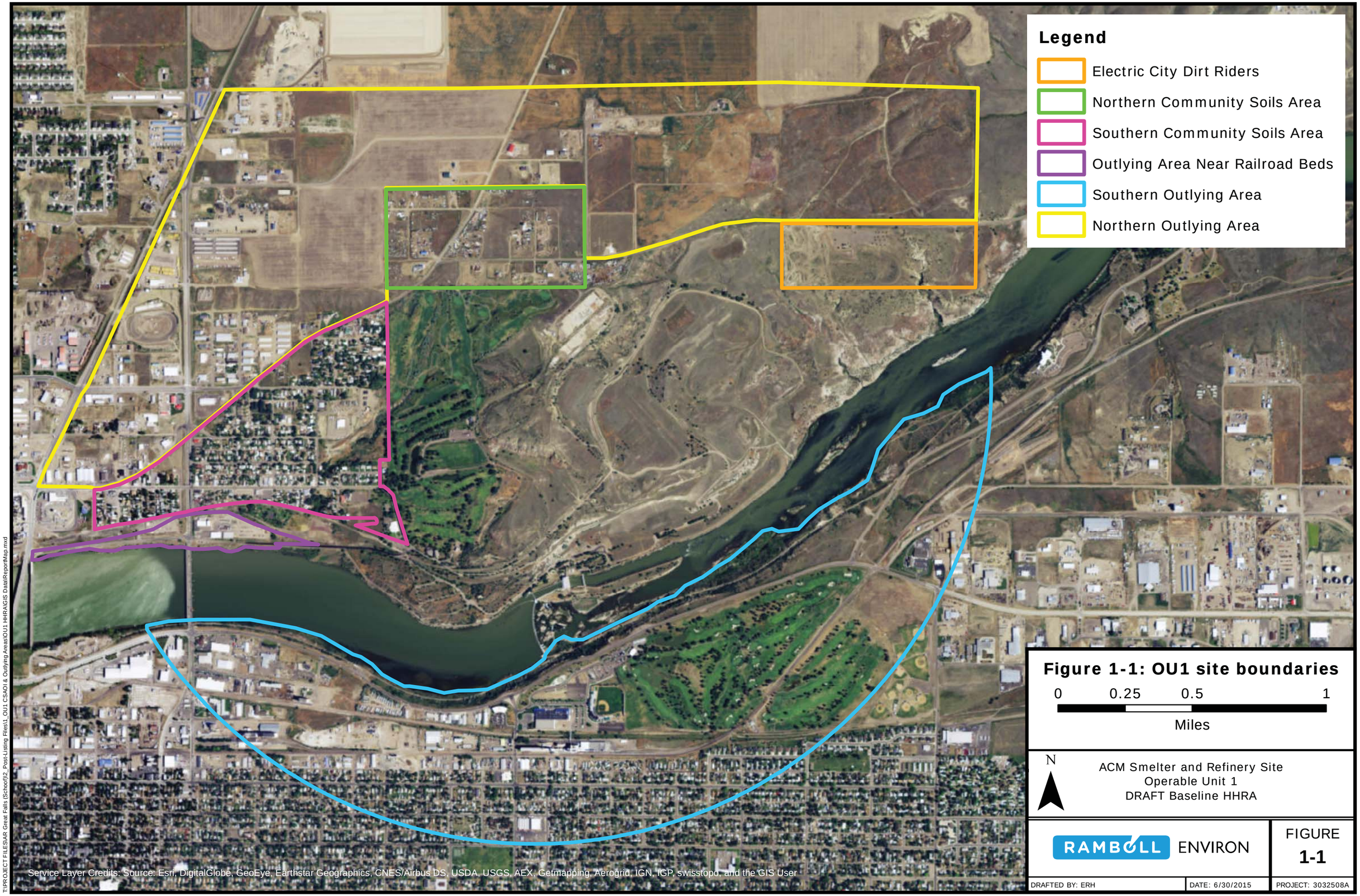

Figure 1-1: OU1 site boundaries

0 0.25 0.5 1

Miles

N

ACM Smelter and Refinery Site
Operable Unit 1
DRAFT Baseline HHRA

RAMBOLL ENVIRON

FIGURE
1-1

DRAFTED BY: ERH | DATE: 6/30/2015 | PROJECT: 3032508A

T:\PROJECT FILES\AR Great Falls (Schoor)\2_Post-Listing Files\1_OU1 CSAOI & Outlying Areas\OU1 HHRA\GIS Data\ReportMap.mxd

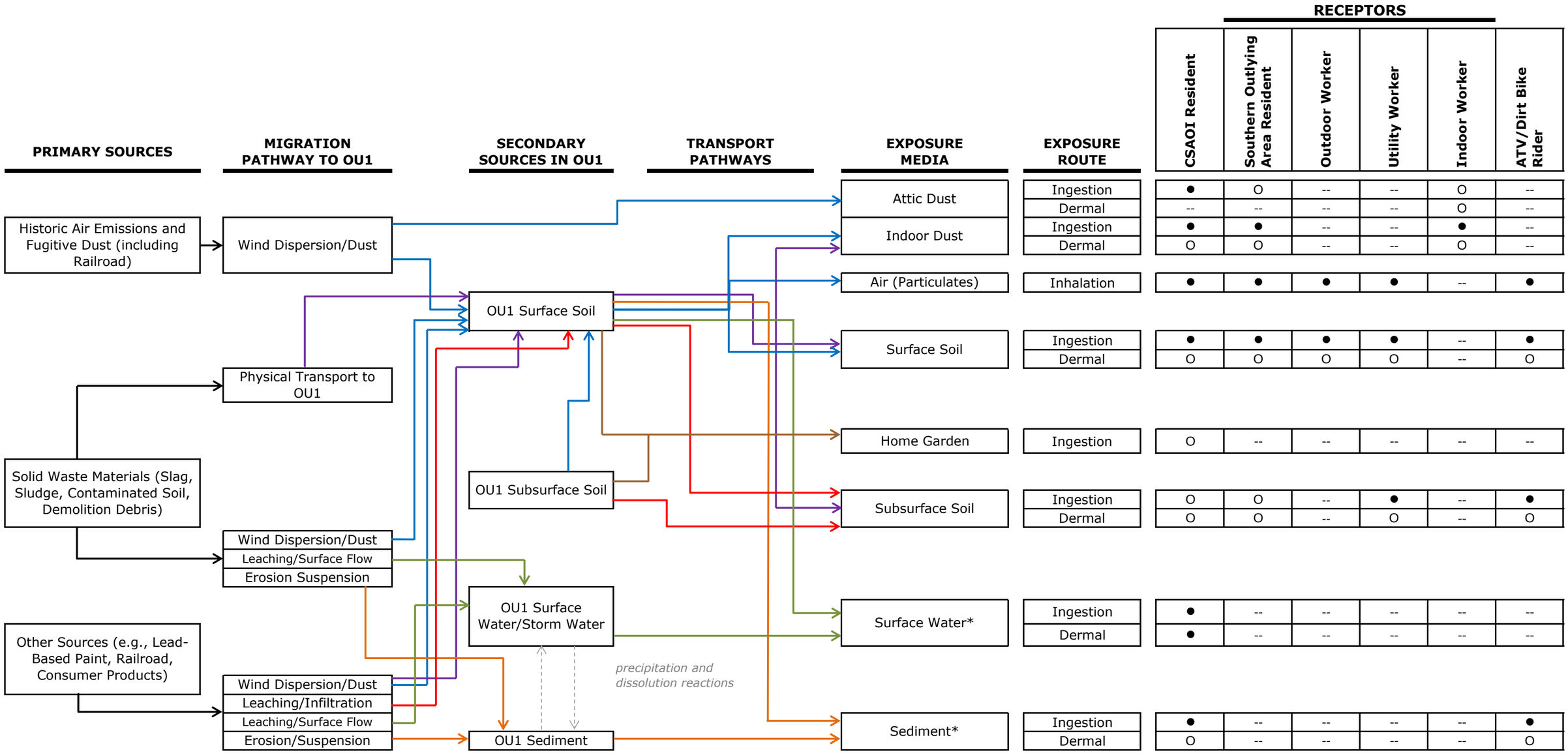

Figure 2-1: OU1 human health conceptual site model

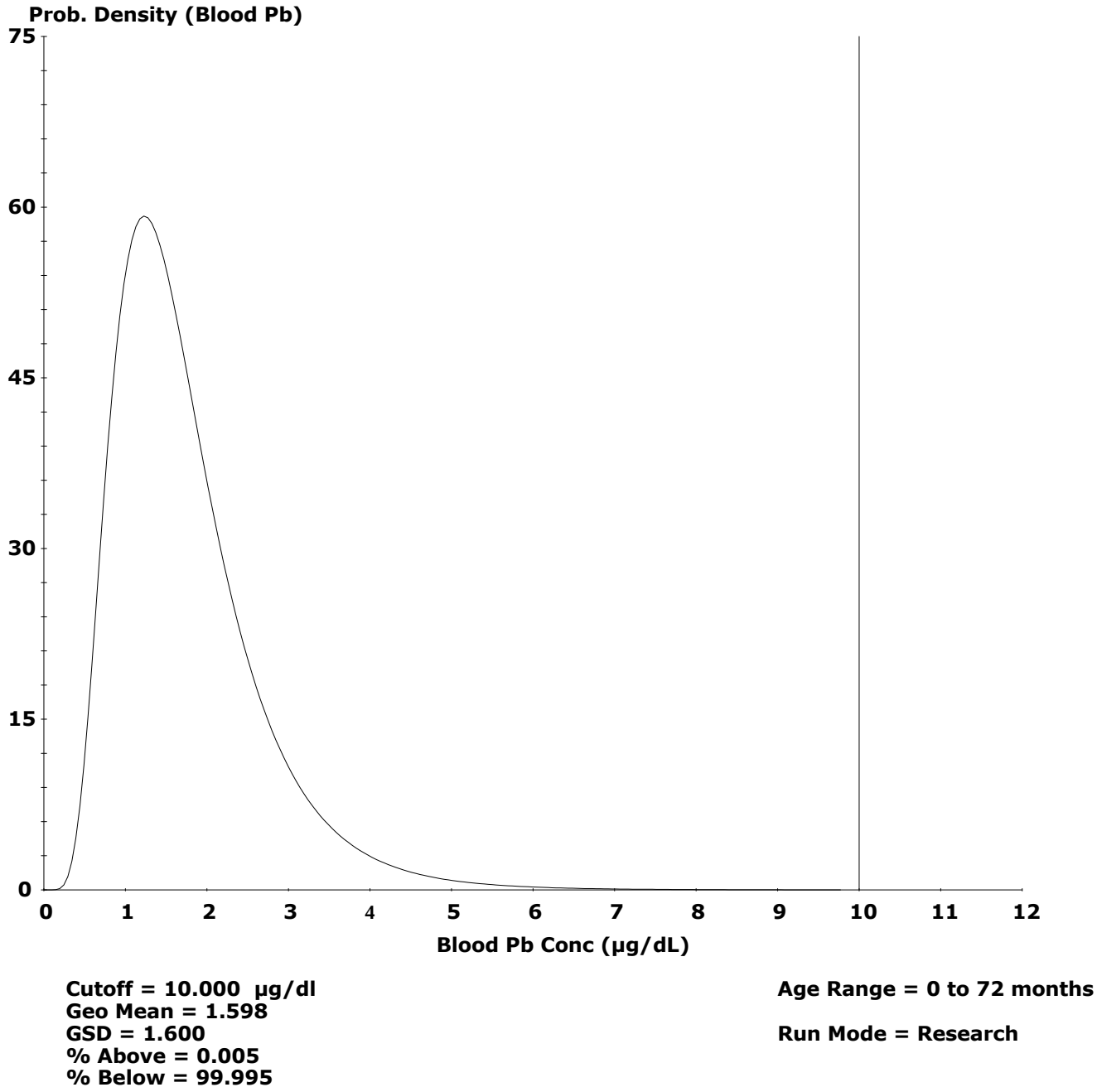

Figure 6-1: IEUBK model blood lead probability density plot for northern CSAOI child using default ingestion rates

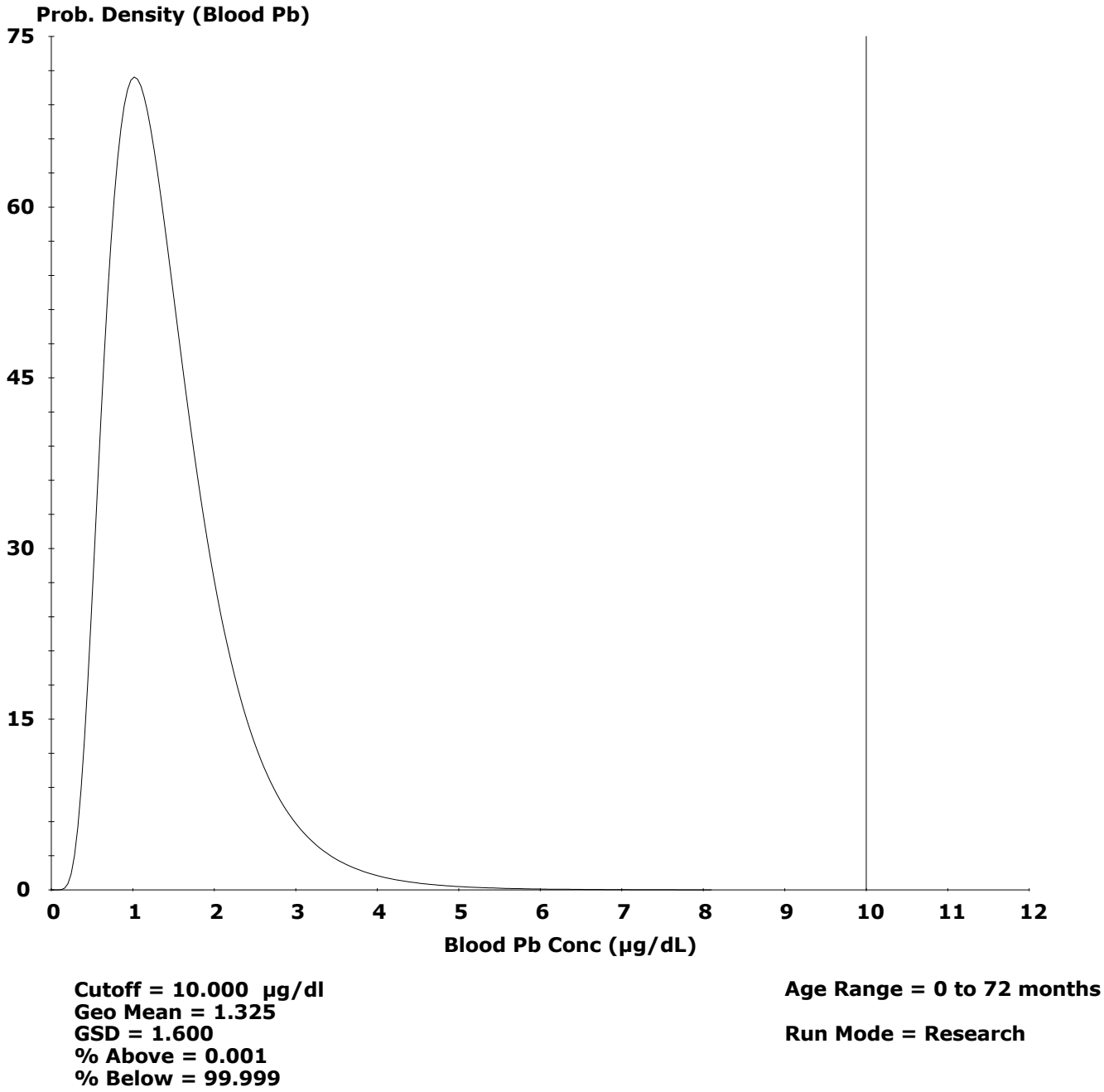

Figure 6-2: IEUBK model blood lead probability density plot for northern CSAOI child using alternate ingestion rates

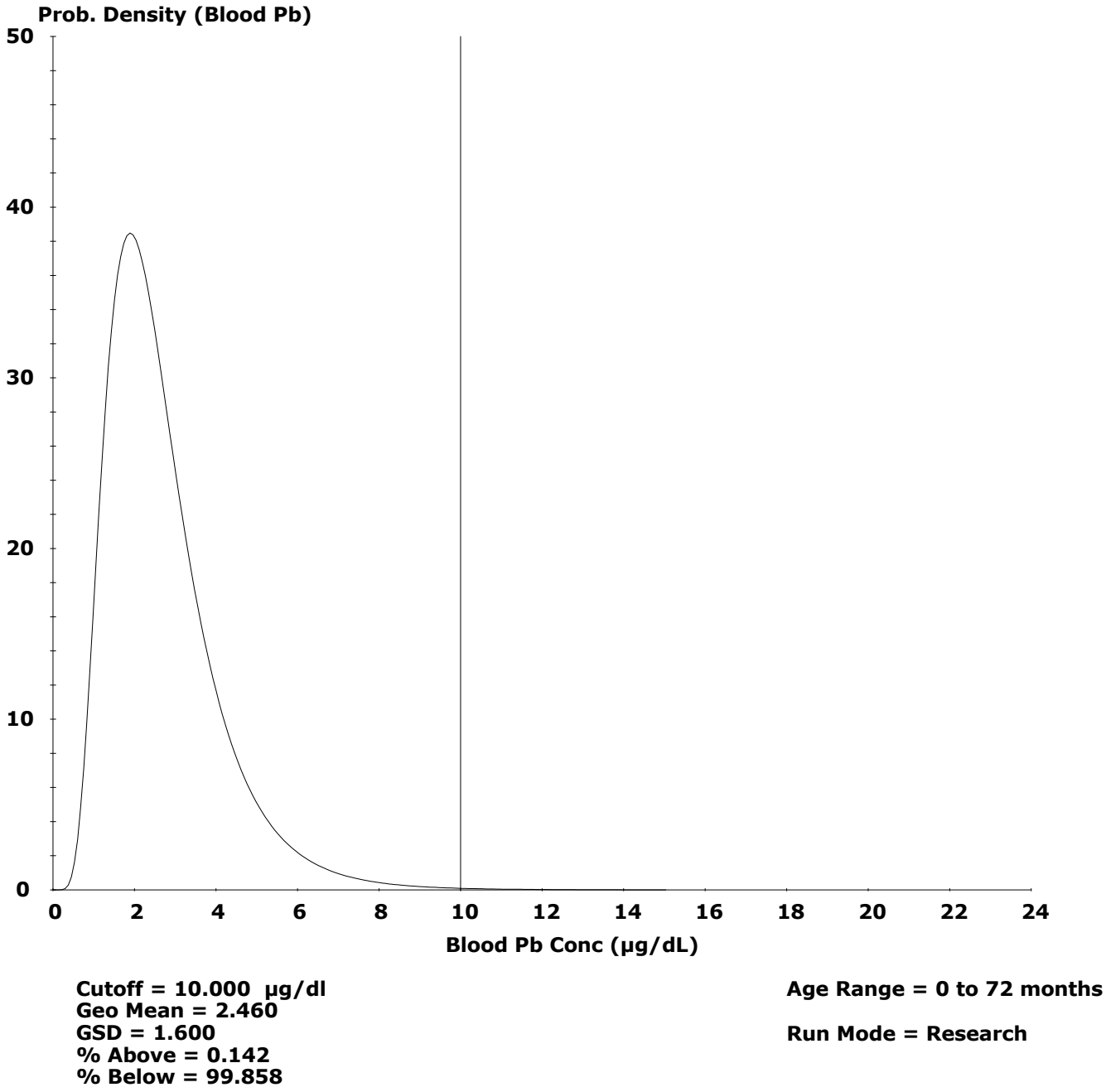

Figure 6-3: IEUBK model blood lead probability density plot for southern CSAOI child using default ingestion rates

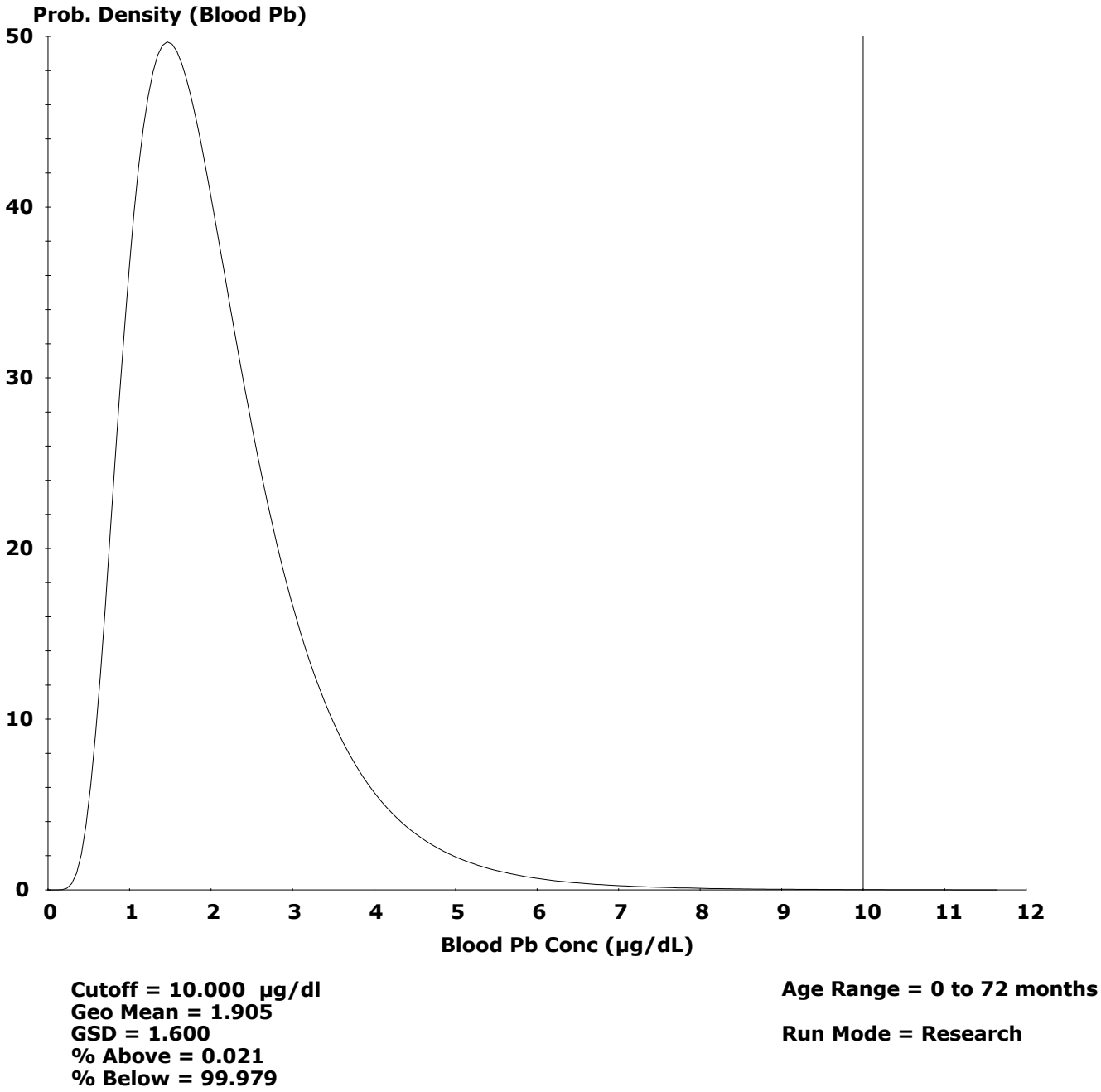

Figure 6-4: IEUBK model blood lead probability density plot for southern CSAOI child using alternate ingestion rates

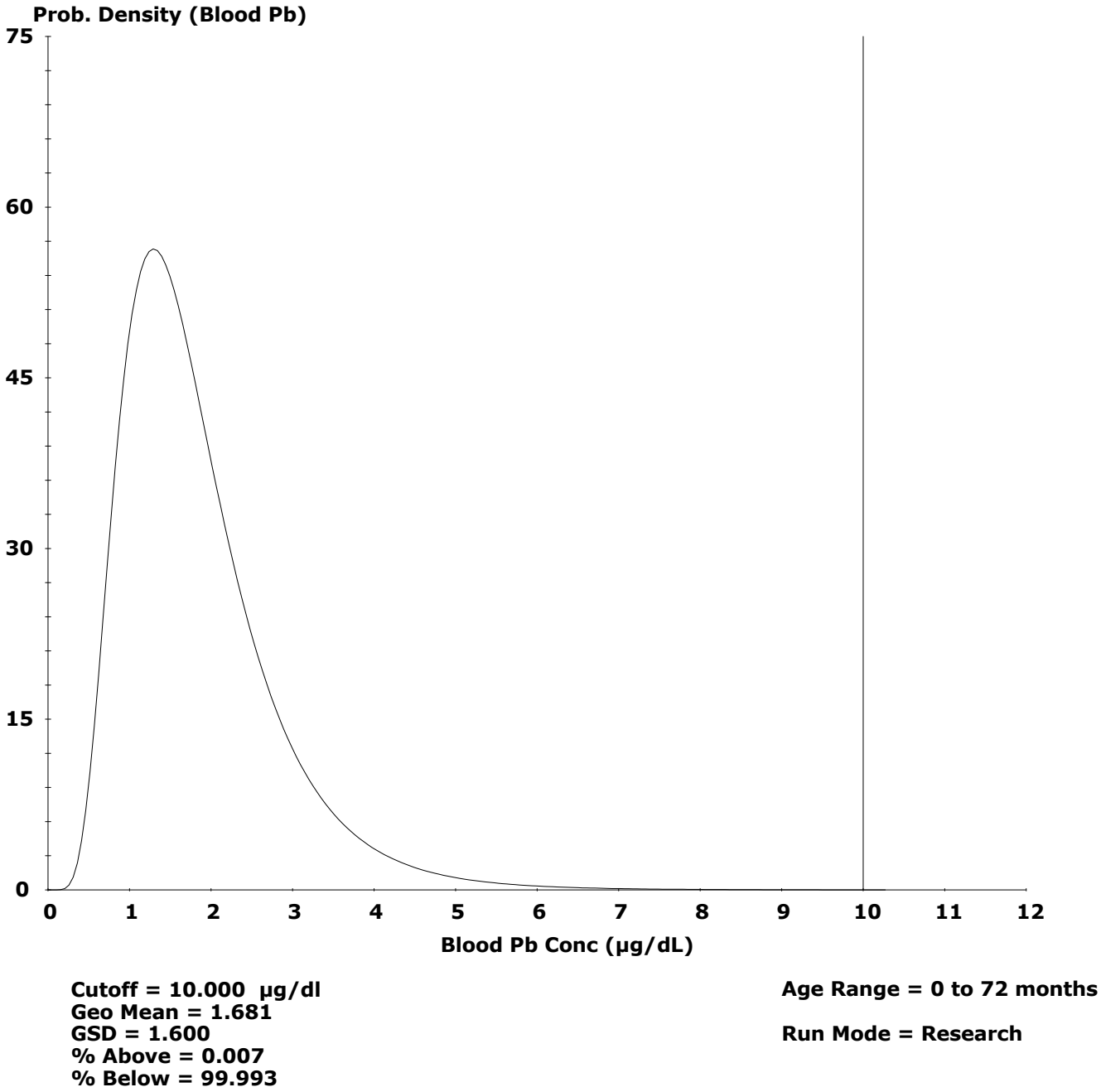

Figure 6-5: IEUBK model blood lead probability density plot for Great Falls child using default ingestion rates

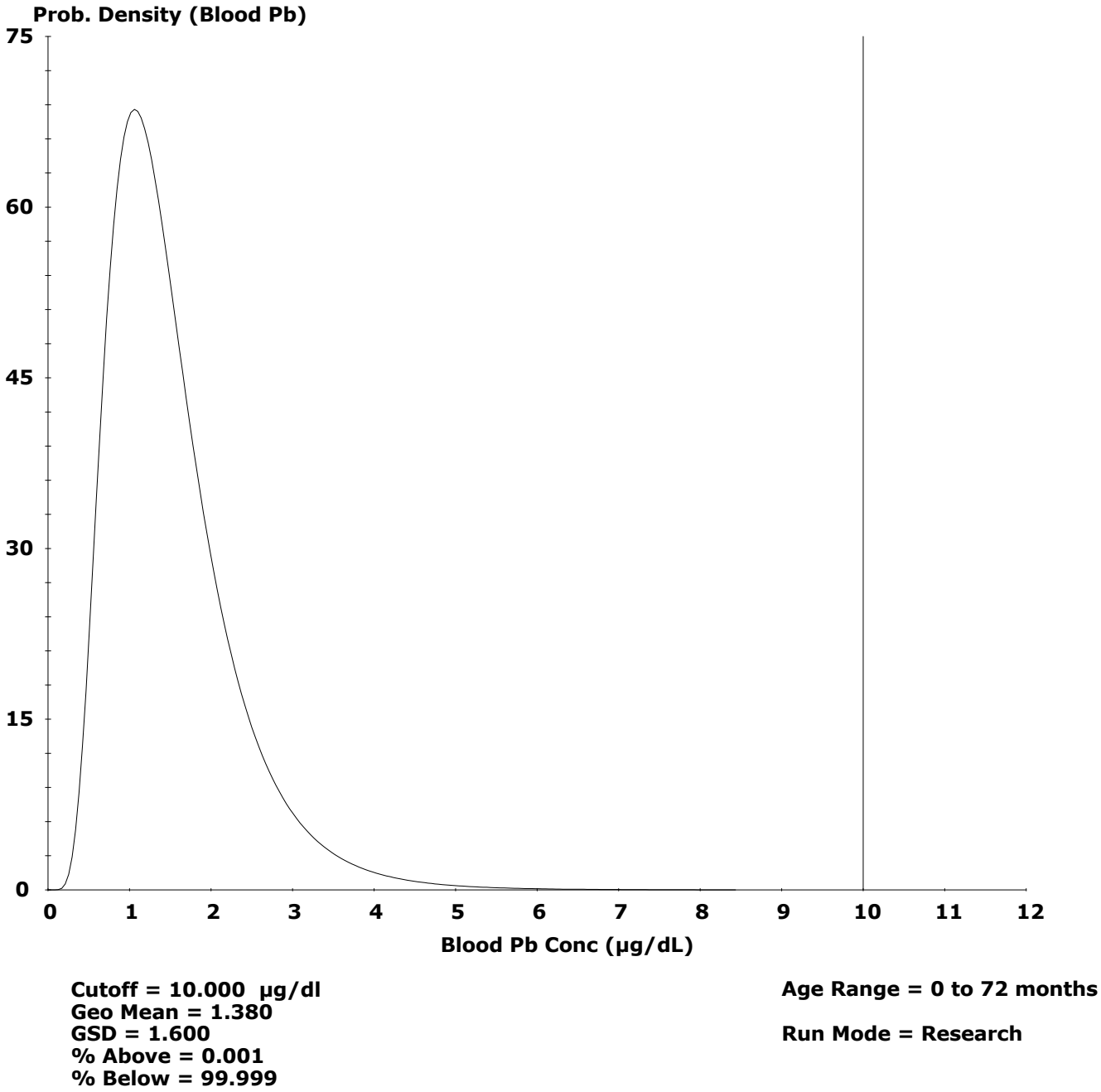

Figure 6-6: IEUBK model blood lead probability density plot for Great Falls child using alternate ingestion rates

EXHIBITS

Exhibit 1: Residential soil PRG equation

$$PRG_{ing+inh} = \frac{1}{\left(\frac{1}{PRG_{ing}}\right) + \left(\frac{1}{PRG_{inh}}\right)}$$

PRG_{ing} = preliminary remediation goal for incidental ingestion of yard soil and interior dust (mg/kg)
PRG_{inh} = preliminary remediation goal for inhalation of particulate from residential yard soil (mg/kg)

Where:

$$PRG_{ing} = \frac{TR \times AT}{CSF_o \times RBA \times F_s \times CF} \times \left(\frac{BW_{child}}{EF \times ED_{child} \times IR_{child}} + \frac{BW_{adult}}{EF \times ED_{adult} \times IR_{adult}}\right)$$

PRG_{ing} = preliminary remediation goal based on soil and dust ingestion (mg/kg)
TR = target risk, 1E-06 to 1E-04
AT = averaging time (days)
CSF_o = oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
RBA = relative oral bioavailability of arsenic in soil (unitless)
F_s = fraction of intake as soil (unitless)
CF = unit conversion factor (10^{-6} kg/mg)
BW = body weight for children and adults (kg)
EF = exposure frequency (days/year)
ED = exposure duration for children and adults (years)
IR = soil/dust ingestion rate for children and adults (kg/day)

And where:

$$PRG_{inh} = \frac{TR \times AT \times PEF}{URF_{inh} \times CF_1 \times CF_2} \times \left(\frac{1}{EF \times ED_{child} \times ET} + \frac{1}{EF \times ED_{adult} \times ET}\right)$$

PRG_{inh} = preliminary remediation goal based on inhalation of soil particulate (mg/kg)
TR = target risk, 1E-06 to 1E-04
AT = averaging time (days)
PEF = particulate emission factor $(kg/m^3)^{-1}$
URF_{ing} = inhalation unit risk factor $(\mu g/m^3)^{-1}$
CF_1 = unit conversion factor (10^3 µg/mg)
CF_2 = unit conversion factor (1/24 day/hours)
EF = exposure frequency (days/year)
ED = exposure duration for children and adults (years)
ET = exposure time (hour/day)

Exhibit 2: Non-residential soil PRG equation

$$PRG_{ing+inh} = \frac{1}{\left(\frac{1}{PRG_{ing}}\right) + \left(\frac{1}{PRG_{inh}}\right)}$$

PRG_{ing} = preliminary remediation goal for incidental ingestion of soil or indoor dust from soil (mg/kg)
PRG_{inh} = preliminary remediation goal for inhalation of particulate from non-residential soil (mg/kg)

Where:

$$PRG_{ing} = \frac{TR \times AT}{CSF_o \times RBA \times F_s \times CF} \times \left(\frac{BW_{adult}}{EF \times ED_{adult} \times IR_{adult}}\right)$$

PRG_{ing} = preliminary remediation goal based on soil or dust ingestion (mg/kg)
TR = target risk, 1E-06 to 1E-04
AT = averaging time (days)
CSF_o = oral cancer slope factor $(mg/kg\text{-}day)^{-1}$
RBA = relative oral bioavailability of arsenic in soil (unitless)
F_s = fraction of intake as soil (unitless)
CF = unit conversion factor (10^{-6} kg/mg)
BW = body weight for adults (kg)
EF = exposure frequency (days/year)
ED = exposure duration for adults (years)
IR = soil ingestion rate for and adults (kg/day)

And where:

$$PRG_{inh} = \frac{TR \times AT \times PEF}{URF_{inh} \times CF_1 \times CF_2} \times \left(\frac{1}{EF \times ED_{adult} \times ET}\right)$$

PRG_{inh} = preliminary remediation goal based on inhalation of soil particulate (mg/kg)
TR = target risk, 1E-06 to 1E-04
AT = averaging time (days)
PEF = particulate emission factor $(kg/m^3)^{-1}$
URF_{ing} = inhalation unit risk factor $(\mu g/m^3)^{-1}$
CF_1 = unit conversion factor (10^3 µg/mg)
CF_2 = unit conversion factor (1/24 day/hours)
EF = exposure frequency (days/year)
ED = exposure duration for adults (years)
ET = exposure time (hour/day)

APPENDIX A
APPROVED BASELINE HHRA WORK PLAN

June 2015 Errata Sheet on May 2015 HHRA Work Plan:

1. Page 34, Section 5.1.2, “0.285” should be “0.295” in the statement: “The absorption value of 0.285 is slightly lower than USEPA’s current default for absorption from soil and indoor dust (0.30).” The correct value is one-half the 59 percent site-specific RBA estimate for lead that is noted in Section 5.1.2.
2. Table 4-1 Reference j: “USEPA 2014c” should be “USEPA 2014d.”
3. Table 5-1, Soil/Dust Absorption Input Value: “31%” should be “29.5%.” The correct value is one-half the 59 percent site-specific RBA estimate for lead that is noted in Section 5.1.2.
4. Table 5-2, AFs Inputs: “0.124” should be “0.118” based on correction of lead RBA.
5. Table 5-2, AFs Source/Basis: “62 percent” should be “59 percent” as detailed in Section 5.1.2.
6. Table 5-2, EFs Input for Indoor Worker: “173” should be “167” as detailed in Section 4.2.9.
7. Table 5-2, EFs Input for Outdoor Worker: “150” should be “173” as detailed in Section 4.2.9.
8. Table 5-2, EFs Input for ATV/Dirt Bike Rider: “52” should be “104” as detailed in Section 4.2.9.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8, MONTANA OFFICE
FEDERAL BUILDING, 10 W. 15th STREET, SUITE 3200
HELENA, MONTANA 59626

Ref: 8MO

June 8, 2015

Mr. Luke Pokorny
Atlantic Richfield Company
317 Anaconda Road
Butte, Montana 59701

Dear Luke:

EPA, in consultation with DEQ, approves with comment, Atlantic Richfield's *Final Human Health Risk Assessment (HHRA) Work Plan for the ACM Smelter and Refinery Site, Operable Unit 1 - Community Soils RI/FS, dated May 22, 2015.* Please note the following comment:

- The determination made in Section 2.5.3, "there is little risk associated with consuming homegrown produce" is premature and not fully supported.

Please proceed with the development of the draft risk assessment in accordance with the AOC schedule. If you have any questions, please give me a call.

Sincerely,

Charles Coleman
ACM Project Manager

cc: Andy Lensink, 8ENF-L (email)
Charles Partridge, 8EPR-PS (email)
Dick Sloan, DEQ (email)
Jon Morgan, DEQ (email)
Robin Witt, PWT (email)

AR: Jack Oman, AR (email)
Brian Johnson, AR (email)
Randy Dann, DGS (email)
Bill Duffy, DGS (email)
Brian Hansen, Formation (email)
Dina Johnson, Environ (email)

Atlantic Richfield Company

317 Anaconda Road
Butte, MT 59701
Main (406) 782 9964
Fax (406) 782 9980

CERTIFIED RETURN RECEIPT REQUESTED

May 22, 2015

Mr. Charlie Coleman
U.S. EPA, Region VIII
Federal Building, 10 West 15th Street
Suite 3200
Helena, Montana 59626-0096

RE: ACM Smelter and Refinery Site Operable Unit 1 RI/FS – Transmittal of Final Human Health Risk Assessment Work Plan for the ACM Smelter and Refinery Site, Operable Unit 1 and Response to Agency Comments on Draft Work Plan

Dear Charlie:

Enclosed for your review is the Final Human Health Risk Assessment (HHRA) Work Plan for the Anaconda Copper Mining Company (ACM) Smelter and Refinery Site, Operable Unit 1 (OU1). The Final HHRA Work Plan details the approaches, methods, and assumptions to be used in conducting the baseline HHRA for OU1 of the ACM Site. USEPA will use the baseline HHRA and the approved RI Report to support risk management decisions for OU1. The approaches outlined in the enclosed work plan reflect agency and community input received as comments to the December 12, 2014 Draft Work Plan and during subsequent meetings and communications with USEPA, MDEQ, and Black Eagle Technical Advisory Committee representatives.

Submittal of the Draft baseline HHRA report is currently planned for July 24, 2015, pending receipt of agency approval on the Final HHRA Work Plan by June 26, 2015.

If you have any questions or comments, please contact me at (406) 723-1832.

Sincerely,

Luke Pokorny
Project Manager

W/enclosures (2)

cc: Charlie Coleman – EPA (electronic copy)
Charles Partridge – EPA (electronic copy)
Andy Lensink – EPA (electronic copy)
Dick Sloan – DEQ (electronic + hard copy)
Jon Morgan – DEQ (electronic copy)
Robin Witt – PWT (electronic + hard copy)

Jack Oman – AR (electronic copy)
Brian Johnson – AR (electronic copy)
Ann Baranowski – AR Library (electronic copy)
Lorri Birkenbuel – BP (electronic copy)
Terry Moore – BP (electronic copy)
James Nolan – BP (electronic copy)
Bill Duffy – DG&S (electronic copy)
Randy Dann – DG&S (electronic copy)
Andy White – Pioneer (electronic + hard copy)
Brian Hansen – Formation (electronic + hard copy)
Don Booth – BC (electronic + hard copy)
Dina Johnson – Environ (electronic copy)

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75.00.50 (letter only w/o enc.)

Final Human Health Risk Assessment Work Plan

ACM Smelter and Refinery Site
Operable Unit 1

Prepared for:
Atlantic Richfield Company
Butte, Montana

Prepared by:
ENVIRON International Corporation
Seattle, Washington

Date:
May 2015

Project Number:
30-32508A

Contents

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Acronyms and Abbreviations

ACM:	Anaconda Copper Mining Company
ADD:	Average Daily Dose
ALM:	Adult Lead Methodology
ATV:	All-Terrain Vehicles
AT:	Averaging Time
BKSF:	Biokinetic slope factor
CDC:	Centers for Disease Control and Prevention
COI:	Chemical of Interest
COPC:	Chemicals of Potential Concern
CSAOI:	Community Soils Areas of Interest
Cm^2:	centimeters squared
CSM:	Conceptual Site Model
CTE:	Central Tendency Exposure
DL:	Detection Limit
ECDR:	Electric City Dirt Riders
EPC:	Exposure Point Concentration
GI:	Gastrointestinal
HHRA:	Human Health Risk Assessment
IEUBK:	Integrated Exposure Uptake Biokinetic
LADD:	Lifetime Average Daily Dose
MCL:	Maximum Contaminant Level
MDEQ:	Montana Department of Environmental Quality
MDL:	Method Detection Limit
mg/day:	milligrams per day
µg/dL:	micrograms per deciliter
mL/hour:	milliliter per hour
MSD:	Mass soil-to-dust transfer factor
NOAEL:	No Observed Adverse Effect Level
OU1:	Operable Unit 1
PEF:	Particulate Emission Factor
PQL:	Practical Quantitation Limit

PRG:	Preliminary Remediation Goal
RBA:	Relative Oral Bioavailability
RfD:	Reference Dose
RI:	Remedial Investigation
RI/FS:	Remedial Investigation and Feasibility Study
RI SAP:	Remedial Investigation Sampling and Analysis Plan
RME:	Reasonable Maximum Exposure
RSL:	Risk-Based Screening level
SCEM:	Site Conceptual Exposure Model
SF:	Slope Factor
SHEDS:	Stochastic Human Exposure and Dose Simulation
SOW:	Statement of Work
TRW:	Technical Review Workgroup
USEPA:	United States Environmental Protection Agency

1 Introduction

Atlantic Richfield Company and ARCO Environmental Remediation, LLC (collectively "Atlantic Richfield") are implementing a Remedial Investigation/Feasibility Study (RI/FS) at Operable Unit 1 (OU1) of the Anaconda Copper Mining Company (ACM) Site pursuant to the Administrative Settlement Agreement and Order on Consent (Settlement Agreement/CO) between Atlantic Richfield and the US Environmental Protection Agency (USEPA) dated September 8, 2011 (USEPA 2011a) and its attached Statement of Work (SOW). USEPA is the lead agency for the OU1 RI/FS, and the Montana Department of Environmental Quality (MDEQ) is participating as a support agency. The SOW specifies that USEPA will conduct the baseline human health risk assessment (HHRA) component of the OU1 remedial investigation (RI) and that assessment of ecological risks for OU1 will be deferred to the future RI/FS for the former smelter and refinery property and the Missouri River. However, in May 2014, USEPA requested that Atlantic Richfield conduct the baseline HHRA.

Atlantic Richfield recently submitted the RI Report (Formation 2014) for OU1 to the agencies for approval. Per the SOW, information from the final approved RI Report and the baseline HHRA will be considered by USEPA, in consultation with MDEQ, to develop remedial action objectives for the ACM Site.

This document provides the draft work plan for the baseline HHRA for OU1. The purpose of the draft work plan is to outline approaches, methods, and assumptions to be used in conducting the baseline HHRA for OU1 of the ACM Site. USEPA will use the baseline HHRA and the approved RI Report to support risk management decisions for OU1. The scope of the HHRA and its findings are not intended to supersede USEPA's consideration of ecological risks for OU1 that has been deferred for evaluation in conjunction with other ACM Site operable units.

1.1 Focus of the Draft Work Plan

As defined by USEPA (2011a) in the Settlement Agreement/CO and described in the RI Report, OU1 includes the Community Soils Areas of Interest (CSAOI) and Outlying Areas as shown on Figure 1-1. USEPA has also designated a portion of the railroad beds within Black Eagle as OU1; RI/FS activities within the "Railroad Corridor" are being conducted under EPA's Unilateral Administrative Order issued to BNSF Railway Company (USEPA 2011b). The former smelter and refinery property and the Missouri River are not included in OU1. Therefore, the focus of this work plan is limited to the CSAOI and Outlying Areas of OU1. The CSAOI includes Black Eagle in the southern portion and residential and undeveloped lots in the northern portion. The Outlying Areas include the northern portion of Great Falls (south of the Missouri River) and unincorporated areas of Cascade County that surround the CSAOI. The Outlying Areas include residential, commercial, industrial, agricultural, recreational, and undeveloped land areas though not all land uses are present in all portions of the Outlying Areas. Future land use within and surrounding OU1 is not expected to differ substantially from current land uses; therefore, land use assumptions included in the baseline HHRA apply to future land uses as well.

The RI Report details the ACM Site history, setting, and physical characteristics, as well as a characterization of available site data and fate and transport mechanisms. As it relates to

conduct of the baseline HHRA, background site information presented in the RI Report is referenced, but not reproduced, in this work plan.

Based on data evaluations conducted during the RI and documented in the RI Report (Formation 2014), two of 14 chemicals of interest (COIs) for OU1 were identified as chemicals of potential concern (COPCs) for further evaluation in the baseline HHRA. As discussed in Section 2.1, these two COPCs, lead and arsenic, are the focus of the risk assessment approaches detailed in this work plan.

1.2 Document Organization

In addition to the introduction, this document consists of the following sections:

- Section 2 – Contaminant Identification and Media Screening
- Section 3 – Current Conceptual Site Model (CSM)
- Section 4 – Arsenic Exposure Assessment Approach
- Section 5 -- Approach to Modeling Lead Risks
- Section 6 – Toxicity Assessment Approach
- Section 7 -- Risk Characterization Approach
- Section 8 – Approach for Evaluating Uncertainties
- Section 9 – Approach for Development of Remedial Goals
- Section 10 – References

All tables and figures are located at the end of the document.

2 Contaminant Identification and Media Screening

As identified in the SOW under the Settlement Agreement/CO (USEPA 2011a), COI for the OU1 RI included:

- Antimony
- Arsenic
- Cadmium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Manganese
- Mercury
- Nickel
- Selenium
- Silver
- Zinc

OU1 environmental data include residential and non-residential (e.g., commercial, agricultural, recreational, and vacant land) soil samples from the CSAOI and Outlying Areas, groundwater from water supply wells, surface water in two natural drainages and storm water culverts, sediment in natural drainages and storm water culverts, indoor dust samples from homes in the CSAOI, and exterior paint tests for lead on homes in the CSAOI.

Tables 2-1 and 2-2 summarize the numbers of samples collected for each sample type. As shown in Table 2-1, the OU1 RI included collection of nearly 8,000 residential soil samples and an additional 756 non-residential soil samples. Four depth intervals from the surface to 18 inches below ground surface were sampled at each of the 422 residential properties investigated. Table 2-3 summarizes the OU1 environmental samples for which each COI was analyzed.

As noted above, arsenic and lead are the focus of the baseline HHRA approaches detailed in this work plan. Conservative risk-based screening comparisons conducted for COIs in soil, groundwater, surface water and sediment form the basis for focusing on arsenic and lead and for identification of the media of concern for further evaluation in the baseline HHRA as described below.

2.1 Selection of COPCs in Soil

Selection of COPCs from the 14 COIs evaluated for OU1 soils is documented in the following ACM Site submittals to the agencies and summarized briefly below:

- Technical Memorandum No. 1: Sampling Design to Identify Contaminants of Potential Concern in Soil (Formation 2011);
- Technical Memorandum No. 2: Preliminary Identification of Chemicals of Potential Concern (Formation 2012a);
- Technical Memorandum No. 3: Preliminary Identification of Chemicals of Potential Concern – Mercury (Formation 2012b);

- Technical Memorandum No. 4: Preliminary Identification of Chemicals of Potential Concern – Chromium (Formation 2012c); and
- Remedial Investigation Sampling and Analysis Plan, Operable Unit 1 – Community Soils Areas of Interest and Outlying Areas (RI SAP), ACM Smelter and Refinery Site (Formation 2013a).

Based on the above documents, antimony, cadmium, chromium (total), cobalt, copper, iron, manganese, mercury, nickel, selenium, silver, and zinc were eliminated from further evaluation based on comparison to USEPA risk-based screening levels (RSLs), which account for exposures to soil via ingestion, dermal contact, and inhalation. USEPA, in consultation with MDEQ, retained arsenic and lead as COPCs for OU1 soils due to exceedances of the RSLs. In addition, USEPA also initially retained hexavalent chromium for further evaluation based on analyses of a representative subset of the 2012 residential soil samples for hexavalent chromium and total chromium (USEPA 2013a). Increased uncertainty was associated with risk-based screening of the 2012 dataset for hexavalent chromium due to the laboratory's estimation of results for 88 percent of the samples at concentrations between the practical quantitation limit (PQL) of 1 mg/kg and the method detection limit (MDL) of 0.2 mg/kg. At the time of the evaluation, USEPA's risk-based screening level (RSL) for hexavalent chromium was 0.29 mg/kg, which is above the MDL but below the PQL. Therefore, evaluation of additional chromium data collected in 2013 included improved analytical precision for measurements of hexavalent chromium in soil at concentrations near the RSL. Considering these additional data, the RI Report (Formation 2014) concluded that hexavalent chromium is not a COPC for OU1. USEPA, in consultation with MDEQ, provided comments on the draft RI Report in a June 10, 2014 transmittal to Atlantic Richfield. Based on these comments, only arsenic and lead are retained as COPCs for OU1 soils.

Since completion of the RI Report, RSLs were modified to include updated inputs for some exposure parameters (USEPA 2014a). The updated soil RSL for hexavalent chromium increased slightly to 0.30 mg/kg. The updated arsenic soil RSL also increased to 0.67 mg/kg. The soil RSL for lead was not affected by the updates. Updates to the soil RSLs do not affect selection of arsenic and lead as COPCs for OU1 soils.

2.2 Selection of COPCs in Groundwater

Two groundwater supply wells were sampled as part of the RI. One of these was located within the northern Outlying Area and was reported by the owner as an "industrial well" rather than a domestic well that would be used for drinking water. That well was connected only to an outdoor faucet. The other well was reportedly used for tap water by the resident; the well and residential property are located outside of the OU1 boundary on Rainbow Dam Road, south of a former landfill area.

Screening of sample data for all 14 COIs in these groundwater supply wells is summarized in Table 2-4. Screening considered federal and state primary drinking water standards as well as USEPA's RSLs for consumption of tap water (USEPA 2009a; MDEQ 2010; USEPA 2014a). As shown, only arsenic exceeds the tap water RSL, which is several orders of magnitude more conservative than the federal and state drinking water standards. None of the 14 COIs exceeds primary drinking water standards. The maximum arsenic concentration is 10 times lower than

the federal and state drinking water standards, which are based on the maximum contaminant level (MCL) for arsenic.

Given that all of the groundwater concentrations are below drinking water standards and available data suggests groundwater is not used for drinking water within the OU1 boundaries, none of the COIs will be carried forward for further evaluation in the baseline HHRA. The groundwater pathway will not be considered for OU1.

2.3 Selection of COPCs in Surface Water

A total of 19 surface water samples were collected from two natural drainages that may be accessed by people and from storm water culverts to describe the magnitude and extent of contamination in these surface water bodies (Formation 2013a). Sample collection was targeted during two different dates to capture high flow (May) and baseline conditions (July). The nature of surface water presence and access by people at each of these surface water sampling locations differs greatly, thus data for each area was screened separately to identify COPCs for further evaluation in the baseline HHRA.

For each area, maximum total and dissolved concentrations of each of the 14 COIs for OU1 were screened against current RSLs for chronic consumption of tap water as drinking water. However, as none of the surface water bodies sampled is accessed by people for drinking water, use of tap water RSLs for screening may be overly conservative for identifying COPCs for further evaluation in the baseline HHRA.

2.3.1 Black Eagle Stream Drainage

Flowing water was present and able to be sampled at all four locations within the Black Eagle stream drainage during both sampling events. As summarized in Table 2-5, maximum concentrations of all COIs except arsenic were below the tap water RSLs for the eight surface water samples collected from the Black Eagle stream drainage. For arsenic, total and dissolved surface water concentrations exceeded the tap water RSL in all samples. Based on these results, arsenic in surface water of the Black Eagle stream drainage will be retained for further evaluation in the baseline HHRA.

2.3.2 Electric City Dirt Riders (ECDR) Drainage

As noted in the RI Report (Formation 2014), surface water was present at only one of the three Electric City Dirt Riders (ECDR) drainage sample locations during both sampling events; the other two locations were dry during both events. The location from which the two surface water samples were collected was described as a seep that was barely flowing at the time of sampling (Formation 2014). As summarized in Table 2-5, with the exception of arsenic (total and dissolved) and lead (total only), concentrations of all other COIs were below the tap water RSLs for each of the two surface water samples collected from the ECDR drainage. However, given the minimal presence of surface water at this drainage that was available for sampling during the two sampling events, exposures to surface water are expected to be negligible. Therefore, none of the COIs in surface water of the ECDR drainage will be retained for further evaluation in the baseline HHRA.

2.3.3 Storm Water Culverts

Surface water collection was attempted from eight storm water culvert locations during the two sampling events. Sufficient surface water flows were able to be sampled from seven of the locations during the May event and from two locations during the July event resulting in a total of nine surface water samples (Formation 2014). Similar to the results for the ECDR drainage, concentrations of all COIs except arsenic (total and dissolved) and lead (total only) were below the tap water RSLs for the nine surface water samples collected from the culverts (Table 2-5). Dissolved and total arsenic concentrations were higher than the tap water RSL in all samples. Total lead concentrations exceeded the tap water RSL in four of the nine culvert samples. As noted in the RI SAP, culverts were sampled to describe the magnitude and extent of contamination in the OU1 surface water bodies (Formation 2013a). Access of these culverts by people is expected to be negligible; therefore, none of the COIs in surface water of the storm water culverts will be retained for further evaluation in the baseline HHRA.

2.4 Selection of COPCs in Sediment

A total of 13 sediment samples were collected from two natural drainages (Black Eagle stream drainage and ECDR drainage) that may be accessed by people and from storm water culverts to describe the magnitude and extent of contamination in OU1 sediment (Formation 2013a). All samples were collected during July 2013 corresponding to the baseline condition surface water sampling event. Maximum concentrations of each of the OU1 COIs (except mercury) were screened against current RSLs for residential exposure to soil as a surrogate for sediment.

As summarized in Table 2-6, arsenic is the only COI that exceeded its residential soil RSL. The arsenic RSL was exceeded in all 13 samples; however, use of the residential soil RSLs for screening sediment is overly conservative for identifying COPCs for further evaluation in the baseline HHRA because none of the sediment locations sampled will be accessed by people with the same frequency and intensity as is assumed for residential exposures to soil. Additionally, as noted above, sampling of the culverts was conducted to support description of the magnitude and extent of contamination, not based on likely access by people to sediment in culverts. Therefore, arsenic in sediment is retained for further evaluation in the baseline HHRA only for the Black Eagle stream drainage and the ECDR drainage.

2.5 Screening of Homegrown Produce Pathway

During residential soil sampling conducted for the RI, 332 soil samples were collected from designated vegetable/fruit (“produce”) garden areas at 83 properties within OU1. Results for these samples were included in the process for selecting lead and arsenic as soil COPCs for further evaluation in the baseline HHRA (see Section 2.1). As a result, direct incidental ingestion of garden soil and incidental ingestion of garden soil particulate tracked into homes will be included in soil and dust ingestion estimates for yard soil in the baseline HHRA. However, because USEPA’s current risk-based residential soil screening levels for lead (400 mg/kg) and arsenic (0.67 mg/kg) in soil do not account for exposure to soil-derived COPCs that may be ingested via consumption of homegrown produce, additional evaluation of this pathway is necessary.

Residential produce gardens may be a source of exposures to arsenic and lead from residential soil primarily via consumption of soil adhered to homegrown produce surfaces and incidental

ingestion of soil and/or soil particulate during and following gardening activities. Uptake of soil lead and arsenic into the produce matrix may also occur but is expected to be low relative to adhered soil for the types of produce grown in home gardens, particularly in the presence of relatively low soil concentrations and given forms of lead and arsenic in garden soil that are not very soluble (Peryea 1999). The lack of screening levels accounting for the garden soil pathway reflects the limited availability of quantitative data for garden-specific exposure factors needed to produce reliable quantitative estimates of exposure for this pathway (USEPA 2013b). Acknowledging the limitations and uncertainties associated with quantitative estimates of exposures to metals from residential gardens, USEPA's Technical Review Workgroup (TRW) recently recommended best management practices for gardening in lead contaminated areas to reduce lead exposure to contaminated soil "based on a review of the literature and best professional judgment to identify appropriate risk mitigating actions associated with the varying ranges of soil lead concentrations in produce gardens." Included among these recommendations are several behavioral techniques designed to reduce exposure to soil contaminants while gardening. For example, discarding outer leaves of leafy vegetables, washing produce to remove soil, peeling root crops, wearing gloves while gardening, keeping soil outside, and washing hands.

Screening of the homegrown produce pathway for lead and arsenic in OU1 garden soils builds upon the TRW's semi-quantitative approach for lead in garden soil. As described below, screening of this pathway considered lead and arsenic concentrations in garden soil used for growing produce at OU1 residences along with information obtained via a survey of OU1 residents regarding local gardening practices and homegrown produce consumption.

2.5.1 OU1 Produce Garden Soil Concentration Summary

OU1 produce garden soils sample results correspond to four depth intervals (0 to 2 inches, 2 to 6 inches, 6 to 12 inches, and 12 to 18 inches) at each of the 83 gardens sampled. The majority (76) of the produce gardens sampled were located on properties within the CSAOI with a few others sampled from the Great Falls area south of the river. Development of garden areas on residential properties is expected to have resulted in mixing of soils throughout the sampled depth range over time and the nature of gardening activities are likely to increase potential contacts with soils beneath the surface unlike other areas of the property with the resident's contact with soil is expected to be limited primarily to the surface (0 to 6 inch depth). Thus, sample results for each produce garden are evaluated as depth-weighted mean concentrations for the 0 to 18 inch depth interval. For the 83 produce gardens sampled, the depth-weighted mean concentration for lead ranged from 17.7 to 1,085 mg/kg with an average of 185 mg/kg (median: 118.1 mg/kg). For arsenic, the range was 5.7 to 92.7 mg/kg with an average of 29 mg/kg (median: 24.2 mg/kg).

For lead, 37 percent of the gardens have depth-weighted mean concentrations below 100 mg/kg, which corresponds to the TRW's "low risk" category for gardening in lead-contaminated soils. The TRW's "potential risk" category spans from 100 to 1,200 mg/kg. The distribution of mean garden soil concentrations within the "potential risk" category is skewed toward the lower end of the range with 92 percent of all garden means less than 400 mg/kg lead. None of the OU1 produce garden means exceeded the TRW's threshold for "high risk" (greater than 1,200 mg/kg lead). For arsenic, 49 percent of the garden means are less than or equal to the State of

Montana's background concentration limit of 22.5 mg/kg (MDEQ 2014) and 87 percent of the gardens have mean arsenic below 40 mg/kg.

Using a paired T-test, the distribution of depth-weighted means for garden soils was compared to the distribution of the depth-weighted property mean[1] from all residential properties where produce gardens were sampled. This analysis showed that the concentrations of lead and arsenic were statistically different, with gardens having lower mean concentrations of arsenic and lead than the yards as a whole. The mean arsenic for garden samples was 29 mg/kg, compared to 32 mg/kg for the corresponding yards ($p=0.0006$[2]). For lead, the mean for garden samples was 185 mg/kg, while the mean for the corresponding yards was 195 mg/kg ($p=0.003$).

2.5.2 OU1 Produce Garden Survey Summary

To better inform assessment of this pathway, additional information regarding home gardening practices was solicited from OU1 residents via a brief survey administered by the Black Eagle Technical Advisory Committee. A copy of the survey and summary of results is presented in Appendix A. Of 32 survey respondents, 30 were residents of Black Eagle and all but one reported having a yard. For those respondents with a yard (29), 17 (59 percent) reported having a produce garden and most gardens (70 percent) are not in raised beds. Many (41 percent) of the survey respondents till their gardens. Most survey respondents (65 percent) amend their garden soil with compost or mulch, manure, or store-bought top soil. Many respondents (40 percent) reported a garden size of less than 50 square feet, 27 percent reported garden sizes of 51-150 square feet and 33 percent reported garden sizes of more than 150 square feet (two respondents did not provide their garden size). Many of these gardens (59 percent) are located near a road or alleyway, drip line, and/or painted building.

A variety of above-ground and below-ground crops are grown by Black Eagle residents. Survey respondents reported growing tomatoes (88 percent of respondents), root crops and peppers (both at 65 percent), beans (59 percent), fruits or berries (47 percent), squash (47 percent), leafy greens (41 percent), corn (29 percent), and herbs (35 percent). It is not known what proportion each crop contributes to total produce intake or what proportion total homegrown produce contributes to total produce intake. Residents typically harvest their produce between July and October, but some report harvesting as early as May and as late as November. More than half of those with gardens (65 percent) are able to preserve (i.e., freeze, can) produce for later consumption.

When survey respondents were asked about practicing specific procedures for minimizing potential exposure to contamination, nearly all respondents (94 percent) reported washing their produce and most (76 percent) wash their hands after gardening. Some respondents reported wearing gloves (41 percent) and fewer remove their shoes after gardening (29 percent). Less than half (41 percent) reported removing the outer layers of leafy crops and conflicting results

[1] This average assumed contact with 0-6 inch soils from all yard components except the garden, where 0-18 inch contact was assumed. A depth weighted mean was calculated for each sample and then all samples for that property were averaged.

[2] P values are from paired t-tests. Data were log transformed before running the t-test, as they were shown to be lognormal.

were obtained regarding peeling root vegetables. When asked if respondents peel root vegetables before eating them, a majority (71 percent) answered “Yes.” However, when this question was asked in the context of minimizing potential exposure to contamination, fewer than half (41 percent) reported that they peel root crops.

The number of survey respondents was small compared to the total population of Black Eagle and we do not know how representative the respondents are for all Black Eagle residents. The survey results allow for the following general characterization of Black Eagle gardening practices:

- Some residents grow produce in their yards and, while gardens range in size, many are 50 square feet or less in area.
- Most gardens likely are not in raised beds and many are located near a road or alleyway, drip line, or painted building.
- Amending and tilling soil are common practices.
- Produce is harvested over a period of roughly four months of the year and many residents are likely to preserve a portion of their harvest for later consumption.
- A variety of above-ground and below-ground crops are grown, but most gardens include tomatoes.
- Many, if not most gardeners will remove outer layers of leafy crops and peel root vegetables.
- Nearly all gardening residents are likely take at least one action to reduce soil contact while gardening (e.g., produce washing, hand washing).
- We do not know how much produce is grown by Black Eagle residents or what proportion of their total diet consists of home-grown produce.

2.5.3 Produce Garden Pathway Screening Conclusions

The garden soil and survey results support the conclusion that there is little risk associated with consuming homegrown produce from gardens in Black Eagle. Most soil samples fall below the TRW’s low risk range for lead or are at the lower end of the TRW’s low risk range and for those residents who garden, most take measures to reduce soil contact, such as washing produce prior to consumption, peeling root vegetables, and washing hands after gardening. While analogous risk categories are not available for arsenic, the data suggest arsenic concentrations tend to be low in produce garden soil.

Soil data from all yard components, including produce gardens, will be included in the baseline HHRA to evaluate direct and indirect pathways associated with ingestion and inhalation of soil and soil particulate. Action levels selected for OU1 will be applicable to all yard component types, including produce garden soil, ensuring that elevated lead and arsenic in garden soils will be addressed. Given that concentrations of lead and arsenic in produce gardens are statistically

lower than corresponding averages for the entire property, risk management decisions based on residential yards are expected to appropriately address produce garden soil as well. Therefore, the homegrown produce pathway will not be included for further evaluation in the OU1 baseline HHRA.

2.6 Screening Summary

As described above, medium-specific screening of the OU1 COIs in soil, groundwater, surface water, and sediment was conducted to determine which COIs and media should be carried forward for further evaluation in the baseline HHRA. Based on this screening, groundwater is eliminated from further evaluation. Arsenic and lead will be further evaluated in soil. Arsenic will also be further evaluated in surface water and sediment for the Black Eagle stream drainage and also in sediment of the ECDR drainage. Available arsenic and lead concentration data collected from unpaved roads and alleys, interior and attic dusts, and other potential sources of lead may also be considered in the baseline HHRA as relevant to specific exposure scenarios evaluated and discussed further in this work plan. A homegrown produce pathway will not be evaluated.

3 Current Conceptual Site Model (CSM)

Chemical sources, release mechanisms, transport pathways, and potential routes of human exposure are summarized in a conceptual site model (CSM) to guide evaluation of site media during the RI and to support development of specific exposure scenarios for evaluation in the baseline HHRA. This section of the work plan describes the current CSM for OU1 including exposure media and receptors to be evaluated in the baseline HHRA. A diagram representing the current CSM is presented as Figure 3-1.

3.1 Refinement of the Preliminary CSM

Section 7 of the RI Report details the data and rationale supporting refinement of the preliminary CSM developed in the early RI planning. USEPA's preliminary CSM[3] (PWT 2011) included the CSAOI and Outlying Areas of OU1, but also encompassed broader areas of interest associated with the ACM Site including the former smelter and refinery, railroad beds, and Missouri River. As such, refinement of the CSM for OU1 addresses only those sources, pathways, media, and receptors applicable to the CSAOI and Outlying Areas of OU1.

As detailed in the RI Report, information on potential waste sources and migration and transport pathways were considered in refining the preliminary CSM for OU1. Based on these considerations, the RI Report identified the following exposure media for possible further evaluation in the baseline HHRA:

- surface soil in residential and non-residential areas of the CSAOI and Outlying Areas;
- subsurface soil in residential and non-residential areas of the CSAOI and Outlying Areas;
- soil along unpaved roads and alleys in the southern CSAOI;
- indoor dust and attic dust in OU1 homes;
- sediment deposited in natural drainages in the CSAOI and Outlying Areas;
- sediment deposited to storm water culverts draining the southern CSAOI; and
- surface water in natural drainages and storm water runoff from the CSAOI and Outlying Areas.

These exposure media are consistent with those resulting from contaminant identification and media screening detailed in Section 2 of this work plan and discussed further below:

- arsenic and lead in residential and non-residential soil from the CSAOI and Outlying Areas;
- arsenic in surface water from the Black Eagle stream drainages within the CSAOI;
- arsenic in sediment deposited in the Black Eagle stream drainage in the CSAOI and in the ECDR drainage in the Outlying Areas;
- arsenic and lead in soil from unpaved roads and alleys from the CSAOI; and

[3] Note: PWT (2011) refers to the preliminary CSM as the "preliminary Site Conceptual Exposure Model (SCEM)." The terms CSM and SCEM are equivalent. CSM is used throughout the RI Report and this work plan.

- arsenic and lead in interior and attic dusts from residential properties within the CSAOI.

In addition, the current CSM considers arsenic and lead in fugitive dusts originating from soil. Fugitive dusts may originate from: windblown disturbance of bare surface soils; vehicle traffic on unpaved roads and alleys; soil-disturbance by landscaping, maintenance, or construction/utility activities; and soil-disturbance by recreational activities, such as dirt bike or all-terrain vehicle (ATV) riding.

3.1.1 Refinement of Preliminary Exposure Scenarios

USEPA's preliminary CSM included several potential receptors; the following may be applicable to OU1 and were identified as having possibly significant exposure pathways:

- A resident who inhales soil-derived particulate in air and ingests surface soil.
- A construction worker who inhales soil-derived particulate in air.
- An ATV/dirt biker who ingests and dermally-contacts surface soils and who inhales and dermally-contacts soil-derived particulate in air.

Other potential receptors included in the preliminary CSM which might have relevance to OU1 were commercial workers, recreational/subsistence fisherman, and hunter/rancher receptors. Some of the exposure pathways for these receptors were identified as "is or may be complete; further evaluation required." No details were provided regarding the specific characteristics of any of the potential receptors or exposure scenarios.

Figure 3-1 represents the current CSM for OU1. Refinement of the preliminary exposure scenarios to develop the current CSM considered contaminant identification and media selection (Section 2) as well as available information about current land uses and activities that occur in OU1, including demographic and climate data as detailed below.

3.1.1.1 Current Site Uses, Population, and Climate

OU1 includes some of the unincorporated Black Eagle community, a portion of the city of Great Falls, and areas of incorporated Cascade County. Land within the southern portion of the CSAOI is predominantly residential, scattered with vacant undeveloped and commercial land. The northern portion of the CSAOI is zoned for residential use, but most of the privately owned properties are vacant or developed for commercial use. The Outlying Area to the north of the CSAOI is associated with agricultural production, recreation, and ranching, along with some commercial and industrial uses, and limited residential use. A former municipal landfill for Great Falls is also present in this area. The Outlying Area to the south of the CSAOI is predominantly commercial/industrial and residential, and overlaps with the northern portion of the city of Great Falls.

Recreational- and community-use areas, such as the Anaconda Hills Golf Course and the Black Eagle Community Center, are present between the Black Eagle residences and the former ACM smelter and refinery property. The primary recreational use areas within OU1 also include the River's Edge Trail, several parks and recreational areas (e.g., baseball fields) located south of the Missouri River, and the ECDR property in the northern Outlying Area, east of Black Eagle. The Rivers Edge Trail is an asphalt and gravel trail developed on abandoned portions of the

former railroad line that starts in Great Falls and continues along the south and east bank of the river for 25 miles. A single-track mountain bike trail is also present along the south bank of the river. The ECDR property is used for dirt bike and ATV riding and racing.

Adjacent to OU1, to the east, is the former ACM smelter and refinery property. All former buildings and infrastructure at this property have been demolished or removed and the former plant area reclaimed. The property is currently vacant and undeveloped save for a scrap metals recycling business and the Anaconda Hills Golf Course. Aside from these developed areas controlled by third parties, entry to the former smelter and refinery area is restricted.

Power lines and associated facilities owned by PPL Montana are present in the vicinity of OU1 along the Missouri River. To the west of OU1 is an oil refinery. OU1 also includes former railroad beds situated within Black Eagle north of the Missouri River. As noted above, the former railroad line right-of-way is being addressed under an EPA Unilateral Administrative Order issued to BNSF Railway Company (USEPA 2011b) and is not addressed by this work plan.

Demographics

Black Eagle has been an unincorporated community since 1891. It was originally developed as a town for the smelter and refinery workers. As of the 2010 census (US Census Bureau 2014a), there were 474 housing units, 904 residents, 427 households, and 225 families in Black Eagle. Many of the homes in the central part of Black Eagle were constructed before 1920, with the majority of all homes built before 1950. Of the 427 occupied units 65% were owner occupied and the remainder renter occupied. Twenty-four percent of the households included children under the age of 18. Household size averaged 2.12, and average family size was 2.79. The median age of residents was 43, with 20% of the residents under the age of 18.

The city of Great Falls encompasses land on both the north and south side of the Missouri River, and is located south and southwest of the former ACM smelter and refinery. Demographic data specific to the portions of Great Falls within OU1 and excluding Black Eagle are not available. Data for the broader city of Great Falls indicate that 58,505 people, 25,301 households, and 15,135 families were located in Great Falls as of the 2010 census (US Census Bureau 2014b). A total of 26,854 housing units were reported, of which, 63% were owner occupied while the remaining were renter occupied. Children under the age of 18 made up 28.6% of the households, with an average household size of 2.26 and average family size of 2.88. The median age of residents was 39, with 22.5% of the residents under the age of 18. Most of the homes in the older, central area were constructed before 1950.

Climate/Meteorology

Cascade County has a semi-arid steppe climate with cold winters, short summers, low precipitation, and moderate to high winds. Great Falls average annual temperature is 45°F. January, the coldest month of the year, has an average temperature of 21°F. July, the hottest month of the year, has an average temperature of 68°F. Summer temperatures commonly exceed 80°F. Sub-zero temperatures are common in winter, and the freeze period averages 158 days (ClimateZone 2014). Historical snowfall data indicate monthly amounts in excess of four inches commonly occur from October through April. Average low temperatures ranging from 14.9 to 30.5°F are recorded for November through April (NOAA 2014a), suggesting that

frozen ground and snow cover are likely to persist for six to seven months of the year. Average highs above freezing during this same period suggest that on some days there may be daily cycles of melting snow/ice with re-freezing at night.

Variable weather patterns result from the Rocky Mountains proximity to the west and the plains to the east of Great Falls. The predominant wind direction is towards the east/northeast from the west/southwest at speeds up to 11 meters per second (approximately 36 feet per second or 24 miles per hour), both as measured by the wind rose at the Great Falls airport, approximately 6 miles southwest of the former smelter and refinery.

Annual precipitation is about 15 inches per year, with the driest months being November through February (NOAA 2014b).

3.1.1.2 Selection of Exposure Scenarios based on Current CSM

Based on the current CSM, people living, working, or recreating within OU1 are most likely to be exposed to lead and arsenic in soil or in dusts originating from soil. Exposures to soil may occur via ingestion, inhalation of airborne soil particulate, or dermal contact. The primary intake route is expected to result from incidentally ingesting lead and arsenic particulate on skin via hand-to-mouth activities. Direct absorption of lead and arsenic through skin is expected to be negligible (Lowney et al. 2007; USEPA 1994; USEPA 2002a).

For a residential exposure scenario, the primary exposure unit will be the residential property where a young child would likely spend the most time at play, contacting yard soil, and/or participating in gardening activities. The resident would also be expected to have contact with dusts originating from yard soil that is tracked in or blown into residential interiors. Residents may also be exposed to dusts originating from interior sources, such as deteriorating painted surfaces within homes where lead-based paint is present. Residents would also be exposed to soil-derived particulate in air from community-wide residential and non-residential soil, such as unpaved roads and alleys.

For residents in the CSAOI, particularly the southern portion that corresponds to the Black Eagle community, periodic play/recreation at natural, seasonal drainages proximal to residential areas may also result in contact with arsenic in surface water and sediment. The steeply sloping terrain surrounding the Black Eagle drainage is expected to limit the frequency of contact in this area. Residents in the Outlying Area to the north and south of the CSAOI are not proximal to this drainage and are unlikely to spend time in this area.

Absent a pathway between residential living spaces and attics that are not part of the residential living space, transmission of attic dust to interior living spaces is expected to be insignificant. Residents may be occasionally exposed to attic dust when accessing attics used for storage. Such exposures are likely to occur infrequently and be of short duration. Other activities, such as remodeling that opens up pathways between attics and living spaces, are expected to temporarily increase potential for exposures of residents to attic dusts, but are also more likely to entail barrier controls (e.g., plastic sheeting between doorways, covering vents, etc.) to reduce the spread of construction dusts and limit exposures of residents. For both types of exposures, inhalation and incidental ingestion of attic dust is possible. Attics are generally not

considered accessible or safe locations for young children to be present, thus exposures of young children are not expected to be significant.

Outdoor workers within OU1 may be exposed to local surface soils at outdoor work locations during routine maintenance activities within the CSAOI and northern Outlying Area. Contact with soil is expected to be limited to the portion of the year when climate conditions favor contact with soil. Outdoor workers may incidentally ingest lead and arsenic from soil or soil-derived dust via hand-to-mouth activity. Workers may also inhale airborne soil particulate from outdoor work locations.

Utility workers within OU1 may be more intensely exposed to non-residential surface and subsurface soils during infrequent and short-term excavation or trenching work within the CSAOI, northern Outlying Area, and within unpaved roads and alleys. Incidental ingestion of soil or soil-derived dust may occur, along with inhalation of airborne soil particulate.

Indoor commercial workers within the CSAOI may have chronic, but limited, exposure to soil-derived interior dust via ingestion. Nearby unpaved roads and alleys may contribute to soil-derived interior dust for indoor workers. Contractors who access residential attics to install insulation or to access structures or electrical equipment may have exposures to dust in attics, but such exposures are likely to be less frequent than for adults living at these residences.

Recreationalists such as hikers may be exposed to lead and arsenic in surface soil. Incidental ingestion of soil while eating on trails within OU1 is possible, but likely to represent a minor exposure relative to other scenarios given the low intensity and frequency of occurrence. ATV/dirt bike riding at the ECDR track represents a more significant recreational activity which would likely expose participants to both surface and subsurface soil, with ingestion and inhalation being the primary routes of exposure. Exposures to sediment from the ECDR drainage may also occur during ATV/dirt bike riding. ECDR membership rules specify that children under 14 years of age must be accompanied by an adult when using the track. While families with younger children may use the track, the frequency and intensity of use by children under the age of 6 years is likely to be much lower than that of older teens and young adults for whom access to the track is not limited by adult oversight. Exposures of spectators to fugitive dusts from ECDR soils is also likely, particularly during racing events held at the track, but these intermittent and sporadic exposures are not expected to exceed those of a frequent track user.

Considering the current CSM as well as current land uses within OU1, the following receptors and exposure scenarios are selected for quantitative evaluation in the baseline HHRA:

- A resident (child and adult) within the CSAOI who periodically visits the Black Eagle drainage area. Exposure pathways for the resident receptors are assumed to include arsenic and lead from residential soils (0 to 6 inch depth interval), dust originating from residential surface soils (0 to 2 inch depth interval), and airborne particulate from community-wide surface soils (0 to 2 inch depth interval). The resident is also assumed to be exposed to arsenic in surface water and sediment from the Black Eagle stream drainage. The CSAOI resident adult is also assumed to be exposed to arsenic and lead in attic dust.

- A resident (child and adult) within the southern portion of the Outlying Areas who is assumed to be exposed to arsenic and lead in residential surface soils (0 to 6 inch depth interval), dust originating from residential soils (0 to 2 inch depth interval), and airborne particulate from community-wide surface soils (0 to 2 inch depth interval).
- An adult outdoor worker within the CSAOI and the northern portion of the Outlying Areas (excluding the ECDR area and associated soils) who is assumed to be exposed to arsenic and lead primarily in non-residential surface soils (0 to 2 inch depth interval) and surface soil-derived airborne particulate.
- An adult utility worker within the CSAOI and the northern portion of the Outlying Areas (excluding the ECDR area and associated soils) acutely exposed to arsenic and lead in non-residential surface and subsurface soils (0-18 inches) through incidental ingestion of soil and inhalation of soil-derived airborne particulate.
- An adult indoor worker within the CSAOI and in the northern Outlying Areas who is assumed to be exposed to arsenic and lead in interior dust within a commercial building that originates from non-residential surface soil (0 to 2 inch depth interval).
- An ATV/dirt bike rider (older teen/young adult) who regularly rides at the ECDR track with assumed exposures to arsenic and lead in ECDR surface and subsurface soils as well as in airborne particulate originating from these soils. The rider is also assumed to be exposed to arsenic in sediment and in sediment-derived airborne particulate from the ECDR drainage while engaged in track use.

4 Arsenic Exposure Assessment Approach

This section of the work plan describes the approaches that will be used in the baseline HHRA to assess exposures of selected subpopulations to arsenic contacted within OU1. The exposure assessment produces pathway-specific intake estimates for exposure to arsenic. These intakes are then combined with toxicity information (Section 6) to characterize arsenic risks (Section 7). Exposure equations that will be used in the baseline HHRA are summarized below followed by a review of proposed input parameters.

4.1 Arsenic Exposure Equations

As detailed in Section 3.1.1.2, the baseline HHRA will quantitatively evaluate exposures of OU1 residents, workers, and recreationalists to arsenic in various exposure media. Several intake equations will be used to support development of the quantitative exposure estimates. The main components of most intake equations include:

- a site-specific and medium-specific concentration (C) that is relevant to the point at which exposure occurs (i.e., the exposure point concentration or “EPC”);
- a medium- and activity-specific contact rate (CR)[4] that describes the amount of arsenic-containing medium contacted by an individual over a day;
- an exposure time (ET) that describes how many hours per day an individual may come into contact with the medium out of a 24 hour day;
- an exposure frequency (EF) that describes how many days over the course of a year an individual may come into contact with the medium;
- an exposure duration (ED) that describes the length of time, in years, during which contact with the medium is assumed to occur;
- an averaging time (AT) in days, that is equivalent to exposure duration for non-cancer endpoints and to a presumed lifetime exposure, usually 70 years, for cancer endpoints; and
- a generic estimate of the exposed child or adult individual’s body weight (BW).4

Equation 1 provides a generic equation for estimating arsenic intake as an average daily dose (ADD) for non-cancer endpoints or lifetime average daily dose (LADD) for the cancer endpoint based on USEPA Risk Assessment Guidance (USEPA 1989). Equation 1 can be applied to most of the exposure scenarios evaluated in the baseline HHRA.

[4] Does not apply to the inhalation pathway.

Equation 1: Generic arsenic intake equation

$$(L)ADD = \frac{C \times CR \times ET \times EF \times ED \times RBA}{BW \times AT}$$

Where:

(L)ADD	= (lifetime) average daily dose (mg/kg-day) for non-cancer or cancer endpoints
C	= arsenic concentration in a specific medium (mg arsenic per quantity of medium)
CR	= contact rate for a specific medium (quantity of medium contacted per time span)
ET	= exposure time (hours/24 hour day)
EF	= exposure frequency (days/year)
ED	= exposure duration (years)
RBA	= relative oral bioavailability of arsenic (used only for soil/dust ingestion pathways; unitless)
AT	= averaging time (days)
BW	= body weight (kg)

Equation 2 provides the general equation for estimating arsenic exposures via inhalation.

Equation 2: Generic equation for inhalation of arsenic in air

$$EC_{inh} = \frac{C_{air} \times ET \times EF \times ED}{AT \times CF}$$

Where:

EC_{inh}	= exposure concentration from inhalation of arsenic in air ($\mu g/m^3$)
C_{air}	= concentration of arsenic in air ($\mu g/m^3$)
ET	= exposure time (hours/day)
EF	= exposure frequency (days/year)
ED	= exposure duration (years)
AT	= averaging time (days)
CF	= conversion factor (24 hours/days)

For OU1 residents, the baseline HHRA will estimate cancer risks based on combined child and adult intake estimates.

Equation 3 shows the general approach to combining input parameters for combined child and adult intakes.

Equation 3: General approach for estimating combined child and adult arsenic intakes

$$LADD = \frac{C \times \left(\frac{ET_c \times EF_c \times ED_c \times CR_c}{BW_c} + \frac{ET_a \times EF_a \times ED_a \times CR_a}{BW_a} \right) \times RBA}{AT}$$

Where:

LADD	= lifetime average daily dose (mg/kg-day) for cancer endpoints
C	= chemical concentration in a specific medium (mg chemical per quantity of medium)
ET_c	= child exposure time (hours/24 hour day)
EF_c	= child exposure frequency (days/year)
ED_c	= child exposure duration (years)
CR_c	= child contact rate for a specific medium (quantity of medium contacted per time span)
BW_c	= child body weight (kg)
ET_a	= adult exposure time (hours/24 hour day)
EF_a	= adult exposure frequency (days/year)
ED_a	= adult exposure duration (years)
CR_a	= adult contact rate for a specific medium (quantity of medium contacted per time span)
RBA	= relative oral bioavailability of arsenic (unitless)
BW_a	= adult body weight (kg)
AT	= averaging time (days)

OU1 residential exposure scenarios will account for ingestion of both soil and dust derived from soil. The general approach used to apportion ingestion for these related media is shown in Equation 4. For the combined child and adult resident, Equation 4 would be modified using the general approach in Equation 3.

Equation 4: General approach for apportioning ingestion of soil and indoor dust derived from soil

$$(L)ADD_{ing} = \frac{((C_{soil} \times IR_s \times F_s) + (C_{dust} \times IR_s \times (1- F_s))) \times RBA \times EF \times ED}{AT \times BW}$$

Where:

$(L)ADD_{ing}$	= (lifetime) average daily dose from ingestion of soil/dust (mg/kg-day)
C_{soil}	= chemical concentration in soil (mg/kg)
C_{dust}	= estimated chemical concentration in dust (mg/kg)
IR_s	= soil/dust ingestion rate (kg/day)
F_s	= fraction of intake as soil (unitless)
EF	= exposure frequency (days/year)
ED	= exposure duration (years)
RBA	= relative oral bioavailability of arsenic in soil (unitless)
AT	= averaging time (days)
BW	= body weight (kg)

Dermal exposures to arsenic in water will be estimated using Equations 5 and 6 below.

Equation 5: Dermally absorbed dose from surface water contact

$$DAD_W = \frac{DA_{event} \times EF \times ED \times SA}{BW \times AT}$$

Where:

DAD_W	= dermally absorbed dose from water (mg/kg-day)
DA_{event}	= absorbed dose per event (mg/cm^2-event) (see Equation 6)
EF	= exposure frequency (events/year)
ED	= exposure duration (years)
SA	= skin surface area available for contact (cm^2)
BW	= body weight (kg)
AT	= averaging time (days)

Equation 6: Absorbed dose per event from dermal surface water contact

$$DA_{event} = K_p \times C_w \times ET$$

Where:

DA_{event}	= absorbed dose per event (mg/cm^2-event)
K_p	= dermal permeability coefficient of arsenic in water (cm/hr)
C_w	= chemical concentration in water (mg/cm^3)
ET	= exposure time (hr/event)

4.2 Proposed Inputs for Arsenic Exposure Equations

Inputs proposed for use in the arsenic exposure assessment are based on a combination of available USEPA guidance, site-specific information, literature values, and/or best professional judgment. A wide range of average daily intake values usually exists among different members of an exposed population. Consistent with USEPA guidance, the baseline HHRA will estimate exposures and risks for each of the selected receptor populations based on 'average' intakes or intakes near the center of the range, called the Central Tendency Exposure (CTE), and on intakes that are near the upper end of the range, also known as the Reasonable Maximum Exposure (RME). Inputs for the CTE estimates incorporate typical or average exposure parameter values. RME inputs incorporate a combination of average and high-end exposure parameters to represent a reasonable, upper-end estimate of exposure (i.e., typically the 90-95th percentile of the exposure distribution. For the OU1 baseline HHRA, CTE and RME estimates will incorporate different input values for resident and worker ingestion rates, resident skin

surface area, and ATV/dirt bike rider exposure frequency. Input assumptions for all other variables will be the same for both the CTE and RME estimates.

Proposed input values for use in the arsenic exposure equations presented in Section 4.1 are summarized in Tables 4-1 and 4-2 and/or described below.

4.2.1 Exposure Point Concentrations

Media-specific concentrations (C) of arsenic are needed for each of the exposure media (i.e., soil, sediment, surface water, fugitive dust in air, indoor dust, and attic dust) evaluated in the baseline HHRA. These inputs, referred to as exposure point concentrations (EPCs), are intended to provide a representative estimate of the arsenic concentration to which an individual may be exposed at a given point of contact, such as a residential yard, inside a commercial/industrial building, or on the ECDR track. For each exposure scenario, average exposure by the individual to the medium of interest is generally assumed to occur randomly over the defined exposure area. For non-lead COPCs like arsenic, USEPA recommends that the 95 percent upper confidence limit (95UCL) of the arithmetic mean be used to represent the EPC (USEPA 1992).

USEPA's software application, ProUCL v5.0 (USEPA 2013c) will be used to calculate 95UCL values for use in the baseline HHRA. A number of factors, including the amount of available data points, the shape of the distribution of the values, and the degree of censoring (e.g., samples below the detection limit [DL]) should all be considered in determining which mathematical approach is most appropriate for 95UCL calculation of a dataset (USEPA 2002b). The ProUCL software includes several different strategies to calculate a 95UCL from the dataset and recommends a preferred value based on the properties of the input dataset.

Site-specific arsenic concentration data collected during the RI will be used directly to calculate scenario-specific EPCs for soil (surface and subsurface), attic dust, sediment, and surface water. Contact with the 0 to 6 inch depth interval will be assumed for incidental ingestion of surface soil by OU1 residents and outdoor workers. Depth-weighted average sample results for the 0 to 2 inch and 2 to 6 inch depth intervals will be calculated for each sampled location to derive 0 to 6 inch depth interval concentrations for calculation of EPCs.

As noted above, average exposure by the individual to each medium of interest is assumed to occur randomly over the defined exposure area. In the case of residential properties, the defined exposure area is the residential lot, which includes multiple soil sample components. However, due to the potential for increased child exposures to soil from play areas located on residential properties, the arsenic concentrations in the play areas warrant special consideration. The arsenic concentrations in soil samples collected from play areas (within residential yards) were statistically compared to property-average arsenic concentrations (based on all of the yard components sampled) to determine whether separate EPCs for residential play areas were needed. The RI included soil sampling of play areas found at 40 of the 391 residential properties sampled. A paired t-test was used to compare the property-average concentration (0 to 6 inches) to the play area concentration associated with each of these 40 properties. The mean arsenic concentration for play areas, 31 mg/kg, is not significantly different ($p = 0.9$ from log-transformed data) from the mean arsenic concentration for the

property, 29 mg/kg.[5] Based on these results, EPCs specific to play areas will not be calculated separately from other residential yard components.

Two outdoor worker soil EPCs will be calculated based on surface soil concentrations in the 0 to 2 inch depth interval samples: one for non-residential soils from the Outlying Areas (excluding the ECDR) and one for CSAOI non-residential soils (excluding unpaved roads and alleys).

Arsenic EPCs for the utility worker will be based on depth-weighted average concentrations for all depth intervals sampled at each location. Separate EPCs will be calculated for unpaved roads and alleys, CSAOI non-residential soils, and non-residential soils of the northern Outlying Areas (excluding the ECDR).

Due to the regular maintenance of the ECDR track and the nature of track use, EPCs for the ECDR track user who incidentally ingests ECDR soils will be based on depth-weighted average soil concentrations for the four depth intervals sampled at each location (i.e., 0 to 2, 2 to 6, 6 to 12, and 12 to 18 inches).

EPCs for surface water will be based on total (not dissolved) arsenic sample results. EPCs for sediment will include all depth intervals sampled. Attic dust EPCs will be based on the attic sample results.

EPCs for arsenic concentrations in fugitive dusts arising from OU1 soils will be estimated based on soil data as detailed below.

EPCs for interior dust will be based on a combination of measured interior dust data and estimated interior dust concentrations as detailed below.

4.2.1.1 Arsenic Fugitive Dust EPCs

As shown in Equation 7, fugitive dust EPCs will be estimated based on arsenic concentrations in surface soils from the 0 to 2 inch depth sample interval where wind-driven particulate emissions are most likely to occur. Following USEPA (1996a, 2002a) soil screening guidance, fugitive dust concentrations will be estimated based on a wind-driven particulate emission factor (PEF) selected to approximate meteorological conditions in the Great Falls area. USEPA (2002a) publishes default PEF values for different US climatic zones. OU1 is located within zone IV, which includes the cities of Boise, Idaho, Casper, Wyoming, Winnemucca, Nevada, Salt Lake City, Utah, and Denver, Colorado. Climate data (i.e., temperatures, rainfall, snowfall, wind speed, etc.) for each of these cities was reviewed in comparison to data for Great Falls, Montana to determine the city with climate conditions most similar to Great Falls. Based on this review, the PEF for Casper, Wyoming was selected as the basis for OU1 fugitive dust estimation.

[5] A similar analysis was conducted for lead. As with arsenic, lead concentrations in play areas were not significantly different from average lead concentrations based on all property soil components. The mean lead concentration is 172 mg/kg for the play areas, compared to 182 mg/kg for whole yards ($p = 0.9$).

Equation 7: Concentration in air from fugitive dust

$$C_{air} = C_{soil} \times PEF \times CF$$

Where:

C_{air}	= fugitive dust concentration in air ($\mu g/m^3$)
C_{soil}	= 95UCL of the arithmetic mean concentration in soil (mg/kg) for receptor-specific exposure area
PEF	= particulate emission factor (kg/m^3; see Table 4-3
CF	=conversion factor (1000 µg/mg)

By default, USEPA PEF values assume 50 percent vegetative cover exists over a 0.5 acre area of soil contamination (i.e., the source area) from which wind-driven fugitive dusts are generated These default assumptions are not appropriate for all OU1 exposure areas to be evaluated in the baseline HHRA, and USEPA guidance allows for site-specific adjustments to be applied, as appropriate. For vegetative cover, values ranging from 0 to 99 percent may be applied. Source area can be adjusted up to 500 acres. Wind-driven PEFs do not account for heavy truck traffic on unpaved roads (which would be more likely with a large construction project); however, USEPA soil screening guidance for a construction worker scenario (2002a) provides a method for developing PEFs from vehicle traffic on unpaved roads which was considered when selecting PEFs for use in the baseline HHRA.

Important distinctions between the assumptions in the construction worker guidance and vehicle generated dusts from roads within the Black Eagle community relate to the frequency and types of vehicles on the unpaved roads. For the construction worker, it is assumed that dust generation is due to frequent passes of heavy vehicles (e.g., large trucks, earth-moving equipment, etc.) back and forth along the road during the period of construction. Within the Black Eagle residential areas, routine traffic is more likely to include passenger vehicles, with heavier construction-type vehicles using roads far less frequently than for a designated construction site. This distinction is important when assessing residential exposures to particulate in air given that the baseline HHRA is focused on chronic exposures by the resident to sources of arsenic and lead at their residence, including that contributed by routine vehicle traffic on adjacent roads near to a residence as well as that contributed by windblown dust from neighborhood soils in general. To address potential contribution to air from vehicle-generated dust within the southern CSAOI, the baseline HHRA will apply two PEFs to unpaved roads and alleys. The first PEF incorporates vegetative cover and acreage assumptions based on the southern CSAOI as a whole and will be applied to all residential and non-residential soil data within the southern CSAOI, including unpaved roads and alleys, to estimate the amount of windblown soil particulate in air from these soils. The second PEF is calculated based on both windblown and vehicle-generated soil particulate models and will be applied only to soil concentrations for the unpaved roads and alleys, resulting in a second set of air particulate estimates for unpaved roads and alleys. Table 4-3 summarizes the assumptions and resulting PEFs for each receptor-specific exposure area. As shown, there is very little difference between

the PEF for the southern CSAOI (8.9E-09 kg/m^3) and the PEF for unpaved roads and alleys (8.6E-09 kg/m^3). All sample-specific estimated air concentrations resulting from application of the two PEFs will be used to calculate the final estimated air concentration for the southern CSAOI. Given the slight differences between the PEFs, soil concentrations, not PEFs, are expected to have the largest impact on the estimated air concentration.

4.2.1.2 Arsenic Indoor Dust EPCs

Both the resident and indoor commercial/industrial workers are assumed to be exposed to arsenic in indoor dust. Indoor dust data for OU1 are limited to samples collected from a subset of residential properties within the CSAOI. Indoor dust is assumed to originate from outdoor soil, so the subset of properties with both dust and soil data can be used to estimate a site-specific mass soil-to-dust transfer factor (MSD). This MSD can then be applied to scenario-specific soil concentrations in Equation 8 to estimate arsenic concentrations in indoor dust for all properties for which measured indoor dust data are not available. EPCs for residential indoor dust will be based on the combined measured and estimated indoor dust dataset.

Equation 8: Estimated arsenic concentration in indoor dust based on soil concentration

$$C_{dust} = MSD \times C_{soil}$$

Where:

C_{dust}	= chemical concentration in dust (mg/kg_{dust})
MSD	= mass soil-to-dust transfer factor (unitless)
C_{soil}	= chemical concentration in soil (mg/kg_{soil})

The site-specific MSD term was derived following USEPA's (1998a) TRW guidance for calculating a site-specific MSD term in the Integrated Exposure Uptake Biokinetic (IEUBK) model as summarized below. The MSD is based on arsenic soil and interior (living space) dust data from a total of 30 OU1 residential properties. Selection of properties for evaluation occurred as detailed in Sampling and Analysis Plan Addendum No. 2 to the OU1 RI SAP (Formation 2013c) and was generally biased toward properties with higher arsenic soil concentrations in sampled yard components. A single composite dust sample was collected from each property, except for property BE-253A, where two composite samples were collected from different living areas of the home.[6] Results for the two composites from BE-253A were averaged prior to analysis of the soil-to-dust transfer relationship based on the OU1 site-specific data.

At each residential property sampled for dust, the average arsenic concentration in soil was determined for all yard components (e.g., front yards, gardens, driveways, etc.) sampled from the 0 to 2 inch depth horizon. As shown in Figure 4-1, the correlation between dust arsenic and

[6] Living areas sampled included a bedroom, laundry room, and living room for one composite and a hallway, play area, living room, and kitchen for the other. The dust arsenic concentrations for these two composites were similar, 3.25 mg/kg and 5.3 mg/kg, respectively.

soil arsenic for the 30 properties was not strong (Pearson correlation coefficient, R = 0.3), suggesting little relationship between surface soil and interior dust arsenic concentrations. Nonetheless, based on an assumption that indoor sources of arsenic are expected to be minimal and arsenic in soil is the primary contributor to arsenic in dust for OU1 residences, an MSD of 0.37 was estimated from the ratio of the mean arsenic concentration for property-specific dust to the mean property-specific soil arsenic concentration. Consistent with TRW guidance (USEPA 1998a), an MSD based on the median of the dust-to-soil ratios for each of the 30 dust/soil pairs was also calculated. According to the TRW, the median approach is less likely to be subject to the influence of outliers in the dust or soil datasets. The median approach produced a similar estimate, 0.39, suggesting little influence of outliers on the site-specific estimate. Nearby soils from unpaved roads and alleys were not included in the analysis given that the sampling methods for the unpaved roads and alleys were not comparable to methods used for yard sampling.

The data were examined to determine if selection of properties for dust sampling based on higher soil arsenic concentrations in individual soil samples may result in an underestimate of the transfer factor due to a soil mean that is biased high relative to the rest of the community. However, the mean soil concentration for the dust sampled properties (33.8 mg/kg) is similar to the mean soil concentration for all of the sampled OU1 residential properties (34.0 mg/kg), suggesting that the biased sample selection approach is not underestimating the MSD. The observed weak correlation might be due to the presence of non-soil sources of arsenic in interior dust that vary between properties and would tend to overestimate the soil to dust transfer factor; however, unlike lead, interior sources of arsenic in residential settings are uncommon. Given these considerations, the weak correlation suggests little relationship between arsenic concentrations in soil and interior dust.

Given the above analysis, a conservative MSD of 0.39 will be applied to the residential and non-residential (excluding unpaved roads and alleys and the ECDR) outdoor surface soil arsenic concentrations to estimate indoor dust arsenic concentrations for the resident and commercial/industrial indoor worker exposure scenarios where measured indoor dust concentrations are not available.

4.2.2 Soil/Dust Ingestion Rates

For the resident child, USEPA (2011c; 2014b) recommended soil/indoor dust ingestion rates of 100 milligrams per day (mg/day; CTE) and 200 mg/day (RME) will be used. For the adult resident, soil/indoor dust ingestion rates of 50 and 100 mg/day will be used for CTE and RME estimates, respectively (USEPA 2011c; USEPA 2014b). The same adult soil/indoor dust ingestion rates will be assumed to apply to attic dust exposures evaluated for the adult resident.

The indoor worker is assumed to be exposed to interior dust derived soil, but not soil directly. USEPA (2002a) assumes a dust ingestion rate of 50 mg/day for the indoor worker. This rate will be applied to the RME worker. For the CTE, the rate is assumed to be 25 mg/day.

The outdoor worker soil ingestion rate is assumed to be 100 mg/day (USEPA 2002a) for the RME and 50 mg/day for the CTE.

The utility worker soil ingestion rate is assumed to be 330 mg/day for both the RME and CTE estimates. EPA uses this value for construction workers engaged in excavation activities (USEPA 2002a).

For the ATV/dirt bike rider, a soil/dust ingestion rate of 165 mg/day will be used for both the CTE and RME estimates based on an assumption of soil ingestion that is one-half the value assumed for a construction worker involved in excavation activities (USEPA 2002a; Tetra Tech 1996).

4.2.3 Fraction of Intake as Soil

For the resident receptors (child and adult), ingestion of arsenic originating from soil will occur directly via incidental ingestion of soil and indirectly via incidental ingestion of indoor (living space) dust that originates from soil. The intake of soil-derived arsenic will be apportioned between soil and dust with 45 percent of the intake coming from soil and 55 percent from dust consistent with USEPA's IEUBK model[7] default assumptions.

For the outdoor worker, utility worker, and ATV/dirt bike rider, 100 percent of intake will be from soil. For the indoor worker, 100 percent of intake will be from dust.

The same assumption for fraction of intake as soil will be applied to both CTE and RME estimates.

4.2.4 Relative Oral Bioavailability

As part of the OU1 remedial investigation, the relative oral bioavailability (RBA) of lead and arsenic was evaluated in 35 soil samples collected from residential yards in Black Eagle between June and August, 2012. Selection of samples for evaluation occurred as detailed in Sampling and Analysis Plan Addendum No. 1 to the OU1 RI SAP (Formation 2013b). Based on this evaluation, ENVIRON (2014) reported a conservative overall site-specific estimate of arsenic oral relative bioavailability in soil for the OU1 of 40 percent (0.4). For the 16 samples with soil concentration greater than 100 mg/kg the relative bioavailability was 46 percent, compared with 36 percent for the 19 samples with arsenic less than 100 mg/kg.

These concentration-specific values will be applied to all CTE and RME intake estimates involving ingestion of soil or dust, including indoor dust and attic dust. The assumption that the RBA value for arsenic in indoor dust is equivalent to that in soil is consistent with USEPA's approach for development of preliminary remedial goals (PRGs) for lead in Anaconda (CDM 2010). Assuming that the source of arsenic in attics is the same as that in soil also supports application of the soil arsenic RBA to attic dust. While the RBA of arsenic in soil and indoor dust will be adjusted to a value of 0.46 (>100 mg/kg arsenic) or 0.36 (<100 mg/kg arsenic) for oral intakes of soil and dust, no RBA adjustment will be applied to arsenic inhaled as fugitive dusts derived from OU1 soils.

[7] IEUBKwin v1.1 build 11

4.2.5 Sediment Ingestion Rates

USEPA does not provide recommended ingestion rates specific to sediment. Instead, ingestion rates for soil/dust are typically applied to sediment as a surrogate for sediment ingestion rates. However, there are several important differences between soil/dust and sediment ingestion rates that should be considered. First, while soil/dust ingestion rates are based on chronic residential exposures, recreational exposures to sediment will be less frequent, but possibly more intensive. Additionally, while USEPA's (2011c; 2014b) recommended default soil/dust ingestion rates assume that the ingestion rates are apportioned between soil and indoor dust derived from soil, sediment is unlikely to be tracked indoors. Thus, use of combined soil and dust ingestion rates to represent sediment ingestion is likely to overestimate intake from sediment. Second, for soil/dust and sediment ingestion, intake is largely dependent on transfer of adhered media from hands-to-mouth, which is affected by a variety of conditions including levels of moisture in contacted media and on skin, particle size adhered to skin, and intensity of contact activities.

The baseline HHRA will evaluate a sediment exposure scenario that involves periodic contact with sediments by CSAOI residents who visit/play in the Black Eagle drainage during summer months when some water is present in the drainage due to runoff from the adjacent golf course. It is assumed that these short-term exposures to sediment may be more intensive than longer term exposures to residential soil; however, contacts will be with wet sediment, which will result in adherence of larger sediment particles to skin relative to dry sediment. Larger sediment particles adhered to skin are less likely to be incidentally ingested, particularly given concurrent contacts with surface water which will promote washing off of adhered material at the time of exposure. In contrast, contact with dry sediment would be expected to behave more like soil, with adherence of finer particles to skin that are more likely to remain for longer periods, increasing potential for incidental ingestion via hand-to-mouth activities. Considering these differences, the baseline HHRA will conservatively assume sediment ingestion rates equal to the soil fraction of RME and CTE soil/dust ingestion rates presented in Section 4.2.3. Thus, for the child resident, RME sediment ingestion will be 90 mg/day (i.e., 0.45 times 200 mg/day) and CTE will be 45 mg/day. Adult residents recreating within the Black Eagle drainage are assumed to ingest sediment at rates of 45 mg/day (RME) and 22.5 mg/day (CTE).

For the ATV/dirt bike rider, arsenic sediment concentrations will be treated as soil data and incorporated into EPCs calculated for soil/dust ingestion along with the ECDR soil data; ingestion of arsenic in ECDR sediment will not be evaluated separately.

4.2.6 Surface Water Ingestion Rates

CSAOI residents are assumed to periodically visit/play at the Black Eagle drainage during summer months when surface water may be present due to runoff from the adjacent golf course. Swimming in the drainage is assumed to be very unlikely, but activities that involve more limited contact with surface water, such as shallow wading, may occur. During such activities, surface water may be incidentally ingested. USEPA (1989) risk assessment guidance recommends a 50 milliliter per hour (mL/hour) surface water ingestion rate for adult and child residential exposures to COPCs in water during swimming. Rates for recreational surface water intake while wading are not provided; however, USEPA Region 4 HHRA supplemental guidance

(2014c) recommends surface water ingestion rates for wading of 50 mL/hour for a child and 10 mL/hour for an adult. These values will be used for both RME and CTE estimates.

4.2.7 Skin Surface Area

Dermal contact with surface water may occur for CSAOI resident children and adults while recreating in the Black Eagle drainage. Activities at the drainage are expected to involve contacts with hands and feet only. USEPA (2004) default for skin surface area for the feet and hands of a child is 813 centimeters squared (cm^2). For the adult resident, a surface area of 2300 cm^2 will be used for CTE and RME estimates.

4.2.8 Dermal Permeability Coefficient

The dermal permeability coefficient for arsenic is used in the dermal exposure to surface water equation to determine the rate of migration of arsenic through the skin. USEPA (2004) recommends a dermal permeability coefficient for arsenic of 0.001 cm/hour. This value will be applied to both CTE and RME estimates.

4.2.9 Exposure Frequency

USEPA (2002a; 2014b) recommends a default exposure frequency assumption of 350 days/year for residential exposures, 250 days/year for indoor workers and 225 days/year for outdoor workers. USEPA (2002a) also states: “site managers conducting simple or detailed site-specific soil screening evaluations may propose alternative, site-specific values for this parameter that are supported by specific information on climatic influences.” Given local climate conditions in Great Falls, contacts with soil and soil-derived dust will be limited during several months of the year, and the default exposure frequency values are likely to overestimate exposures to COPCs from OU1 soil.

As described in Section 3.1.1.1, historical climate data for Cascade County indicate monthly snowfall amounts in excess of four inches commonly occur from October through April, with average low temperatures ranging from 14.9 to 30.5°F recorded for November through April. Given that average high temperatures during this same period range from 34.6 to 57.7°F, it is likely that ground surfaces during these six to seven months of the year are either frozen, snow covered, or muddy. Frozen and/or snow-covered ground limits direct contact with soils and indirect contact with soil-derived particulate in air as well as soil tracked into building interiors. Similarly, muddy conditions also limit dust generation. Additionally, soil contact-intensive activities by people within OU1 (e.g., yard work, gardening, landscaping, utility work, etc.) will be more limited during the coldest months of the year further reducing potential for exposure. Personal information provided by Black Eagle residents indicates that, during milder winters, yard work such as raking, or outdoor construction or remodeling are commonly undertaken.

Given these climate conditions, the baseline HHRA will employ a reduced exposure frequency of 225 days/year for the OU1 resident. This value assumes residents have direct contact with surface soil as follows:

- two day per week during the months of January and February;
- four days per week during March and April;

- seven days per week from May through August;
- four days per week during September and October; and
- two days per week during November and December.

The outdoor worker is assumed to have contact with soil during eight months of the year due to frequently frozen conditions occurring during at least four months of the year. Thus, an exposure frequency of 150 days/year is assumed for the outdoor worker based on adjustment of the default outdoor worker assumption (225 days/year) by 75 percent.

It is assumed that during periods when contact with soil is possible, it is also possible for soil to be blown in or tracked into homes or commercial buildings. Therefore, the default indoor worker exposure frequency (250 days/year) is also adjusted by 75 percent resulting in an exposure frequency of 167 days/year.

The utility worker is exposed to soils during excavation or trenching activities for 10 days/year based on an assumption that such work would be completed within a two week period.

For the ATV/dirt bike rider, exposure frequency assumptions from MDEQ's risk-based clean-up guidelines were considered (Tetra Tech 1996). These estimates, 15 and 32 days per year, assume moderate or high ATV/motorcycle riding activity at such sites may occur and that exposure will occur primarily during the summertime (13 weeks of the year). Tetra Tech (1996) notes that the estimates are supported by 1993 surveys of dirt bike riders near the Anaconda smelter and also "found to be in good accord with a larger demographic survey performed by the University of Cincinnati." Given potential for increased access to ATV/dirt bike riding at the ECDR track compared to non-designated areas near the Anaconda smelter, it is reasonable to assume exposure frequencies associated with the ECDR track may be slightly higher. Therefore, or the RME estimates, the ATV/dirt bike rider is assumed to ride at the ECDR track two times per week from May through October for an exposure frequency of 52 days/year. For the CTE estimates, the ATV/dirt bike rider is assumed to use the ECDR track half as often as the RME estimate for an exposure frequency of 26 days/year.

For CSAOI residential exposures to sediment and surface water in the Black Eagle drainage, exposure frequency is assumed to be limited to a 12 week period during the summer when children are out of school and most likely to frequent the drainage. Access to the drainage is limited by steep terrain and significant vegetation surrounding the area. Thus, CSAOI child residents (both RME and CTE) are assumed to visit the drainage two times per week during this 12 week period resulting in an exposure frequency of 24 days/year. CSAOI adult residents are assumed to visit the drainage half as frequently (i.e., 12 days/year).

Attic dust exposures are not expected to be limited by local climate conditions. For the adult resident entering the attic, exposures are conservatively assumed to occur once per week or 52 days/year.

4.2.10 Exposure Time

Child and adult residential exposures to soil/indoor dust (CTE and RME) are assumed to occur for 24 hours per day. Residents are assumed to contact surface water and sediment for one hour per event.

Adult residents entering attics are assumed to have an exposure time of two hours per event.

The indoor worker is assumed to spend eight hours per workday at work while the outdoor worker and utility worker is assumed to spend eight hours per workday outside (USEPA 2014b). These assumptions apply to both CTE and RME estimates.

The ECDR ATV/dirt bike rider is assumed to spend three hours at the track per visit for both the CTE and RME estimates.

4.2.11 Exposure Duration

Based on USEPA (2014b) recommended default exposure assumptions, the baseline HHRA will assume a resident child has an exposure duration of 6 years, while a resident adult has an exposure duration of 20 years.

Outdoor and indoor worker exposure durations are assumed to be 25 years (USEPA 2014b). The utility worker exposure duration is assumed to be one year (USEPA 2002a).

The ATV/dirt bike rider is assumed to have an exposure duration equivalent to the adult resident.

The same exposure duration values will be applied to both CTE and RME estimates for each scenario evaluated.

4.2.12 Averaging Time

Averaging time for non-cancer exposures is equal to the exposure duration multiplied by 365 days per year (USEPA 1989). For cancer, the averaging time is 70 years multiplied by 365 days per year (USEPA 2014b).

4.2.13 Body Weight

Current USEPA (2014b) default body weights will be assumed: 15 kg and 80 kg for child and adult, respectively. Body weight does not vary for CTE vs. RME estimates.

5 Approach to Modeling Lead Risks

Different approaches are utilized to assess risks from exposure to lead versus non-lead chemicals such as arsenic. In residential settings, USEPA assumes that a young child will be the most sensitive receptor at risk for lead exposure. Lead risks for children are then evaluated in terms of predicted blood lead levels using USEPA's IEUBK model. For non-residential settings such as commercial/industrial work sites, USEPA's Adult Lead Methodology (ALM) is used. A description of each model is provided below along with the proposed model inputs for use in the OU1 baseline HHRA.

5.1 IEUBK Model

The current IEUBK model is used in Superfund risk assessments for lead to predict the risk, as a probability, that a typical child (0 to 6 years old) will have a blood lead level greater than 10 micrograms per deciliter (µg/dL) when exposed to a combination of specified media concentrations of lead (USEPA 2002c). The model includes three modules. The exposure module calculates media-specific lead intake rates to estimate how much lead is taken into a child's body from air (indoor and outdoor), soil, dust (indoor), diet, and other sources such as lead-based paint. The uptake model incorporates absorption factors to estimate the fraction of lead intake that crosses into the bloodstream from the lungs or gastrointestinal tract. The transfer of lead between blood and other body tissues and through elimination pathways is addressed by the biokinetic module.

The model incorporates numerous default input values and recommends the use of site-specific data where doing so would more accurately predict child blood lead levels. The baseline HHRA will incorporate site-specific data in place of model defaults for the MSD and soil/dust absorption input values. Alternate soil ingestion rates will also be incorporated in the baseline HHRA. The basis for each of these site-specific/alternate model assumptions is described below. EPCs for residential soil input in the model will be calculated as geometric means consistent with model guidance. Table 5-1 summarizes the IEUBK model inputs that will be used in the baseline HHRA.

Note, the TRW is currently finalizing updates to several IEUBK model default assumptions that are anticipated to be released in the near future. Details regarding specific changes and the technical basis for each are currently not available for consideration in this work plan.

5.1.1 MSD for Lead – Site-Specific

As described previously for arsenic, site-specific dust lead data were obtained from interior dust sampling at a subset of OU1 residential properties for which soil lead data are also available. The correlation between average dust lead and average soil lead (0-2 inch depth, all components) for the 30 properties sampled (Pearson correlation coefficient, R = 0.6) is stronger than for arsenic, however, as with arsenic, it does not suggest a clear relationship between soil lead and interior dust lead (Figure 5-1). Based on the 30 properties with paired data, the median of the property-specific indoor dust to soil ratios for lead, 0.43, is slightly higher than the corresponding median for arsenic (0.39). Perfect agreement between arsenic and lead is not expected given the increased potential for non-soil sources of lead within residential interiors to be contribute to indoor dust lead concentrations. As noted by the TRW in its site-specific MSD

recommendations, “where there are other significant sources of [lead] in dust, attempts to use measured [lead] concentration data for soil and dust to estimate MSD become more problematic.” A likely source of lead in interiors is lead-based paint, which may directly influence interior dust lead concentrations in addition to lead derived from residential soil. The prevalence of deteriorating lead-based paint (both interior and exterior) is expected to be high within OU1 given the age of the housing stock. Year-built information is available for 365 OU1 residential properties with soil lead data. Of these, 76 percent were built prior to 1950. Additionally, property selection for lead dust sampling was biased toward older houses with 27 of the 30 homes sampled for dust built prior to 1950 and the remaining three built after 2000.

House age has been found to be a significant predictor of soil lead and interior dust lead. In a 1996 study of the distribution of soil lead in the nation’s housing stock, EPA concluded: “The strongest statistical predictor of soil lead in private and public housing for all sample locations is the housing unit's date of construction. For private housing units, soil lead around homes built before 1940 were significantly greater than lead in soil around homes built between 1960 and 1979.” (USEPA 1996b). Gaitens et al. (2009) reported year of construction was a significant predictor of floor dust lead greater than or equal to 10 micrograms per square foot (μg/ft^2) and that homes built after 1950 had lower window sill dust lead concentrations compared with those built before 1950 ($p<0.001$).

In the EPA study, soil samples were collected from drip line, entryway, and remote locations (still within the property boundaries). EPA reported: “The presence of lead-based paint was shown to have a significantly positive effect on soil lead concentrations at all three locations, but to a larger extent at the drip line and entryway.” Based on a logistic model for lead dust ≥100 μg/ft^2, Gaitens et al. reported: “the odds that sill PbD [lead in dust] was ≥ 100 μg/ft^2 for homes with large areas of exterior deteriorated paint was about three times higher than for homes with no exterior deteriorated paint.” Similarly, for the logistic model for lead dust greater than or equal to 250 μg/ft^2, the odds that lead dust was greater than or equal to 250 μg/ft^2 were about three times higher if the interior paint deterioration was large in two or more rooms, than if there was no interior paint deterioration. Given these findings, it is reasonable to conclude that the presence of lead-based paint within homes would also positively influence interior dust lead concentrations and that this additional source of lead to interior dust, which is not related to the former ACM site, would result in a higher MSD for lead than for arsenic. Further, after contributions of lead from soil are addressed by cleanup, lead contributed from indoor sources of lead-based paint would continue to drive estimates of the dust-to-soil relationship upward relative to arsenic, overestimating the contribution of lead transferred from residential soil.

Thus, assuming arsenic and lead in soil behave similarly with regard to transport and deposition into indoor areas, and absent indoor sources of lead that are not derived from soil, the MSD for lead is expected to be similar to that for arsenic, for which historical smelter emissions are likely to be the dominant source of arsenic in site soils. Consequently, the lead MSD input for the IEUBK model will be equal to the arsenic MSD of 0.39.

5.1.2 Soil/Dust Absorption – Site-Specific

The default RBA of lead in soil and dust is 60% (0.6) based on 30% (0.30) absorption from soil or dust relative to 50% absorption from water/diet. As summarized above for arsenic, the OU1

RI included evaluation of site-specific data for relative oral bioavailability of lead and arsenic. Based on this evaluation, 59 percent (0.59) was recommended as a conservative site-specific RBA estimate for lead in soil for OU1 risk assessment (ENVIRON 2014). The absorption value of 0.285 is slightly lower than USEPA's current default for absorption from soil and indoor dust (0.30).

5.1.3 Age-Dependent Soil Ingestion Rates - Alternate

The IEUBK model is designed to use central tendency values of all input parameters including soil ingestion rate (USEPA 1999), which is intended to include both outdoor soil and indoor dust. The current default IEUBK model values for age-dependent soil ingestion rates range from 0.085 to 0.135 g/day and are based on observational studies of soil/dust ingestion in US children published by Binder et al. (1986), Clausing et al. (1987), Calabrese et al. (1989 and 1991), Van Wijnen et al. (1990), and Davis et al. (1990). The default age-dependent rates yield an average child soil/dust ingestion rate of 109 mg/day. In contrast, lower ingestion rates are provided in USEPA's Exposure Factors Handbook (2011c); these yield an average soil/dust ingestion rate of 94 mg/day for children less than 7 years of age based on studies by Davis and Mirick (2006), Hogan et al. (1998), Davis et al. (1990), Van Wïjnen et al. (1990), and Calabrese and Stanek (1995).

More recent soil ingestion data re-analyses by Stanek et al. (2012 a, b) result in an average soil ingestion rate of 26 mg/day for children between one and seven years of age, which is roughly one-fourth of the average IEUBK model default values and the rates recommended by USEPA (2011c) for the same age range (113 and 100 mg/day, respectively). Stanek et al. (2012 a,b) assume that the ingestion rate pertains to incidentally ingested soil, which may underestimate combined soil and dust ingestion; however, USEPA (2011c) recommendations for soil without dust result in an average ingestion rate (50 mg/day) that is still nearly two times higher. Thus, the data re-analysis by Stanek et al. (2012 a, b) suggests that current IEUBK model default values likely overestimate child soil ingestion rates.

Another analysis of soil ingestion developed using USEPA's Stochastic Human Exposure and Dose Simulation (SHEDS) model predicted a mean combined soil and dust ingestion rate of 68 mg/day for children ages 3 to 6 years old (Ozkaynak et al. 2011); 41 mg/day for soil ingestion alone. SHEDS predicted that approximately 60 percent of total soil and dust intake is attributable to soil ingestion, while 30 percent and 10 percent is ingested from dust on hands and on objects, respectively. Based on the current IEUBK model and USEPA (2011c), corresponding average rates for children ages 3 to 6 years are 108 and 100 mg/day, respectively, further suggesting these rates are overestimated. Similarly, Wilson et al. (2013) estimated soil ingestion rates using a probabilistic mechanistic model. Separate soil and dust ingestion rates were estimated, with a mean probabilistic combined soil and dust ingestion rate of 61 mg/day, for toddlers age 7 months through 4 years old. Considering similar ages, this value is approximately 50 to 60 percent of the current IEUBK defaults and USEPA (2011c) recommendations, respectively.

Additionally, using blood lead biomonitoring at the Bunker Hill Superfund Site in the Silver Valley of Idaho, Stifelman et al. (2015 unpublished) recently presented estimates of children's soil and dust ingestion rates at the 2015 Society of Toxicology Annual Meeting. Stifelman et al.

recommends reduction of the current IEUBK default soil ingestion rate, 109 mg/day, to 70 mg/day “based on concordance between IEUBK model predictions and blood lead observations representing the more than half of resident children for 15 consecutive years.“ The Stifelman et al. estimate is consistent with reduced soil ingestion rate estimates reported by Ozkaynak et al. 2011 and Wilson et al. 2013.

The combined results of these efforts by Stanek et al. (2012 a, b), Ozkaynak et al. (2011), Wilson et al. (2013), and Stifelman et al. (2015 unpublished) support the use of lower soil ingestion rates than those currently recommended by USEPA (2011c) and provided in the IEUBK model. The age-specific soil and dust ingestion rates estimated by Stifelman et al., which yield an average rate of 70 mg/day will be used to evaluate child lead risk in the baseline HHRA in addition to evaluating child lead risks using the current model default soil ingestion rates.

5.2 Adult Lead Model (ALM)

USEPA’s ALM is typically used to evaluate lead risk for adult commercial/industrial workers. In this setting, USEPA (2013d) assumes “the most sensitive receptor is the fetus of a worker who develops a body burden as a result of non-residential exposure to lead. This body burden is available to transfer to the fetus for several years after exposure ends.”

The ALM predicts the fetal geometric mean blood lead level based on assumed proportionality between fetal and adult blood lead levels. The central tendency adult blood lead level is estimated as the sum of the baseline blood lead level (PbB_0) that would occur without a site-related exposure, and the increment in blood lead estimated from exposure to contaminated soil in the non-residential setting, most typically, the work site. The increment of blood lead estimated from the site is determined by multiplying the daily average uptake of lead by a biokinetic slope factor (BKSF) that relates the quasi-steady state increase in typical adult blood lead concentration to average daily lead uptake. The basic equation for estimating the fetal geometric mean blood lead level is provided as Equation 9.

Equation 9: Geometric mean fetal blood lead equation

$$PbB_{fetal,GM} = R_{fetal/maternal} \times \left[PbB_{adult,0} + \frac{Pbs \times BKSF \times IRs \times AFs \times EFs}{AT}\right]$$

Where:

$PbB_{fetal,GM}$ = central estimate of blood lead concentrations (µg/dL) for fetuses carried by women of child-bearing age who have exposures to soil at the site at lead concentration, PbS

$R_{fetal/maternal}$ = constant of proportionality between fetal and maternal blood lead concentrations.

$PbB_{adult,0}$ = typical blood lead concentration (µg/dL) in women of child-bearing age absent site-specific soil lead exposure

BKSF = biokinetic slope factor relating increase in typical adult blood lead concentrations (µg/dL) to average daily lead uptake (µg/day) under quasi-steady state conditions

Pbs = lead concentration in soil to which exposures occur (µg/g)

IRs = intake rate of soil (g/day), including both outdoor soil and indoor dust derived from outdoor soil

AFs = absolute gastrointestinal absorption fraction for lead in soil and indoor dust derived from soil (unitless)

EFs = exposure frequency for contact with soil (and/or soil-derived indoor dust) to which exposure occurs (days/year)

AT = averaging time over which the soil contact may occur (days/year)

From this equation, the probability that the fetal blood lead concentration exceeds 10 µg/dL is calculated based on Equation 10.

Equation 10: Probability of fetal blood lead exceeding 10 µg/dL

$$z = \frac{\ln(10) - \ln(GM)}{\ln(GSD)}$$

Where:

z	= probability that fetal blood lead exceeds 10 µg/dL (unitless)
GM	= fetal geometric mean blood lead (µg/dL; from Equation)
GSD	= estimated value of the individual geometric standard deviation (µg/dL) among women of child-bearing age who have similar site-related exposures to lead in soil and soil-derived dust, but have a non-uniform response to site lead (i.e., in terms of intake and biokinetics) and to off-site lead exposures

Table 5-2 summarizes the parameters selected for use in the ALM to evaluate exposures to adult residents accessing the attic, adult workers and adult ATV/dirt bike riders in the baseline HHRA. The basis for each parameter is also provided.

6 Toxicity Assessment Approach

Consistent with USEPA risk assessment guidance for Superfund (USEPA 1989), the purpose of the toxicity assessment is to characterize the nature of potential toxic effects and provide an estimate of the dose-response relationship for relevant effects that can be used to characterize risks for exposed individuals. The dose-response relationship is estimated based on evaluation of the strength of available data that support the potential for a chemical to cause adverse health effects in individuals at a given exposure level, by a particular route of exposure, and over a specific period of time. The toxicity assessment considers both non-cancer and cancer effects for the chemicals evaluated.

For the baseline HHRA, the toxicity assessment will be limited to arsenic and lead. The toxicity of both arsenic and lead has been well-studied resulting in abundant quantitative and qualitative information that is available for consideration in the baseline HHRA. Both animal and human data will be considered along with other supporting types of information, such as pharmacokinetic studies and biomonitoring studies, as appropriate.

Sensitive subpopulations will be considered as well. For instance, young children are the receptor of greatest concern for residential exposures to lead because they are expected to have higher lead absorption rates and higher exposure per unit body weight than adults. Because lead is a neurotoxicant, young children are also more susceptible to the effects of lead given the high rate of neurodevelopment occurring in the first few years of life. From a population of adults, women of child-bearing age are of greatest interest given the potential for adverse effects on the fetus resulting from elevated maternal blood lead.

Consideration will also be given to the forms of arsenic and lead that are most relevant to OU1 exposure media. For instance, arsenic is a natural element that is widely distributed in the environment, including in soil, groundwater, and surface water, and in plants and animals. In soil and water, most arsenic is present as inorganic arsenic, but in some plants and animals organic forms of arsenic are present. Because arsenic occurs naturally in the environment, all humans are exposed to low doses. For most populations, the primary source of exposure to inorganic arsenic is the diet. In addition, human activities have caused widespread increases in concentrations of inorganic arsenic in soil and water. Inorganic arsenic is the most toxic form and is most relevant to OU1 exposure media; therefore, inorganic arsenic will be the focus of the arsenic risk characterization in the baseline HHRA.

6.1 Arsenic Toxicity Values

Toxicological benchmarks (i.e., reference doses and cancer slope factors) for arsenic relevant to OU1 media are summarized below.

6.1.1 Cancer Effects

Arsenic is classified by the USEPA as a human carcinogen. Skin and internal organ cancers increase in populations exposed to arsenic in drinking water. Cancer risks are described by using the slope of the dose-response curve at low doses, known as the slope factor (SF). The units of the SF are dimensions of risk of cancer per unit dose. The oral SF for arsenic is 1.5 $(mg/kg\text{-}day)^{-1}$ (USEPA 1998b).

Sufficient data exist to show that lung cancer mortality also increases with arsenic inhalation. The inhalation unit risk factor for arsenic is 0.0043 $(\mu g/m^3)^{-1}$, based on lung cancer in humans occupationally exposed.

6.1.2 Non-Cancer Effects

Early epidemiology studies identified skin as the most sensitive non-cancer endpoint of long-term oral arsenic exposure. Hyperkeratinization of the skin, formation of multiple hyperkeratinized corns or warts, and hyperpigmentation of the skin with interspersed spots of hypopigmentation are the most common types of lesions associated with oral arsenic exposure (ATSDR 2007). Studies in humans have also reported cardiovascular effects following oral exposures to arsenic. Cardiac effects include altered myocardial depolarization, cardiac arrhythmias, and ischemic heart disease. Chronic exposure to arsenic has also been shown to lead to effects on the vascular system (ATSDR 2007). USEPA is also currently reviewing a wide range of other toxic endpoints potentially associated with arsenic exposure, including effects on the endocrine system such as diabetes mellitus.

The non-cancer oral reference dose (RfD) for arsenic is 3E-4 mg/kg-day. This value was derived from a no-observable-adverse-effect-level (NOAEL) for a critical effect based on human chronic oral exposure resulting in hyperpigmentation and keratosis (Tseng 1977; Tseng et al. 1968). The NOAEL was divided by an uncertainty factor of three, due to a lack of reproductive toxicity data and uncertainty in whether the NOAEL is protective of all sensitive individuals.

The USEPA does not provide a reference concentration for inhalation exposures. However, the California USEPA Office of Environmental Health Hazard Assessment provides a value of 0.015 $\mu g/m^3$.

6.1.3 Dermal Toxicity Values

When considering dermal risks, the RfD or SF must be adjusted due to the fact that most chemicals are not completely absorbed in the gastrointestinal (GI) tract. The reference dose or slope factor may not be protective of dermal exposures where a greater percentage of the chemical may be absorbed through the surface of the skin. However, for arsenic, this adjustment is not necessary as a significant portion of inorganic arsenic dissolved in water is absorbed by the GI tract. The oral RfD and SF without adjustment will be used for dermal toxicity to arsenic.

6.2 Lead Toxicity Assessment

Lead exposures result in a wide range of adverse effects, including effects on the nervous system, cardiovascular system, immune function, heme synthesis and red blood cell function, and reproductive and developmental function. A no effect level has not been established for lead exposures (ACCLP 2012; CDC 2012; NTP 2012; USEPA 2013e).

Young children are the receptor of greatest concern for residential exposures because they are expected to have higher lead absorption rates and higher exposure per unit body weight than adults. Children are also more susceptible to the effects of lead (USEPA 2006; NTP 2012). From a population of adults, women of child-bearing age are of greatest interest given the potential for adverse effects on the fetus resulting from elevated maternal blood lead.

USEPA does not have standard toxicity values for lead because a no-effect dose has not been identified. Instead, USEPA has identified a target blood lead level to use in risk management. Until 2012, the Centers for Disease Control and Prevention (CDC) recommended 10 µg/dL as a blood lead "level of concern" when based on a confirmed venous blood draw. Based on the CDC level of concern, USEPA specifies a goal that the probability that any exposed child or pregnant female will have a blood lead level above 10 µg/dL should not be greater than 5 percent. For convenience, the probability of a blood lead value exceeding 10 µg/dL is referred to as P10. In accord with this approach, in the HHRA health risks from lead will be judged to be acceptable if the value of P10, calculated using the IEUBK model or the ALM, does not exceed 5 percent. P10 values are based on all sources of lead exposure, including both site related exposures and "baseline" (non-site related) exposures.

CDC (2012) no longer uses the "level of concern" concept for lead and currently recommends using a reference level of 5 µg/dL, stating that "This new level is based on the US population of children ages 1-5 years who are in the highest 2.5 percent of children when tested for lead in their blood." Conceptually, the new reference level is not the same as the level of concern and USEPA has not yet determined if or how the new level may be used in risk management for lead sites. In particular, reliance on a 5 percent probability of not exceeding the reference level is not a workable basis for setting soil clean up levels in many communities that have older housing and other lead sources. In those communities, more than 5 percent of the population is likely to have BLLs greater than 5 µg/dL without soil lead influence. Possible implications of the new reference level will be considered in the uncertainty analysis.

7 Risk Characterization Approach

To characterize risks for arsenic and most other chemicals, quantitative estimates of exposure and toxicity are combined to yield numerical estimates of potential health risk for noncarcinogenic and carcinogenic effects. For lead, risks are characterized by use of mathematical models to estimate the distribution of blood lead values in a population of people exposed to lead under a specified set of conditions. The proposed approaches for characterizing arsenic and lead risks for OU1 receptors are summarized below.

7.1 Arsenic

Characterization of risks for arsenic differ for non-cancer versus cancer effects.

7.1.1 Characterization of Non-Cancer Risk

Noncarcinogenic health risks are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of chemical exposure. The non-cancer hazard quotient is calculated using the average daily dose of the chemical and the reference dose, as shown in Equation 11. For inhalation, the reference concentration in air is used in place of the reference dose as shown in Equation 12. A hazard quotient equal to or less than one indicates that no adverse health effects are expected from exposure to the chemical. A hazard quotient greater than one does not mean that adverse health effects will occur, but rather that further evaluation is needed. Hazard quotients will be calculated for each receptor for exposure to arsenic in soil/indoor dust, fugitive dust in air, attic dust, sediment, and surface water.

Equation 11: Generic non-cancer hazard quotient for ingestion and dermal exposure

$$HQ = \frac{ADD}{RfD}$$

Where:

HQ	= hazard quotient (unitless)
ADD	= average daily dose (mg/kg-day)
RfD	= reference dose (mg/kg-day)

Equation 12: Non-cancer hazard quotient for inhalation exposure

$$HQ = \frac{EC}{RfC}$$

Where:

HQ = hazard quotient (unitless)

EC = exposure concentration ($\mu g/m^3$)

RfC = reference concentration ($\mu g/m^3$)

7.1.2 Characterization of Cancer Risk

The cancer risk estimates derived using standard risk assessment methods are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to site-related chemicals. The term “incremental” reflects the fact that the calculated risk associated with site-related exposure is in addition to the background risk of cancer experienced by all individuals in the course of daily life. For the resident receptors, child and adult exposures will be combined to estimate lifetime cancer risk. The risk estimates will be compared with the USEPA target risk range for carcinogens of one-in-one million to one-in-ten thousand (1E-06 to 1E-04). Cancer risk is calculated using the lifetime average daily dose of the chemical and the slope factor as shown in Equation 13. Cancer risks will be calculated for each receptor for exposure to arsenic in soil/indoor dust, fugitive dust in air, attic dust, sediment, and surface water.

Equation 13: Generic cancer risk equation

$$CR = LADD \times SF$$

Where:

CR = cancer risk (unitless)

LADD = average daily dose from ingestion of soil (mg/kg-day)

SF = cancer slope factor ($(mg/kg\text{-}day)^{-1}$)

7.1.3 Combining Risks Across Exposure Pathways

Risks for a single receptor (e.g., a resident) from multiple exposure pathways (i.e., soil/dust ingestion, periodic attic dust exposures, recreational contact with surface water/sediment, and fugitive dust inhalation) will be added to determine the combined risk for each receptor. Both cancer risks and non-cancer hazards are assumed to be additive if they are for the same population over the same time period. For non-cancer health effects for each receptor, the hazard quotients from the relevant exposure media are summed to generate a hazard index. Cancer risks will also be summed for the relevant exposure media for a receptor to determine

the total incremental cancer risk and to facilitate risk management decision-making with regard to setting medium-specific action levels, if needed.

7.2 Lead

The IEUBK model will be run to predict the risk (probability) that a typical or hypothetical child exposed to lead in soil and dust at their residence will have a blood lead level that equals or exceeds 10 µg/dL. The ALM model will be used to estimate blood lead concentrations for the following scenarios: an adult resident accessing the attic, an adult indoor worker, an adult outdoor worker, an adult utility worker, and an adult ATV/dirt bike rider.

Based on proposed model inputs described in Section 5, IEUBK and ALM modelled lead risks will be characterized as acceptable if the probability that any exposed child or fetus of a pregnant female will have a predicted blood lead level above 10 µg/dL is not greater than 5 percent.

8 Approach to Evaluating Uncertainties

The baseline HHRA report will include an evaluation of uncertainties with a table identifying the specific factors that may result in an over- or underestimation of risks. Additionally, a sensitivity analysis may be necessary to quantify the uncertainty associated with specific exposure parameters and model inputs (e.g., MSD). To further understand the uncertainty and variability in the risk assessment assumptions, a probabilistic analysis of specific arsenic exposure pathways or scenarios may be performed. For lead, a matrix of outcomes based on multiple assumptions will be provided and discussed. The evaluation of uncertainties will also include a qualitative discussion of potential combined exposures for a resident who may also work within OU1 and/or ride ATVs/dirt bikes within the ECDR.

9 Approach to Developing Remedial Goals

Remedial goals for arsenic and lead will be developed for media with scenario-specific risks based on the baseline HHRA that exceed USEPA's guidelines. Remedial goals will consider both direct and indirect exposure pathways associated with a given medium. For example, soil-based remedial goals will include contributions from direct contact with soil as well as soil particulate in fugitive dusts and indoor (living space) dust. Attic dust does not derive from soil and would not be included in a soil remediation goal. Remedial goals will be calculated using typical "backward" risk methodologies based on exposure assumptions employed in development of the baseline HHRA. Additionally, alternate assumptions may be used for some inputs to generate a range of plausible remedial goals for consideration by USEPA in risk management decision-making for OU1.

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Tables

Table 2-1: Number of OU1 soil samples by sample type

Sample Type	Samples	Samples by depth (in)			
		0-2	2-6	6-12	12-18
Unpaved roads/alleys	112	28	28	28	28
Black Eagle – residential	7298[a]	1830	1820	1827	1821
Black Eagle – non-residential	204	51	51	51	51
Outlying Area – residential	640[b]	160	160	160	160
Outlying Area – non-residential	496	124	124	124	124
ECDR	56	14	14	14	14
Total	8862	2221	2211	2218	2212

[a]Samples were collected from a total of 391 residential properties.
[b]Samples were collected from a total of 31 residential properties.

Table 2-2: Number of OU1 samples (excluding soil) by sample type	
Sample Type	**Samples**
Groundwater – supply wells	2
Surface water – streams, culverts	19
Sediment – streams, culverts	12
Interior dust – attics	18
Interior dust – floors	30
Exterior paint	30
Bioaccessibility	35

Table 2-3: Number of OU1 environmental samples by COI analyzed

COPC	Res. Soil	Non Res. Soil	Unpaved Roads/Alleys	Groundwater[a]	Surface Water[a]	Sediment	Dust	Paint	Bioaccessibility	ECDR
Antimony	295	700	--	2	19	13	--	--	--	56
Arsenic	7937	700	112	2	19	13	48	--	35	56
Cadmium	7938	700	112	2	19	13	--	--	--	56
Chromium, total	6283	700	112	2	19	13	--	--	--	56
Chromium VI	79	10	--	--	--	--	--	--	--	4
Cobalt	295	--	--	2	19	13	--	--	--	--
Copper	7938	700	112	2	19	13	--	--	--	56
Iron	1950	--	--	2	19	13	--	--	--	--
Lead	7938	700	112	2	19	13	48	920	35	56
Manganese	295	--	--	2	19	13	--	--	--	--
Mercury	372	--	--	2	19	--	--	--	--	--
Nickel	295	--	--	2	19	13	--	--	--	--
Selenium	295	--	--	2	19	13	--	--	--	--
Silver	295	--	--	2	19	13	--	--	--	--
Zinc	7938	700	112	2	19	13	--	--	--	56

[a] Samples were analyzed for both total and dissolved concentrations of each element.

Table 2-4: Screening results for groundwater data

Chemical	n	Percent Detected	Minimum (mg/L)	Maximum (mg/L)	Mean* (mg/L)	Tap Water Screening Level (mg/L; HQ 1.0)	Federal MCL (mg/L)	Montana GW Standard (mg/L)
Total								
Antimony	2	0	0.000056	0.000056	0.000028	0.0078	0.006	0.006
Arsenic	2	100	0.00017	0.001	0.000585	**0.000052**	0.01	0.01
Cadmium	2	0	0.000032	0.000032	0.000016	0.0092	0.005	0.005
Chromium	2	100	0.00038	0.0005	0.00044	22	0.1	0.1
Cobalt	2	50	0.000052	0.00016	0.000093	0.006	--	--
Copper	2	100	0.00081	0.0076	0.004205	0.8	1.3	1.3
Iron	2	100	0.0639	0.116	0.08995	14	--	--
Lead	2	100	0.0002	0.0002	0.0002	--	0.015	0.015
Manganese	2	100	0.0015	0.188	0.09475	0.43	--	--
Mercury	2	0	0.00003	0.00003	0.000015	0.00063	0.002	0.002
Nickel	2	100	0.00021	0.0003	0.000255	0.39	--	0.1
Selenium	2	50	0.00012	0.0099	0.00498	0.1	0.05	0.05
Silver	2	0	0.00005	0.00005	0.000025	0.094	--	0.1
Zinc	2	100	0.0031	0.0104	0.00675	6	5	2
Dissolved								
Antimony	2	50	0.000056	0.000064	0.000046	0.0078	0.006	0.006
Arsenic	2	100	0.00013	0.00097	0.00055	**0.000052**	0.01	0.01
Cadmium	2	0	0.000032	0.000032	0.000016	0.0092	0.005	0.005
Chromium	2	100	0.00027	0.00036	0.000315	22	0.1	0.1
Cobalt	2	100	0.00011	0.00024	0.000175	0.006	--	--
Copper	2	100	0.00044	0.0075	0.00397	0.8	1.3	1.3
Iron	2	100	0.01	0.0658	0.0379	14	--	--
Lead	2	100	0.000066	0.00011	0.000088	--	0.015	0.015
Manganese	2	100	0.0015	0.191	0.09625	0.43	--	--
Mercury	2	0	0.00003	0.00003	0.000015	0.00063	0.002	0.002
Nickel	2	0	0.00015	0.00015	0.000075	0.39	--	0.1
Selenium	2	50	0.00012	0.0095	0.00478	0.1	0.05	0.05
Silver	2	0	0.00005	0.00005	0.000025	0.094	--	0.1
Zinc	2	100	0.0019	0.0084	0.00515	6	5	2

Bolded values indicate screening value is exceeded by the maximum COI concentration.
*Mean summary statistics are calculating using DL/2 for samples below the DL.

Table 2-5: Screening results for surface water data

Chemical	n	Percent Detected	Minimum (mg/L)	Maximum (mg/L)	Mean[a] (mg/L)	Median (mg/L)	Tap Water Screening Level (mg/L; HQ=1)
Black Eagle Stream Drainage – Total Metals							
Antimony	8	100	0.00017	0.00071	0.00028	0.0002	0.0078
Arsenic	8	100	0.0015	0.014	0.0055	0.0036	**0.000052**[b]
Cadmium	8	87.5	0.000032	0.00074	0.00023	0.00013	0.0092
Chromium	8	100	0.0003	0.0043	0.0015	0.00097	22
Cobalt	8	100	0.000071	0.0024	0.00077	0.00026	0.006
Copper	8	100	0.0012	0.032	0.0097	0.0034	0.8
Iron	8	100	0.064	4.6	1.2	0.52	14
Lead	8	100	0.00012	0.011	0.0025	0.001	0.015[c]
Manganese	8	87.5	0.00092	0.18	0.070	0.05	0.43
Mercury	8	62.5	0.00003	0.00019	0.000081	0.000065	0.00063
Nickel	8	100	0.00046	0.0054	0.0020	0.001	0.39
Selenium	8	100	0.0049	0.019	0.0092	0.0084	0.1
Silver	6	33.3	0.00005	0.000079	0.00004	0.00005	0.094
Zinc	8	100	0.0031	0.12	0.033	0.014	6
Black Eagle Stream Drainage – Dissolved Metals							
Antimony	8	100	0.00017	0.00072	0.00028	0.0002	0.0078
Arsenic	8	100	0.00091	0.0094	0.0032	0.0026	**0.000052**[b]
Cadmium	8	50	0.000032	0.00018	0.000064	0.000033	0.0092
Chromium	8	100	0.00029	0.00078	0.00045	0.00038	22
Cobalt	8	100	0.00012	0.002	0.00062	0.0004	0.006
Copper	8	100	0.00051	0.014	0.0027	0.00097	0.8
Iron	8	75	0.01	0.10	0.025	0.014	14
Lead	8	50	0.000046	0.00029	0.000097	0.000046	0.015[c]
Manganese	8	100	0.0061	0.075	0.040	0.038	0.43
Mercury	8	0	0.00003	0.00003	0.000015	0.00003	0.00063
Nickel	8	87.5	0.00015	0.0018	0.00067	0.00057	0.39
Selenium	8	100	0.0046	0.012	0.0077	0.0076	0.1
Silver	8	12.5	0.00005	0.000082	0.000032	0.00005	0.094
Zinc	8	100	0.0023	0.017	0.0085	0.0071	6

Table 2-5: Screening results for surface water data (continued)

Chemical	n	Percent Detected	Minimum (mg/L)	Maximum (mg/L)	Mean[a] (mg/L)	Median (mg/L)	Tap Water Screening Level (mg/L; HQ=1)
ECDR Drainage – Total Metals							
Antimony	2	100	0.0011	0.0013	0.0012	--	0.0078
Arsenic	2	100	0.018	0.031	0.024	--	**0.000052**[b]
Cadmium	2	100	0.0011	0.0039	0.0025	--	0.0092
Chromium	2	100	0.0029	0.0052	0.0041	--	22
Cobalt	2	100	0.0012	0.0032	0.0022	--	0.006
Copper	2	100	0.086	0.17	0.13	--	0.8
Iron	2	100	2.7	4.4	3.6	--	14
Lead	2	100	0.020	0.067	0.043	--	**0.015**[c]
Manganese	2	100	0.14	0.35	0.24	--	0.43
Mercury	2	100	0.000046	0.00016	0.00010	--	0.00063
Nickel	2	100	0.0055	0.01	0.0078	--	0.39
Selenium	2	100	0.0073	0.011	0.0094	--	0.1
Silver	2	100	0.00018	0.0002	0.00019	--	0.094
Zinc	2	100	0.25	0.84	0.54	--	6
ECDR Drainage – Dissolved Metals							
Antimony	2	100	0.00038	0.00081	0.00060	--	0.0078
Arsenic	2	100	0.010	0.012	0.011	--	**0.000052**[b]
Cadmium	2	100	0.000035	0.00017	0.00010	--	0.0092
Chromium	2	100	0.00045	0.00066	0.00056	--	22
Cobalt	2	100	0.0011	0.0016	0.0014	--	0.006
Copper	2	100	0.003	0.024	0.013	--	0.8
Iron	2	50	0.01	0.018	0.012	--	14
Lead	2	100	0.0011	0.0019	0.0015	--	0.015[c]
Manganese	2	100	0.084	0.12	0.10	--	0.43
Mercury	2	0	0.00003	0.00003	0.000015	--	0.00063
Nickel	2	100	0.0029	0.0037	0.0033	--	0.39
Selenium	2	100	0.0062	0.0109	0.0086	--	0.1
Silver	2	0	0.00005	0.00005	0.000025	--	0.094
Zinc	2	100	0.018	0.028	0.023	--	6

Table 2-5: Screening results for surface water data (continued)

Chemical	n	Percent Detected	Minimum (mg/L)	Maximum (mg/L)	Mean[a] (mg/L)	Median (mg/L)	Tap Water Screening Level (mg/L; HQ=1)
Storm Water Culverts – Total Metals							
Antimony	9	100	0.00019	0.0023	0.0011	0.00087	0.0078
Arsenic	9	100	0.0011	0.027	0.012	0.0077	**0.000052**[b]
Cadmium	9	100	0.000039	0.0029	0.00089	0.00061	0.0092
Chromium	9	100	0.00036	0.010	0.0043	0.0046	22
Cobalt	9	100	0.000078	0.0032	0.0018	0.0026	0.006
Copper	9	100	0.002	0.11	0.042	0.036	0.8
Iron	9	88.9	0.01	9.8	4.1	3.6	14
Lead	9	100	0.000065	0.16	0.039	0.013	**0.015**[c]
Manganese	9	100	0.00099	0.26	0.093	0.072	0.43
Mercury	9	77.8	0.00003	0.00054	0.00015	0.0001	0.00063
Nickel	9	100	0.00064	0.0075	0.0044	0.0048	0.39
Selenium	9	100	0.00036	0.016	0.0039	0.001	0.1
Silver	8	37.5	0.00005	0.00072	0.00020	0.00005	0.094
Zinc	9	100	0.008	0.65	0.26	0.21	6
Storm Water Culverts – Dissolved Metals							
Antimony	9	100	0.00017	0.0025	0.0010	0.001	0.0078
Arsenic	9	100	0.001	0.023	0.0071	0.005	**0.000052**[b]
Cadmium	9	100	0.000038	0.00064	0.00026	0.00016	0.0092
Chromium	9	100	0.00036	0.0038	0.0011	0.00081	22
Cobalt	9	100	0.00044	0.0036	0.0019	0.0018	0.006
Copper	9	100	0.0013	0.034	0.017	0.019	0.8
Iron	9	77.8	0.01	0.13	0.052	0.048	14
Lead	9	88.9	0.000046	0.0023	0.00075	0.00039	0.015[c]
Manganese	9	100	0.0012	0.072	0.024	0.017	0.43
Mercury	9	0	0.00003	0.00003	0.000015	0.00003	0.00063
Nickel	9	100	0.00048	0.0033	0.0017	0.0017	0.39
Selenium	9	100	0.00026	0.014	0.0033	0.00085	0.1
Silver	9	22.2	0.00005	0.00015	4.3E-05	0.00005	0.094
Zinc	9	100	0.0063	0.27	0.062	0.016	6

Bolded values indicate screening value is exceeded by the maximum COI concentration.
[a] Mean summary statistics are calculating using DL/2 for samples below the DL.
[b] Federal drinking water standard (maximum contaminant level, MCL) is 0.01 mg/L, which is the same as the MDEQ human health standard for groundwater (i.e., for consumption as drinking water).
[c] Lead value is the USEPA MCL.

Table 2-6: Screening results for sediment data

Chemical	n	Percent Detected	Minimum (mg/kg)	Maximum (mg/kg)	Mean* (mg/kg)	Median (mg/kg)	Residential Soil Screening Level (mg/kg; HQ=1)	Industrial Soil Screening Level (mg/kg; HQ=1)
Antimony	13	46	0.51	2.4	0.823	0.63	31	470
Arsenic	13	100	5.3	102	31.3	17	**0.67**	**3**
Cadmium	13	100	0.19	13.4	4.78	2.4	70	980
Chromium	13	100	10.3	20.5	14.7	14.2	120000	1800000
Cobalt	13	100	3.9	9.7	6.94	7.2	23	350
Copper	13	100	21.8	510	159	71.9	3100	47000
Iron	13	100	12900	26600	19046	19500	55000	820000
Lead	13	100	14.7	234	86.5	46.3	400	800
Manganese	13	100	192	1510	599	429	1800	26000
Nickel	13	100	8.2	25.3	17.1	17.7	1500	22000
Selenium	13	85	0.37	5.4	1.77	0.87	390	5800
Silver	13	38	0.51	2	0.772	0.63	390	5800
Zinc	13	100	73	3640	1109	491	23000	350000

Bolded values indicate screening value is exceeded by the maximum COI concentration.
*Mean summary statistics are calculating using DL/2 for samples below the DL

Table 4-1: Arsenic exposure parameters for resident receptors

Parameter	Units	Child Resident		Adult Resident	
		CTE	RME	CTE	RME
Duration of Exposure (ED)	years	6 (a)		20 (a)	
Body Weight (BW)	kg	15 (a)		80 (a)	
Averaging Time for Cancer (AT_c)	days	25550 (a)		25550 (a)	
Averaging Time for Non-Cancer (AT_{nc})	days	2190 (b)		7300 (b)	
Soil/Indoor Dust/Fugitive Dust					
Soil/Dust Exposure Time (ET)	hours/day	24 (a)		24 (a)	
Soil/Dust Exposure Frequency (EF)	days/year	225 (a,c)		225 (a,c)	
Soil/Dust Ingestion Rate (IR_s)	mg/day	100 (d)	200 (a)	50 (d)	100 (a)
Fraction of Ingested Intake as Soil (F_s)	unitless	0.45 (e)		0.45 (e)	
Soil/Dust Relative Oral Bioavailability (RBA), varies based on arsenic concentration	unitless	0.36-0.46 (f)		0.36-0.46 (f)	
Attic Dust					
Attic Dust Exposure Time (ET)	hours/event	N/A		2 (g)	
Attic Dust Exposure Frequency (EF)	days/year	N/A		52 (g)	
Attic Dust Ingestion Rate (IR_{attic})	mg/day	N/A		50 (h)	100 (h)
Attic Dust Relative Oral Bioavailability (RBA), varies based on arsenic concentration	unitless	N/A		0.36-0.46 (f)	
Sediment					
Sediment Exposure Time (ET)	hours/event	1 (i)		1 (i)	
Sediment Exposure Frequency (EF)	days/year	24 (i)		12 (i)	
Sediment Ingestion Rate (IR_{sed})	mg/day	45 (d,e)	90 (a,e)	22.5 (d,e)	45 (a,e)
Surface Water					
Surface Water Exposure Time (ET)	hours/event	1 (i)		1 (i)	
Surface Water Exposure Frequency (EF)	events/year	24 (i)		12 (i)	
Incidental Surface Water Ingestion Rate (IR_{sw})	mL/hr	50 (j)		10 (j)	
Skin Surface Area (hands and feet) (SA)	cm^2	813 (k)		2300 (k)	

References:
a. USEPA 2014b
b. USEPA 1989
c. Adjusted for local climate; see Section 4 for details
d. USEPA 2011c
e. IEUBK model assumption
f. ENVIRON 2014
g. URS 2003
h. Assumed equal to soil/dust ingestion rate values for adult resident
i. Best professional judgment; see Section 4 for details
j. USEPA 2014c
k. USEPA 2004

Table 4-2: Arsenic exposure parameters for non-residential receptors

Parameter	Units	Adult Dirt Bike Rider		Outdoor Worker		Indoor Worker		Utility Worker	
		CTE	RME	CTE	RME	CTE	RME	CTE	RME
Duration of Exposure (ED)	years	20 (a,b)		25 (a)		25 (a)		1 (d)	
Body Weight (BW)	kg	80 (a)		80 (a)		80 (a)		80 (a)	
Averaging Time for Cancer (AT_c)	days	25550 (a)		25550 (a)		25550 (a)		25550 (a)	
Averaging Time for Non-Cancer (AT_{nc})	days	7300 (c)		9125 (c)		9125 (c)		365 (c)	
Soil Ingestion Rate (IR_s)	mg/day	165 (d,e)		50 (d,f)	100 (d)	25 (d,f)	50 (d)	330 (d)	
Fraction of Intake as Soil (F_s)	unitless	1 (f)		1 (f)		0 (f)		1 (f)	
Relative Oral Bioavailability (RBA), varies based on arsenic concentration	unitless	0.36-0.46 (g)		0.36-0.46 (g)		0.36-0.46 (g)		0.36-0.46 (g)	
Soil Exposure Time (ET)	hours/day	3 (f)		8 (a)		8 (a)		8 (a)	
Soil Exposure Frequency (EF)	days/year	26 (f)	52 (f)	150 (d,h)		167 (d,h)		10 (f)	

References:

a. USEPA 2014b
b. Assumed equal to an adult resident ED
c. USEPA 1989
d. USEPA 2002a
e. Tetra Tech 1996
f. Best professional judgment; see Section 4 for details
g. ENVIRON 2014
h. Adjusted for local climate; see Section 4 for details

Table 4-3: PEF Values and Basis for OU1 Exposure Areas

Exposure Area	Vegetative Cover (%)	Site Area (acres)	PEF (kg/m3)
Northern CSAOI[1]	50	80	8.1E-09
Southern CSAOI[2] + Railroad Corridor[3]	50	165	8.9E-09
Vehicle traffic on unpaved roads and alleys in the Southern CSAOI[4]	0	3.5	8.6E-09
Northern Outlying Areas[5]	25	500	1.6E-08
Southern Outlying Area	50	500	1.0E-08
ECDR	0	51	1.5E-08

[1] Includes residential and non-residential lots which are assumed to have very little area that is not covered by vegetation or structures.

[2] Includes unpaved roads and alleys which are assumed to have 0 percent vegetative cover and residential and non-residential lots which are assumed to have very little area that is not covered by vegetation or structures.

[3] The railroad corridor is assumed to have 0 percent vegetative cover, but represents a relatively small portion of the total area encompassed by the Southern CSAOI.

[4] The contaminated unpaved road area from which vehicle-generated dusts are generated was assumed to be an estimate of the total length of unpaved roads in Black Eagle, assuming the unpaved roads total 3,136 meters with a width of 4.5 meters. Traffic traversing the roads per day was assumed to be 10 cars (weighing 1.5 tons each) and 10 sport utility vehicles or pick-up trucks (weighting 2 tons each). Default values (for Casper, WY) were used for constants required in the Q/Coff equation. The number of days per year with at least 0.01 inches of precipitation from NOAA is 97 days. The exposure duration was assumed to be 20 years.

[5] Excluding the ECDR.

Table 5-1: IEUBK model input values selected for use in the baseline HHRA				
IEUBK Model Parameter	**Input Value**	Source		
Maternal Blood Lead (µg/dl)	1	IEUBK model default[1]		
Soil-Dust Relationship (MSD)	0.39	Site-specific; see Section 5.1.1		
Air concentration (µg/m^3)	0.1	IEUBK model default[1]		
Soil/Dust Absorption	31%	Site-specific; see Section 5.1.2		
Drinking water concentration (µg/L)	4	IEUBK model default[1]		
Age-Dependent IEUBK Default Parameters				
Age (years)	**Vent. Rate (m^3/day)[1]**	**Diet (µg/day)[1]**	**Water (L/day)[1]**	**Soil (g/day)[2]**
0-1	2	2.26	0.2	0.085 (0.086)
1-2	3	1.96	0.5	0.135 (0.094)
2-3	5	2.13	0.52	0.135 (0.067)
3-4	5	2.04	0.53	0.135 (0.063)
4-5	5	1.95	0.55	0.100 (0.067)
5-6	7	2.05	0.58	0.090 (0.052)
6-7	7	2.22	0.59	0.085 (0.055)

[1] IEUBKwin v1.1 build 11
[2] IEUBK model default (Alternate input; see Section 5.1.3)

Table 5-2: ALM inputs selected for use in the baseline HHRA

Parameter	Units	Resident in Attic	Indoor Worker	Outdoor Worker	ATV/Dirt Bike Rider	Source/Basis
$R_{fetal/maternal}$	unitless	0.9	0.9	0.9	0.9	USEPA (2003) default
$PbB_{adult,0}$	µg/dL	0.8	0.8	0.8	0.8	Anticipated TRW update
PbS	µg/g	Site-specific	Site-specific	Site-specific	Site-specific	OU1 RI soil or dust data for soil that the receptor will contact
BKSF	µg/dL per µg/day	0.4	0.4	0.4	0.4	USEPA (2003) default
IRs	g/day	0.050	0.050	0.100	0.100	Resident & Indoor Worker: USEPA (2003) default Outdoor Worker & ATV/Dirt Bike Rider: USEPA (2013b) recommendation for contact-intense worker
AFs	unitless	0.124	0.124	0.124	0.124	USEPA (2003) default adjusted for 62 percent site-specific RBA
EFs	days/year	52	173	173	104	Resident: professional judgment Workers and ATV/Dirt Bike Rider: site-specific (see Section 4.2.9)
AT	days/year	365	365	365	365	USEPA (2003) default
$GSD_{i,adult}$	unitless	1.8	1.8	1.8	1.8	USEPA 2009b

References:

a. USEPA 2003
b. USEPA 2009b
c. USEPA 2013b

Figures

Legend

- Northern Community Soils Area
- Southern Community Soils Area
- Outlying Areas

N

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

Figure 1-1: OU1 site boundaries

0 0.25 0.5 1

Miles

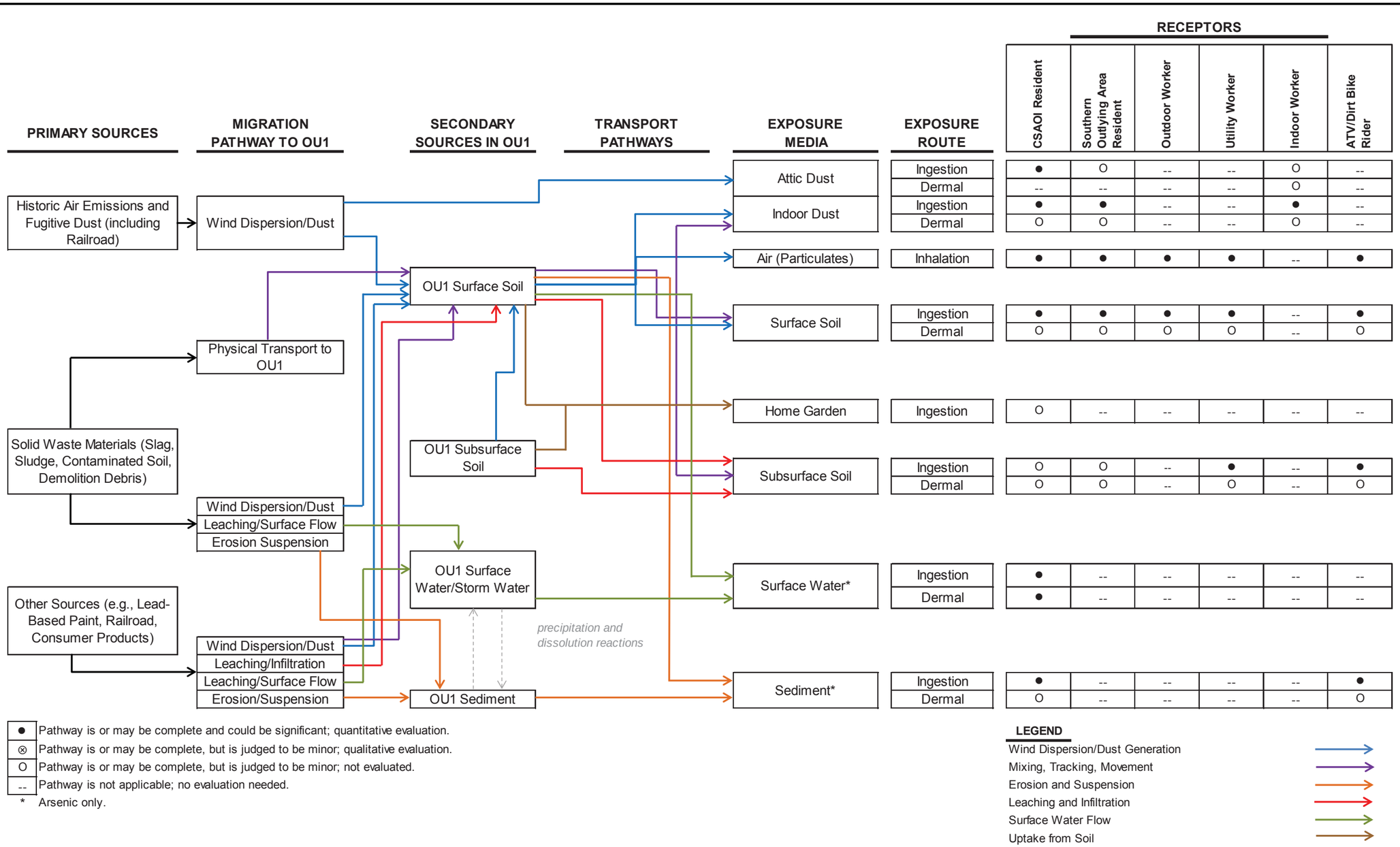
ACM Smelter and Refinery Site
Operable Unit 1
Baseline HHRA Workplan

ENVIRON

FIGURE
1-1

DRAFTED BY: ERM	DATE: 12/3/2014	PROJECT: 3032508A

T:\PROJECT FILES\AR Great Falls (School)\2_Post-Listing Files\1_OU1 CSAOI & Outlying Areas\OU1 HHRA\Working Files\ERM\GIS\Figure1-1_SiteLocation.mxd



EXPOSURE MEDIA	EXPOSURE ROUTE	CSAOI Resident	Southern Outlying Area Resident	Outdoor Worker	Utility Worker	Indoor Worker	ATV/Dirt Bike Rider
Attic Dust	Ingestion	●	O	--	--	O	--
	Dermal	--	--	--	--	O	--
Indoor Dust	Ingestion	●	●	--	--	●	--
	Dermal	O	O	--	--	O	--
Air (Particulates)	Inhalation	●	●	●	●	--	●
Surface Soil	Ingestion	●	●	●	●	--	●
	Dermal	O	O	O	O	--	O
Home Garden	Ingestion	O	--	--	--	--	--
Subsurface Soil	Ingestion	O	O	--	●	--	●
	Dermal	O	O	--	O	--	O
Surface Water*	Ingestion	●	--	--	--	--	--
	Dermal	●	--	--	--	--	--
Sediment*	Ingestion	●	--	--	--	--	●
	Dermal	O	--	--	--	--	O

Figure 3-1: Refined conceptual site model

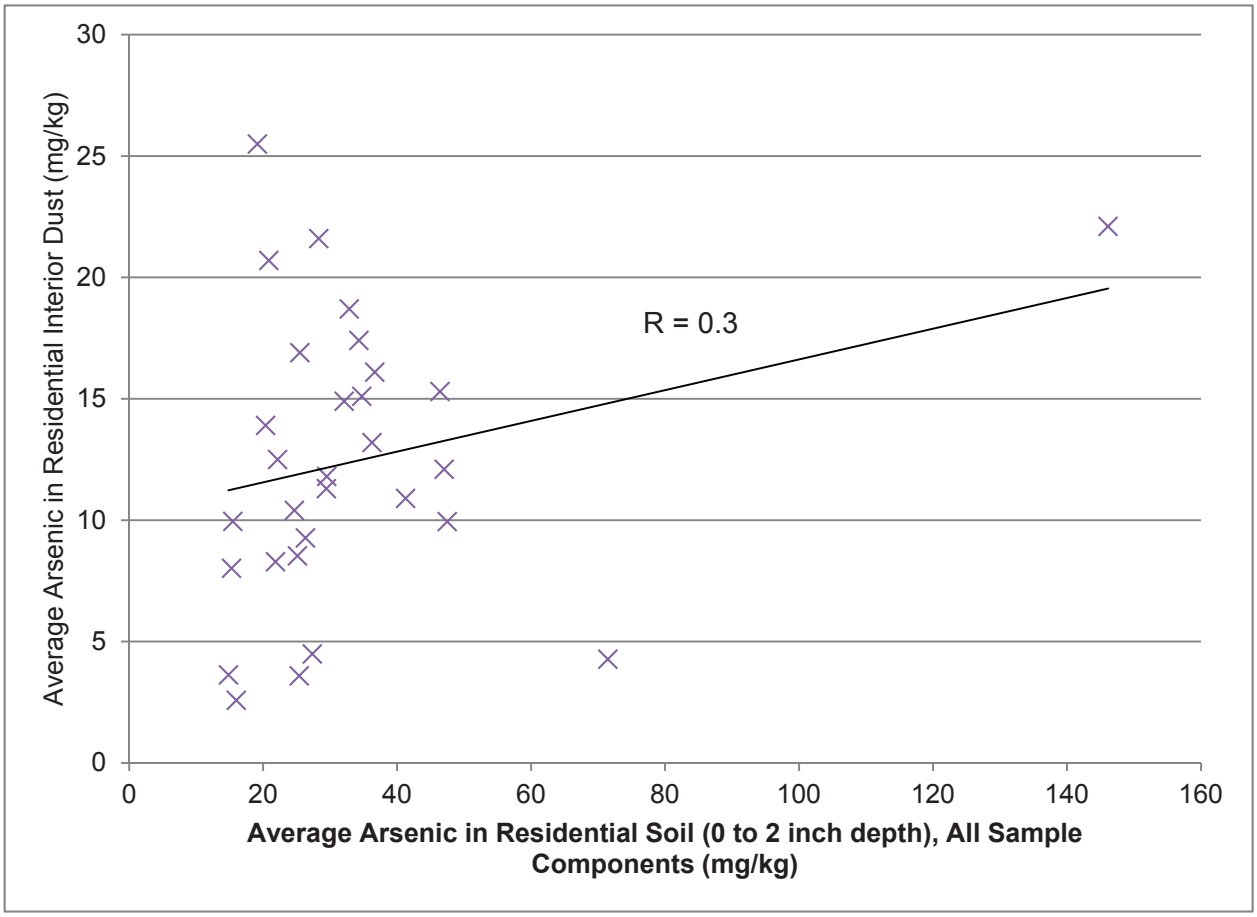


Figure 4-1: Arsenic soil-to-dust relationship (n=30)

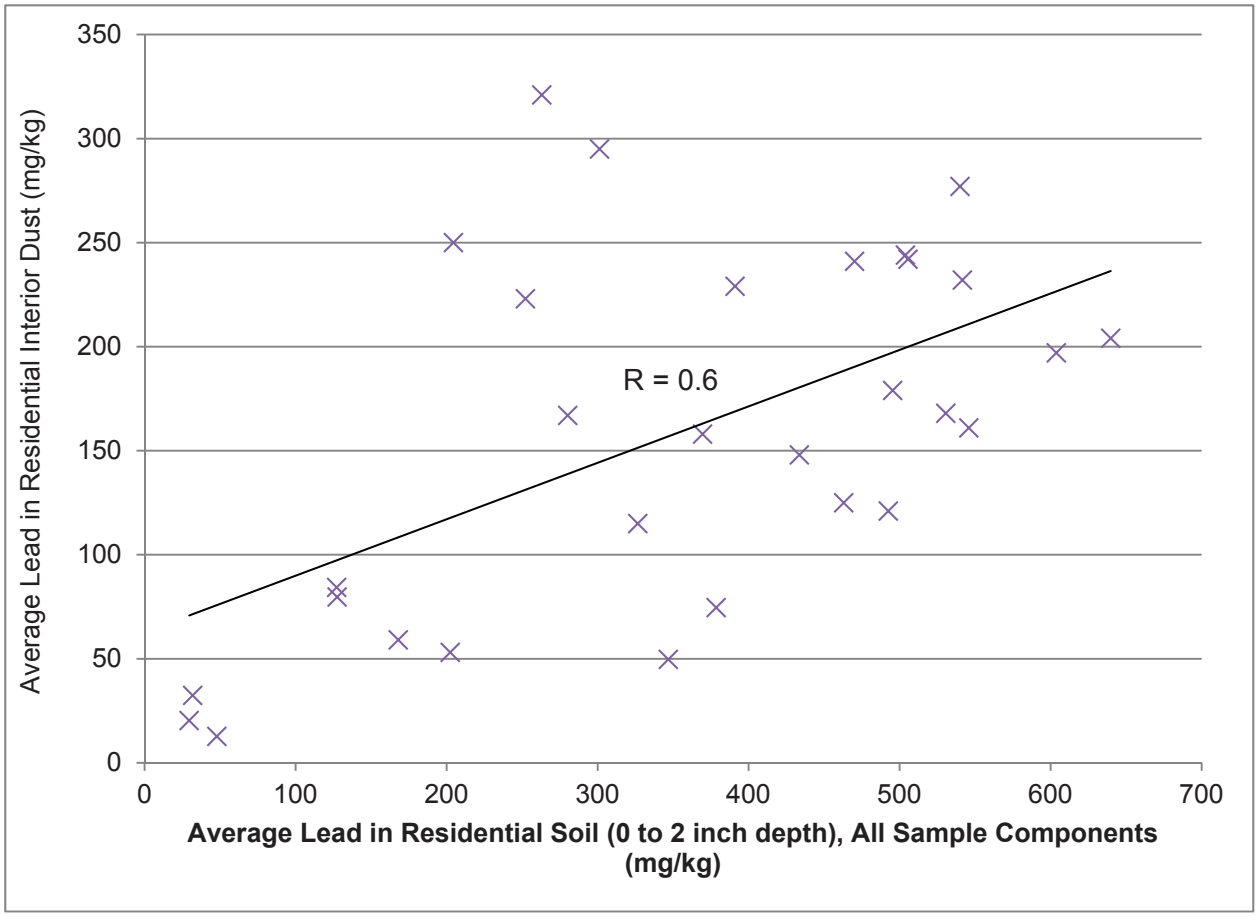


Figure 5-1: Lead soil-to-dust relationship (n=30)

Appendix A

Summary of Garden Practices Surveys

Brief Survey on Black Eagle Gardening Practices
Supporting EPA's Superfund Cleanup

Return with your January water bill to:

Black Eagle Water, P.O. Box 1, Black Eagle, MT 59414.

Or at a drop box to be located at the main entrance to the Black Eagle Community Center

A large response from residents (owners and renters living in Black Eagle) is important!

The Black Eagle Technical Assistance Group (TAG) is led by local citizen volunteers for the purpose of participating effectively in EPA's Superfund cleanup of the Black Eagle community and the former smelter site. The TAG is undertaking the attached survey on local gardening practices in support of the assessment of residential areas in Black Eagle. Please take a few minutes to complete the attached questionnaire. If you don't garden, please answer questions 1 to 3. A large number of responses from gardeners and non-gardeners is needed to provide useful information that accurately reflects the potential for exposure to contamination during gardening. Your response will kept confidential as no personal identification information is being requested on this survey.

Why are we doing this?

The Superfund program is assessing data collected from residential yards to determine whether, and to what extent soil cleanup is necessary. The assessment considers unique aspects of a community like Black Eagle that can affect the potential for exposure to contamination. The nature of gardening conducted in Black Eagle is an area where more information would be useful for understanding exposure and improving cleanup decisions.

Where can I get more information?

Gardening provides healthful exercise and nutrition benefits. The enclosed flier explains how to minimize exposure to any contaminants. The TAG maintains a library of reports at the Community Center that describe the work thus far completed to assess the degree and extent of contamination. Information and project reports are also available on EPA's web site: http://www2.epa.gov/region8/acm-smelter-and-refinery.

1. Do you live within Black Eagle?	☐ Yes ☐ No
2. If the answer above is no, do you live within a mile of Black Eagle?	☐ Yes ☐ No
3. Do you live in a residence with a yard?	☐ Yes ☐ No If no, stop here.
4. On average, how many days per week would you estimate you spend time in your yard during the nicest weather (June, July, August, September)?	Days per week:
5. On average, how many days per week would you estimate you spend time in your yard during the spring and fall (April, May, October, November)?	Days per week:
6. On average, how many days per week would you estimate you spend time in your yard during the winter months (December, January, February, March)?	Days per week:
7. Do you have a produce garden in your yard?	☐ Yes ☐ No

-- turn over --

8. If the answer above is yes, how big is your garden?	☐ <50 sq. ft. (e.g. 1-2 beds, 4 ft. x 6 ft. each) ☐ 51-150 sq. ft. (e.g. 3-6 beds, 4 ft. x 6 ft. each) ☐ >150 sq. ft. (e.g. more than 8 ft. x 20 ft.)
9. What is the month of your earliest harvest?	Month:
10. What is the month of your last harvest?	Month:
11. Do you can, freeze, or preserve your homegrown produce?	☐ Yes ☐ No
12. When possible, do you peel your root vegetables before eating them?	☐ Yes ☐ No
13. Is your garden in a raised bed?	☐ Yes ☐ No
14. Do you add soil or soil amendments to your garden and if so, what kind and how much? Where did you get the soil/soil amendments?	
15. Do you regularly plow or use a rototiller in your garden?	☐ Yes ☐ No

16. Is your garden located next to any of the following (check all that apply):

☐ painted building ☐ roof drip line ☐ road or alleyway

17. Check the box below next to any produce that you have grown and eaten from your home garden in recent years:

☐ Leafy greens (e.g. lettuce, kale, chard, etc)	☐ Tomatoes	☐ Squashes
☐ Root vegetables (e.g. potatoes, beets, onions, etc)	☐ Corn	☐ Peppers
☐ Beans	☐ Fruit or berries	☐ Herbs

Other produce:

18. Do you regularly practice any of the following procedures for minimize potential exposure to contamination that may be derived from historic smelter operation and many other contemporary sources (check all that apply):

☐ wear gloves during gardening ☐ wash hands after gardening ☐ wash produce

☐ remove footwear after gardening ☐ peel root crops ☐ remove outer layer of leafy crops

Summary of Responses to Black Eagle Gardening Practices Survey

Respondent #	Q1 (yes or no)	Q2 (yes or no)	Q3 (yes or no)	Q4 (days/week)	Q5 (days/week)	Q6 (days/week)	Q7 (yes or no)	Q8			Q9 (month)	Q10 (month)	Q11 (yes or no)	Q12 (yes or no)	Q13 (yes or no)	Q14		Q15 (yes or no)	Q16			Q17										Q18					
								<50 sq. ft.	51-150 sq. ft.	>150 sq. ft.						Add soil or amendments?	Details		painted building	roof drip line	road or alleyway	Leafy greens	Root vegetables	Beans	Tomatoes	Corn	Fruit or berries	Squashes	Peppers	Herbs	Other	wear gloves during gardening	wash hands after gardening	wash produce	remove footwear after gardening	peel root crops	remove outer layer leafy crops
1	Y		Y	7	7	1	Y		x		May	Nov	Y	Y		Y	compost	Y	Y		Y	Y	Y		Y				Y	Y			Y				Y
2	Y		Y	7	7	7																														
3	Y		Y	7	2.5	0	Y		x		Sep	Oct	Y	Y		Y	fertilizer							Y	Y			Y					Y	Y	Y		
4	Y		Y	5	1	0																															
5	Y		Y	6	3	1	Y	x			July	Sept	Y	Y		Y	store bags		Y	Y	Y		Y		Y		Y	Y	Y			Y	Y	Y	Y	Y	Y
6	Y		Y	5	4	0	Y			x	July	Oct	Y	Y				Y			Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y
7																																				
8	Y		Y	5	3	0	Y	x			July	Oct	Y	Y		Y	store soil			Y			Y	Y	Y				Y			Y	Y	Y	Y	Y	Y
9	Y		Y	3	3	0																															
10	Y		Y	7	7	2	Y	x			May	Oct	Y		1	Y	top soil, horse manure		Y		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	peas		Y	Y			Y
11	Y		Y	1	0.5	0																															
12	Y		Y	4	5	0																															
13	Y		Y	5	2	0																															
14	Y		Y	5	4	0	Y	x			Aug	Aug		Y											Y								Y	Y			
15	Y		Y	7	3	2	Y			x	July	Oct	Y	Y	1	Y	manure						Y	Y	Y	Y	Y	Y	Y			Y	Y	Y		Y	
16	Y		Y	4	4	2																															
17	Y		Y	6	5	1	Y		x		Aug	Aug		Y		Y	compost								Y		Y		Y			Y	Y	Y		Y	
18	Y		Y	3.5	1.5	1	Y																														
19	Y		Y	5.5	4	2.5	Y	x			July	Nov		Y	1	Y	store mulch		Y			Y	Y	Y	Y	Y	Y		Y	Y			Y	Y	Y		Y	Y
20	Y		Y	7	5	3	Y	x			Oct	Oct						Y			Y				Y						pumpkins			Y			
21	Y		Y	4	2	0	Y		x		July	Oct		Y				Y					Y	Y	Y	Y		Y	Y			Y	Y	Y	Y		Y
22	Y		Y	7	6	2	Y				Aug	Sept	Y	Y																	apples		Y	Y			
23	Y																																			
24	Y		Y	7	7	7																															
25	Y		Y	7	5	0	Y			x	June	Oct	Y	Y	1	Y	compost	Y		Y		Y	Y	Y	Y		Y		Y	Y			Y	Y		Y	
26	Y		Y	5	2	0																															
27	Responses not included because resident lives more than a mile outside of Black Eagle and does not have a produce garden.																																			
28	Y		Y	4	3	0																															
29	Y		Y	7	7	5	Y			x	June	Oct	Y			Y	top soil, steer manure, mulch/compost	Y		Y	Y	Y	Y	Y	Y	Y			Y		Y				Y			
30	Y		Y	4	2.5	1											has flower bed																				
31	Y		Y	0	0	0																															
32	Y		Y	7	5	3	Y			x	June	Oct	Y		1	Y	only some raised bed	Y			Y	Y	Y	Y	Y		Y	Y	Y	Y			Y	Y			

Note: Y= yes

ATLANTIC RICHFIELD COMPANY'S RESPONSES TO EPA'S TECHNICAL COMMENTS[1] ON THE DRAFT HUMAN HEALTH RISK ASSESSMENT WORK PLAN FOR THE ACM SMELTER AND REFINERY SITE, OPERABLE UNIT 1[2]

SPECIFIC COMMENTS

1. **Section 2.1, page 4**. This section provides a general discussion of the process for the selection of chemicals of potential concern (COPCs) in soil. The first full paragraph on page 4 indicates that there is increased uncertainty associated with the hexavalent chromium results because several of the values were estimated concentrations between the practical quantitation limit and the method detection limit. It is unclear to what degree these estimated values may impact the overall uncertainty of the hexavalent chromium data set. For clarity, please replace the descriptor "several" with a percentage of the total hexavalent chromium results which were estimated.

   Response: *The descriptor "several" has been replaced with "88 percent of the".*

2. **Section 2.2, page 5**. The discussion of selection of groundwater COPCs presented in this section is generally acceptable, as is a statement that further investigation of groundwater will not be completed at this time. However, for clarity, please add a statement to the effect that only an abbreviated groundwater investigation was completed, and a more thorough investigation of groundwater is anticipated to be completed to support the ecological risk assessment. The planned sampling of the Electric City Dirt Riders (ECDR) well, which was proposed but not completed as part of the RI, should also be identified as a potential data gap.

   Response: *While it is true that sampling of groundwater was limited to only two wells, we disagree that investigation of groundwater to support the OU1 RI was "abbreviated." The groundwater data quality objective (DQO) for the OU1 RI pertained to determining whether or not groundwater in OU1 was used by people and, if so, what concentrations of COPCs were present. As detailed in section 4.6.1 of the RI Report:*

   "In addition to the 20 groundwater wells identified through a search of the GWIC database, 15 monitoring wells and 1 nested piezometer were identified at the former Great Falls municipal landfill located just north of the ECDR property on the north side of Rainbow Dam Road. …Following completion of the GWIC database search, each well's owners of record were contacted, if possible, to confirm the existence of a groundwater well at each of these locations. Based on the location of the wells and the water uses either reported in GWIC and/or confirmed by the current owners, nine wells were identified for sampling in support of the OU1 RI. Groundwater samples were collected at two of the nine wells as summarized on Table 4-12. The other seven wells were not sampled because the field crew was not able to either locate the well or gain access from the property owner, or it was not possible to collect samples from the well (e.g., well connected to storage tank)."

[1] EPA's comments were provided in a letter to Atlantic Richfield dated February 23, 2015. EPA also provided supplemental information pertaining to Comment 10 of the February 23, 2015 letter via email to Atlantic Richfield on April 9, 2015.

[2] The draft work plan is dated December 2014.

The investigative efforts taken to inventory and sample groundwater wells as part of the RI support the statement in section 2.2 of the HHRA work plan that "available data suggests groundwater is not used for drinking water within the OU1 boundaries." Further, while section 1 of the work plan acknowledges that "assessment of ecological risks for OU1 will be deferred to the future RI/FS for the former smelter and refinery property and the Missouri River" adding more detail to the work plan regarding further investigations to support the ecological risk assessment does not seem warranted and is likely to introduce confusion as to the scope of the baseline HHRA.

We agree that planned sampling of the ECDR well that did not occur represents a data gap for the RI; however, as stated in the RI Report, the ECDR well is used to obtain water for dust suppression at the ECDR track. Available information regarding use of the ECDR well does not indicate the well is used for consumption by people. Further, a review of groundwater monitoring data for 2002-2006 for the ECDR well found no exceedances of the arsenic or lead federal drinking water standards (MCLs). To the extent that arsenic and lead concentrations in water from the ECDR well contribute to respective concentrations of these COPCs in ECDR soils, such exposures are addressed by the HHRA work plan for the dirt bike rider scenario.

Given the above, the requested additions to section 2.2 have not been made. However, for additional clarity, the final sentence in section 2.2 has been revised to: "The groundwater pathway will not be considered for OU1."

3. **Section 2.3, page 5**. This section discusses the selection of COPCs in surface water. Please revise the last sentence of this section as follows: "use of tap water RSLs for screening may be overly conservative for identifying COPCs for further evaluation in the baseline HHRA."

   Response: *The text has been revised to replace "is" with "may be."*

4. **Section 2.3.2, page 5**. This section discusses possible exposures to people using the ECDR facility. The annual flow in the ECDR drainage is not known, but the exposure of recreational users to soils, surface waters and mud is increased by the nature of the activity (riding motorcycles/ATVs). Please retain the ECDR drainage surface water pathway for evaluation in the HHRA.

   Response: *We agree that exposure of recreational users to soils, either wet or dry, is likely to be increased by the nature of the activity; however, we disagree that these activities will increase direct exposures to surface water that was found to be minimally present at the ECDR drainage based on two sampling events (May and July). In addition to the documented minimal presence of surface water at the drainage, track users are required to use helmets as a condition of track use. Further, to the extent that surface water from the ECDR drainage influences concentrations in collocated sediment, surface water concentrations are also addressed by the HHRA work plan's screening of arsenic and lead sediment from the ECDR drainage. As summarized in the work plan, comparing sediment concentrations to conservative risk-based screening levels based on chronic exposure to soil in a residential setting resulted in retention of arsenic, but not lead in ECDR drainage sediment. As stated in the HHRA work plan, arsenic in sediment of the ECDR drainage will be evaluated in the HHRA. However, as detailed above, direct exposure to surface water from the ECDR drainage is expected to be negligible and does not warrant retention in the HHRA as a separate exposure pathway.*

5. **Section 2.3.3, page 6**. This section discusses the potential for people to contact surface water at eight culverts which drain to the Missouri River. Please retain arsenic and lead as COPCs.

   Response: *DQO #7 of the RI/FS Work Plan, Step 2, states: "If there are no bodies of surface water in OU1 that are accessible by people, or no COPCs are found in surface water above screening levels, no further evaluations of the surface water exposure pathway will be necessary." Per EPA risk assessment guidance for Superfund: "Exposure is defined as the contact of an organism (humans in the case of health risk assessment) with a chemical or physical agent (EPA 1988a)." While arsenic and lead were detected above conservative risk-based screening levels for consumption of water as tap water in OU1 storm water culvert samples (Table 2-5 of the HHRA work plan), photographs of the culvert outfalls included as Figures 4-13 and 4-14 of the RI Report suggest exposures to surface water (and/or to sediment) at these settings are likely to be infrequent, of short duration, and, should they occur, limited with regard to the ingestion route. In contrast, access to surface water in the Black Eagle drainage is more likely to occur and represents a more reasonable setting within OU1 for assessing the surface water exposure pathway. Given the negligible exposures to arsenic and lead that would be expected to occur at the culverts and that such exposures via surface water will be addressed in the HHRA at the Black Eagle drainage, arsenic and lead have not been retained as COPCs in surface water at the culverts.*

6. **Section 2.5, page 6**. The summary presented in this section should be updated to reflect edits on the parts of Section 2. For clarity, please add "until the ecological risk assessment is completed." at the end of the sentence regarding groundwater being eliminated from further evaluation.

   Response: *Based on responses to comments 2 through 5, no changes to this section are necessary. While we acknowledge the request for clarity regarding the ecological risk assessment, as noted in response to comment 2, section 1 of the work plan already acknowledges that "assessment of ecological risks for OU1 will be deferred to the future RI/FS for the former smelter and refinery property and the Missouri River." For clarity, the following statement has been added to section 1: "The scope of the HHRA and its findings are not intended to supersede USEPA's consideration of ecological risks for OU1 that has been deferred for evaluation in conjunction with other ACM Site operable units."*

7. **Section 2.5, page 6**. The last sentence of this section mentions that exterior lead paint will be considered in the HHRA, but there is no indication of whether a quantitative or qualitative evaluation is proposed. Please remove the reference to exterior lead paint, and replace with "and other potential sources of lead may also..."

   Response: *The text has been revised to replace "exterior paint will" with "other potential sources of lead may..."*

8. **Section 3.1, page 7**. This section discusses refinements to the conceptual site model based on evaluation of data collected during the RI. Please revise the two bullet lists on this page to account for the changes requested to Section 2.

   Response: *The first set of bullets refers to exposure media that the RI Report (not the HHRA work plan) identified for possible further evaluation in the baseline HHRA; therefore, those bullets are not affected by the requested changes to section 2. Additionally, based on responses to comments 2 through 5 above, changes to the second set of bullets are not necessary.*

9. **Section 3.1.1.1, page 10**. This section discusses the climate of the Great Falls area, presenting some general climate information collected by NOAA, and draws conclusions about the likelihood of snow cover and frozen ground based on this general climate data. However, Black Eagle is located on a south facing hillside above the Missouri River, causing it to receive significantly more winter sunshine than does Great Falls. The agencies have deferred to the Black Eagle TAG for this exposure assumption. Black Eagle residents have indicated that during milder winters, yard work such as raking, or outdoor construction or remodeling are commonly undertaken. Please revise this discussion to present an assumption of four months (120 days) of frequently frozen conditions, rather than six or seven months.

   Response: *The information provided by the Black Eagle Technical Advisory Committee (TAC) relates to residents' activity patterns during milder winters in Black Eagle and is better suited for addition to section 4.2.9 rather than section 3.1.1.1. The following sentence has been added to Section 4.2.9: "Personal information provided by Black Eagle residents indicates that, during milder winters, yard work such as raking, or outdoor construction or remodeling are commonly undertaken."*

   It is important to understand that the exposure frequency assumptions included in the HHRA work plan are activity-based and do not reflect simple proration based on an assumption of the number of months per year that soil access might be limited due to frozen, snow covered, or muddy ground. The activity-based approach assumes that residents are exposed during all months of the year, with exposure occurring over fewer days per week during certain months than others as detailed in section 4.2.9. The number of days assumed per week for different months of the year considers how the climate affects the availability of bare soil that can be contacted as well as how climate affects the nature and intensity of contacts by people with bare soil when it is available. These assumptions also are intended to reflect the range of climate conditions, including both mild and severe winters that would be expected to occur over many years (e.g., 26 years for the resident). Based on consideration of the additional information provided by the Black Eagle Technical Advisory Committee and in responses to garden surveys by local residents, section 4.2.9 has been updated to assume residents have direct contact with surface soil two days per week (instead of one) during the months of January and February and four days per week (instead of three) during the months of March and April. Assumed exposure frequencies during other months are unchanged. The result of these changes is an assumed maximum soil/dust exposure frequency of 225 days per year for the resident.

10. **Section 3.1.1.1, page 10**. To ensure consistency across the risk assessment for the RCOU1 and the risk assessment for the CSAOIs and the Outlying Areas, separate exposure scenarios for Construction Workers, Utility Workers, and Outdoor Workers should be established. Please include these higher exposure rate, shorter duration scenarios.

    Response: *As response to this comment was limited by lacking information regarding the scenarios and assumptions proposed for the RCOU1 risk assessment, EPA supplemented this comment with additional information via email sent to Atlantic Richfield on April 9, 2015; this supplemental information is attached for reference. Based on the supplemental information provided, the work plan will be revised as follows to address the agencies' request for continuity with the RCOU1 HHRA assumptions:*

    1. *The Outdoor Worker scenario will be revised to be consistent with the RCOU1 Outdoor Worker assumptions. Specifically, exposures will be assumed to be limited to surface soil (0-2 inch depths) for a period of 150 days per year for 25 years. Soil ingestion rates for the Outdoor Worker will be 50 milligrams per day (mg/day) for the central tendency exposure (CTE) estimate*

and 100 mg/day for the reasonable maximum exposure (RME) estimate, as originally proposed in the draft work plan and consistent with EPA's supplemental information regarding the RCOU1 assumptions. Exposures by the Outdoor Worker will be evaluated separately for nonresidential soils of the Community Soils Areas of Interest (CSAOI) and the Northern Outlying Areas (NOA). Exposures by the Outdoor Worker to soils from unpaved roads and alleys will not be evaluated given the absence of commercial/industrial work sites on unpaved roads and alleys. Exposure pathways will be limited to incidental soil ingestion and inhalation of fugitive dust originating from soil. Dermal exposure to soil will not be evaluated as direct absorption of lead and arsenic through skin is expected to be negligible (Lowney et al. 2007; USEPA 1994; USEPA 2002) and is frequently excluded from EPA Region 8 HHRAs.

2. *More intense worker exposures to surface and subsurface soils will be addressed by a separate Utility Worker scenario with short-term exposure, 10 days per year for one year, to soils from all sampled depths at a soil ingestion rate of 330 mg/day, which is consistent with EPA soil screening guidance for a construction worker scenario. Evaluation of soil exposures by the Utility Worker will be limited to arsenic consistent with the RCOU1 assessment and EPA ALM guidance. The Utility Worker exposures will include contact with arsenic in soil from incidental ingestion and inhalation of fugitive dust from soil. Dermal exposures to soil will not be evaluated as direct absorption of lead and arsenic through skin is expected to be negligible (Lowney et al. 2007; USEPA 1994; USEPA 2002) and is frequently excluded from EPA Region 8 HHRAs. Exposures by the Utility Worker will be evaluated separately for nonresidential soils of the Community Soils Areas of Interest (CSAOI), the Northern Outlying Areas (NOA), and unpaved roads and alleys. Exposure point concentrations (EPCs) for each area will be calculated using a depth-weighted averaging approach that assumes the worker contacts arsenic in soil from a uniform mixture of concentrations at all depths sampled.*

11. **Section 3.1.1.2, page 10**. This section continues the discussion of the previous section by describing the selected exposure scenarios for the HHRA. Consistent with comments on Section 2, please revise the third paragraph of this section to mention potential exposure to lead as well as arsenic from sediment and surface water at the eight stormwater culverts.

    Response: *Comments on section 2 did not pertain to sediment samples collected from the storm water culverts; however, response to comment 5 provides the rationale for excluding the surface water pathway at the storm water culvert locations, and this rationale applies also to the exclusion of the sediment pathway at these locations. Specifically, photographs of the culvert outfalls included as Figures 4-13 and 4-14 of the RI Report suggest exposures to surface water and sediment at these settings are likely to be infrequent, of short duration, and, should they occur, limited with regard to the ingestion route. While potential exposure to lead or arsenic at the storm water culverts is expected to be negligible, surface water and sediment exposure pathways will be addressed for media of the Black Eagle drainage given the increased likelihood that non-negligible exposures could reasonably occur at this location.*

12. **Section 3.1.1.2, page 11**. This comment relates to the bullet list on page 11 and 2, which identifies each of the pathways selected for quantitative evaluation through the HHRA.

    First Bullet -Please revise this bullet to include mention of the ECDR drainage and the eight stormwater culverts as potential exposure locations for Black Eagle residents, in addition to the Black Eagle drainage.

Response: *Please refer to responses to comments 4, 5, and 11 above.*

Fifth Bullet -Please add surface water to the potential exposures for an ECDR ATV/Dirt bike rider.

Response: *Please refer to response to comment 4 above.*

Additional Bullet -Please add a bullet to address the potential for maximum reasonable cumulative exposure, that is, the young adult ATV rider who lives in Black Eagle, works as a construction/utility worker, and eats produce from a home garden. While this should overestimate the risk for most people in Black Eagle, it is useful to establish an upper bound for the discussion of residential risk. The community has expressed concern about a scenario such as this.

Response: *We appreciate the concern expressed by the community; however, we do not believe the HHRA would be better informed by inclusion of a maximum reasonable cumulative exposure for a Black Eagle resident who consumes homegrown produce, works in construction/utility work within OU1 and also recreates at the ECDR. EPA risk assessment guidance for Superfund sites defines reasonable maximum exposure (RME) as "the highest exposure that is reasonably expected to occur at a site." Further, the guidance states: "RMEs are estimated for individual pathways. If a population is exposed via more than one pathway, the combination of exposures across pathways also must represent an RME." Exposure assumptions consistent with RME estimates are already included in the work plan for the resident, ATV rider, and worker scenarios. As proposed in the work plan and further updated in response to comment 9, the RME resident is assumed to be exposed to arsenic and lead in soils and soil-derived dust at his or her residence for a maximum of 225 days per year for 24 hours per day. Within these 225 days per year of potential exposure to soil, the worker is assumed to be in contact with soil/dust at a work location for 191 days, 8 hours per day, and the ATV rider is assumed to have contact with soil/dust at the ECDR for 104 days, 3 hours per day. Given these assumptions, it is not reasonably plausible to assume that each of these receptors is the same individual. Mathematically, combining these pathways to estimate cumulative RME risks would require reduction in assumed values for individual exposure parameters (e.g., exposure frequency, exposure time, etc.) for each receptor scenario to ensure the combined exposure could reasonably be expected to occur at the site. Further, consumption of homegrown produce will be addressed semi-quantitatively and cannot be added to other quantitative exposure estimates. Generating risk estimates for a resident with combined, but reduced exposures to arsenic and lead in residential soils, in nonresidential soils at work, and ECDR soils is less likely to yield information that is helpful to making risk management decisions specific to different exposure media at the site than evaluating each scenario separately. Instead, we propose adding a qualitative discussion of potential exposures for a resident who may also work within OU1 and/or ride ATVs/dirt bikes within the ECDR.*

13. **Section 4.2.1, page 19**. Please clarify whether exposure point concentrations (EPCs) will be calculated on a yard component basis, a yard by yard basis, or a community wide basis.

    Response: *Exposure point concentrations (EPCs) for residential yards will be calculated based on assumed average exposure over the defined area, which is the residential lot for residential properties. As described in section 4.2.1, all yard components will be included in the soil EPC for residential yards.*

14. **Section 4.2.1, third paragraph, page 19**. This section discusses EPCs. Please revise the third paragraph

to include Utility Worker and Construction Worker scenarios, as well as a discussion on the appropriate soil intervals that will be assumed for incidental soil ingestion for these workers.

Response: *As discussed in response to comment 10, the work plan has been revised to include evaluation of an Outdoor Worker and a separate Utility Worker. As necessary, all sections of the work plan that pertain to worker-related exposure scenarios and assumptions have been revised in accordance with response to comment 10.*

15. **Section 4.2.1, page 19, and Table 4-1**. Please revise exposure assumptions to reflect previous comments on exposure frequency.

Response: *Revisions have been made consistent with response to comment 9.*

16. **Section 4.2.2, page 23**. This section describes the soil/dust ingestion rate assumptions. It does not seem plausible that the outdoor worker soil ingestion RME is equal to both the CTE and the RME of an ATV rider. Please revise, or provide additional rationale for this assumption.

Response: *As referenced in the work plan, the assumed soil ingestion rate for the ATV rider was selected based on consideration of values used within EPA Region 8 to evaluate similar scenarios. The assumed value, 100 milligrams per day, is based on adult intakes and is consistent with the assumptions used for adult ATV riders at other sites in EPA Region 8 (CDPHE 2011; CDM 1999). Since receipt of these comments, this value has been confirmed to be appropriate for use in this HHRA by EPA's risk assessor, Dr. Charles Partridge via an email to ENVIRON dated March 2, 2015 (attached for reference). Subsequently, EPA requested a value used by the State of Montana at abandoned mine sites (Tetra Tech 1996) be considered. Based on this source, a soil/dust ingestion rate of 165 mg/day will be used for both the CTE and RME estimates for the ATV/dirt bike rider based on an assumption of soil ingestion for this receptor is one-half the value assumed for a construction worker involved in excavation activities (USEPA 2002a; Tetra Tech 1996). An email confirming EPA's concurrence with this value is provided in the attached email dated May 7, 2015.*

17. **Section 4.2.9, page 25**. Please revise this section to reflect previous comments on exposure frequency.

Response: *Revisions have been made consistent with response to comment 9. In addition, for the ATV/dirt bike rider, exposure frequency assumptions have also been revised in consideration of estimates for recreational backcountry ATV/motorcycle riding at abandoned mine sites (Tetra Tech 1996). These estimates, 15 and 32 days per year, assume moderate or high ATV/motorcycle riding activity at abandoned mine sites may occur and that exposure will occur primarily during the summertime (13 weeks of the year). Tetra Tech (1996) notes that the estimates are supported by surveys of dirt bike riders near the Anaconda smelter reported by Life Systems (1993) and also "found to be in good accord with a larger demographic survey performed by the University of Cincinnati." Given potential for increased access to ATV/dirt bike riding at the ECDR track compared to non-designated areas near the Anaconda smelter, it is reasonable to assume exposure frequencies associated with the ECDR track may be slightly higher. Therefore, or the RME estimates, the ATV/dirt bike rider is assumed to ride at the ECDR track two times per week from May through October for an exposure frequency of 52 days/year. For the CTE estimates, the ATV/dirt bike rider is assumed to use the ECDR track half as often as the RME estimate for an exposure frequency of 26 days/year. An email confirming EPA's concurrence with these values is provided in the attached email dated May 7, 2015..*

18. **Section 5.1.2, page 29-30**. Please revise this to reflect correctly calculated soil/adsorption rates.

    Response: *Comment acknowledged. Text has been revised to reflect correction of 62 percent lead relative bioavailability to 59 percent.*

19. **Section 5.1.3, last paragraph, page 30**. Please add the following text "Although USEPA adopted a different soil ingestion rate, the efforts of Stanek, Ozkaynak, and Wilson may provide support for the use of a lower soil ingestion rate than that currently recommended by USEPA and the IEUBK model. The combined soil and dust ingestion rate estimated by Wilson will be used to evaluate child lead risk in the baseline HHRA alongside the standard ingestion rate defaults presented in the IEUBK model."

    Response: *Comment acknowledged. The work plan has been revised to indicate that child lead risks in the baseline HHRA will be evaluated using IEUBK default soil/dust ingestion rates in addition to proposed alternate values.*

Reference List

Lowney YW, Wester RC, Schoof RA, Cushing CA, Edwards M, Ruby MV. 2007. Dermal absorption of arsenic from soils as measured in the rhesus monkey. Toxicol Sci. 100(2):381-392.

Attachments

From: Coleman, Charles [mailto:COleman.Charles@epa.gov]
Sent: Thursday, April 09, 2015 10:21 AM
To: Pokorny, Luke N
Cc: Sloan, Richard
Subject: FW: HHRA assumptions

Luke,

You have likely seen these already. These are the clarifications that came out of the March 2nd meeting between Dina and CharlieP. I do not plan to send any additional direction. Please let me know when we should expect to see a final HHRA work plan. If you think we need to discuss further, please let me know asap.

Charlie

From: Partridge, Charles
Sent: Wednesday, April 08, 2015 12:58 PM
To: Dina Johnson
Cc: Coleman, Charles
Subject: HHRA assumptions

Dina,

Please see below for some of the HHRA assumptions to ensure continuity between the RR corridor and Black Eagle Residential

Default exposure assumptions values recommended in the Human Health Evaluation Manual, Supp. Guidance (2014) will generally be used. Site specific values will also be used for scenarios that don't have default values.

Below are some site specific values for several scenarios (outdoor worker, utility worker and recreational scenario)

The outdoor worker scenario does not incorporate trenching or excavating that would result in direct contact beneath the surface (0-2 inches)

The frequency of 150 days/year was derived by adjusting the default assumption of 225 days per year to account for frozen ground during four months. Exposure duration is 25 years. Outdoor worker is assumed to spend 100% of the work day conducting work activities.

The ALM will be used to evaluate exposures to lead in soil by outdoor workers. ALM default values will be used for all parameters except for exposure frequency and RBA.The default central tendancy value used in the ALM will be used. This default value is currently 50mg/day.

Site Specific values

EF-150days/year
ED-25yr

Soil IR 100mg/day

Utility worker-typical trenching activities are assumed to extend up to 5ft bgs. Potential contact with soil within trenches through incidental ingestion, dermal contact and inhalation.Utility workers are those assumed to be conducting utility trenching or heavy excavation activities.

Exposure frequency of 10 days per year based on the assumption that utility work would be completed in two weeks. Exposure duration is 1 year. Worker is assumed to spend 100% of the work day conducting such activities. The rate of incidental ingestion isbases on the 2014 EPA value for construction work. The rate is assumed to be 330mg/day based on the 95th percentile.

Utility workers exposure to lead will not be quantified since it does not meet the minimum requirements of one day per week and a duration of three months to meet the assumptions of the ALM.

EF-10 days/year
ED-1
Soil IR- 330 mg/day

I know we did not mention this but just as an FYI for the recreational user scenario we are using a typical user and a heavy user.
Typical User EF-35 days/year (assumes 1 day a week for 8 months of the year)
Heavy User EF- 139 days/year (assumes 4 days a week for 8 months of the year)

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Dina Johnson

From: Partridge, Charles <Partridge.Charles@epa.gov>
Sent: Monday, March 02, 2015 12:58 PM
To: Dina Johnson; Rosalind Schoof
Subject: atv

Dina and Roz,

You are correct. I was remembering the ingestion rates for kid ATV use. 100 is an acceptable number for adult ingestion rate.

cp

Charles R Partridge, Ph.D.
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Dina Johnson

From: Charlie Partridge <crpartridge@gmail.com>
Sent: Thursday, May 07, 2015 12:23 PM
To: Dina Johnson
Cc: coleman.charles@epa.com; rwitt@pwt.com; Charlie
Subject: Re: ACM ATV/Dirt Bike Rider Ingestion Rate and Exposure Frequency

Dina,
The proposed changes to IR and frequency are acceptable. Please include a brief summary in the RA, of the thought process for the selection of these.

Thanks,

Charlie

Sent from my iPhone

Charlie Partridge

On May 7, 2015, at 9:40 AM, Dina Johnson <DLJohnson@environcorp.com> wrote:

> Hi Charlie, As we discussed, the MDEQ source recommended for the soil ingestion rate for the rider includes information regarding exposure frequencies for such riders and that information is supported by surveys of riders from the Anaconda area, which is relevant to ACM. Below is what I would propose for the ingestion rate and exposure frequencies for this scenario. Please confirm that this is acceptable. Thank you. Dina
>
> Soil Ingestion Rate:
>
> For the ATV/dirt bike rider, a soil/dust ingestion rate of 165 mg/day will be used for both the CTE and RME estimates based on an assumption of soil ingestion that is one-half the value assumed for a construction worker involved in excavation activities (USEPA 2002a; Tetra Tech 1996).
>
> Exposure Frequency:
>
> For the ATV/dirt bike rider, exposure frequency assumptions considered estimates for recreational backcountry ATV/motorcycle riding at abandoned mine sites based on risk-based clean-up guidelines MDEQ recommends for such sites (Tetra Tech 1996). These estimates, 15 and 32 days per year, assume moderate or high ATV/motorcycle riding activity at abandoned mine sites may occur and that exposure will occur primarily during the summertime (13 weeks of the year). Tetra Tech (1996) notes that the estimates are supported by surveys of dirt bike riders near the Anaconda smelter reported by Life Systems (1993) and also “found to be in good accord with a larger demographic survey performed by the University of Cincinnati.” Given potential for increased access to ATV/dirt bike riding at the ECDR track compared to non-designated areas near the Anaconda smelter, it is reasonable to assume exposure frequencies associated with the ECDR track may be slightly higher. Therefore, or the RME estimates, the ATV/dirt bike rider is assumed to ride at the ECDR track two times per week from May through October for an exposure frequency of 52 days/year. For the CTE estimates, the ATV/dirt bike

rider is assumed to use the ECDR track half as often as the RME estimate for an exposure frequency of 26 days/year.

Yours sincerely

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APPENDIX B
JULY 2015 UPDATE TO ENVIRON 2015A

(main text, tables, and figures only)



Data Summary Report

Evaluation of Lead and Arsenic Mineralogy and Bioaccessibility In Black Eagle Soils

Great Falls, Montana

Prepared for:
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Butte, Montana

Prepared by:
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Date:
February 2015
(Updated July 2015)

Project Number:
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ENVIRON

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List of Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
bgs	below ground surface
EMPA	Electron Microprobe Analysis
ICIVC	*In Vivo-In Vitro* Correlation
ICP	Inductively Coupled Plasma
IVBA	*In Vitro* Bioaccessibility Assay
LEGS	Laboratory for Environmental and Geological Studies
MS	Mass Spectrometer
NAS	National Academy of Sciences
SBRC	Solubility/Bioavailability Research Consortium
SOP	Standard Operating Procedure
USEPA	United States Environmental Protection Agency

Units of Measurement

°C	degrees Celsius
g	gram
kg	kilogram
M	molar
mg	milligram
mL	milliliter
mm	millimeter
µm	micron or micrometer

1 Introduction

This data summary report presents the results of oral bioavailability and mineralogy of lead and arsenic in residential soil samples from the community of Black Eagle, located on the northeast edge of Great Falls, Montana. Lead and arsenic contamination present in residential yards may be attributed to historical aerial emissions from multiple sources, plus imported fill materials, historical use of lead arsenate and arsenical pesticides, leaded gasoline, non-refinery industrial impacts, or the presence of lead-based paint. The soil characteristic studies summarized in this report examined the mineral forms of the soil lead and arsenic and the degree to which these metals are likely to dissolve in the gastrointestinal tract of children and other people who might ingest the soil.

A brief discussion of lead and arsenic bioavailability and mineralogy is provided below, followed by the methods for collection and analysis of samples and test results. A discussion of the analytical results completes the report.

The information contained in this data summary report was gathered in accordance with *Addendum No. 1: Evaluation of Bioavailability of Arsenic and Lead in Residential Soils* (Formation, 2013b) to the approved *ACM Refinery and Smelter NPL Site, Black Eagle Residential Soils Sampling and Analysis Plan (SAP)* (Formation 2013a). Given the timing of data collection and analysis summarized in this report, this DSR is being provided as an appendix to the 2014 *Remedial Investigation Report for the ACM Smelter and Refinery Site Operable Unit 1 – Community Soils Areas of Interest and Outlying Areas*.

1.1 Oral Bioavailability

It is a fundamental principle of toxicology that chemicals that are not absorbed will not cause systemic toxicity. For lead and arsenic, systemic toxicity is the primary concern. In order for ingested soil lead and arsenic to be absorbed into the body, it generally must first dissolve in the gastrointestinal tract. Consequently, studies of soil lead and arsenic dissolution under conditions that mimic those of the gastrointestinal tract can help predict the degree to which soil lead and arsenic will be absorbed. The degree to which a chemical is absorbed into the body is expressed as bioavailability. In this report, we will discuss both absolute and relative bioavailability.

Absolute bioavailability is the fraction of the dose of a chemical that enters and is absorbed by the body after being ingested (Kelley et al. 2002, USEPA 2007b). Lead absorption varies with age, nutritional status, and fed vs. fasted state. More lead is absorbed if the stomach is empty. Maddaloni et al. (1998) found that 26 percent of lead was absorbed by fasted adults, whereas only 2.5 percent was absorbed after a meal. While infants are thought to absorb a much higher fraction of lead compared with adults, there is little data to determine how quickly lead absorption declines after weaning. In assessing risks from exposure to lead, United States Environmental Protection Agency (USEPA) assumes that the absolute bioavailability of lead from water or diet averages 50 percent in children and 20 percent in adults (USEPA 2007a, b).

In other words, one-half of the lead ingested from water or diet is assumed to be absorbed by very young children, and one-fifth of the lead ingested from these sources is assumed to be absorbed by adults. These are upper-bound estimates that may overestimate average lead absorption in both adults and young children.

When evaluating risks associated with arsenic, it is estimated that water-soluble forms of inorganic arsenic are well-absorbed through the oral route. Studies in humans demonstrate that greater than 95 percent of water-soluble arsenic may be absorbed (Agency for Toxic Substances and Disease Registry [ATSDR] 2007).

Relative bioavailability is a measure of the difference in absorption between different forms of a chemical or between different dosing vehicles (e.g., lead in water, food, or soil). In risk assessment, the relative bioavailability is the ratio of the absorbed dose of a chemical in the environmental exposure medium (e.g., soil) to its absorbed dose in the dosing vehicle used in the critical study upon which its toxicity is estimated. Use of relative bioavailability information in site-specific risk assessments adjusts exposure estimates when the medium of exposure in the exposure assessment differs from the medium of exposure associated with the toxicity value (cancer slope factor, reference dose value, etc.).

In the absence of site-specific data, the absolute bioavailability of lead from soil and dust ingested by young children is currently estimated by USEPA to average 30 percent (USEPA 2007a)[1]. Thus, when comparing the bioavailability for soil lead (0.3, or 30 percent) with the bioavailability of lead in drinking water (0.5, or 50 percent), the relative bioavailability of soil lead versus drinking water lead is 60 percent (i.e., 0.3/0.5) (USEPA 2007c). USEPA (2007c) reported that estimates of lead relative bioavailability for 19 soil and soil-like test materials, when compared to water, ranged from 6 percent to 105 percent. When the relative bioavailability of lead in soil from a particular site is determined to be different from USEPA's assumption of 60 percent relative bioavailability, exposures to lead in that soil may be lower or higher than the default assumptions used in the USEPA lead exposure models (USEPA 2007c). Site-specific relative bioavailability data can be used to adjust the default bioavailability assumptions in the exposure models and derive exposure estimates that are more representative of site conditions.

Less soluble forms of arsenic are reported to be one-tenth to one-half as bioavailable as the more soluble forms of arsenic (Roberts et al. 2007). Based on an upper percentile from a data set of 103 estimates of arsenic relative bioavailability reported in a series of studies in monkeys, swine, and mice, USEPA (2012) recommends a default value of 60% for arsenic relative bioavailability in soil when compared to water, which is supported by the fact that less than 5% of the arsenic relative bioavailability estimates exceeded 60%. In general, USEPA recommends that efforts be made to collect data that support site-specific estimates, rather than relying on the default value.

[1] USEPA anticipates increasing the default soil lead bioavailability assumption, a change that may occur later in 2014.

1.2 Site-Specific Relative Oral Bioavailability Studies

Numerous *in vivo* studies (i.e., studies in animal models) or *in vitro* studies (i.e., non-animal, "test tube" studies) of relative bioavailability have evaluated the site-specific bioavailability of lead and arsenic in soil and mine wastes at former mining and mineral processing sites. A number of USEPA regions and states have relied upon these studies, allowing adjustments of default bioavailability assumptions based on site-specific study results.

Historically, assessing human exposures to lead and arsenic in soil has focused on *in vivo* studies of relative bioavailability. The results of a series of *in vivo* studies of the oral absorption of lead from a variety of different environmental media (i.e., soils and mining tailings) using juvenile swine as the animal model are summarized in Drexler and Brattin (2007) and USEPA (2007c). USEPA considers juvenile swine to be a good physiological model for gastrointestinal absorption in children (USEPA 2007c). As noted above, the relative oral absorption of soil arsenic has been tested in a series of studies in juvenile swine (USEPA 2010), cynomolgus monkey (Roberts et al. 2007), and mice (Bradham et al. 2011; Makris et al. 2008; Bradham et al. 2015). These studies included soils from mining and smelting sites, sites with historical arsenical pesticide use, and hazardous waste sites.

In vitro procedures have been developed that provide a faster and less costly alternative for estimating the relative bioavailability of lead and arsenic in soil (Kelley et al. 2002; Ruby et al. 1996, 1999; Ruby 2004; Rodriguez et al. 1999). The *in vitro* methods are based on the concept that the extent of solubilization in the gastrointestinal fluid is the principal determinant of relative bioavailability *in vivo*. As such, most *in vitro* tests are designed to measure the extent of metals solubilization in an extraction solvent that mimics physiological conditions in the human gastrointestinal tract (Kelley et al. 2002; Ruby et al. 1996, 1999; Rodriguez et al. 1999). The fraction of metal that solubilizes in an *in vitro* system is referred to as bioaccessibility. Thus, bioaccessibility is the measurement of the fraction of metal that is soluble and available for absorption. It has been determined that estimates of bioaccessibility of lead and arsenic from *in vitro* procedures correlate well with estimates of bioavailability from *in vivo* studies, and therefore, *in vitro* procedures can be used to estimate the relative bioavailability of lead and arsenic from soil (Ruby et al. 1999; National Academy of Sciences [NAS] 2003; Rodriguez et al. 1999).

In 2007, USEPA published detailed guidance on the use of an *in vitro* method, the *in vitro* bioaccessibility (IVBA) test, to estimate lead relative bioavailability from soil (USEPA 2007c). The guidance stated that this method correlated well with results from an *in vivo* swine model for mining, milling, and smelting derived materials. Atlantic Richfield Company used this *in vitro* method to estimate lead relative bioavailability from yard soils collected in the Black Eagle community.

The same method has been used to assess the relative bioavailability of soil arsenic based on data suggesting a good correlation between *in vitro* and in *vivo* studies of mining and smelting site soils (Brattin et al., 2013; Bradham et al. 2015).

1.3 Site-Specific Mineralogy Studies

In addition to evaluating site-specific relative oral bioavailability of lead and arsenic in soil, a considerable amount of information can be gained by studying the site history and mineralogy of the metal species present in soil. As summarized in Table 1 for lead, results of such studies are useful in qualitatively describing site-specific bioavailability characteristics and can be used to support bioavailability test data (Ruby 2004; Schoof 2004, Brattin et al. 2013 and USEPA 2007b). The information in Table 1 also demonstrates the variability of bioavailability depending upon a number of site characteristics and, therefore, the importance of collecting such information to accurately assess lead risks at a specific site. Mineralogy data on different arsenic phases is also helpful in qualitatively characterizing arsenic bioavailability in soil.

2 Methods

The relative oral bioavailability of lead and arsenic was evaluated in 35 soil samples collected by Pioneer Technical Services from 26 residential yards in Black Eagle, Montana between June and August, 2012. All 35 samples were evaluated using the *in vitro* extraction test to measure the fraction of lead and arsenic that could become liberated in the human gastrointestinal tract and thus be available for absorption. Electron microprobe analysis of the lead- and arsenic-bearing mineral phases was also conducted with all 35 samples to quantify the distribution of lead and arsenic among mineral phases in the soil and to characterize where lead and arsenic phases are located within or on soil particles. The *in vitro* extraction testing and electron microprobe analysis (EMPA) were performed by Dr. John Drexler at the Laboratory for Environmental and Geological Studies (LEGS), University of Colorado at Boulder. The LEGS report is included as Attachment A.

2.1 Soil Sample Selection and Preparation

The 35 yard soil samples were selected to be spatially distributed across the Black Eagle community and also to represent the range of total lead and arsenic concentrations (Figure 1). Samples were collected from varying depths between 0 and 18 inches below ground surface (bgs).

Samples were first dried (<40 degrees Celsius [°C]), and then sieved to obtain particles with a diameter of less than 250 microns (µm) using a 60 mesh screen prior to analysis. This is the fraction of soil that is most likely to adhere to human hands and become ingested during hand-to-mouth activity (Duggan and Inskip 1985; Kissel et al. 1996). The 250 µm size fraction has become the standard for use in oral bioavailability studies to estimate human exposures from incidental soil ingestion (Casteel et al. 1997; Freeman et al. 1995; Maddaloni et al. 1998; Roberts et al. 2002).

The total lead and arsenic concentrations in the <250 µm size fraction of each soil sample was estimated using USEPA Method 3050 digestions (hot nitric acid) followed by USEPA Method 6020 analysis [inductivity coupled plasma/mass spectroscopy (ICP/MS)]. Digestion and total lead and arsenic analyses were conducted by LEGS at the University of Colorado in Boulder.

2.2 *In Vitro* Bioaccessibility Test

The *in vitro* bioaccessibility tests were conducted according to the Standard Operating Procedures (SOPs) presented in Attachments B and C. The SOP for lead was developed by the Solubility/Bioavailability Research Consortium (SBRC) (Ruby et al. 1999), a consortium of government, industry and consulting scientists organized to oversee a validation program, and subsequently adopted by reference in USEPA's document *Estimation of relative bioavailability of lead in soil and soil-like materials using in vivo and in vitro methods* (EPA 2007c). The arsenic *in vitro* method has also been validated with the relative bioavailability of arsenic-bearing materials tested in swine (Brattin et al. 2013) and in mice (Bradham et al. 2015).

The *in vitro* test used to evaluate lead and arsenic in soil mimics the stomach phase of human digestion because the stomach phase alone was observed to correlate well with oral lead and arsenic bioavailability based on values from animal studies (Ruby et al. 1999; Medlin 1997; Rodriguez et al. 1999). This is a simplified version of the original *in vitro* extraction test that included both stomach and intestinal incubation phases (Ruby et al. 1996).

Briefly, the apparatus used was a Plexiglass tank containing a 37 °C water bath with a flywheel that drove a rotor holding a series of bottles containing the extraction fluid and sample. The extraction fluid was maintained near a pH of 1.5, using a buffered solution of 0.4 molar (M) glycine. One hundred (100) milliliters (mL) of the extraction fluid and one gram (g) of test substrate were added to each bottle, and the bottles were rotated end over end for one hour. After extraction, a sample was taken directly from the bottle with a syringe. A 0.45-µm cellulose acetate disk filter (25 millimeter [mm] diameter) was attached to the syringe, and the extract was filtered into a sample vial for analysis. Filtered samples were stored in a refrigerator at 4 °C until they were analyzed. Extracts were analyzed for lead and arsenic concentrations following USEPA Method 6020.

2.3 Mineralogy Analysis

The soil samples were subjected to EMPA to identify the primary lead- and arsenic-bearing mineral phases according to the SOP provided in Attachment D. EMPA involves mounting the soil sample in an epoxy matrix, polishing a flat surface on this soil/epoxy "puck," and scanning across this surface with a focused electron beam. A low-energy beam can be applied to a wide area (e.g., a few hundred micrometers across) to generate picture-like black-and-white back-scatter images of the samples ("photomicrographs"), where the brightness of individual mineral grains is approximately proportional to the molecular weight of the elements in the minerals. For more quantitative analysis, a high-energy narrow electron beam can be focused on individual grains (e.g., as small as ~1 µm), providing quantitative estimates for the concentration of elements in this sample from the intensity and frequency of the energy emitted from the target.

The EMPA for this project used a "point counting" sampling method to determine the dominant lead- and arsenic-bearing mineral phases in each sample. Specifically, point counting involves overlaying a regular grid across each soil sample, then measuring the composition of the individual mineral grains at each point in the grid. By analyzing a large number of grains in each sample (typically over 100 in each sample), sufficient lead- and arsenic-bearing phases are encountered to identify the dominant minerals hosting these metals and the concentrations of metals in each phase.

Interpretation of the EMPA point-count benefits from an explanation of the reported parameters: the "frequency of occurrence" and "relative mass" for specific mineral phases.

Frequency of occurrence is the fraction (based on volume) that a particular lead- or arsenic-bearing mineral phase contributes to the total of all of lead- or arsenic-bearing mineral phases. This is calculated for each sample by summing the volume of all the grains of a specific mineral

phase that contained measurable lead or arsenic, and then dividing by the total volume of all grains in the sample with measurable lead or arsenic. The frequency of occurrence is the relative volume of each lead- or arsenic-bearing phase, thus the frequencies of occurrence for all reported phases in a sample sum to one. This parameter illustrates which lead- or arsenic-bearing phase is the most commonly observed in the sample.

Relative mass is the fraction (based on mass) of the total lead or arsenic in a sample that resides in a particular phase. This is calculated by summing the estimated mass of lead or arsenic in all the grains of a particular phase, then dividing by the estimated total mass of lead or arsenic in all grains with detectable lead or arsenic. As with frequency of occurrence, because the metal content in each phase is relative to the total mass, the sum of the relative mass values for all phases in a sample sum to one. This parameter provides information as to which lead- or arsenic-bearing phase(s) in a sample are likely to control the total bulk concentration for lead or arsenic.

The formulas used to calculate frequency of occurrence and relative mass from the EMPA point counts are presented in Attachment D.

3 Results

3.1 *In Vitro* Bioaccessibility

As described above, lead and arsenic bioaccessibility values were calculated for each sample by dividing the total mass of metal in the extract (extract concentration x extract volume) by the total mass of metal in the soil being extracted (soil concentration x soil mass). The *in vitro* bioaccessibility results are summarized in Tables 2a and 2b, and shown graphically by sample in Figure 2. Tables 2a and 2b also include the total soil concentrations for lead and arsenic (operationally defined as the lead and arsenic recovered by hot nitric acid by USEPA Method 3050 extraction).

For lead, USEPA (2007c) specifies use of a linear regression model (*in vivo-in vitro* correlation [ICIVC] model) developed by Drexler and Brattin (2007) to estimate relative bioavailability based on correlations between *in vitro* and *in vivo* testing:

$$\text{Relative Bioavailability} = 0.878 \times \textit{in vitro}\ \text{Bioaccessibility} - 0.028$$

with *in vitro* bioaccessibility and relative bioavailability expressed as a fraction (not as a percent).

Summary statistics of relative bioavailability estimates for lead based on this regression are presented in Table 3a for all the 35 samples, for samples with soil lead concentrations less than 400 milligram per kilogram (mg/kg) and greater than 400 mg/kg, and for samples collected at depths of 0-2 inches bgs, between 0 and 6 inches bgs (i.e., including 0-2 and 2-6 inch intervals) and from intervals greater than 6 inches bgs. The relative bioavailability for lead was plotted versus lead concentration in soil in Figure 3a for samples collected at depths of 0-6 inches bgs and in Figure 3b for samples collected at depths of greater than 6 inches bgs.

The mean lead relative bioavailability was 59 percent for all samples. As shown in Table 3a and Figures 3a and 3b, the mean lead relative bioavailability (56 percent) for samples in the low soil concentration range (less than 400 mg/kg) was slightly lower than the mean relative bioavailability (62 percent) for samples in the high soil concentration range (greater than 400 mg/kg), while samples in the high soil concentration range had a larger variation in relative bioavailability (larger standard deviation) than samples in the low soil concentration range. The mean relative bioavailability was 61 percent for shallow soil samples (both 0-2 inches bgs and 0-2 plus 2-6 inches bgs combined). Mean relative bioavailability for deep soil samples (greater than 6 inches bgs) was lower (55 percent). Deep soil samples had a larger variation in relative bioavailability than shallow soil samples.

For shallow soil samples, the relative bioavailability for lead exhibited a limited correlation with soil lead concentration in the low concentration range, but did not correlate with soil lead concentration in the high concentration range (Figure 3a). For deep soil samples, the relative bioavailability for lead did not correlate with soil lead concentration in either the low

concentration range or the high concentration range (Figure 3b). Also, some lower relative bioavailability estimates were observed in samples with higher soil lead concentrations. For example, a relative bioavailability of 42 percent was observed in Sample BE-055-FY-0002 at a depth of 0-2 inches bgs with a soil lead concentration of 1,890 mg/kg, while a relative bioavailability of 19 percent was observed in BE-088-FY-0612 at a depth of 6-12 inches bgs with a soil lead concentration of 1,127 mg/kg.

For arsenic, the model developed by Bradham et al. (2015) using mouse data was used to estimate relative bioavailability based on correlations between *in vitro* and *in vivo* testing:

$$\text{Relative Bioavailability} = 0.65 \times \textit{in vitro}\ \text{Bioaccessibility} + 7.8$$

with *in vitro* bioaccessibility and relative bioavailability expressed as a percent (not as a fraction).

Summary statistics of relative bioavailability estimates for arsenic based on this regression are presented in Table 3b for all the 35 samples, for samples collected at depths of 0-2 inches bgs, 0-6 inches bgs (i.e., including 0-2 and 2-6 inch intervals) and from intervals greater than 6 inches bgs. The relative bioavailability for arsenic was plotted versus arsenic concentration in soil in Figure 4a for samples collected at depth intervals between 0 and 6 inches bgs and in Figure 4b for samples collected at depth intervals greater than 6 inches bgs.

For arsenic, the mean relative bioavailability was 29 percent for all samples. Contrary to lead, the mean arsenic relative bioavailability (28 percent) for shallow soil samples (intervals between 0 and 6 inches bgs) was lower than the mean relative bioavailability (32 percent) for deep soil samples (greater than 6 inches bgs). Surface soil samples from 0-2 inches bgs exhibited even lower average relative bioavailability (24 percent). Similar to lead, deep soil samples had a larger variation in arsenic relative bioavailability than shallow soil samples.

The relative bioavailability for arsenic exhibited a limited correlation with soil arsenic concentration only in shallow soil samples (Figures 4a and 4b). Also, a lower arsenic relative bioavailability of 22 percent was observed in Sample BE-055-FY-0002 at a depth of 0-2 inches bgs with a higher soil arsenic concentration of 546 mg/kg. At the same location, a lower lead relative bioavailability (45 percent) with a higher soil lead concentration (1,890 mg/kg) was also observed.

3.2 Mineralogy

The distribution of lead and arsenic in soil minerals from all 35 soil samples is summarized in Tables 4a, 4b, and 4c. Histograms of relative mass and frequency of occurrence for all samples are presented graphically in Figure 5. Backscatter photomicrographs of soil particles captured using EMPA are presented in Attachment E.

The mineralogy of lead and arsenic phases can, in some cases, indicate either the general source of lead and arsenic in a sample or their expected relative bioavailability on a qualitative

basis. The dominant lead-bearing phase was iron oxy-hydroxide (FeOOH) in 15 samples with relative lead mass of 25-96 percent, phosphate in eight samples with relative lead mass of 41-82 percent, cerussite ($PbCO_3$) in six samples with relative lead mass of 33-84 percent, manganese oxy-hydroxide (MnOOH) in two samples with relative lead mass of 45-55 percent, anglesite ($PbSO_4$) in two samples with relative lead mass of 29-30 percent, galena (PbS) in one sample with relative lead mass of 53 percent, and lead silicate ($PbSiO_4$) in one sample with relative lead mass of 70 percent (Table 4b, Figure 5). FeOOH, phosphate, $PbCO_3$, and MnOOH usually result from natural weathering conditions with relatively high solubility (at the low pH conditions of the *in vitro* test procedure) and high relative bioavailability, while anglesite, galena, and $PbSiO_4$ have relatively low solubility (at low pH) and low relative bioavailability (Table 1).

The dominant arsenic-bearing phase was FeOOH in 28 samples with relative arsenic mass of 35-100 percent, phosphate in two samples with relative arsenic mass of 52-55 percent, arsenopyrite (FeAsS) in two samples with relative arsenic mass of 43-66 percent, lead oxide (PbMO) in one sample with relative arsenic mass of 57 percent, iron arsenic oxy-hydroxide (FeAsOOH) in one sample with relative arsenic mass of 78 percent, and arsenic oxide (AsMO) in one sample with relative arsenic mass of 64 percent (Table 4c, Figure 5). FeOOH, phosphate, PbMO, FeAsOOH, and AsMO usually result from natural weathering conditions with relatively high solubility (at the low pH conditions of the *in vitro* test procedure) and high relative bioavailability, while arsenopyrite has relatively low solubility (at low pH) and low relative bioavailability (Table 1).

As shown in Table 4b, the dominant mineral phases for lead for the majority of samples (31 out of 35) were oxides, phosphates, and carbonates resulting from natural weathering and attenuation conditions. These minerals are usually considered to have high relative bioavailability (Table 1). However, among all the samples, the correlation between the relative lead bioavailability and the relative lead mass in the most abundant mineral phase (FeOOH) was poor, as indicated in Figure 6a. Also, the sum of the relative lead mass in other phases with expected high relative bioavailability, including phosphate, cerussite, MnOOH, paint, PbMO, copper oxide (CuMO), tin oxide (SnMO), and FeAsOOH, could explain approximately 30% (R^2 value = 0.29) of the variation in relative lead bioavailability, which was the largest among any combination of mineral phases (Figure 6b).

As shown in Table 4c, the dominant mineral phases for arsenic for the majority of samples (33 out of 35) were oxides and phosphates resulting from natural weathering and attenuation conditions. These minerals are usually considered to have high relative bioavailability (Table 1). However, among all the samples, the correlation between the relative arsenic bioavailability and the relative arsenic mass in the most abundant mineral phase (FeOOH) (Figure 6c) or in any combination of mineral phases was poor.

To further explore the relationships between the relative bioavailability and the relative mass in the highly soluble mineral phases, subgroups of shallow soil samples with high soil lead or arsenic concentrations were evaluated. Among the 14 shallow soil samples with soil lead

concentrations greater than 400 mg/kg (Table 2a), no better correlation between the relative lead bioavailability and the relative lead mass in typically high relative bioavailability phases was found. Among the seven shallow soil samples with soil arsenic concentrations greater than 100 mg/kg (Table 2b), the sum of the relative arsenic mass in the phases of phosphate, PbMO, and CuMO with high expected relative bioavailability could explain approximately 61% (R2 value = 0.61) of the variation in relative arsenic bioavailability (Figure 6d).

Weathering of the oxide, phosphate, and carbonate mineral phases may cause lead or arsenic ultimately be incorporated into more stable iron and manganese oxide phases over time (Table 1), and this may explain the poor correlation with the relative lead or arsenic bioavailability. While mineral phases may be generally reliable predictors of the magnitude of relative bioavailability, other factors such as particle size and presence of encapsulation around lead-or arsenic-minerals may influence results. For example, the relative bioavailability of highly soluble mineral phases may be reduced if they are present in larger particles or are embedded within a particle matrix. The polished surfaces of the soil samples prepared for EMP analysis provides for quantification of the interior of particles as well. Conversely, less soluble phases may be more bioavailable if present on the surface of very small particles. As indicated in Table 4a, the particle size of mineral phases varied significantly, both within the same sample (large standard deviation) and among different samples, and this may be another reason for the poor correlation with the relative lead or arsenic bioavailability. For example, in Sample BE-055-FY-0002, AsMO is the dominant mineral phase with a relative arsenic mass of 64 percent. However, due to the very large particle size (105 µm, fine sand) of AsMO in this sample, the relative arsenic bioavailability is only 22 percent.

Solubility is a relative property of the mineral phases, and is a function of soil properties and weathering conditions. For example, the iron and manganese oxides may become less soluble in reducing environments, while carbonate minerals are not very soluble in calcareous soils like the site in this analysis. Relative bioavailability may also correlate with other soil characteristics such as carbonate or iron content that are estimates of soil attenuation capacity.

Finally, paint chips likely are contributing to the high observed relative bioavailability of the soil lead. Although 15 percent of the samples studied were collected from home driplines and “paint chips” were observed by the samplers, lead paint particles were seen in approximately 30 percent of the samples (10 out of 35), but with a lower relative lead mass of 0.27-23 percent when compared to the dominant minerals listed above. The inconsistency between the mineralogy data and the field observations may be explained by the fact that the observation of “paint chips” by field personnel does not equate with “lead paint”. Many particles of paint can often be seen in soils, but may contain no lead pigment and are primarily barite, and anatase (TiO_2).

Use of the <250 µm fraction of soil, although providing better information on bioaccessible forms of metals, will often reduce the observation of commonly large particles such as paint chips (Attachment E). Particles in these forms can be removed during the sieving process of less than

250 µm), and that may be another reason why relative lead mass associated with paint is low. Finally, the identification of lead paint is primarily based on chemistry (percent of lead) and morphology. Paint particles have a classical shape (plate-shaped if viewed perpendicular and needle-like one long dimension and another narrow in other dimensions, see Attachment E. It is more difficult for such identification with old soils contaminated with paint because paint chips may break down and the pigments may release as discrete particles or weathered to other minerals. Thus, a 1-µm cerussite particle weathered from a paint chip cannot be easily distinguished from a similar particle from mining/milling/smelting operations. It is usually assumed that a portion of the small (1-10 µm size) cerussite and anglesite is likely paint derived. Lead chromate ($PbCrO_4$) and lead titanate ($PbTiO_2$) are also likely paint-derived.

Of the ten samples with lead paint particles observed, five were shallow soil samples with soil lead concentrations greater than 400 mg/kg, one was a shallow soil sample with soil lead concentration less than 400 mg/kg, three were deep soil samples with soil lead concentrations greater than 400 mg/kg, and one was a deep soil sample with soil lead concentration less than 400 mg/kg. Soils with higher shrink-swell capacity provide an avenue for location of paint particles at the deeper depths. As discussed above, slightly higher relative bioavailability for lead was observed in shallow soil samples in the high soil lead concentration range which was consistent with the observation of the majority of lead paint particles.

4 Conclusions

The mean lead relative bioavailability was 59 percent for all samples. For samples with greater than 400 mg/kg lead the relative bioavailability was 62 percent, compared with 56 percent mean lead relative bioavailability for samples with less than 400 mg/kg lead. The mean relative bioavailability was 61 percent for shallow soil samples (from intervals between 0 and 6 inches bgs) compared with 55 percent mean relative bioavailability for deeper soil samples (greater than 6 inches bgs). These differences are quite small, and we recommend use of the overall mean value of 59 percent in the risk assessment.

For arsenic, the mean relative bioavailability was 29 percent for all samples. Contrary to lead, the mean arsenic relative bioavailability (28 percent) for shallow soil samples (from intervals between 0 and 6 inches bgs) was lower than the mean relative bioavailability (32 percent) for deep soil samples (greater than 6 inches bgs). Surface soils, 0-2 inches bgs had even lower relative bioavailability. Overall, we recommend 29 percent as a conservative estimate of relative bioavailability for risk assessment.

In conclusion, the dominant mineral phases containing both lead and arsenic were minerals usually considered to have relatively high bioavailability. Although only limited correlations between the relative bioavailability of lead and arsenic in soils and the expected relative bioavailability of specific mineral phases was observed, the relative bioavailability of lead and arsenic was further explained by other factors such as weathering, particle size, presence of encapsulation, and soil characteristics. Finally, the confirmed presence of paint chips in some shallow soil samples in the high soil lead concentration range may contribute to the high relative bioavailability of lead in those samples.

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Tables

Table 1. Impact of Lead Minerals and Soil Chemistry on Relative Oral Bioavailability from Soil

Site History/Chemistry		Relative Bioavailability		
		Low	Moderate	High
Mineral Forms Released				
	Sulfides	X		
	Elemental	X		
	Sulfates	X		
	Carbonates			X
	Oxides			X
Particle Size				
	Small			X
	Large	X		
Weathering/Aging Time				
	Sulfides	X[1]		
	Elemental	X[1]		
	Carbonates			X[2]
	Oxides			X[2]
Soil pH				
	Acidic		X	
	Basic			X
Soil Components				
	High Total Organic Content			X
	Sulfide-producing soil		X	

Notes:
Source: Modified from Ruby 2004.
(1) Sulfides and elemental lead become increasingly bioavailable over time (to low moderate and moderately high, respectively).
(2) Carbonates and oxides become less bioavailable over time (to moderately high and moderate, respectively).

Table 2a. Summary of *In Vitro* Bioassay Results for Lead

Sample ID	Depth inch bgs	Soil Lead Concentration mg/kg (<250 µm fraction)	Soil Mass kg	Lead Concentration in Extract mg/L	Extract Solution Volumn L	*In Vitro* Bioaccessibility[1] %	Relative Bioavailability[2] %
BE-014-FY-0612	6-12	95	0.001	0.67	0.1	70	58
BE-021B-DZ-0002	0-2	1,098	0.001	8.0	0.1	73	61
BE-031-DZ-0206	2-6	1,041	0.001	8.3	0.1	79	67
BE-039-FG-1218	12-18	657	0.001	5.3	0.1	80	68
BE-046-FY-0002	0-2	1,158	0.001	9.6	0.1	83	70
BE-055-FY-0002	0-2	1,890	0.001	9.6	0.1	51	42
BE-057-DZ-0002	0-2	1,389	0.001	11	0.1	77	65
BE-064-BY-0206	2-6	630	0.001	4.1	0.1	65	54
BE-064-FY-0612	6-12	613	0.001	3.4	0.1	54	45
BE-088-FY-0612	6-12	1,127	0.001	2.8	0.1	24	19
BE-205-ED-0204	2-4	727	0.001	5.1	0.1	69	58
BE-206D-BY-0206	2-6	1,166	0.001	12	0.1	99	84
BE-216-DZ-1218	12-18	1,489	0.001	13	0.1	89	75
BE-236B-BA-0206	2-6	507	0.001	4.0	0.1	78	66
BE-248-ED-0206	2-6	257	0.001	1.8	0.1	70	58
BE-253A-BY-0206	2-6	531	0.001	4.3	0.1	80	68
BE-253B-FY-1218	12-18	213	0.001	1.5	0.1	68	56
BE-324-BA-0612	6-12	170	0.001	1.4	0.1	78	66
BE-335-DZ-1218	12-18	48	0.001	0.30	0.1	62	52
BE-335-RG-0002	0-2	1,539	0.001	14	0.1	88	74
BE-411-VG-0002	0-2	33	0.001	0.20	0.1	61	51
BE-429-ED-1218	12-18	27	0.001	0.15	0.1	53	44
BE-429-FG-0612	6-12	310	0.001	2.3	0.1	75	63
BE-430-BY-0002	0-2	529	0.001	4.7	0.1	88	74
BE-430-FY-0206	2-6	162	0.001	1.2	0.1	73	61
BE-447-BY-0206	2-6	167	0.001	1.2	0.1	73	61
BE-447-FG-1218	12-18	36	0.001	0.28	0.1	75	63
BE-506-FY-0206	2-6	244	0.001	1.6	0.1	65	55
BE-508-RG-0206	2-6	728	0.001	5.4	0.1	73	62
BE-514-FG-0002	0-2	310	0.001	2.4	0.1	79	67
BE-514-FY-0612	6-12	58	0.001	0.36	0.1	61	51
BE-516A-BA-0002	0-2	667	0.001	5.2	0.1	78	65
BE-527B-FY-0002	0-2	145	0.001	1.0	0.1	69	58
BE-702-BY-0206	2-6	47	0.001	0.21	0.1	44	36
BE-702-DZ-0002	0-2	149	0.001	0.89	0.1	59	49

Notes:

bgs = below ground surface

kg = kilogram

L = liter

mg = milligram

µm = micrometer

(1) Calculated according to: *In Vitro* Bioaccessibility (%) = 100 x (Lead Concentration in Extract x Extract Solution Volume) / (Soil Lead Concentration x Soil Mass)

(2) Predicted based on Drexler and Brattin (2007): Relative Bioavailability = 0.878 x *In Vitro* Bioaccessibility - 0.028

Table 2b. Summary of *In Vitro* Bioassay Results for Arsenic

Sample ID	Depth inch bgs	Soil Arsenic Concentration mg/kg (<250 µm fraction)	Soil Mass kg	Arsenic Concentration in Extract mg/L	Extract Solution Volumn L	*In Vitro* Bioaccessibility[1] %	Relative Bioavailability[2] %
BE-430-BY-0002	0-2	16	0.001	0.035	0.1	21	22
BE-429-FG-0612	6-12	17	0.001	0.033	0.1	19	20
BE-205-ED-0204	2-4	17	0.001	0.044	0.1	25	24
BE-527B-FY-0002	0-2	17	0.001	0.031	0.1	17	19
BE-516A-BA-0002	0-2	20	0.001	0.043	0.1	21	22
BE-514-FG-0002	0-2	21	0.001	0.039	0.1	19	20
BE-702-DZ-0002	0-2	21	0.001	0.025	0.1	12	15
BE-021B-DZ-0002	0-2	21	0.001	0.047	0.1	22	22
BE-335-RG-0002	0-2	25	0.001	0.067	0.1	27	25
BE-429-ED-1218	12-18	29	0.001	0.055	0.1	19	20
BE-031-DZ-0206	2-6	30	0.001	0.081	0.1	27	25
BE-057-DZ-0002	0-2	31	0.001	0.092	0.1	29	27
BE-506-FY-0206	2-6	39	0.001	0.11	0.1	29	26
BE-206D-BY-0206	2-6	43	0.001	0.14	0.1	32	29
BE-447-BY-0206	2-6	43	0.001	0.15	0.1	34	30
BE-430-FY-0206	2-6	54	0.001	0.17	0.1	32	29
BE-216-DZ-1218	12-18	80	0.001	0.30	0.1	37	32
BE-046-FY-0002	0-2	90	0.001	0.32	0.1	36	31
BE-702-BY-0206	2-6	94	0.001	0.33	0.1	35	30
BE-014-FY-0612	6-12	104	0.001	0.67	0.1	64	49
BE-411-VG-0002	0-2	104	0.001	0.48	0.1	46	38
BE-324-BA-0612	6-12	109	0.001	0.49	0.1	44	36
BE-335-DZ-1218	12-18	121	0.001	0.49	0.1	40	34
BE-088-FY-0612	6-12	127	0.001	0.27	0.1	22	22
BE-248-ED-0206	2-6	141	0.001	0.45	0.1	32	29
BE-064-BY-0206	2-6	142	0.001	0.54	0.1	38	32
BE-253A-BY-0206	2-6	144	0.001	0.68	0.1	47	38
BE-236B-BA-0206	2-6	145	0.001	0.72	0.1	50	40
BE-447-FG-1218	12-18	149	0.001	0.72	0.1	48	39
BE-039-FG-1218	12-18	157	0.001	0.79	0.1	50	40
BE-508-RG-0206	2-6	158	0.001	0.84	0.1	53	42
BE-514-FY-0612	6-12	175	0.001	0.61	0.1	35	30
BE-253B-FY-1218	12-18	241	0.001	1.2	0.1	48	39
BE-064-FY-0612	6-12	244	0.001	0.74	0.1	30	27
BE-055-FY-0002	0-2	546	0.001	1.2	0.1	22	22

Notes:

bgs = below ground surface

kg = kilogram

L = liter

mg = milligram

µm = micrometer

(1) Calculated according to: *In Vitro* Bioaccessibility (%) = 100 x (Arsenic Concentration in Extract x Extract Solution Volume) / (Soil Arsenic Concentration x Soil Mass)

(2) Predicted based on Bradham et al. (2015): Relative Bioavailability (%) = 0.65 x *In Vitro* Bioaccessibility (%) + 7.8

Table 3a. Summary Statistics of Lead Relative Bioavailability		
All Samples		
	N	35
	Mean Relative Bioavailability (%)	59
	Standard Deviation (%)	12
	95% Confidence Interval (%)	55 - 63
Samples with Soil Lead Concentrations < 400 mg/kg		
	N	17
	Mean Relative Bioavailability (%)	56
	Standard Deviation (%)	8.1
	95% Confidence Interval (%)	52 - 60
Samples with Soil Lead Concentrations > 400 mg/kg		
	N	18
	Mean Relative Bioavailability (%)	62
	Standard Deviation (%)	15
	95% Confidence Interval (%)	55 - 69
Samples with Depths at 0-2 inches bgs		
	N	11
	Mean Relative Bioavailability (%)	61
	Standard Deviation (%)	11
	95% Confidence Interval (%)	55 - 68
Samples with Depths at 0-6 inches bgs		
	N	23
	Mean Relative Bioavailability (%)	61
	Standard Deviation (%)	11
	95% Confidence Interval (%)	57 - 65
Samples with Depths > 6 inches bgs		
	N	12
	Mean Relative Bioavailability (%)	55
	Standard Deviation (%)	15
	95% Confidence Interval (%)	47 - 63

Notes:
N = sample size
bgs = below ground surface
kg = kilogram
mg = milligram

Table 3b. Summary Statistics of Arsenic Relative Bioavailability		
All Samples		
	N	35
	Mean Relative Bioavailability (%)	29
	Standard Deviation (%)	8.0
	95% Confidence Interval (%)	27 - 32
Samples with Depths at 0-2 inches bgs		
	N	11
	Mean Relative Bioavailability (%)	24
	Standard Deviation (%)	6
	95% Confidence Interval (%)	20 - 28
Samples with Depths at 0-6 inches bgs		
	N	23
	Mean Relative Bioavailability (%)	28
	Standard Deviation (%)	7
	95% Confidence Interval (%)	25 - 31
Samples with Depths > 6 inches bgs		
	N	12
	Mean Relative Bioavailability (%)	32
	Standard Deviation (%)	9
	95% Confidence Interval (%)	27 - 38

Notes:
N = sample size
bgs = below ground surface
kg = kilogram
mg = milligram

Table 4a. Frequency of Occurrence and Particle Size of Mineral Phases by Electron Microprobe Analysis

Sample ID	FeOOH		Phosphate		$FeSO_4$		MnOOH		Cerussite		Anglesite		Paint		Clay		Galena		PbMO[1]		CuMO[1]		SnMO[1]		Slag	
	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (μm)
BE-014-FY-0612	72	22 (22)	7.9	25 (22)	6.2	8 (11)	6.6	36 (34)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	7.3	160 (ND)
BE-021B-DZ-0002	10	23 (24)	46	24 (97)	--	--	4.9	26 (31)	11	21 (42)	--	--	29	113 (37)	--	--	--	--	--	--	--	--	--	--	--	--
BE-031-DZ-0206	33	22 (14)	18	6.4 (16)	0.63	8 (ND)	34	31 (15)	12	12 (29)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-039-FG-1218	38	11 (12)	37	31 (43)	11	20 (11)	1.3	13 (7.8)	2.5	3.4 (9.1)	--	--	1.3	24 (ND)	1.2	22 (ND)	6.8	32 (26)	0.58	11 (ND)	--	--	--	--	--	--
BE-046-FY-0002	22	21 (27)	39	18 (36)	6.4	16 (18)	23	14 (26)	--	--	0.41	4 (0)	4.6	90 (ND)	0.51	10 (ND)	--	--	--	--	--	--	--	--	2.4	24 (30)
BE-055-FY-0002	77	37 (42)	--	--	3.7	22 (16)	11	82 (49)	2.4	4.7 (7.8)	1.1	40 (ND)	--	--	--	--	0.53	19 (ND)	--	--	--	--	--	--	--	--
BE-057-DZ-0002	46	42 (39)	49	9.2 (21)	1.1	17 (ND)	2.4	18 (5)	--	--	0.070	1 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-064-BY-0206	69	23 (32)	6.0	8.1 (7.7)	10	30 (33)	2.2	11 (6.3)	--	--	0.25	5 (ND)	2.2	11 (3.6)	0.94	19 (ND)	0.60	1.7 (1.1)	--	--	--	--	--	--	--	--
BE-064-FY-0612	88	21 (26)	4.5	21 (23)	3.7	9.6 (8.8)	3.2	7.3 (5)	--	--	--	--	--	--	--	--	--	--	0.54	5 (2.8)	--	--	--	--	--	--
BE-088-FY-0612	60	15 (17)	11	5.6 (8.2)	18	18 (16)	--	--	0.39	5 (ND)	--	--	1.1	14 (ND)	1.2	15 (ND)	--	--	--	--	--	--	--	--	--	--
BE-205-ED-0204	49	12 (9.1)	12	11 (13)	--	--	13	17 (15)	2.3	7 (1)	--	--	21	195 (ND)	--	--	--	--	--	--	--	--	--	--	--	--
BE-206D-BY-0206	8.8	23 (27)	11	7.6 (15)	1.6	8 (10)	0.68	2 (0)	19	9 (17)	5.0	26 (15)	--	--	7.0	145 (ND)	--	--	29	37 (34)	--	--	--	--	--	--
BE-216-DZ-1218	26	16 (15)	--	--	--	--	13	15 (13)	47	3.8 (12)	7.8	135 (ND)	6.0	53 (57)	--	--	--	--	--	--	--	--	--	--	--	--
BE-236B-BA-0206	51	17 (26)	31	20 (19)	--	--	--	--	--	--	0.44	9 (ND)	--	--	--	--	--	--	0.97	20 (ND)	--	--	4.3	22 (21)	--	--
BE-248-ED-0206	83	20 (27)	1.4	4.5 (5.1)	0.62	6 (1.4)	3.9	25 (27)	--	--	--	--	--	--	--	--	1.0	2 (0)	--	--	--	--	0.26	5 (ND)	9.8	190 (ND)
BE-253A-BY-0206	54	49 (51)	24	29 (45)	9.6	5.4 (9.6)	9.7	71 (34)	0.37	2 (0)	0.18	4 (ND)	--	--	0.23	5 (ND)	--	--	0.78	1.3 (1.1)	0.46	10 (ND)	--	--	--	--
BE-253B-FY-1218	82	34 (35)	2.7	15 (9.6)	5.0	3 (3.2)	3.1	5.2 (8)	--	--	--	--	--	--	2.3	30 (ND)	--	--	--	--	0.33	7 (ND)	4.7	34 (54)	--	--
BE-324-BA-0612	74	17 (24)	6.8	2.3 (1.9)	8.7	21 (28)	9.5	16 (14)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.83	1.1 (0.33)	--	--
BE-335-DZ-1218	89	21 (31)	1.2	7.5 (0.71)	9.1	2.9 (2.9)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-335-RG-0002	20	19 (16)	13	12 (12)	0.52	11 (ND)	33	18 (21)	4.3	1.5 (1.6)	7.8	5.3 (6.5)	11	230 (ND)	--	--	--	--	--	--	--	--	--	--	12	245 (ND)
BE-411-VG-0002	69	7.6 (16)	0.73	9 (ND)	9.4	8.4 (7.6)	3.6	23 (19)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-429-ED-1218	97	45 (31)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-429-FG-0612	52	14 (27)	0.55	2.5 (0.71)	1.9	5.7 (2.9)	43	5.9 (4.4)	--	--	--	--	1.8	16 (ND)	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-BY-0002	25	7.9 (9.5)	4.4	3.3 (6.6)	1.6	4.3 (2.3)	64	8.6 (12)	3.6	1.8 (0.75)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-FY-0206	60	17 (25)	7.5	3.3 (4.8)	19	17 (22)	14	8.4 (14)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-BY-0206	69	27 (36)	1.1	13 (ND)	1.0	12 (ND)	16	31 (28)	13	7.3 (16)	0.33	4 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-FG-1218	82	9.1 (16)	0.74	5.5 (5)	15	15 (28)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-506-FY-0206	70	13 (19)	4.9	6.6 (5.6)	1.3	17 (ND)	12	19 (46)	4.3	58 (ND)	0.82	2.2 (1.6)	3.1	42 (ND)	3.3	15 (7.4)	0.30	2 (0)	--	--	--	--	--	--	--	--
BE-508-RG-0206	33	20 (57)	11	5.5 (7.3)	--	--	1.8	8.3 (2.5)	1.7	1.9 (1.6)	3.8	8.7 (16)	--	--	--	--	--	--	1.6	11 (14)	0.44	6 (ND)	8.4	115 (ND)	--	--
BE-514-FG-0002	63	24 (20)	34	15 (26)	--	--	--	--	0.40	2 (ND)	--	--	--	--	2.4	12 (ND)	--	--	--	--	--	--	--	--	--	--
BE-514-FY-0612	69	22 (32)	--	--	29	7.5 (15)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.5	3.1 (1.9)	--	--
BE-516A-BA-0002	58	32 (26)	15	6.8 (9.6)	1.8	17 (ND)	4.2	20 (13)	1.5	14 (ND)	6.0	2.5 (2.4)	--	--	--	--	--	--	4.0	1.1 (0.33)	9.5	90 (ND)	--	--	--	--
BE-527B-FY-0002	31	18 (18)	56	15 (22)	--	--	8.3	11 (2)	--	--	--	--	--	--	--	--	2.5	10 (ND)	--	--	--	--	--	--	--	--
BE-702-BY-0206	84	18 (23)	1.8	28 (ND)	12	7.8 (15)	--	--	--	--	--	--	--	--	2.3	36 (ND)	--	--	--	--	0.25	4 (ND)	--	--	--	--
BE-702-DZ-0002	65	26 (37)	6.8	9.7 (6.5)	3.3	28 (ND)	--	--	--	--	--	--	--	--	--	--	3.5	3 (0.94)	--	--	1.6	14 (ND)	--	--	20	85 (99)

Notes:
-- = Not Available
ND = Not Detected
SD = Standard Deviation
μm = micrometer
(1) "M" indicates the occurrence of small quantities of Sb and Sn.
(2) Frequency of Occurrence is the fraction (based on volume) that particular lead- or arsenic- bearing mineral phases contribute to the total of all of lead- or arsenic- bearing mineral phases.

Table 4a. Frequency of Occurrence and Particle Size of Mineral Phases by Electron Microprobe Analysis

Sample ID	$PbSiO_4$		Arsenopyrite		FeAsOOH		Lead Solder		ZnMO[1]		Pyrite		Plumbobarite		AsMO[1]		$PbTiO_2$		$PbCrO_4$		CaAsO		PbAsO		Sulfo Salt	
	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)	Frequency of Occurrence[2] (%)	Mean (SD) Particle Size (µm)
BE-014-FY-0612	--	--	--	--	--	--	--	--	--	--	0.14	3 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-021B-DZ-0002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-031-DZ-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.6	1 (0)	--	--	--	--	--	--
BE-039-FG-1218	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-046-FY-0002	--	--	1.2	8 (3.6)	--	--	--	--	--	--	--	--	0.51	10 (ND)	0.31	6 (ND)	--	--	--	--	--	--	--	--	--	--
BE-055-FY-0002	--	--	--	--	--	--	--	--	0.70	25 (ND)	0.33	12 (ND)	--	--	2.9	105 (ND)	--	--	--	--	--	--	--	--	--	--
BE-057-DZ-0002	0.74	11 (ND)	--	--	--	--	--	--	--	--	--	--	1.0	15 (ND)	--	--	--	--	--	--	--	--	--	--	--	--
BE-064-BY-0206	--	--	0.15	3 (ND)	1.8	6 (1.4)	--	--	--	--	5.6	28 (25)	0.40	8 (ND)	--	--	--	--	--	--	--	--	--	--	0.25	1.7 (1.2)
BE-064-FY-0612	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-088-FY-0612	--	--	--	--	--	--	7.7	17 (13)	--	--	--	--	--	--	--	--	0.15	2 (ND)	--	--	--	--	--	--	--	--
BE-205-ED-0204	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.3	1.3 (0.48)	--	--	--	--	--	--	--	--
BE-206D-BY-0206	18	122 (27)	--	--	--	--	1.0	11 (3.5)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-216-DZ-1218	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-236B-BA-0206	11	38 (35)	--	--	--	--	--	--	2.2	11 (5.5)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-248-ED-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-253A-BY-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.50	5.5 (3.5)	--	--	--	--
BE-253B-FY-1218	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-324-BA-0612	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-335-DZ-118	--	--	--	--	0.69	9 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-335-RG-0002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-411-VG-0002	--	--	1.9	23 (ND)	16	18 (35)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-429-ED-1210	3.3	9 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-429-FG-0612	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-BY-0002	--	--	1.1	9 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-FY-0206	--	--	--	--	--	--	0.39	2.5 (0.71)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-BY-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-FG-1218	--	--	--	--	2.1	32 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-506-FY-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-508-RG-0206	33	20 (27)	--	--	--	--	2.7	37 (ND)	2.6	36 (ND)	--	--	--	--	--	--	--	--	--	--	--	--	0.66	9 (ND)	--	--
BE-514-FG-0002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-514-FY-0612	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-516A-BA-0002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-527B-FY-0002	--	--	--	--	--	--	--	--	2.5	1.3 (0.46)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-702-BY-0206	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-702-DZ-0002	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Notes:
-- = Not Available
ND = Not Detected
SD = Standard Deviation
µm = micrometer
(1) "M" indicates the occurrence of small quantities of Sb and Sn.
(2) Frequency of Occurrence is the fraction (based on volume) that particular lead- or arsenic- bearing mineral phases contribute to the total of all of lead- or arsenic- bearing mineral phases.

Table 4b. Distribution of Lead in Mineral Phases by Electron Microprobe Analysis

Sample ID	Relative Mass[1] (%)																					
	FeOOH	Phosphate	$FeSO_4$	MnOOH	Cerussite	Anglesite	Paint	Clay	Galena	$PbMO^2$	$CuMO^2$	$SnMO^2$	Slag	$PbSiO_4$	FeAsOOH	Lead Solder	$ZnMO^2$	Plumbobarite	$AsMO^2$	$PbTiO_2$	$PbCrO_4$	PbAsO	Sulfo Salt
BE-014-FY-0612	66	26	1.6	5.0	--	--	--	--	--	--	--	--	1.2	--	--	--	--	--	--	--	--	--	--
BE-021B-DZ-0002	1.6	44	--	1.7	46	--	6.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-031-DZ-0206	7.9	12	0.040	13	56	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	10	--	--
BE-039-FG-1218	7.4	45	0.56	0.47	10	--	0.27	0.55	35	0.34	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-046-FY-0002	5.6	80	0.49	9.9	--	2.0	1.4	0.19	--	--	--	--	0.13	--	--	--	--	0.13	0.43	--	--	--	--
BE-055-FY-0002	42	--	0.44	9.8	27	11	--	--	7.8	--	--	--	--	--	--	--	0.080	--	1.7	--	--	--	--
BE-057-DZ-0002	12	82	0.11	1.7	--	0.39	--	--	--	--	--	--	--	4.0	--	--	--	0.31	--	--	--	--	--
BE-064-BY-0206	53	20	4.3	3.8	--	3.4	1.9	1.0	12	--	--	--	--	--	0.29	--	--	0.28	--	--	--	--	0.020
BE-064-FY-0612	38	41	1.7	8.9	--	--	--	--	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-088-FY-0612	40	35	6.5	--	5.5	--	0.82	1.5	--	--	--	--	--	--	--	9.8	--	--	--	0.59	--	--	--
BE-205-ED-0204	25	24	--	8.2	24	--	12	--	--	--	--	--	--	--	--	--	--	--	--	6.5	--	--	--
BE-206D-BY-0206	0.75	4.2	0.040	0.090	33	7.3	--	0.80	--	33	--	--	--	21	--	0.14	--	--	--	--	--	--	--
BE-216-DZ-1218	2.3	--	--	1.8	84	12	0.57	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-236B-BA-0206	13	42	--	--	--	2.3	--	--	--	3.5	--	0.61	--	39	--	--	0.17	--	--	--	--	--	--
BE-248-ED-0206	62	8.5	0.14	5.1	--	--	--	--	22	--	--	0.070	2.2	--	--	--	--	--	--	--	--	--	--
BE-253A-BY-0206	25	56	1.2	7.9	3.9	1.6	--	0.16	--	4.8	0.040	--	--	--	--	--	--	--	--	--	--	--	--
BE-253B-FY-1218	74	18	1.1	3.0	--	--	--	3.0	--	--	0	1.5	--	--	--	--	--	--	--	--	--	--	--
BE-324-BA-0612	61	24	2.0	12	--	--	--	--	--	--	--	0.20	--	--	--	--	--	--	--	--	--	--	--
BE-335-DZ-1218	81	9.5	9.4	--	--	--	--	--	--	--	--	--	--	--	0.36	--	--	--	--	--	--	--	--
BE-335-RG-0002	4.2	13	0.030	11	19	29	23	--	--	--	--	--	0.60	--	--	--	--	--	--	--	--	--	--
BE-411-VG-0002	87	0.090	3.2	7.5	--	--	--	--	--	--	--	--	--	--	2.4	--	--	--	--	--	--	--	--
BE-429-ED-1218	65	--	--	--	--	--	--	--	--	--	--	--	--	35	--	--	--	--	--	--	--	--	--
BE-429-FG-0612	37	1.9	0.39	55	--	--	6.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-BY-0002	10	9.3	0.21	45	35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-FY-0206	47	31	3.5	18	--	--	--	--	--	--	--	--	--	--	--	0.58	--	--	--	--	--	--	--
BE-447-BY-0206	16	1.3	0.080	6.1	75	1.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-FG-1218	94	2.0	4.2	--	--	--	--	--	--	--	--	--	--	--	0.060	--	--	--	--	--	--	--	--
BE-506-FY-0206	26	11	0.16	8.4	41	6.5	1.6	2.0	3.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-508-RG-0206	1.2	7.4	--	0.68	5.0	9.5	--	--	--	4.4	0	0.050	--	70	--	0.72	0.080	--	--	--	--	1.2	--
BE-514-FG-0002	19	76	--	--	2.5	--	--	2.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-514-FY-0612	88	--	11	--	--	--	--	--	--	--	--	0.68	--	--	--	--	--	--	--	--	--	--	--
BE-516A-BA-0002	14	27	0.14	2.4	8.8	30	--	--	--	14	3.4	--	--	--	--	--	--	--	--	--	--	--	--
BE-527B-FY-0002	10	64	--	4.4	--	--	--	--	22	--	--	--	--	--	--	--	0.14	--	--	--	--	--	--
BE-702-BY-0206	96	0.38	3.4	--	--	--	--	0	--	--	0	--	--	--	--	--	--	--	--	--	--	--	--
BE-702-DZ-0002	24	18	2.4	--	--	--	--	--	53	--	0.17	--	2.2	--	--	--	--	--	--	--	--	--	--

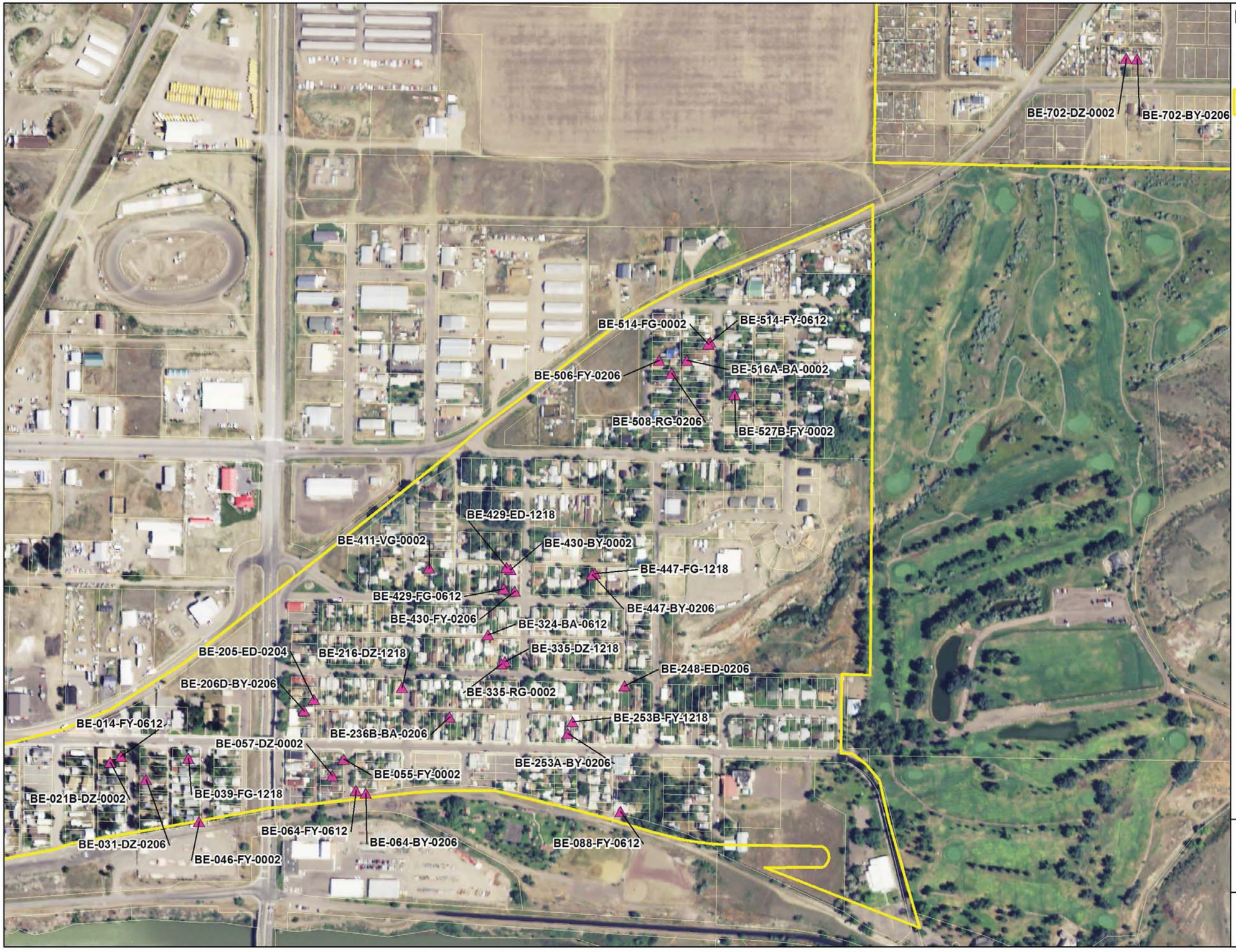
Notes:
-- = Not Available
(1) Relative mass is the fraction (based on mass) of the total lead or arsenic in a sample that resides in a particular phase.
(2) “M” indicates the occurrence of small quantities of Sb and Sn.

Table 4c. Distribution of Arsenic in Mineral Phases by Electron Microprobe Analysis

Sample ID	Relative Mass[1] (%)																		
	FeOOH	Phosphate	$FeSO_4$	MnOOH	Clay	Paint	$PbMO^2$	$CuMO^2$	$SnMO^2$	Slag	$PbSiO_4$	Arsenopyrite	FeAsOOH	Lead Solder	$ZnMO^2$	Pyrite	$AsMO^2$	CaAsO	PbAsO	Sulfo Salt
BE-014-FY-0612	70	19	9.4	0.59	--	--	--	--	--	0.21	--	--	--	--	--	0.23	--	--	--	--
BE-021B-DZ-0002	47	52	--	0.56	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-031-DZ-0206	80	15	2.2	3.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-039-FG-1218	30	55	14	0.27	0.060	0	0.89	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-046-FY-0002	17	23	6.2	0.86	0.020	0	--	--	--	0.040	--	43	--	--	--	--	10	--	--	--
BE-055-FY-0002	33	--	1.5	0.38	--	--	--	--	--	--	--	--	--	--	0.10	0.92	64	--	--	--
BE-057-DZ-0002	63	34	3.1	0.12	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--
BE-064-BY-0206	50	4.5	12	0.17	0.050	0	--	--	--	--	--	5.5	19	--	--	6.9	--	--	--	1.4
BE-064-FY-0612	92	2.6	5.2	0.24	--	--	0.34	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-088-FY-0612	76	3.5	20	--	0.030	0	--	--	--	--	--	--	--	0.32	--	--	--	--	--	--
BE-205-ED-0204	91	8.2	--	1.1	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-206D-BY-0206	20	9.1	4.9	0.060	1.1	--	57	--	--	--	8.0	--	--	0.070	--	--	--	--	--	--
BE-216-DZ-1218	98	--	--	2.1	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-236B-BA-0206	75	20	--	--	--	--	0.97	--	1.6	--	0	--	--	--	2.1	--	--	--	--	--
BE-248-ED-0206	98	0.53	1.1	0.20	--	--	--	--	0.070	0.080	--	--	--	--	--	--	--	--	--	--
BE-253A-BY-0206	45	12	19	0.34	0.010	--	0.46	3.3	--	--	--	--	--	--	--	--	--	20	--	--
BE-253B-FY-1218	87	2.7	8.2	0.25	0.16	--	--	0.41	1.1	--	--	--	--	--	--	--	--	--	--	--
BE-324-BA-0612	81	4.8	14	0.59	--	--	--	--	0.44	--	--	--	--	--	--	--	--	--	--	--
BE-335-DZ-1218	84	1.7	8.3	--	--	--	--	--	--	--	--	--	5.9	--	--	--	--	--	--	--
BE-335-RG-0002	67	16	2.6	4.2	--	2.7	--	--	--	7.7	--	--	--	--	--	--	--	--	--	--
BE-411-VG-0002	8.7	0.76	2.0	0.020	--	--	--	--	--	--	--	11	78	--	--	--	--	--	--	--
BE-429-ED-1218	100	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--
BE-429-FG-0612	92	0.36	4.7	2.8	--	0.24	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-430-BY-0002	26	1.9	2.7	2.8	--	--	--	--	--	--	--	66	--	--	--	--	--	--	--	--
BE-430-FY-0206	68	3.8	27	0.59	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	--
BE-447-BY-0206	97	0.38	1.4	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-447-FG-1218	47	2.0	29	--	--	--	--	--	--	--	--	--	22	--	--	--	--	--	--	--
BE-506-FY-0206	95	2.2	2.2	0.51	0.27	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-508-RG-0206	35	5.1	--	0.35	--	--	9.5	13	15	--	1.7	--	--	0	1.1	--	--	--	19	--
BE-514-FG-0002	81	16	--	--	3.3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
BE-514-FY-0612	63	--	37	--	--	--	--	--	0.26	--	--	--	--	--	--	--	--	--	--	--
BE-516A-BA-0002	84	8.1	3.7	0.23	--	--	3.7	0.15	--	--	--	--	--	--	--	--	--	--	--	--
BE-527B-FY-0002	67	29	--	0.67	--	--	--	--	--	--	--	--	--	--	3.55	--	--	--	--	--
BE-702-BY-0206	68	11	13	--	0.34	--	--	8.1	--	--	--	--	--	--	--	--	--	--	--	--
BE-702-DZ-0002	82	2.5	4.8	--	--	--	--	10	--	0.47	--	--	--	--	--	--	--	--	--	--

Notes:
-- = Not Available
(1) Relative mass is the fraction (based on mass) of the total lead or arsenic in a sample that resides in a particular phase.
(2) “M” indicates the occurrence of small quantities of Sb and Sn.

Figures



Legend

- Mineralogy and Bioavailability Soil Sample Locations
- Community Soils Area Of Interest

ATLANTIC RICHFIELD COMPANY

ACM SMELTER AND REFINERY SITE

DATE: August 2014

2013 Aerial Photo (NAIP-USDA)
Provided by: Formation Environmental

N

0 250 500
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Figure 1: Mineralogy and Bioavailability Soil Sample Locations

ENVIRON

T:\PROJECT FILES\AR Great Falls (School)\2_Post-Listing Files\1_OU1 CSAOI & Outlying Areas\OU1 Bioavailability Study\ENVIRON Report\Fig1 Map\Fig1_Bioavail_MineralogyLocs.mxd

Figure 2. Relative Bioaccessibility Results for Lead and Arsenic by Sample

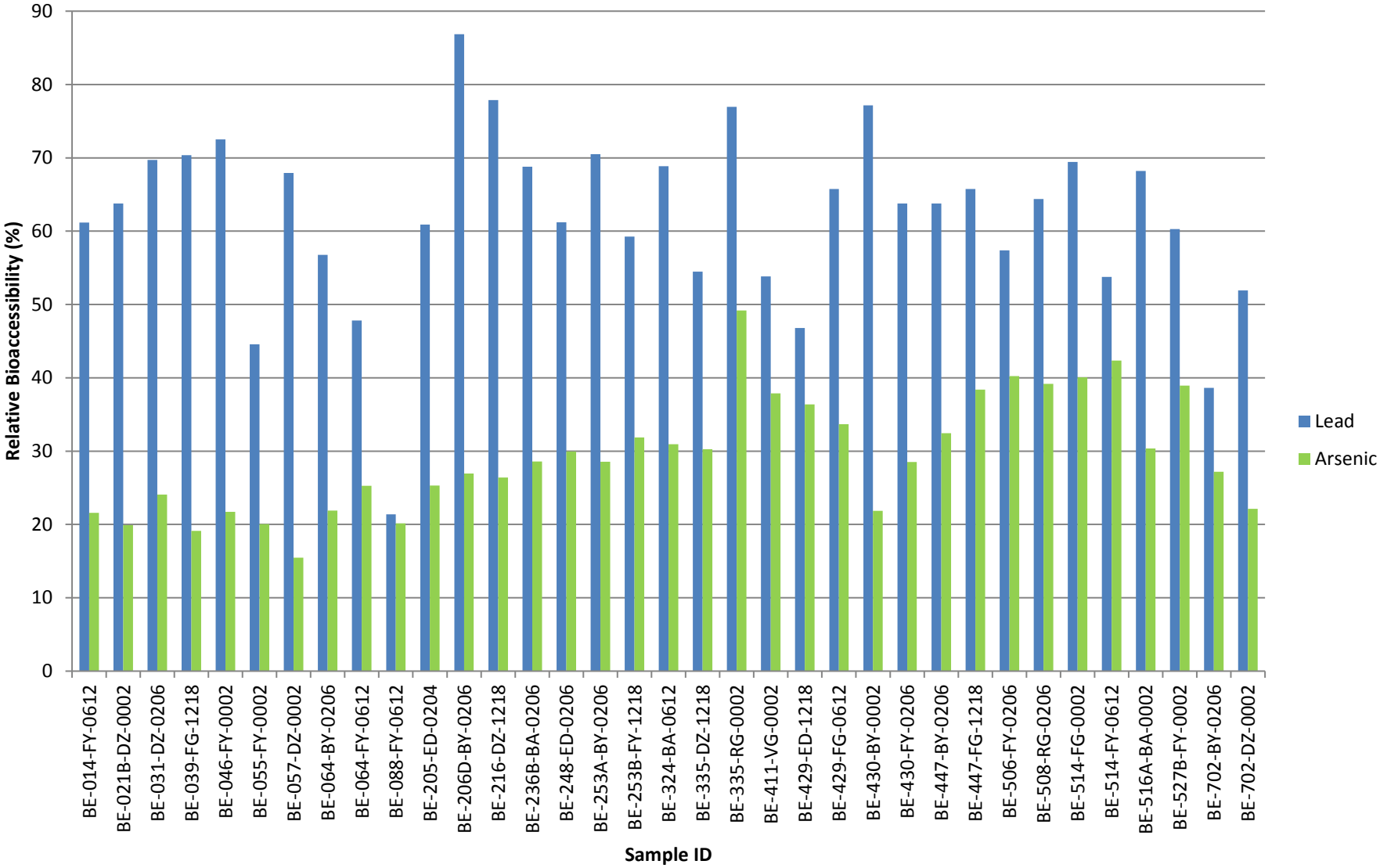


Figure 3a. Lead Concentration in Soil versus Relative Bioavailability (Depth at 0-6 inches bgs)

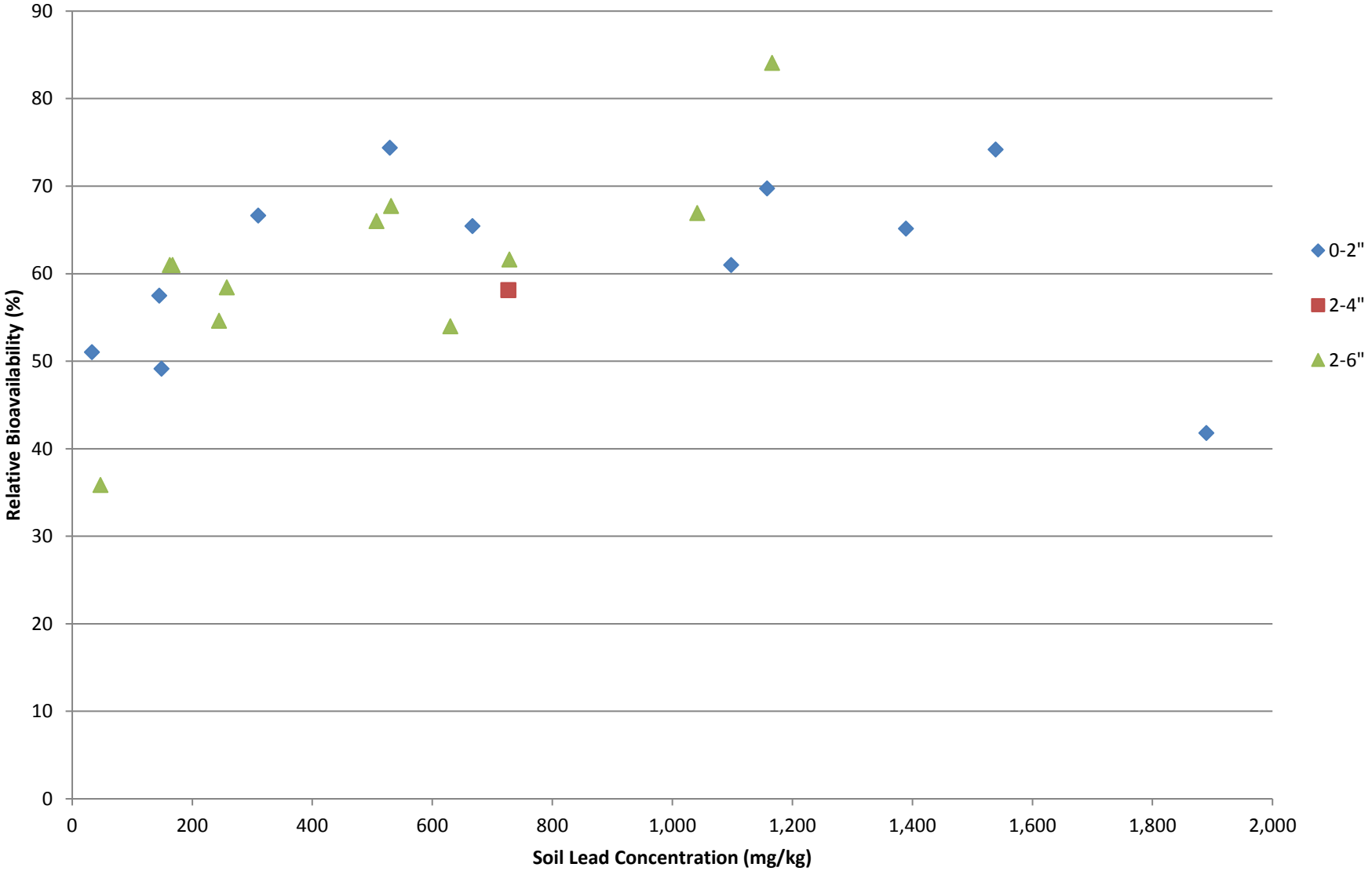


Figure 3b. Lead Concentration in Soil versus Relative Bioavailability (Depth at > 6 inches bgs)

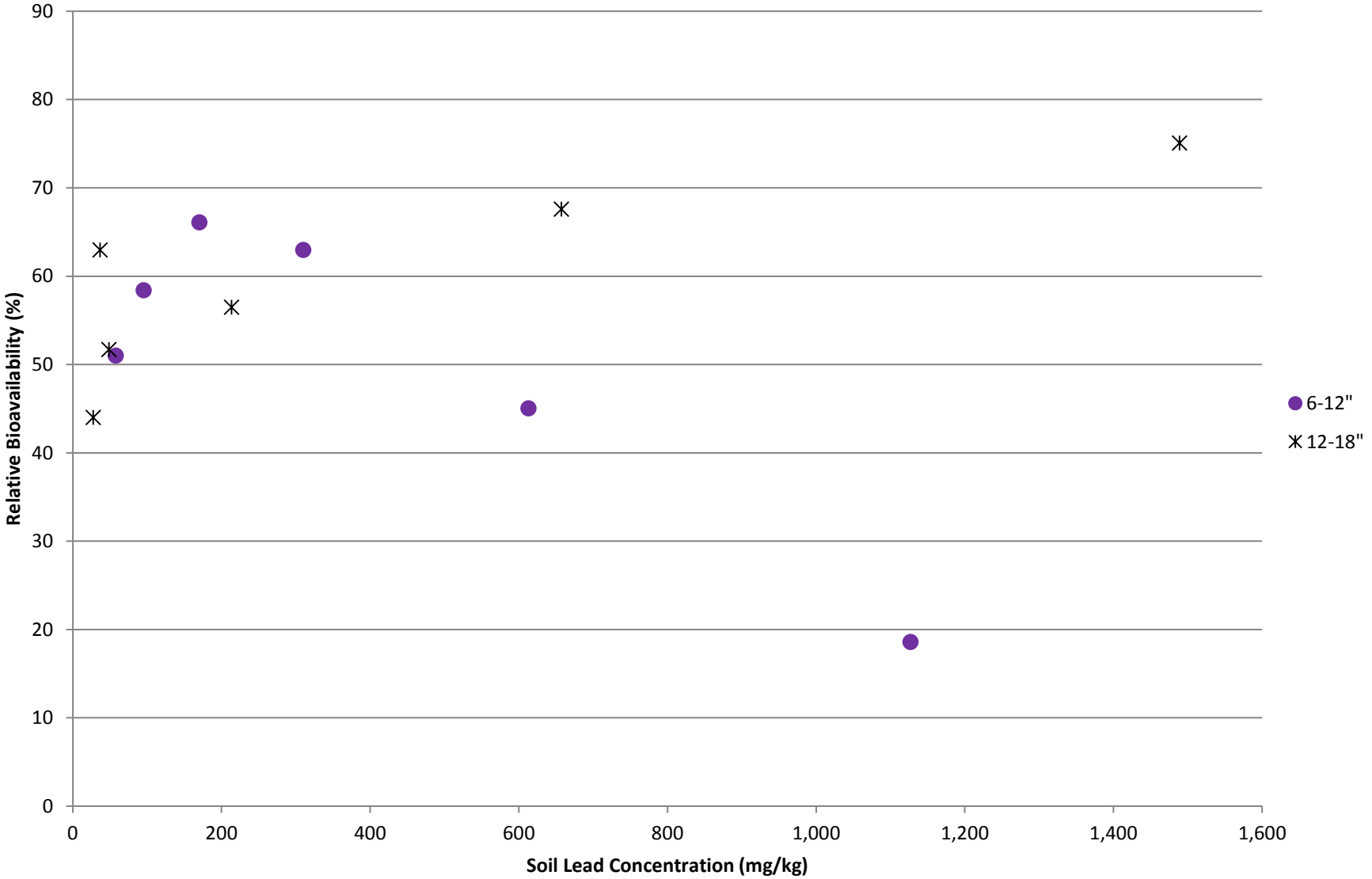


Figure 4a. Arsenic Concentration in Soil versus Relative Bioavailability (Depth at 0-6 inches bgs)

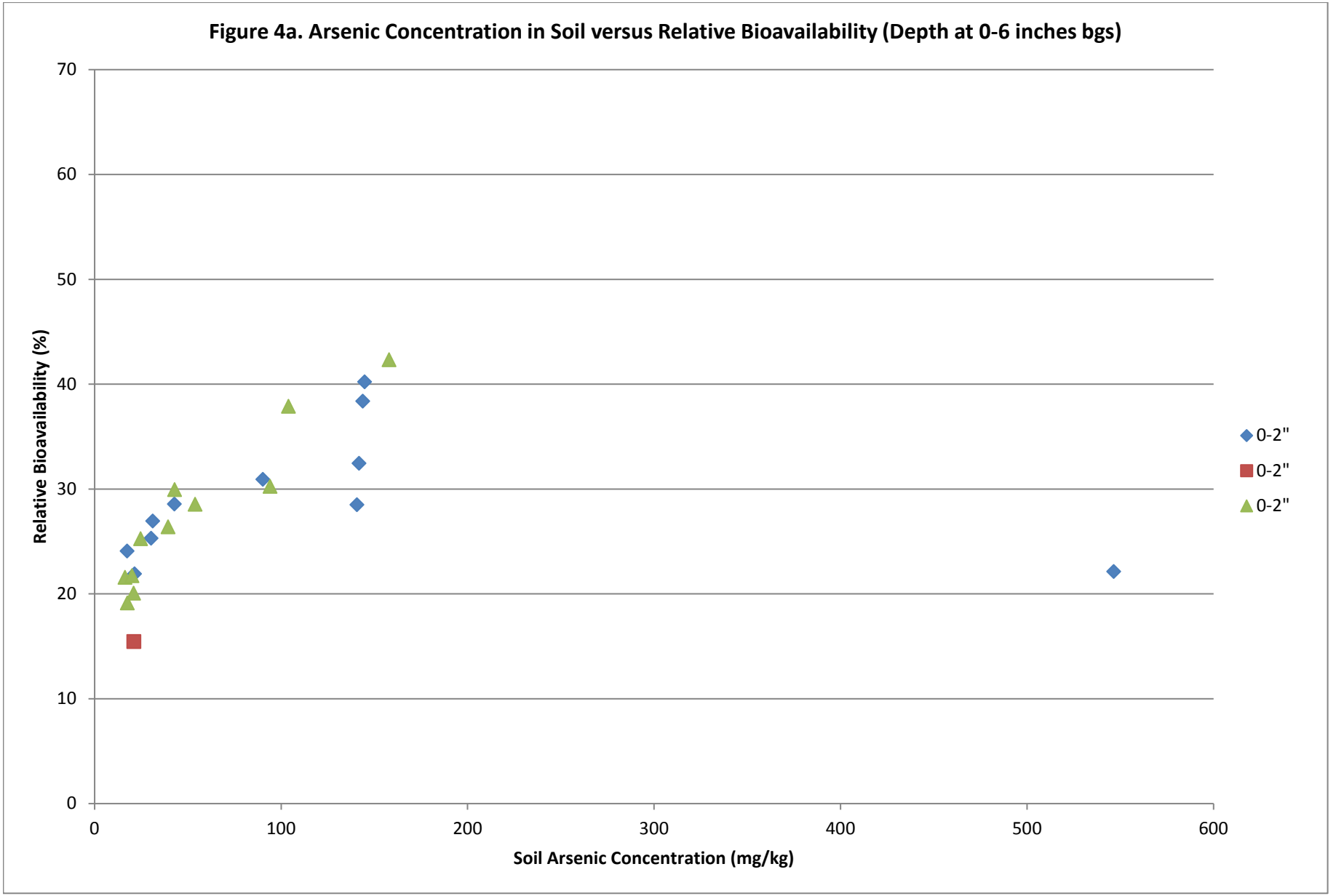


Figure 4b. Arsenic Concentration in Soil versus Relative Bioavailability (Depth at > 6 inches bgs)

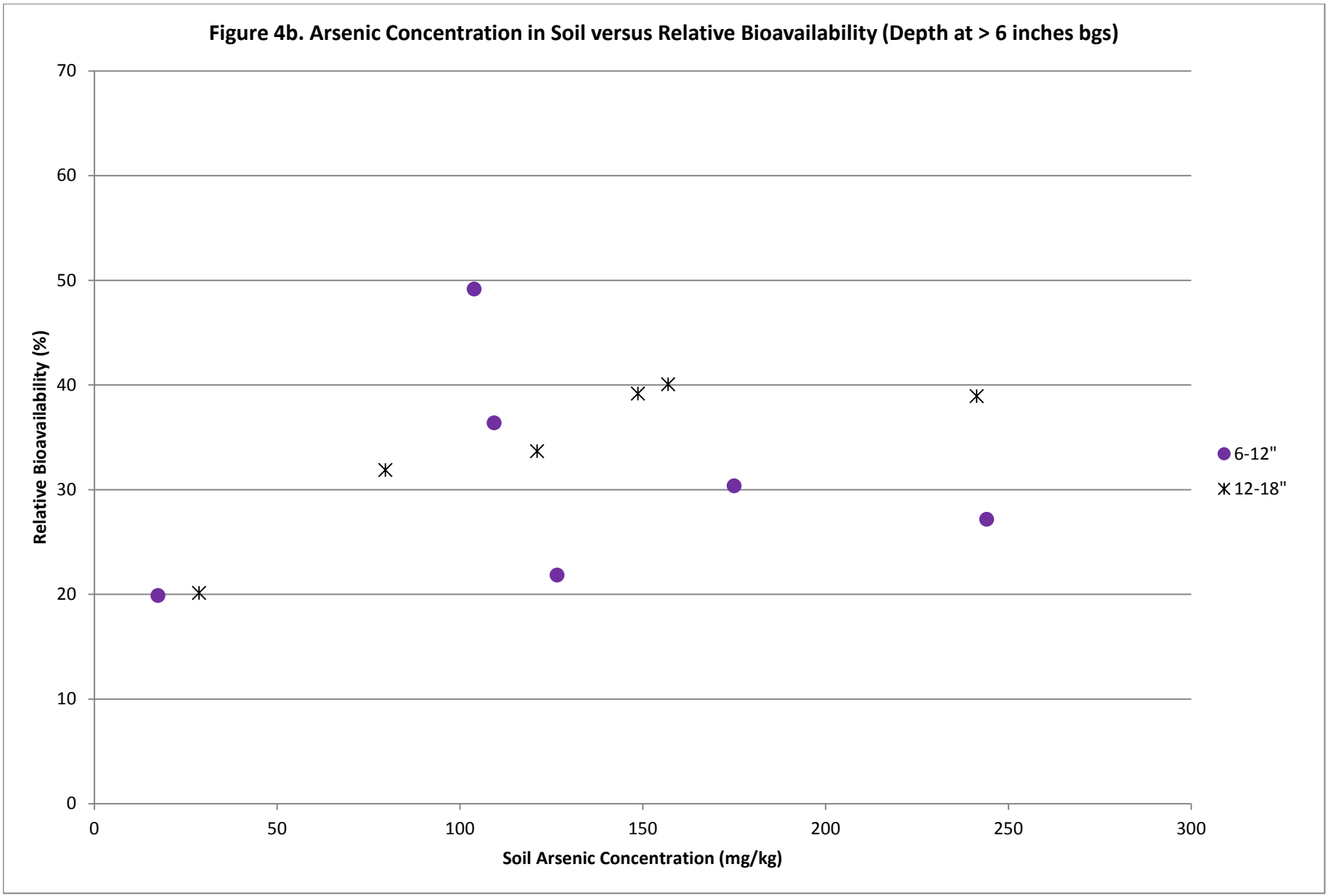
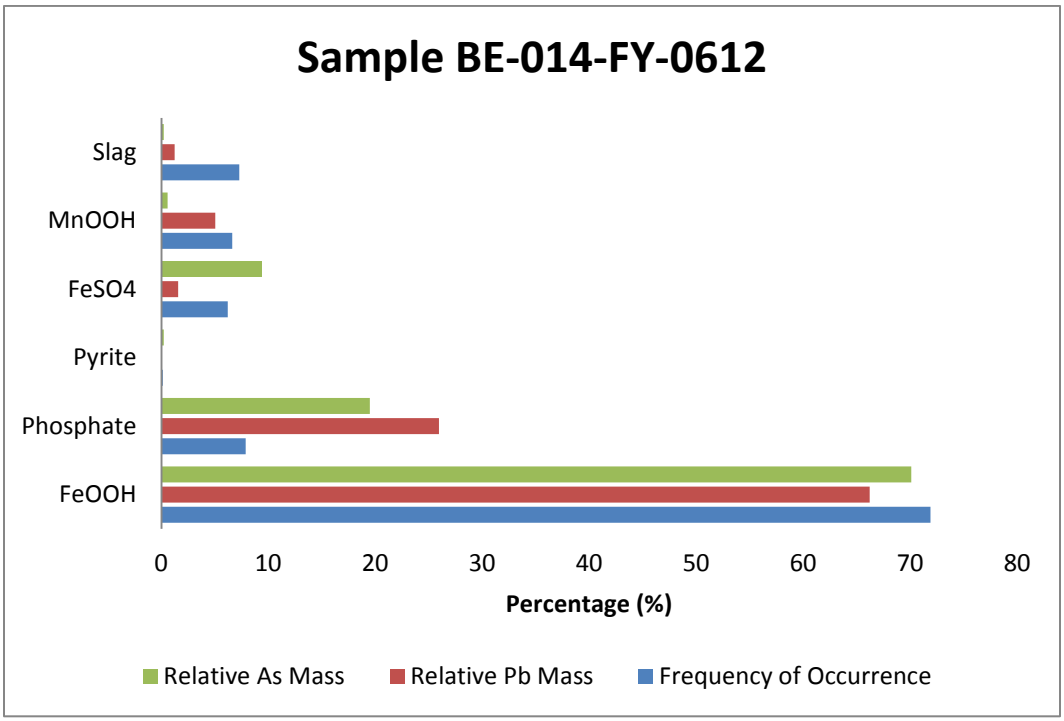


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence



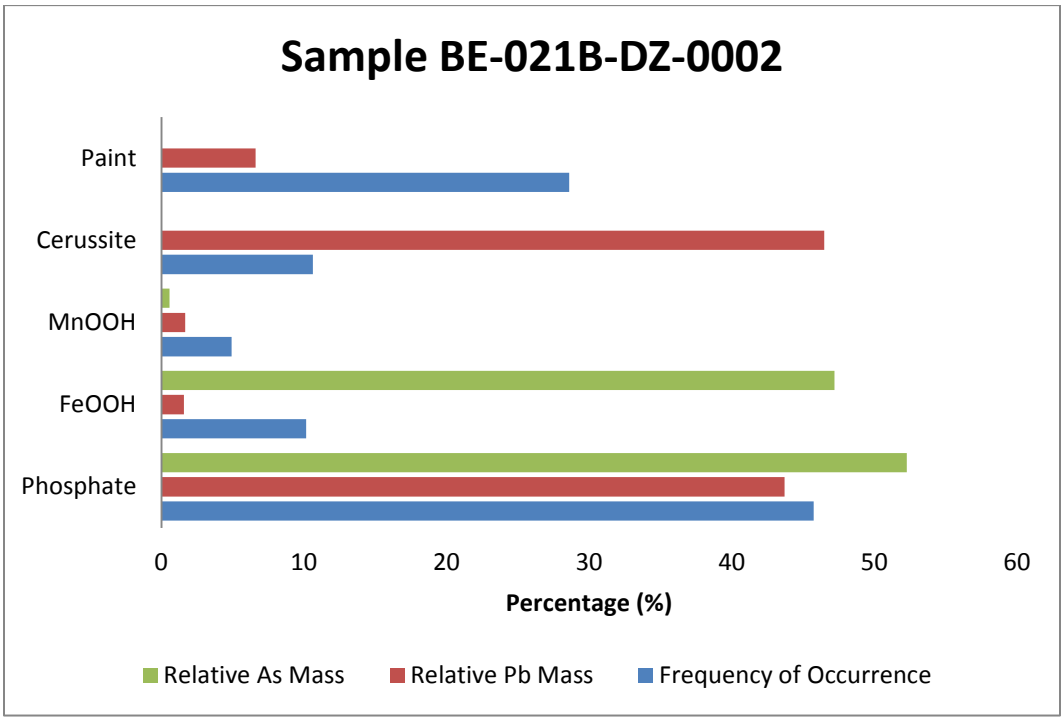
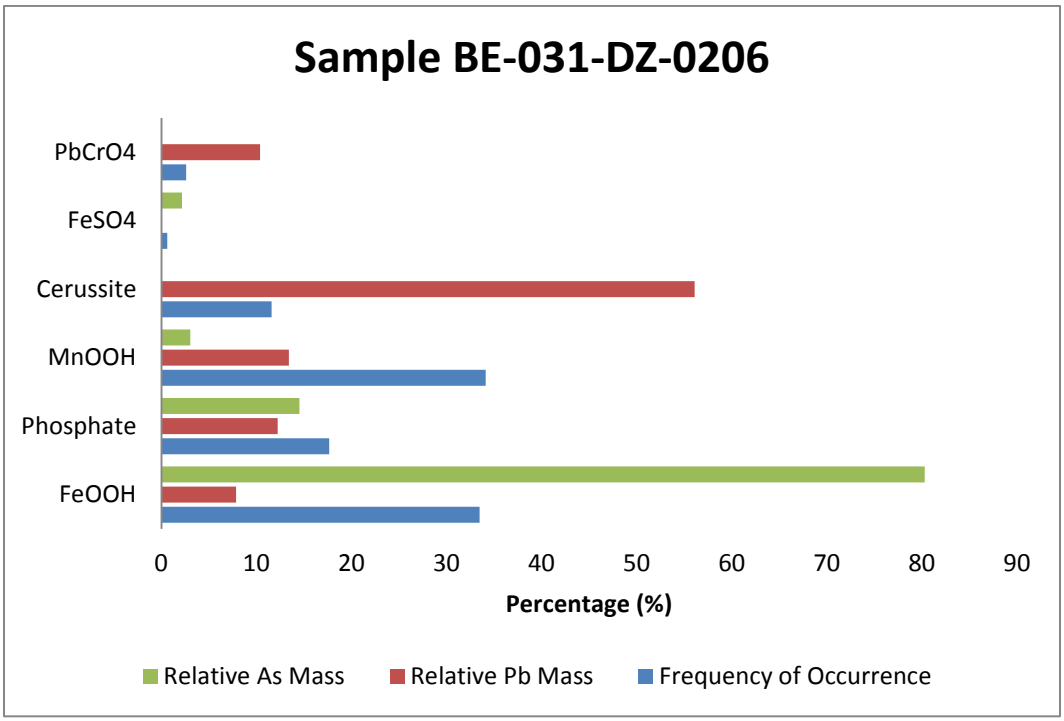


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



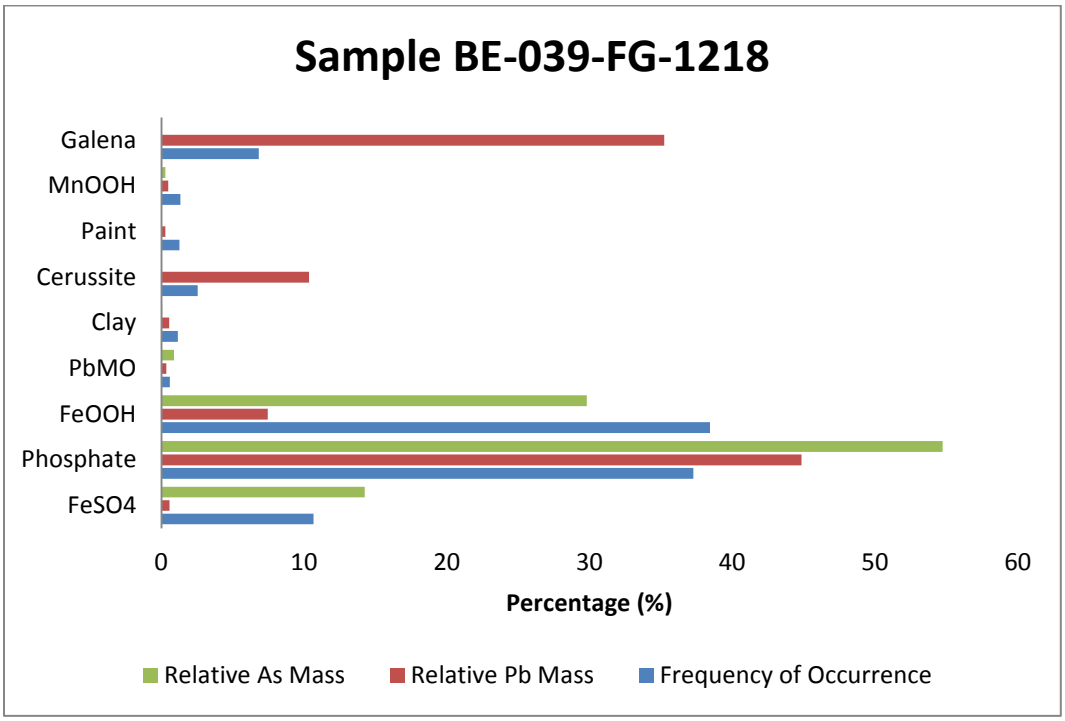
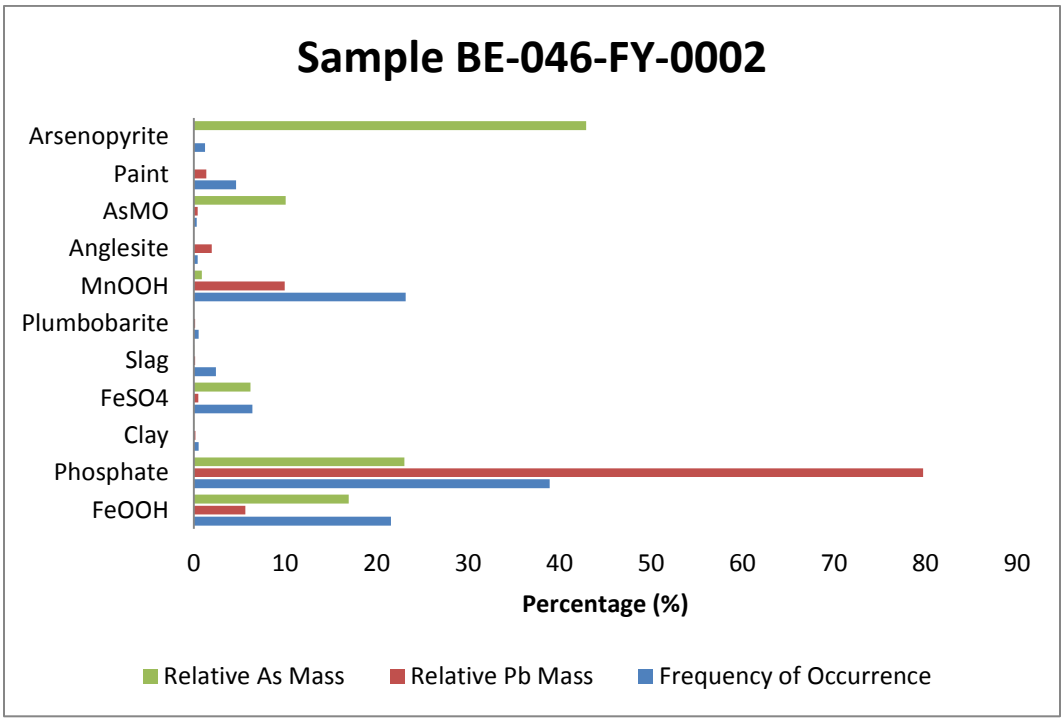


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



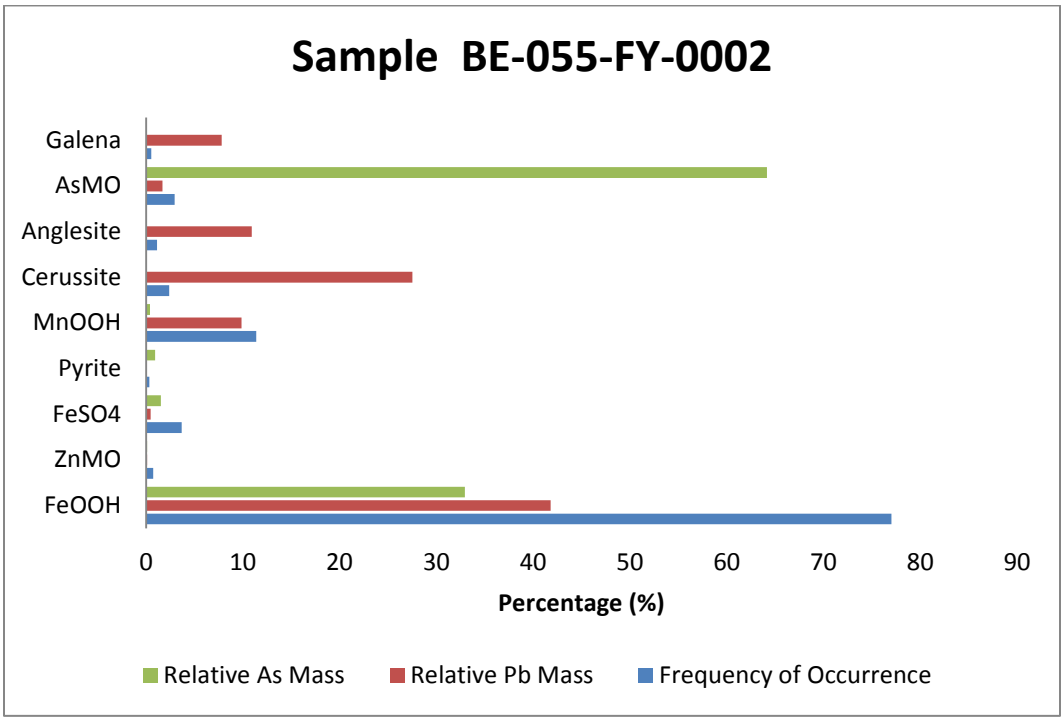
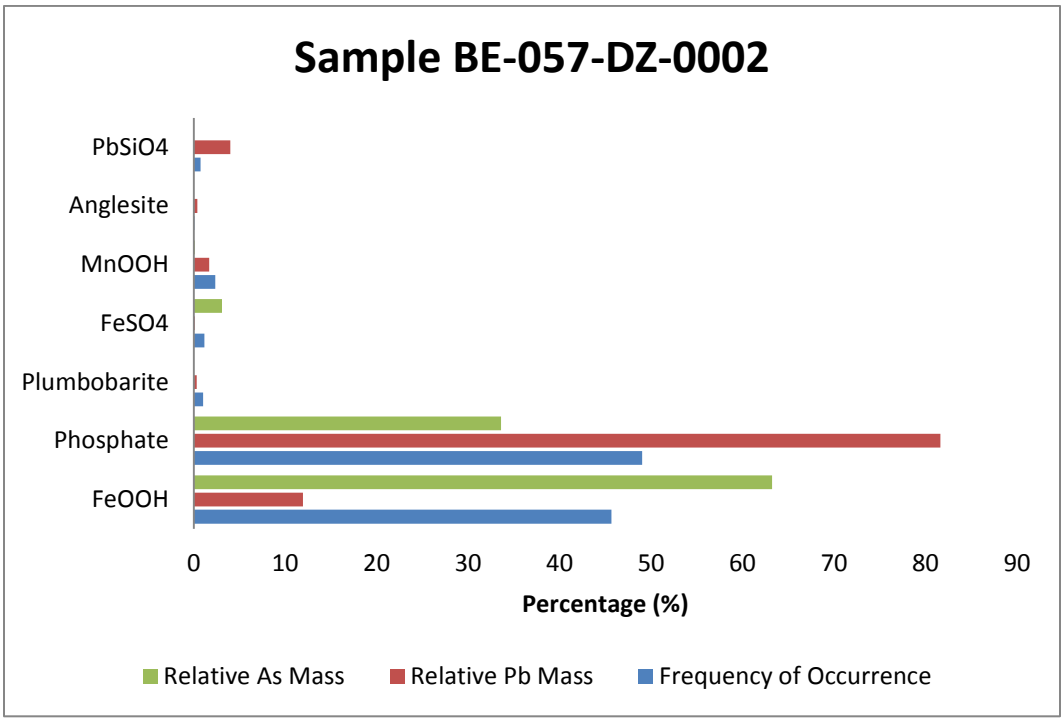
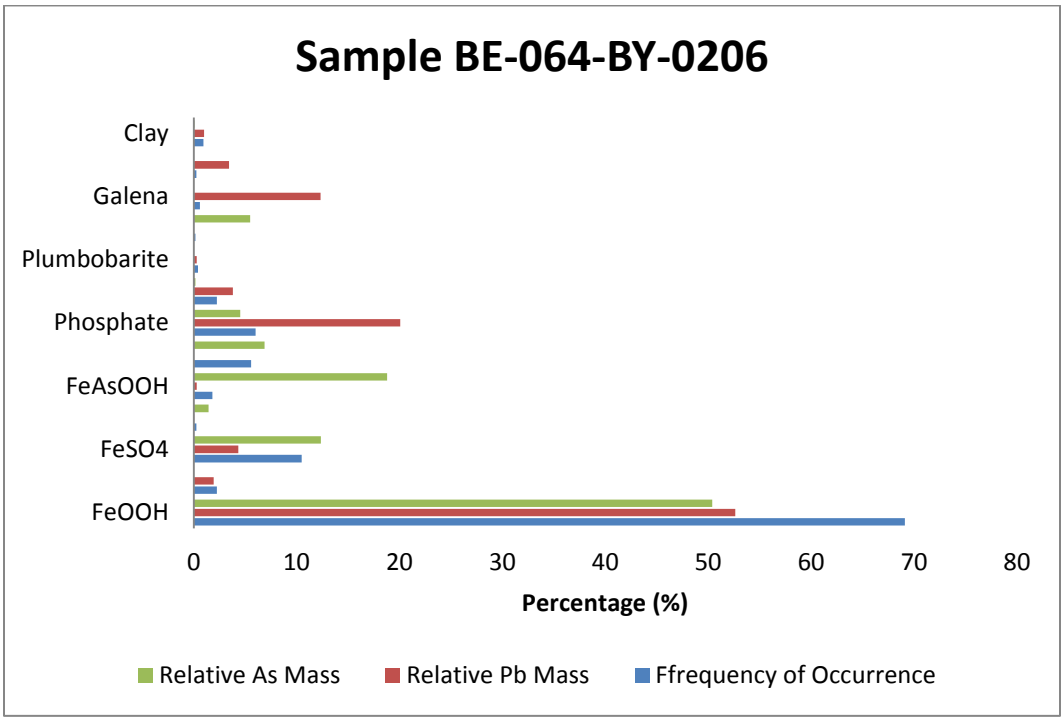


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)





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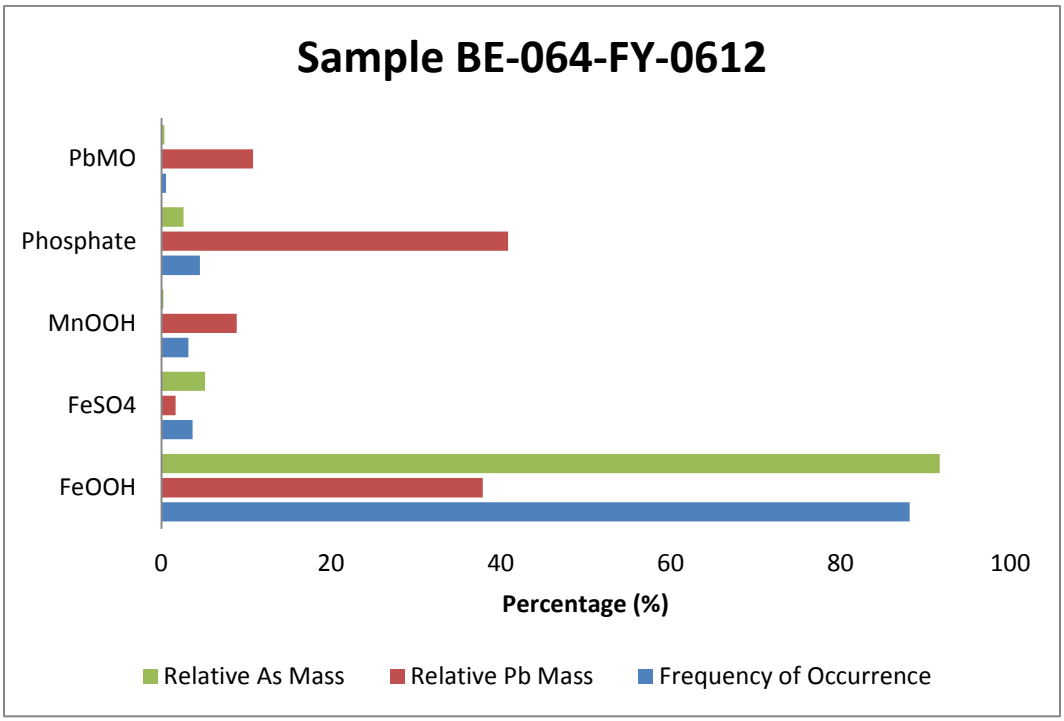


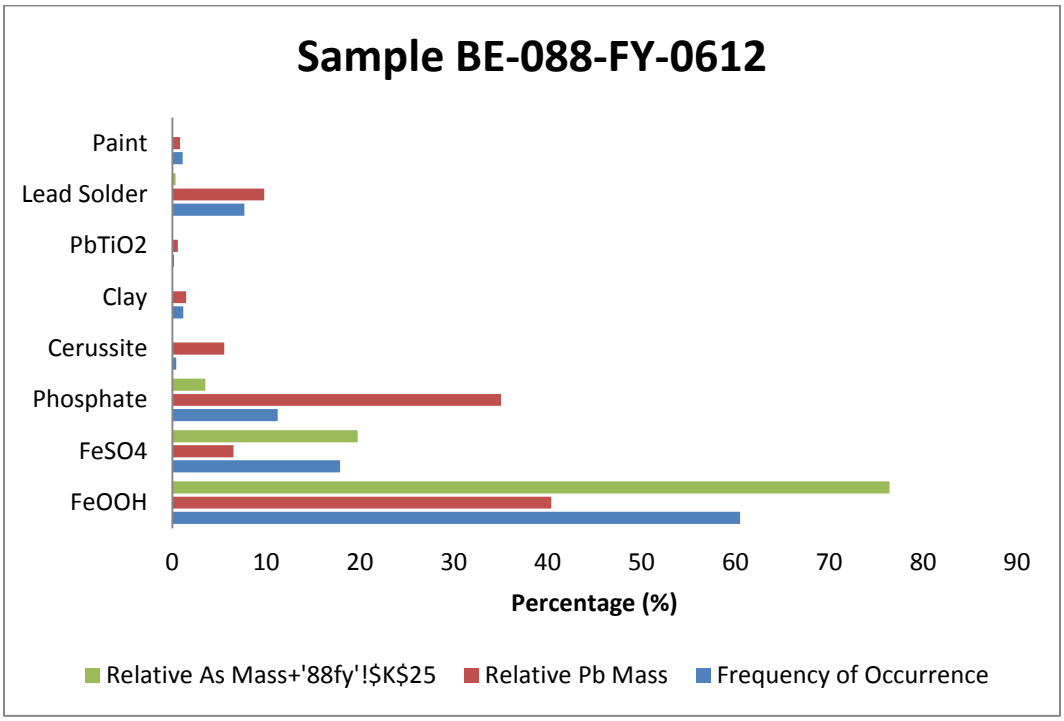
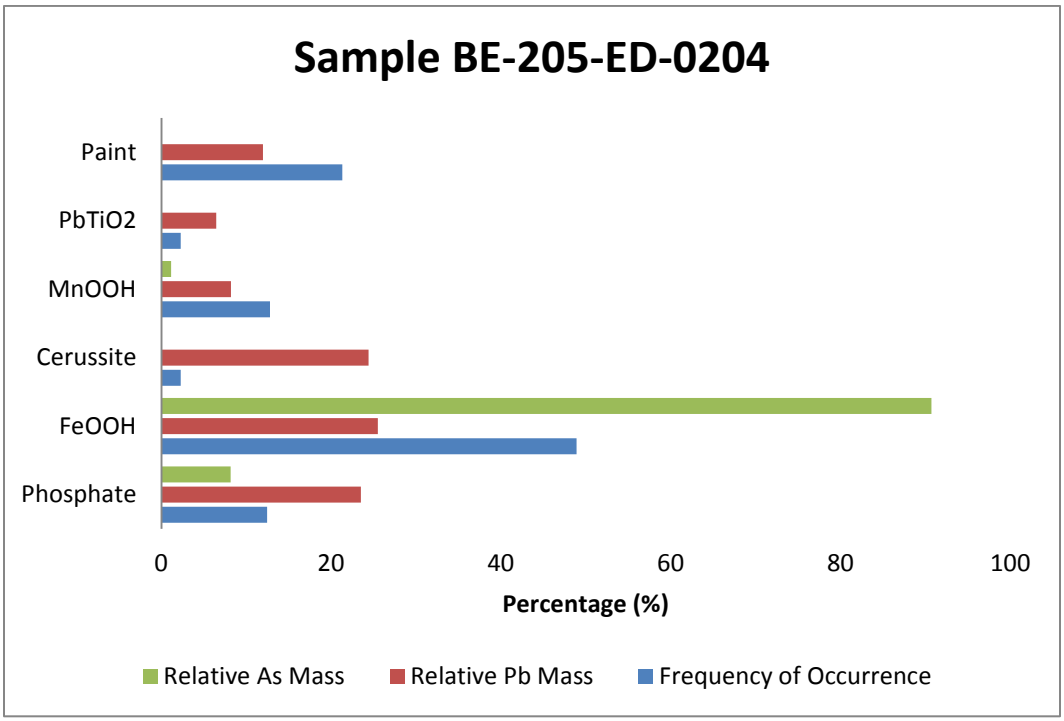


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



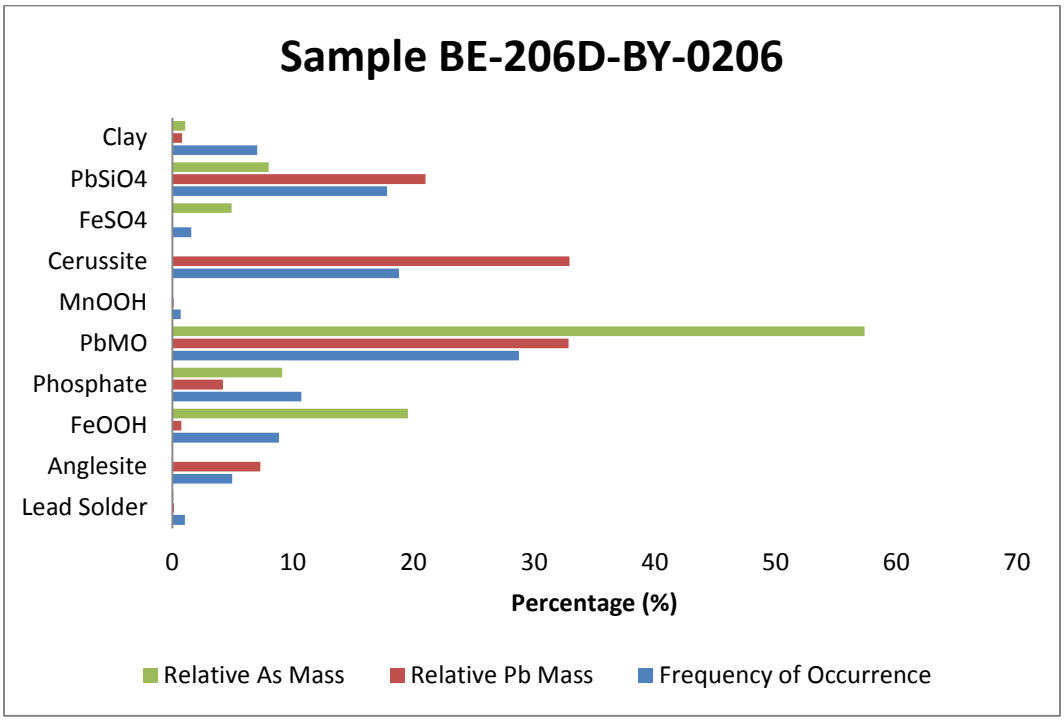
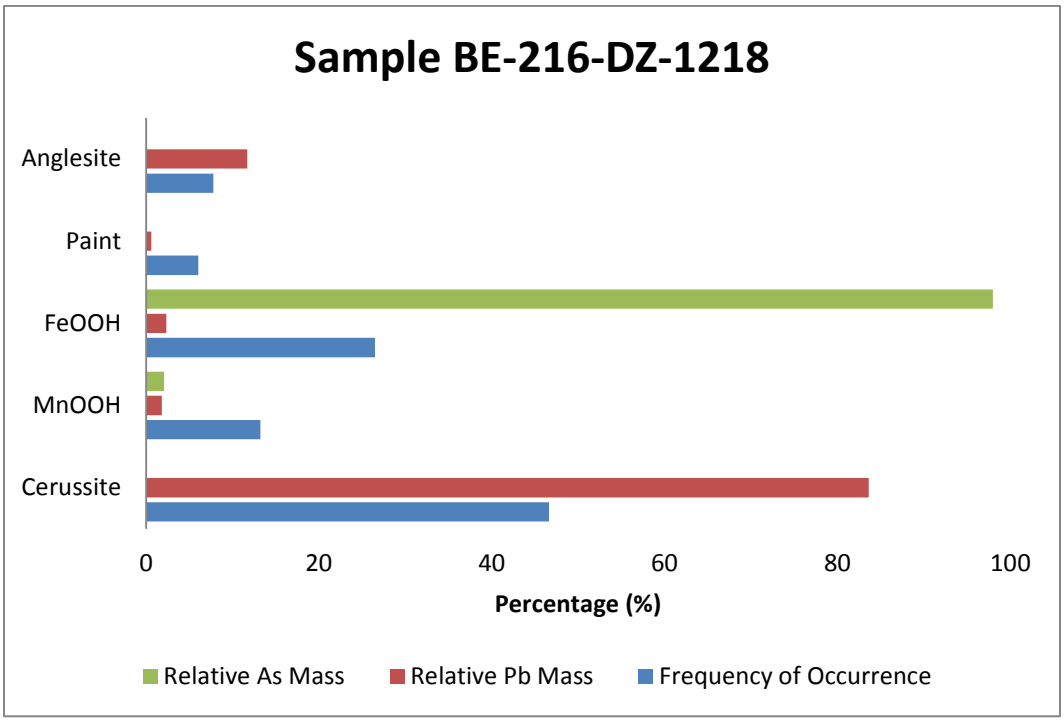


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



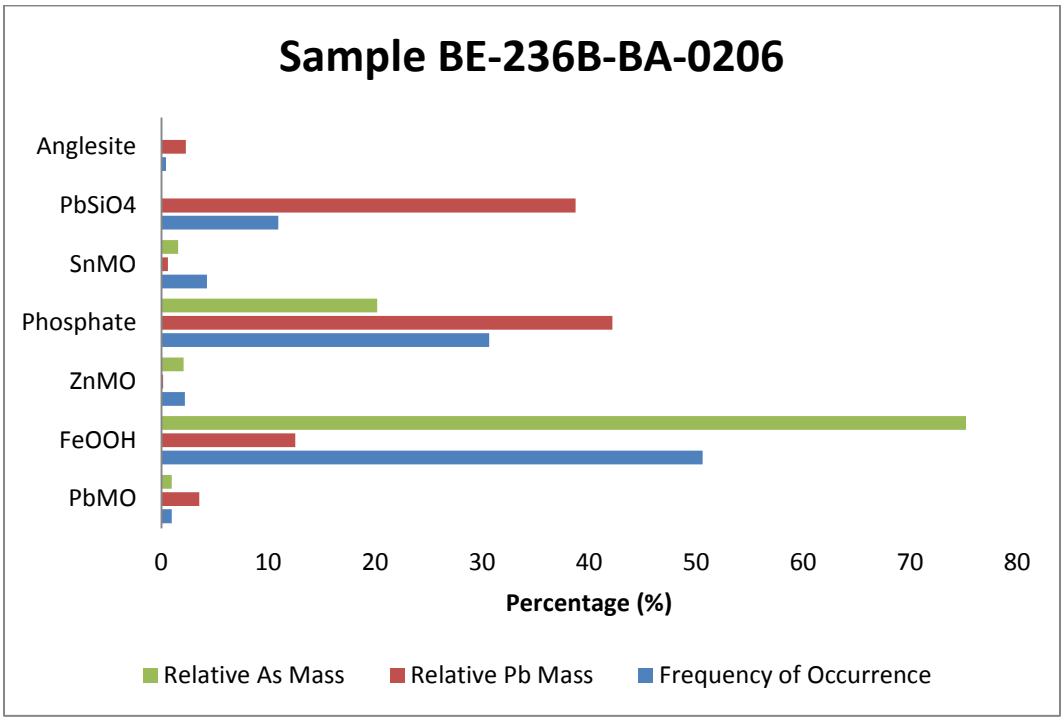
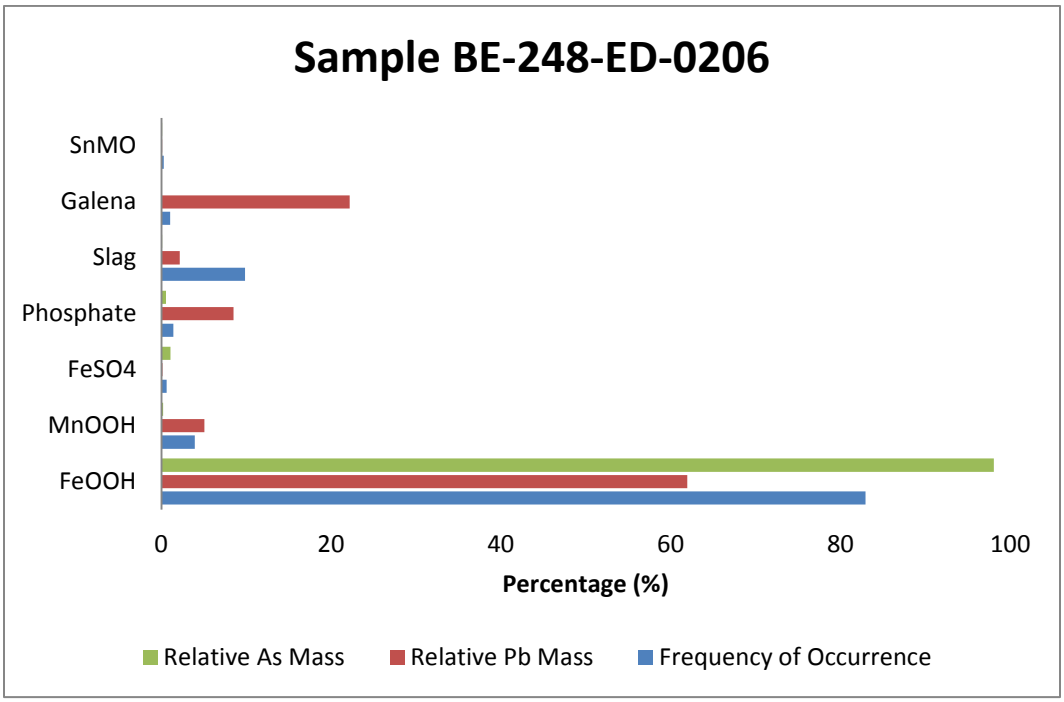


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



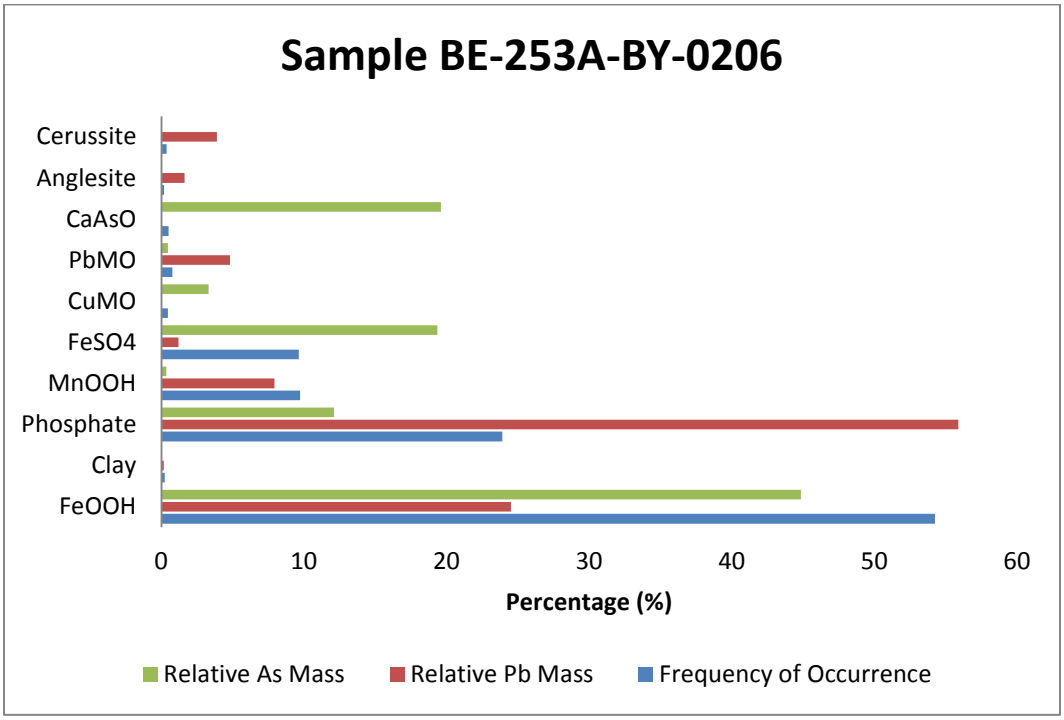
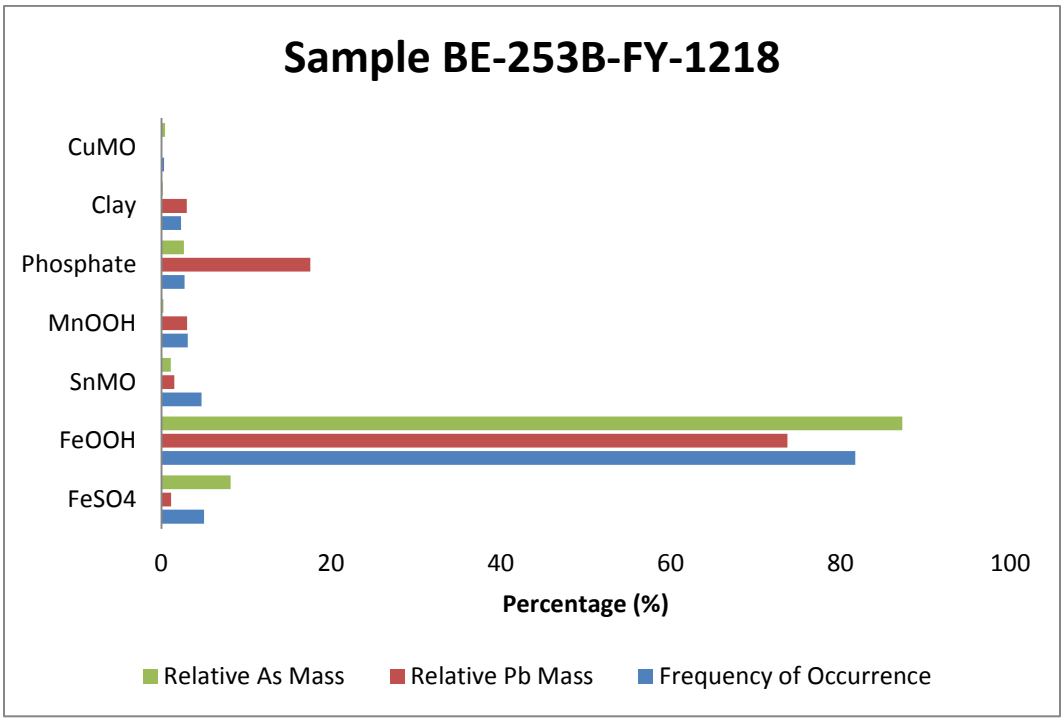


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



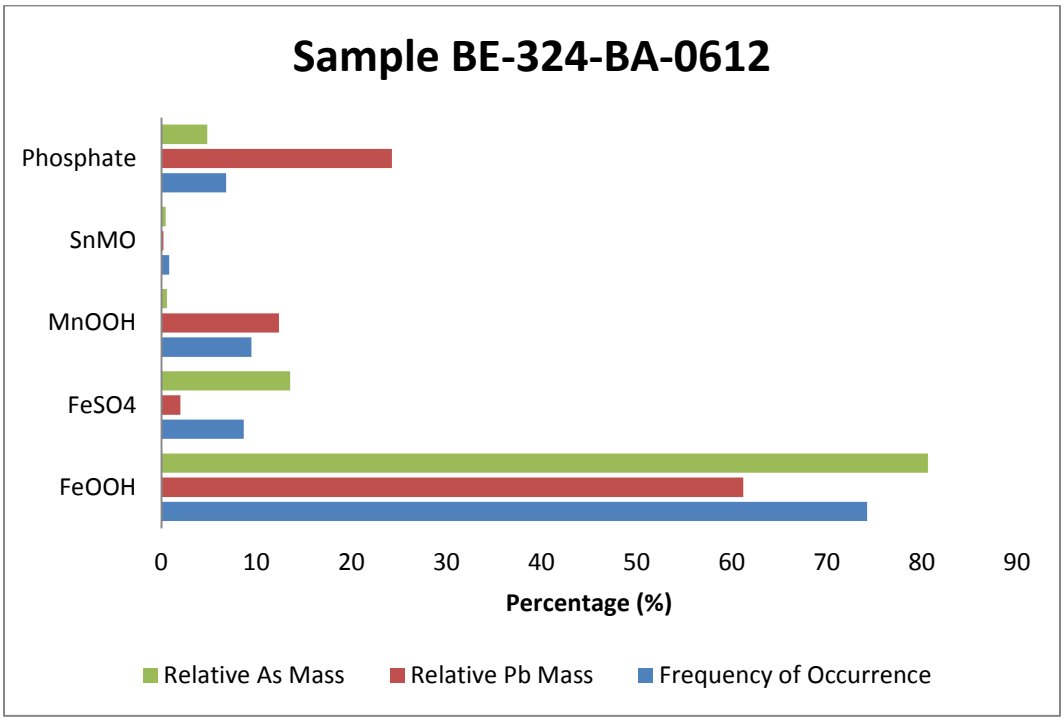
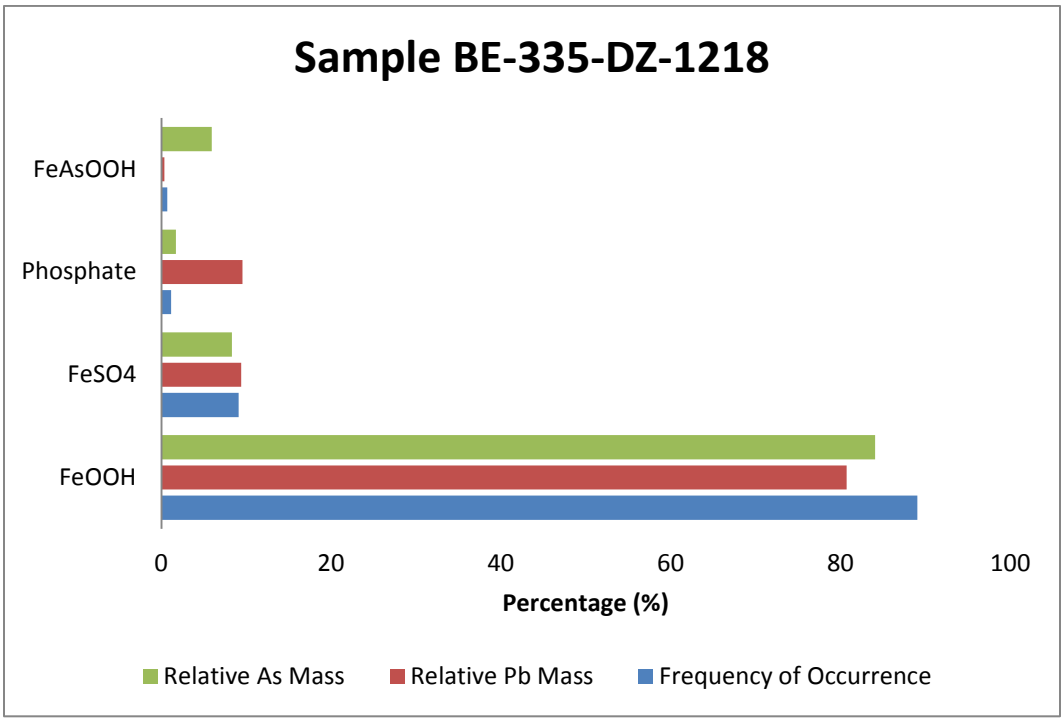
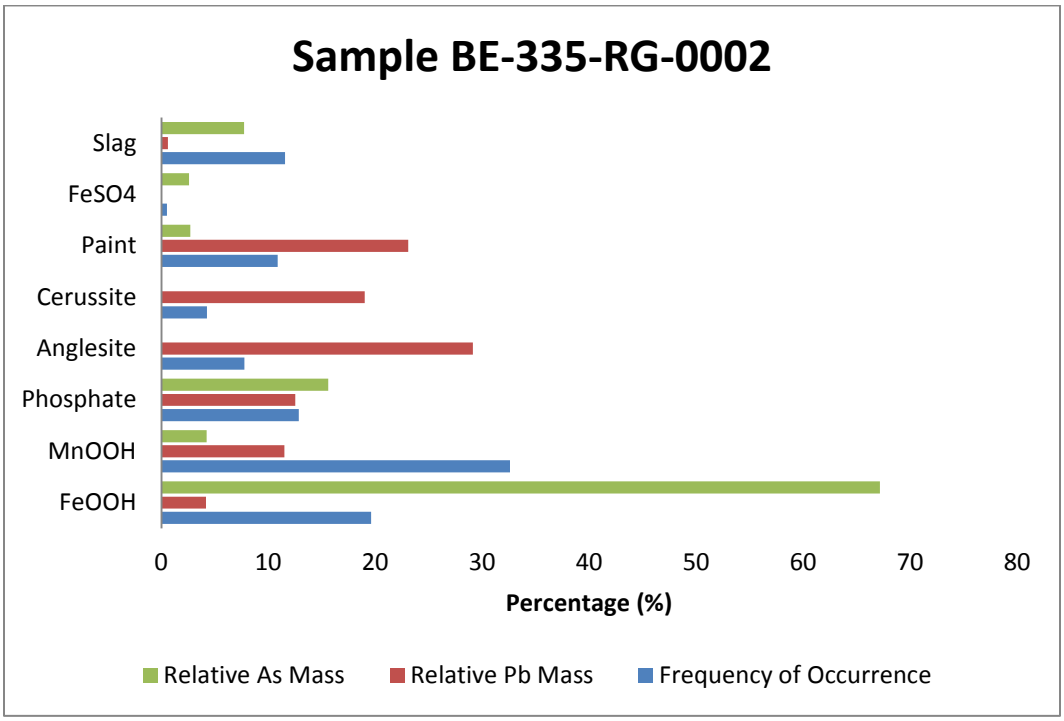


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)





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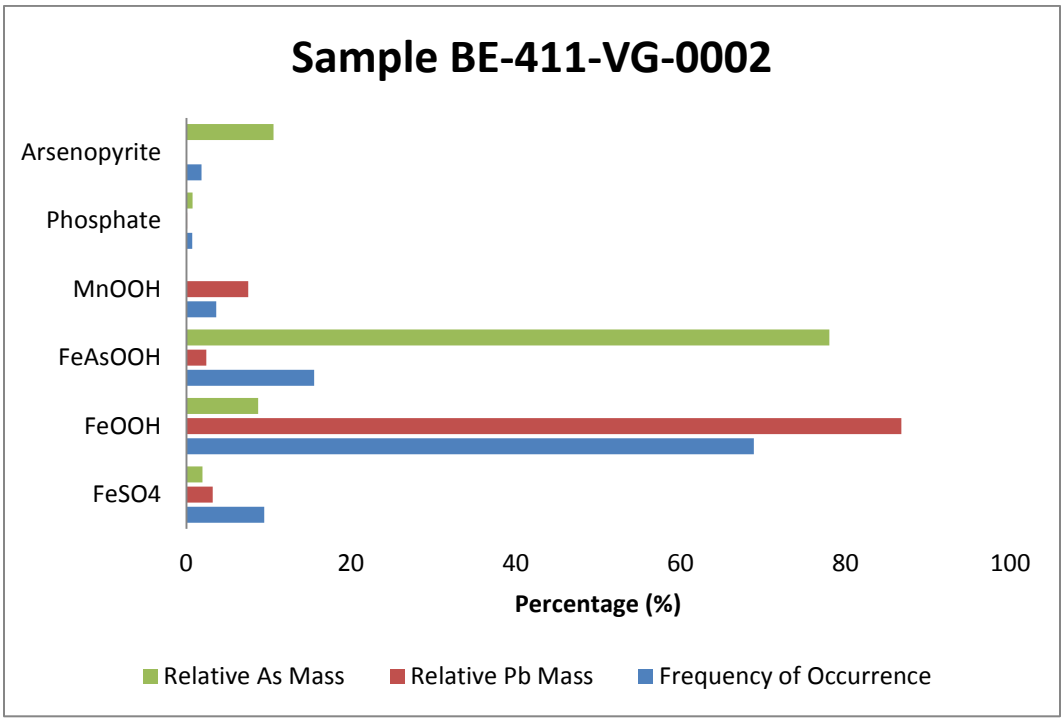


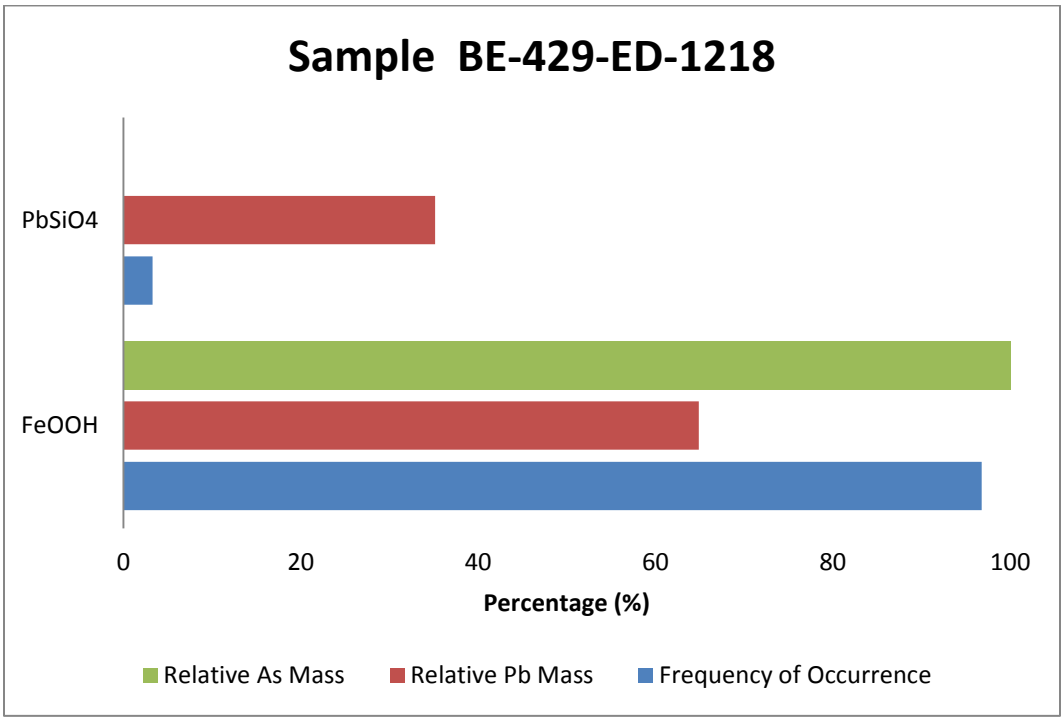
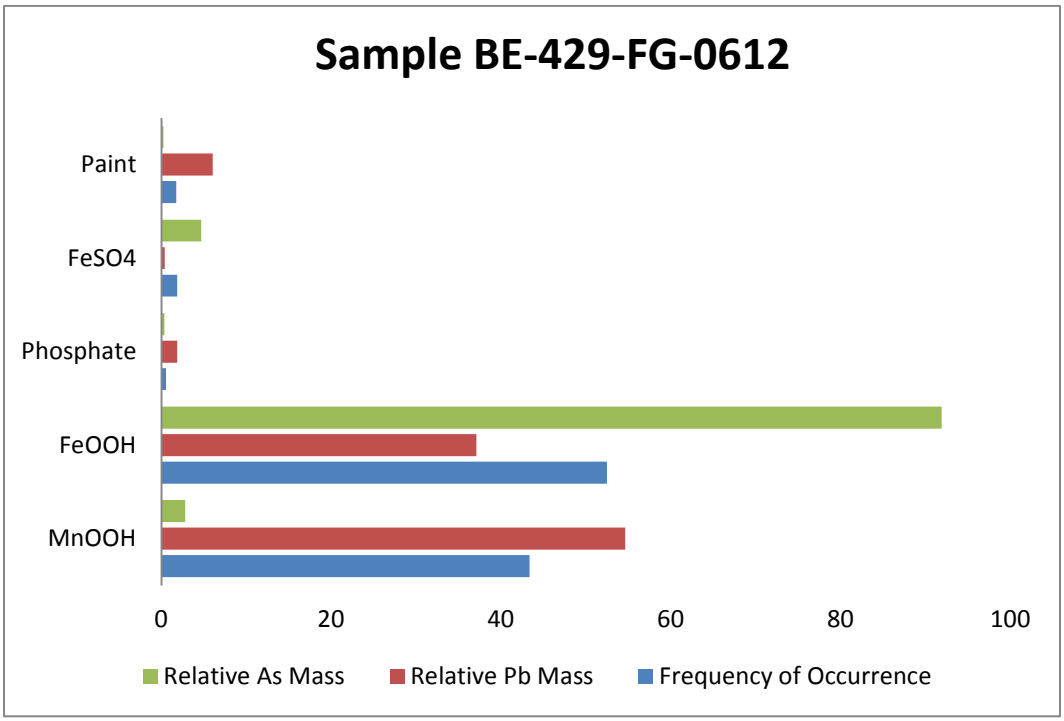


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



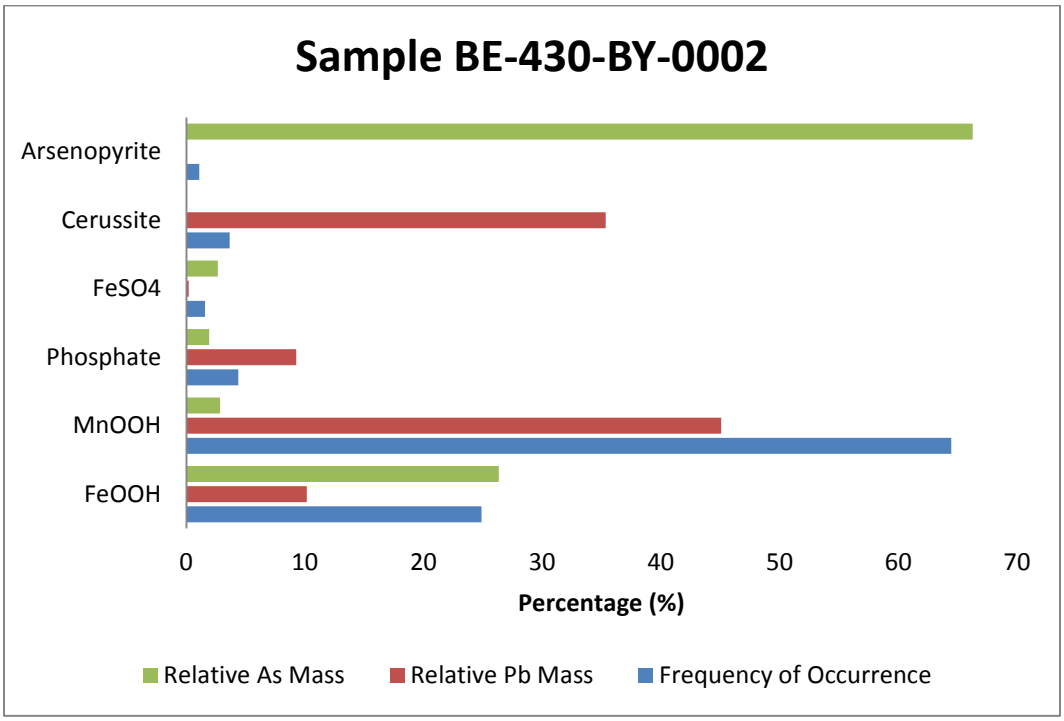
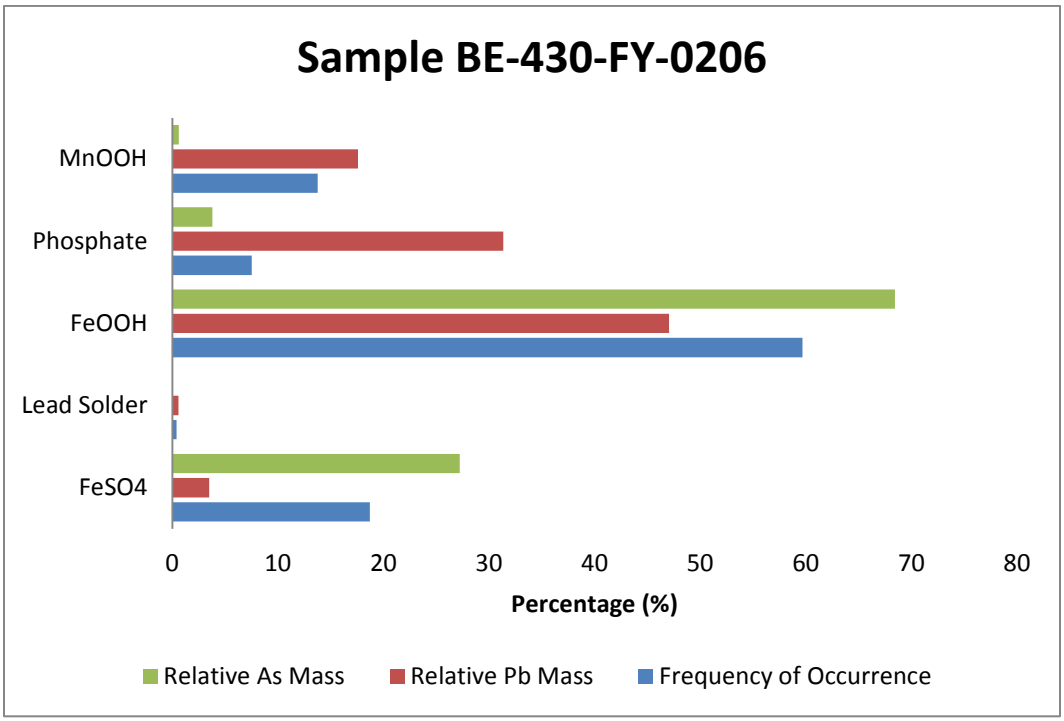


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



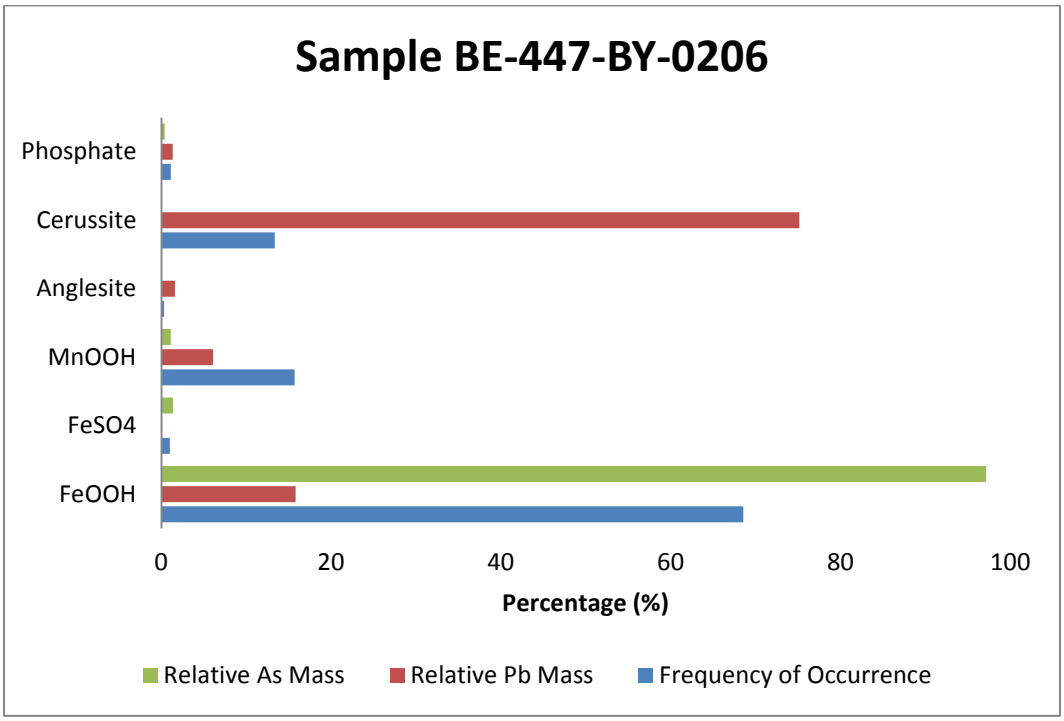
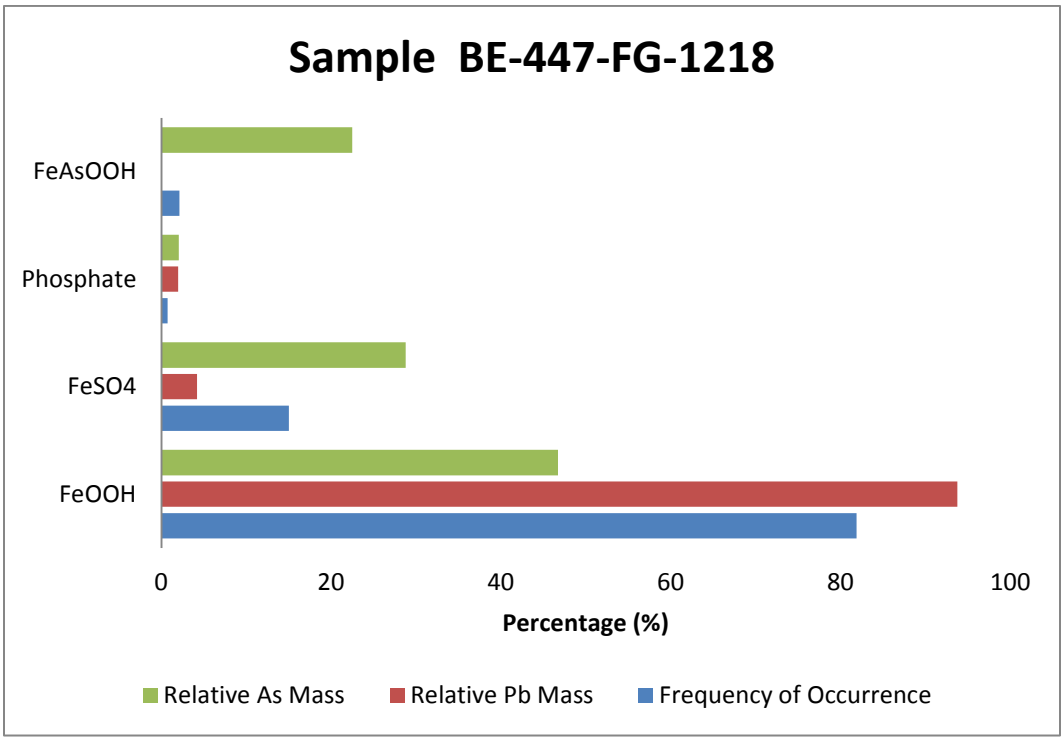


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



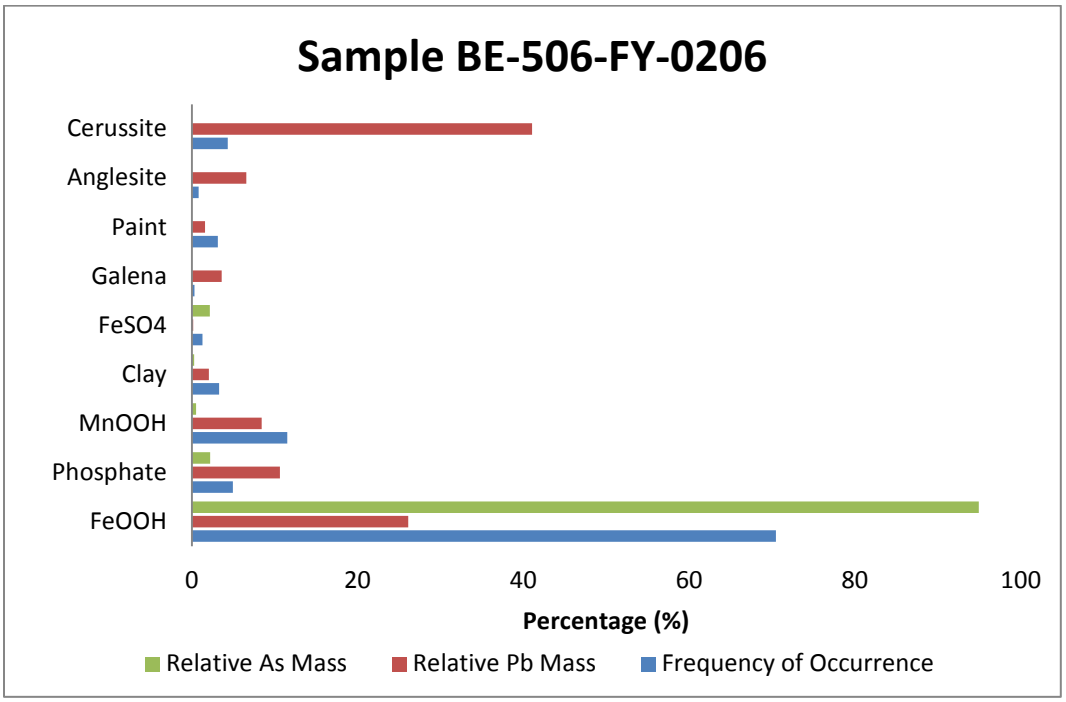
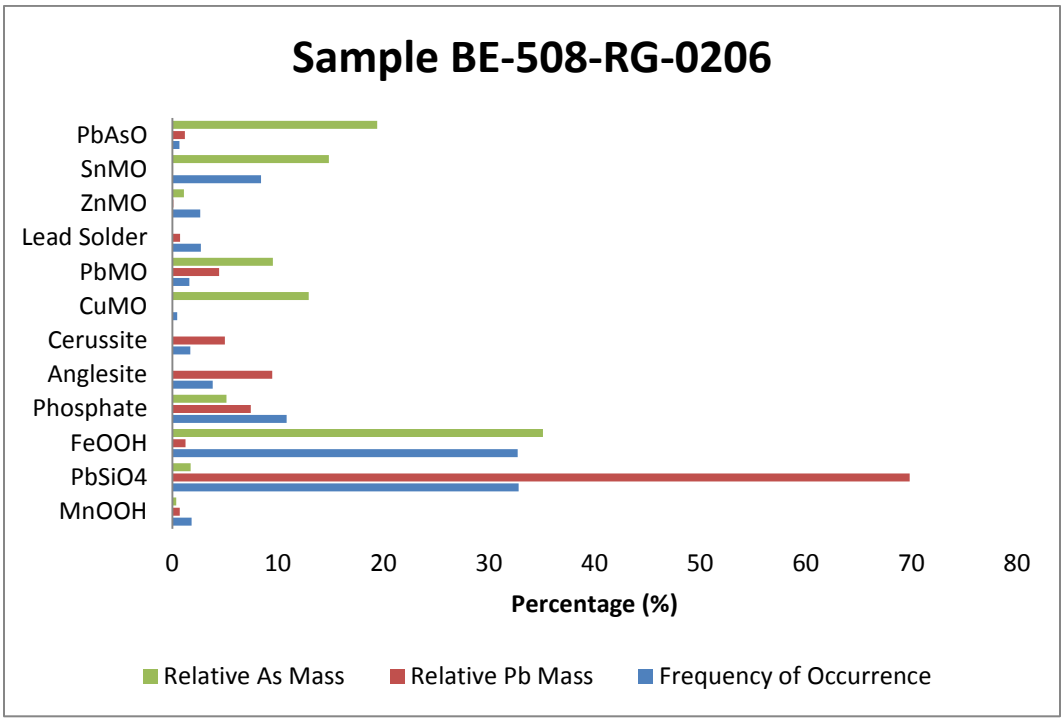


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



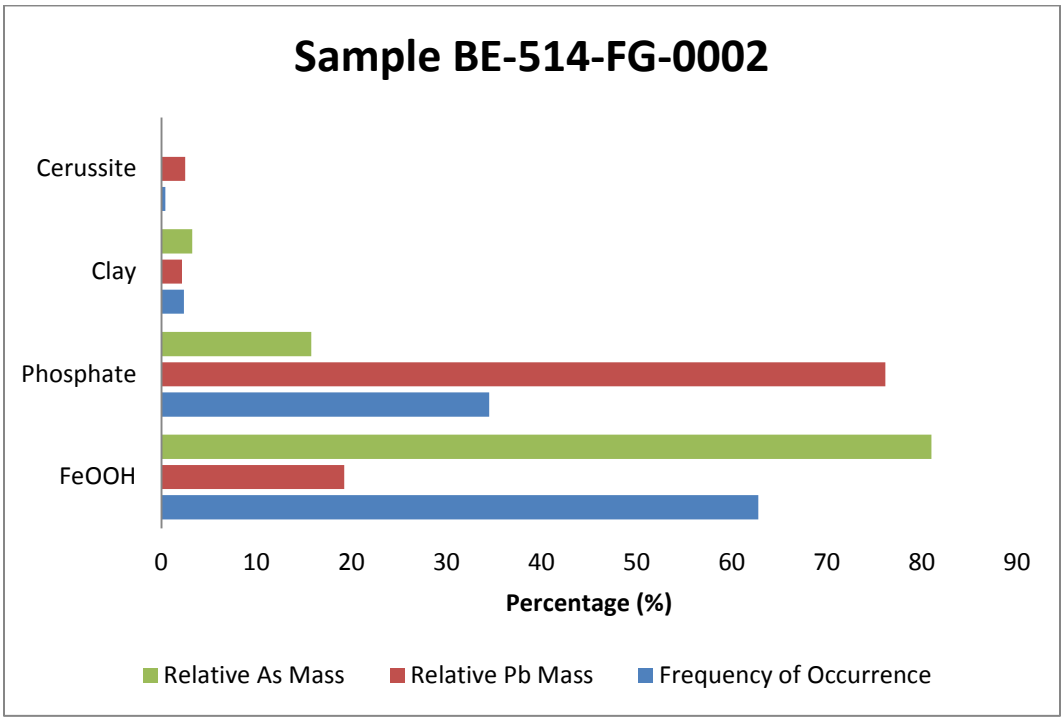
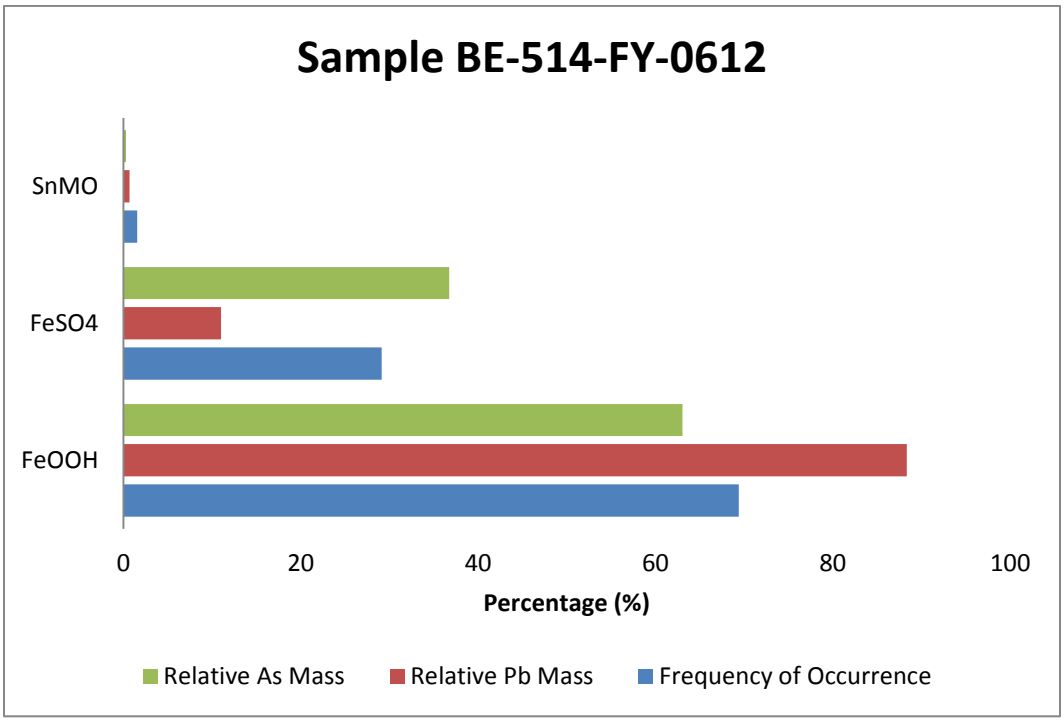


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



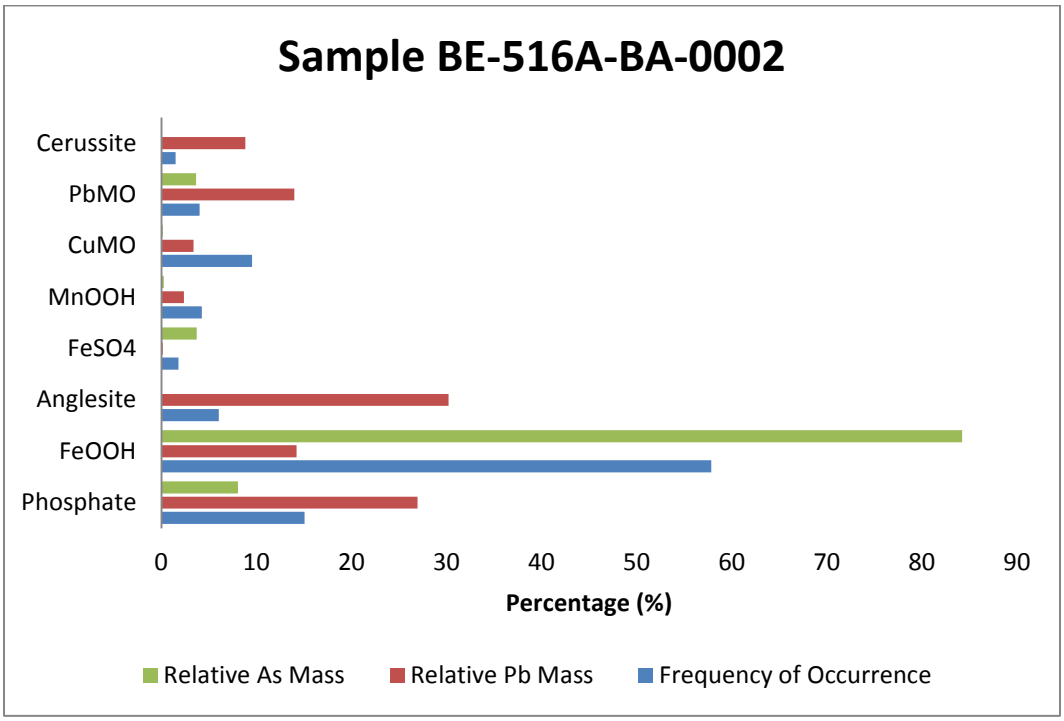
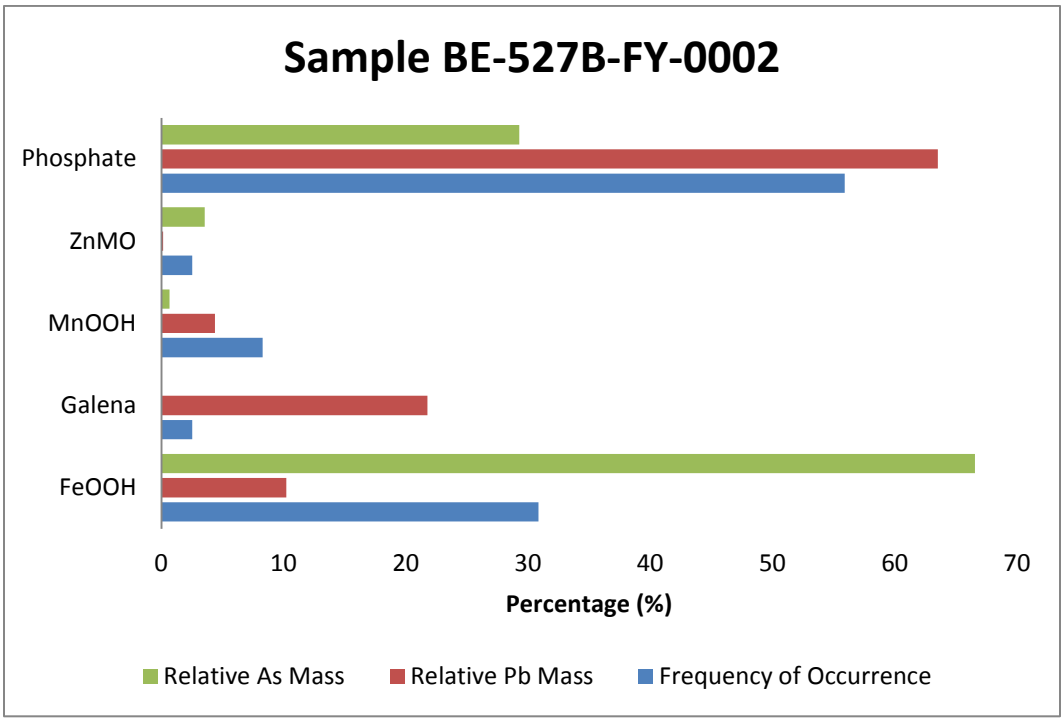


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)



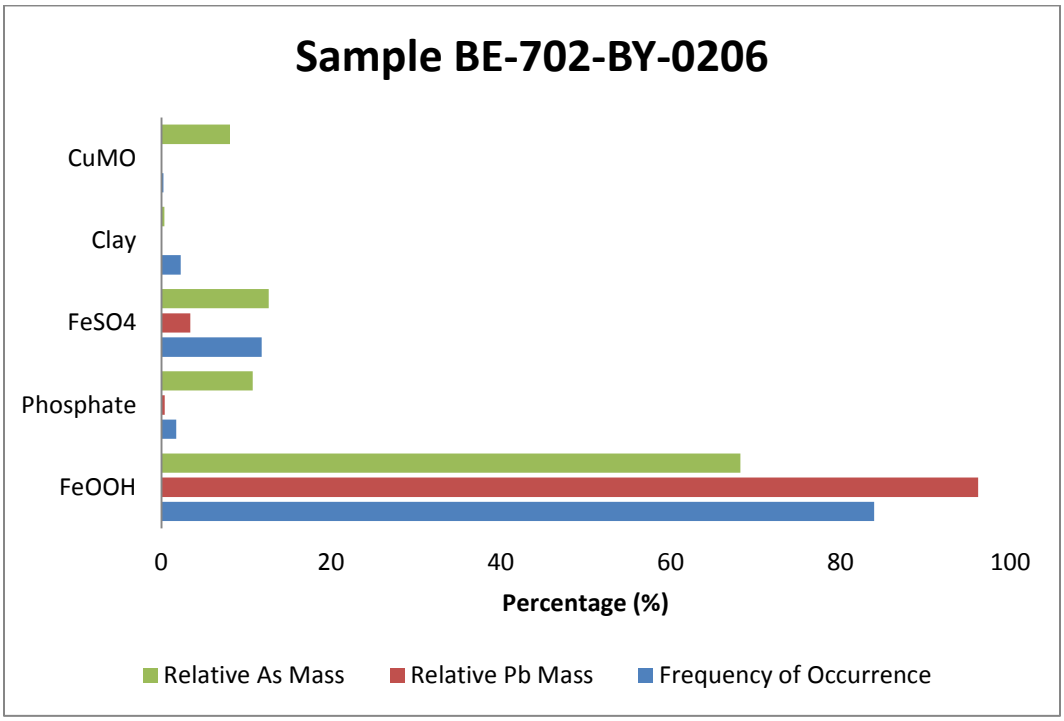


Figure 5. Histograms of Relative Mass of Lead and Arsenic and Frequency of Occurrence (continued)

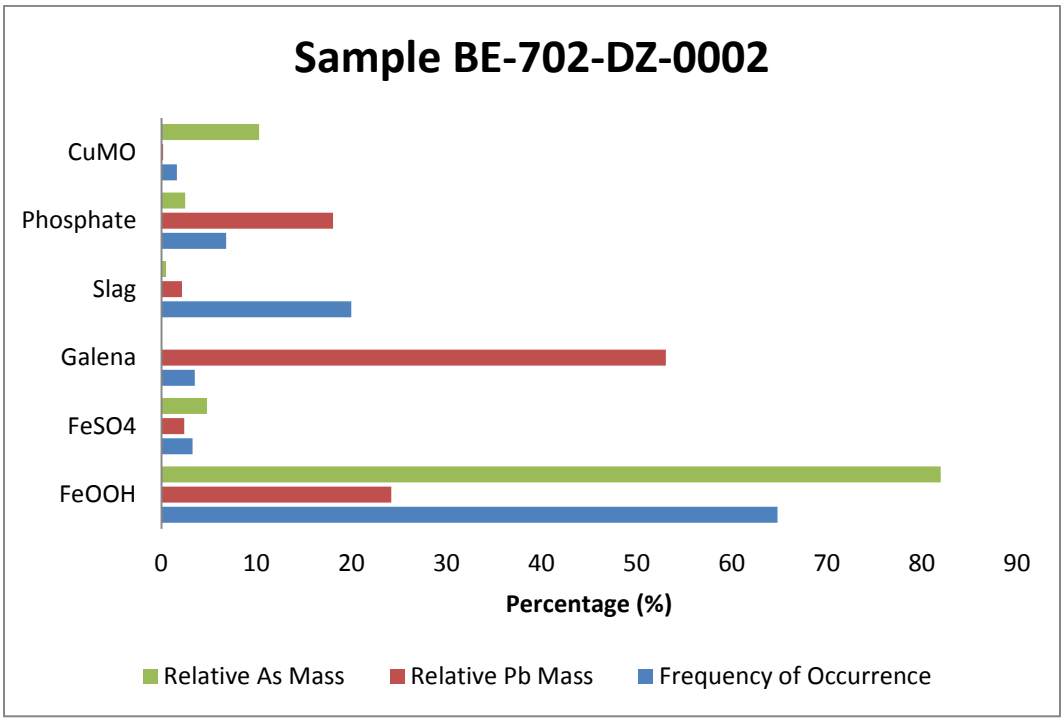


Figure 6a. Relative Lead Bioavailability versus Relative Lead Mass in FeOOH

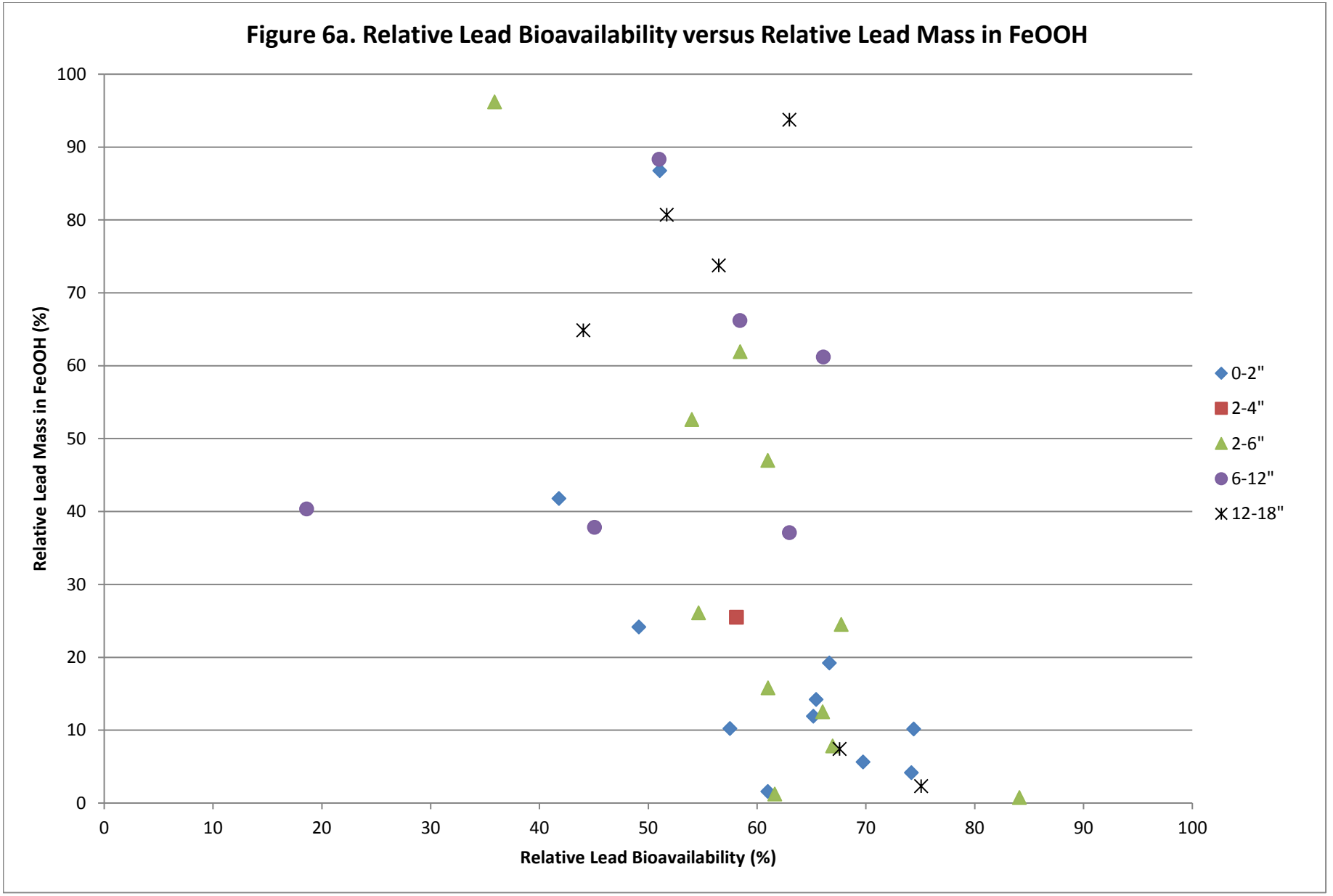


Figure 6b. Relative Lead Bioavailability versus Relative Lead Mass in Highly Bioavailable Phases except FeOOH

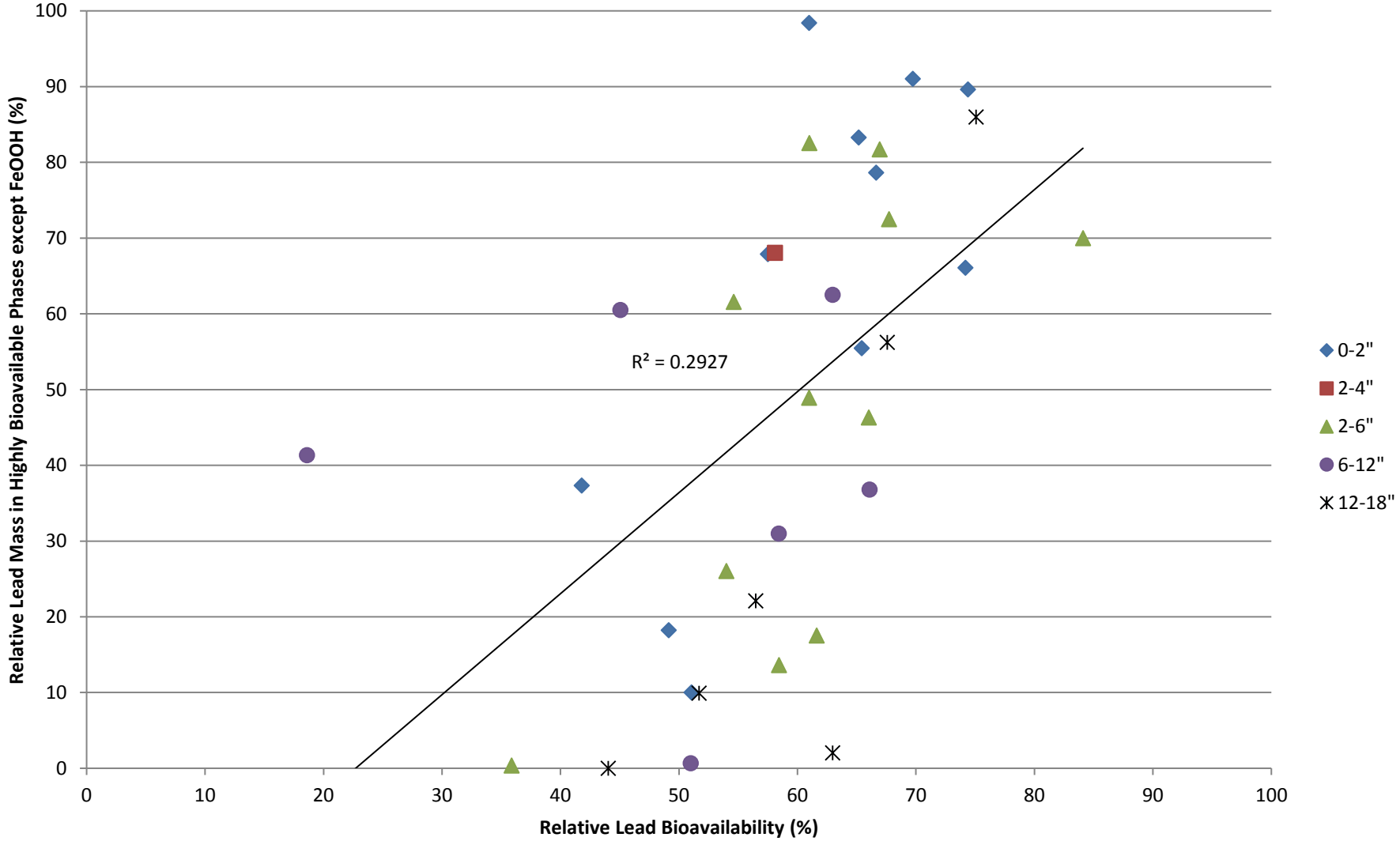


Figure 6c. Relative Arsenic Bioavailability versus Relative Arsenic Mass in FeOOH

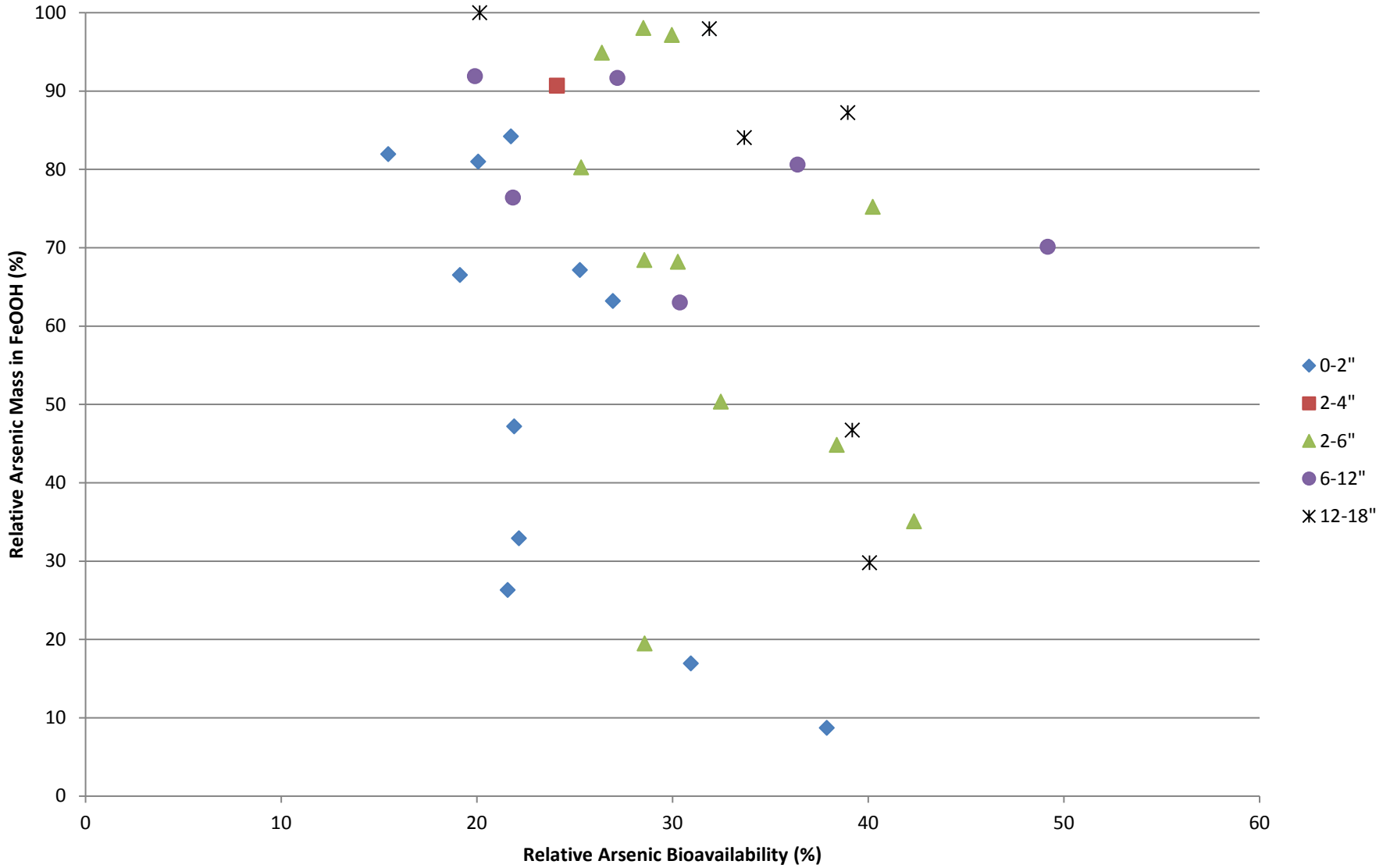
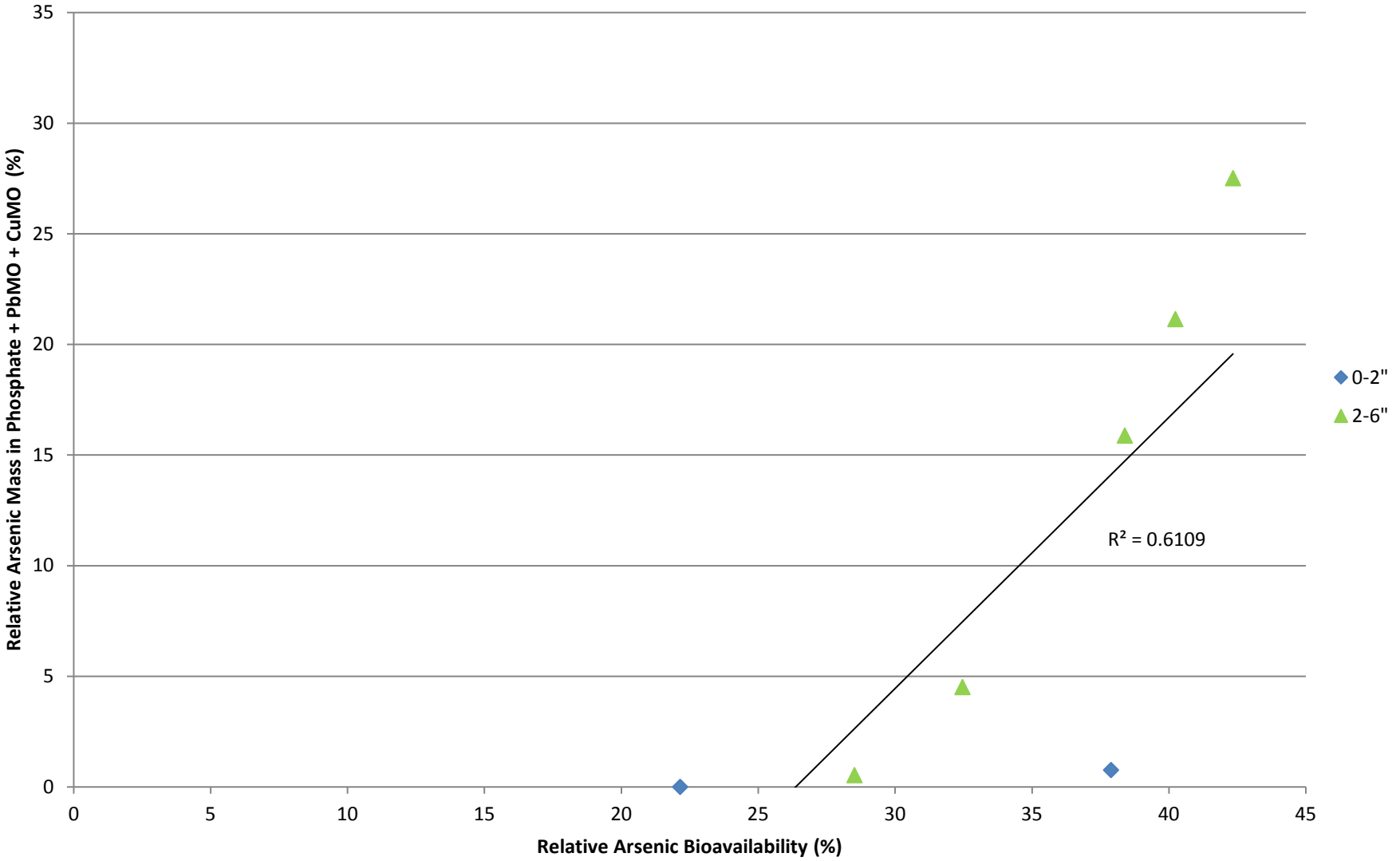


Figure 6d. Relative Arsenic Bioavailability versus Relative Arsenic Mass in Phosphate + PbMO + CuMO (Depths of 0-6 inches bgs)



APPENDIX C
PARTICULATE EMISSIONS FACTOR CALCULATIONS

Unit Acronyms

g:	grams
g/m^2-s:	grams per square meter per second
kg/m^3:	kilograms per cubic meter
km:	kilometers
m/s:	meters per second
m^2:	square meters
mg/m^3:	milligrams per cubic meter

References

USEPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. US Environmental Protection Agency, Office of Soil Waste and Emergency Response. December.

Ramboll Environ. 2015. Final Baseline Human Health Risk Assessment. ACM Smelter and Refinery Site Operable Unit 1. Prepared for Atlantic Richfield Company, Butte, Montana, by Ramboll Environ, Seattle, Washington. October.

Wind-driven Particulate Emissions Factor (PEF) Derivation

Wind-driven PEF (USEPA 2002, Equation 4-5)

$$PEF\ (kg/m^3) = \frac{1}{Q/C \times \left(\frac{3600}{0.036 \times (1-V) \times (U_m/U_t)^3 \times F(x)}\right)}$$

Where:

Q/C = Inverse of the ratio of the geometric mean air concentration to the wind emission flux at the center of a square source (g/m^2- s per kg/m^3; see below for equation and values by area)

V = Fraction of vegetative cover (unitless; see Ramboll Environ 2015, Table 3)

U_m = Mean annual wind speed for Casper, Wyoming (5.77 m/s)

U_t = Equivalent threshold value of windspeed at 7 meters for Casper, Wyoming (11.32 m/s)

F(x) = Function dependent on U_m/U_t for Casper, Wyoming (0.57, unitless)

Dispersion Factor Q/C (USEPA 2002, Equation D-1)

$$Q/C\ \left(g/m^2 - s\ per\ \ kg/m^3\right) = A\ \times \exp\left[\frac{(lnA_{site} - B)^2}{C}\right]$$

Where:

A = Constant from USEPA 2002, Exhibit E-3 - Casper, Wyoming (7.1414, unitless)

A_{site} = Site area (acres; see Ramboll Environ 2015, Table 3)

B = Constant from USEPA 2002, Exhibit E-3 - Casper, Wyoming (31.1794, unitless)

C = Constant from USEPA 2002, Exhibit E-3 - Casper, Wyoming (382.6078, unitless)

Wind-driven Q/C values for each area

Area	Q/C (g/m^2- s per kg/m^3)
Northern CSAOI (0-2 inches)	46.65078579
Southern CSAOI (0-2 inches)	42.2060454
Northern Outlying Area (0-2 inches)	36.40978501
Southern Outlying Area (0-2 inches)	36.40978501
ECDR (0-18 inches)	49.78729123

Unpaved Road Particulate Emissions Factor (PEF) Derivation

Unpaved Road Traffic PEF (Adapted from USEPA 2002, Equation 5-9)

$$PEF\ (kg/m^3) = \frac{J'_T}{Q/C}$$

Where:

J'_T = total time-averaged emission flux (1.29E-05 g/m^2-s; see equation below)

Q/C = inverse of ratio of the geometric mean air concentration to the emission flux at the boundary of a square source (134 g/m^2 per kg/m^3; see equation below)

Total Time-averaged Emission Flux (Adapted from USEPA 2002, Equation 5-9)

$$J'_T\left(g/m^2 - s\right) = \frac{M_{road}}{A_{site} \times ED}$$

Where:

M_{road} = unit mass emitted from unpaved road traffic (8.5E+05 g; see equation below)

A_{site} = Site area (2,023 m^2; see note below)

ED = Exposure duration (1 year, converted to 3.2E+07 seconds)

Mass of Dust Emitted from Road Traffic (USEPA 2002, Equation 5-10)

$$M_{road}(g) = 556\ \times\ (W/3)^{0.4} \times\ [(365 - p)/365] \times \Sigma VKT$$

Where:

W = Mean vehicle weight (1.8 tons)

p = Days per year with at least 0.01 inches of precipitation (97 days/year)

ΣVKT = Vehicle kilometers traveled (2,462 km; 15 cars per day across 0.45 km of road per year)

Dispersion Factor Q/C (USEPA 2002, Equation E-30)

$$Q/C\ \left(g/m^2 - s\ per\ \ kg/m^3\right) = A\ \times \exp\left[\frac{(lnA_{site} - B)^2}{C}\right]$$

Where:

A = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (18.4275, unitless)

A_{site} = Site area (0.5 acres; see note below)

B = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (22.9015, unitless)

C = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (280.6949, unitless)

Vehicle Assumptions

Type	Vehicles per Day	Tons per Vehicle
Cars	5	1.5
Sport Utility Vehicles/Pickup Trucks	10	2

Note:

PEF equations valid for minimum 0.5 acre (2,023 m^2) site. Average unpaved road width in southern Community Soils Area of Interest is 4.5 meters, resulting in an assumed road segment length of 450 meters. This overestimates the actual length of unpaved road segments adjacent to individual residential properties.

Excavation Particulate Emissions Factor (PEF) Derivation

PEF for Excavation Worker (USEPA 2002, Equation E-26)

$$PEF\ (kg/m^3) = \frac{J'_T \times F_D}{Q/C}$$

Where:

J'_T = Total time-averaged PM10 unit emission flux for construction activities other than traffic on unpaved roads (8.30E-05 g/m^2-s; see equation below)

Q/C = Inverse of the ratio of the 1-hour geometric mean air concentration and the emission flux at the center of the square emission source (14.3 g/m^2-s per kg/m^3; see equation below)

F_D = Dispersion correction factor (0.185; unitless)

Total Time-Averaged Emission Factor (Adapted from USEPA 2002, Equation E-25)

$$J'_T\ (g/m^2 - s) = \frac{M_{excav} + M_{wind}}{A_c \times T}$$

Where:

M_{excav} = Unit mass emitted from excavation soil dumping (180 g; see equation below)

M_{wind} = Unit mass emitted from wind erosion (48,168 g; see equation below)

A_c = Areal extent of site soil contamination (2,023 m^2; see note below)

T = Duration of construction (10 days/year for 8 hours/day, converted to 2.9E+05 seconds)

Unit Mass Emitted from Dumping of Excavated Soils (USEPA 2002, Equation E-21)

$$M_{excav}(g) = 0.35 \times 0.0016 \times \frac{(U_m/2.2)^{1.3}}{(M/2)^{1.4}} \times \rho_{soil} \times A_{excav} \times d_{excav} \times N_A \times 10^3$$

Where:

U_m = Mean windspeed during construction for Casper, Wyoming (5.77 m/s)

M = Gravimetric soil moisture content (12 percent, default)

ρ_{soil} = In situ soil density (1.68 mg/m^3, default)

A_{excav} = Areal extent of excavation (224 m^2; see note below)

d_{excav} = Average depth of excavation (1.5 m)

N_A = Number of times soil is dumped (2 times; based on assumed scope and duration of work)

Unit Mass Emitted from Wind Erosion (USEPA 2002, Equation E-20)

$$M_{wind}(g) = 0.036 \times (1 - V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x) \times A_{surf} \times ED \times 8{,}760\ hr/yr$$

Where:

V = Fraction of vegetative cover (unitless; see Ramboll Environ 2015, Table 3)

U_m = Mean annual wind speed for Casper, Wyoming (5.77 m/s)

U_t = Equivalent threshold value of windspeed at 7 m for Casper, Wyoming (11.32 m/s)

F(x) = Function dependent on U_m/U_t for Casper, Wyoming (0.57, unitless)

A_{surf} = Areal extent of site with surface soil contamination (2,023 m^2; see note below)

ED = Exposure Duration (1 year)

Note:

PEF equations valid for minimum 0.5 acre (2,023 m^2) contaminated site. Excavation area assumed to be 2 meters wide and the length of the average unpaved road (112 meters).

Excavation Particulate Emissions Factor (PEF) Derivation

Dispersion Factor Q/C (USEPA 2002, Equation E-15)

$$Q/C\left(g/m^2 - s\ per\ \ kg/m^3\right) = A\ \times \exp\left[\frac{(lnA_{site} - B)^2}{C}\right]$$

Where:

A = Constant from USEPA 2002, Equation E-15 (2.4538, unitless)

A_{site} = Site area (0.5 acres)

B = Constant from USEPA 2002, Equation E-15 (17.566, unitless)

C = Constant from USEPA 2002, Equation E-15 (189.0426, unitless)

ATV / Dirt Bike Particulate Emissions Factor (PEF) Derivation

Unpaved Road Traffic PEF (USEPA 2002, Equation 5-9)

$$PEF\ (kg/m^3) = \frac{J'_T}{Q/C}$$

Where:

- J'_T = total time-averaged emission flux (4.0E-05 g/m^2-s; see equation below)
- Q/C = inverse of ratio of the geometric mean air concentration to the emission flux at the boundary of a square source (66.4 g/m^2-s per kg/m^3; see equation below)

Total Time-averaged Emission Factor (Adapted from USEPA 2002, Equation 5-9)

$$J'_T\left(g/m^2 - s\right) = \frac{M_{road}}{A_{site} \times ED}$$

Where:

- M_{road} = unit mass emitted from unpaved road traffic (4.7E+06 g; see equation below)
- A_{site} = Site area (206,390 m^2; approximate area of Electric City Dirt Riders property)
- ED = Exposure duration (1 year for 52 days/year, 3 hours/day, converted to 5.6E+05 seconds)

Mass of Dust Emitted from Road Traffic (USEPA 2002, Equation 5-10)

$$M_{road}(g) = 556\ \times\ (W/3)^{0.4} \times\ [(365 - p)/365] \times \Sigma VKT$$

Where:

- W = Mean vehicle weight (0.15 tons)
- p = Days per year with at least 0.01 inches of precipitation (97 days/year)
- ΣVKT = Sum of vehicle kilometers traveled (37,440 km; assumed distance 10 riders can travel during 3 hours/day, 52 days/year, at a speed of 24 km/hr)

Dispersion Factor Q/C (USEPA 2002, Equation E-30)

$$Q/C\ \left(g/m^2 - s\ per\ \ kg/m^3\right) = A\ \times \exp\left[\frac{(lnA_{site} - B)^2}{C}\right]$$

Where:

- A = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (18.4275, unitless)
- A_{site} = Site area (51 acres; approximate area of Electric City Dirt Riders property)
- B = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (22.9015, unitless)
- C = Constant from USEPA 2002, Exhibit E-5 - Casper, Wyoming (280.6949, unitless)

APPENDIX D
IEUBK MODEL SCREEN SHOTS

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Air Data

Indoor air lead concentration (percentage of outdoor): 30

Outdoor Air Pb Concentration (µg/m³):

- (•) Constant Value: 0.1
- ( ) Variable Values

OK | Cancel | Reset | Help?

Input for different age groups

	AGE (Years)						
	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Air Pb Concentration (µg/m³):	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Time Spent Outdoors (hr/day):	1	2	3	4	4	4	4
Ventilation Rate (m³/day):	2	3	5	5	5	7	7
Lung Absorption (%):	32	32	32	32	32	32	32

TRW Homepage: http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Dietary Data

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Dietary Lead Intake (µg/day)	2.26	1.96	2.13	2.04	1.95	2.05	2.22

OK
Cancel
Reset
Help?

DIETARY VALUES

Use alternate dietary values? (•) No ( ) Yes

	Concentration (µg Pb/g)	Percent of Food Class	
Home Grown Fruits	0	0	(% of all fruits)
Home Grown Vegetables	0	0	(% of all vegetables)
Fish from Fishing	0	0	(% of all meat)
Game Animals from Hunting	0	0	(% of all meat)

GI Values / Bioavailability

GI / Bio Change Values

TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Run Multi Find Batch D M

Drinking Water Data

Water Consumption (L/day)

AGE (Years)

0-1	1-2	2-3	3-4	4-5	5-6	6-7
0.2	0.5	0.52	0.53	0.55	0.58	0.59

OK
Cancel
Reset
Help?

Use alternate water values?

(•) No If No, please enter the lead concentration in drinking water (µg/L): 4

( ) Yes If Yes, please fill in the information below.

LEAD CONCENTRATION IN DRINKING WATER

Percent of Total Consumed as First Draw:	50
Concentration of Lead in First Draw (µg/L):	4
Concentration of Lead in Flushed (µg/L):	1
Percentage of Total Consumed from Fountains:	15
Concentration of Lead in Fountain Water (µg/L):	10

GI Values / Bioavailability

GI / Bio Change Values

TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Maternal Data

Mother's Blood Lead Concentration at Childbirth (µg Pb/dL): 0.8

OK

Cancel

Reset

Help?

TRW Homepage:
http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Run Find Multi Batch

GI Values/Bioavailability Information

MEDIA	ABSORPTION FRACTION PERCENT
Soil	29.5
Dust	29.5
Water	50
Diet	50
Alternate	0

Access alternate bioavailability parameters? No Yes

FRACTION PASSIVE/ TOTAL ACCESSIBLE: 0.2

HALF SATURATION Level (µg/day): 100

OK

Cancel

Reset

Help?

TRW Homepage: http://www.epa.gov/superfund/health/contaminants/lead/index.htm

NCSAOI using alternate ingestion rates

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 92.7
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set

Multiple Source Avg: 46.153

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	92.7	92.7	92.7	92.7	92.7	92.7	92.7
Indoor Dust Lead Levels:	46.153	46.153	46.153	46.153	46.153	46.153	46.153

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.086	0.094	0.067	0.063	0.067	0.052	0.055

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

NCSAOI using default ingestion rates

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 92.7
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set

Multiple Source Avg: 46.153

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years)						
	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	92.7	92.7	92.7	92.7	92.7	92.7	92.7
Indoor Dust Lead Levels:	46.153	46.153	46.153	46.153	46.153	46.153	46.153

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years)						
	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.085	0.135	0.135	0.135	0.100	0.090	0.085

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm

SCSAOI using alternate ingestion rates

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 203
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set

Multiple Source Avg: 89.17

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	203	203	203	203	203	203	203
Indoor Dust Lead Levels:	89.17	89.17	89.17	89.17	89.17	89.17	89.17

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.086	0.094	0.067	0.063	0.067	0.052	0.055

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

SCSAOI using default ingestion rates

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 203
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set
- Multiple Source Avg: 89.17

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	203	203	203	203	203	203	203
Indoor Dust Lead Levels:	89.17	89.17	89.17	89.17	89.17	89.17	89.17

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.085	0.135	0.135	0.135	0.100	0.090	0.085

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Run Find Multi Batch

Great Falls using alternate ingestion rates

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 103
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set

Multiple Source Avg: 50.17

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	103	103	103	103	103	103	103
Indoor Dust Lead Levels:	50.17	50.17	50.17	50.17	50.17	50.17	50.17

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.086	0.094	0.067	0.063	0.067	0.052	0.055

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm

IEUBKwin32 Lead Model Version 1.1 Build11

File Start View Parameter Input Computation Output Graph Help

Open Save Reset Air Diet Water Soil/Dust Maternal Alternate GI/Bio Run Multiple Blood vs. Media Find Batch

Great Falls using default ingestion rates

Site Specific Soil Dust Data

Soil/Dust Ingestion Weighting Factor (percent soil): 45

OK Cancel Reset Help?

Outdoor Soil Lead Concentration (µg/g)

- (•) Constant Value 103
- ( ) Variable Values

Indoor Dust Lead Concentration (µg/g)

- ( ) Constant Value 200
- ( ) Variable Values
- (•) Multiple Source Analysis Set

Multiple Source Avg: 50.17

Soil/Indoor Dust Concentration (µg/g)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Outdoor Soil Lead Levels:	103	103	103	103	103	103	103
Indoor Dust Lead Levels:	50.17	50.17	50.17	50.17	50.17	50.17	50.17

Amount of Soil/Dust Ingested Daily (g/day)

	AGE (Years) 0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total Dust + Soil Intake:	0.085	0.135	0.135	0.135	0.100	0.090	0.085

GI Values/Bioavailability

GI / Bio Change Values

TRW Homepage:

http://www.epa.gov/superfund/health/contaminants/lead/index.htm