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April 24, 2015

Electronically Delivered

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**Re: Review of Response to Comments, Voluntary Remediation Program
Baseline Human Health Risk Assessment Work Plan, Freeport-
McMoRan Sierrita Mine Green Valley, Arizona; Site Code: 100073-03**

Dear Ms. Taber:

This letter has been prepared in response to the Arizona Department Environmental Quality (ADEQ) February 19, 2015 letter (Letter) regarding Freeport-McMoRan Sierrita Inc.'s (Sierrita) Voluntary Remediation Program Baseline Human Health Risk Assessment Work Plan (Work Plan) submitted to ADEQ in February 2013. Comments from the Letter are reproduced below in italics, followed by Sierrita's response to each comment. As recommended by ADEQ, Sierrita has revised the BHHRA Work Plan to address the comments made by ADEQ in the November 18, 2014 and the February 19, 2015 letters and that document is included herein.

General Comments

Comment #4:

The VRP acknowledges Sierrita's response; however, if Sierrita determines that a probabilistic risk assessment (PRA) is warranted, the VRP requests for Sierrita to submit a technical memorandum outlining PRA methods and assumptions 90 days prior to submittal of the draft Baseline Human Health Risk Assessment (BHHRA) to the VRP for review and consensus.

Sierrita Response: In the event a probabilistic risk assessment (PRA) is warranted, Sierrita will submit to the VRP for review, at least 90 days before submittal of the BHHRA, a technical memorandum outlining the proposed PRA methods and assumptions to be used in the BHHRA report.

Comment #7:

The VRP acknowledges Sierrita's response; however, the comment was intended to obtain information on the current use and the amount and type of vegetation at the former location of the Rhenium Ponds. Please provide.

Sierrita Response: The former Rhenium Ponds location is vacant and no activities occur at the area. In 1999, the area was capped with 12 inches of growth medium and seeded with native grasses. Following the seeding, native vegetation typical of the Arizona Upland/Eastern Sonoran Basins ecoregion (e.g., grama

grasses, creosote bush, bursage) established itself in the former Rhenium Ponds area. Currently, the area continues to be unoccupied, with no buildings or workers, and native vegetation re-established.

Comment #10:

The VRP acknowledges Sierrita's response; however please revise Section 3.0 to make clear that the chemicals of potential concern (COPCs) discussed in this section were identified as such in previous investigations but are not necessarily COPCs for the risk assessment that is to be prepared under this work plan. Also, please indicate in Section 3.0 that the issue of which COPCs are appropriate for the risk assessment will be revisited and that COPCs will be identified for the risk assessment as discussed in Section 4.3 of the work plan.

Sierrita Response: Section 3 of the BHHRA Work Plan has been revised to clarify that the chemicals of potential concern (COPCs) discussed in Section 3 were identified as COPCs in previous site investigation reports and therefore may not necessarily be identified as BHHRA COPCs following the COPC selection process that is presented in Section 4.3 of the Work Plan.

Comment #12:

The VRP understands that Section 3.0 of the BHHRA work plan describes previous investigations and that this information will be updated for the risk assessment, however, groundwater investigations are described without providing a connection between these investigations and the risk assessment. If groundwater will not be evaluated in the risk assessment, then provide a discussion as to why groundwater will not be evaluated in the risk assessment.

Sierrita Response: The scope of the BHHRA is to address soil and sediments (0 to 15 ft bgs), and as such, groundwater will not be assessed in the BHHRA. As discussed in Section 5.1.1.4.2 of the BHHRA Work Plan, groundwater is not an exposure medium for the receptors identified in the work plan because none of the constituents of interest in groundwater are volatile, and because groundwater is not currently being used at the site, nor is it expected to be used as a potable source in the future. Therefore, there are no complete exposure pathways to groundwater and it will not be evaluated in the BHHRA.

The potential exposure pathway that involves leaching of COPCs from soil and sediments to groundwater was partially addressed in the Soil and Sediment Characterization Report (SSCR), and summarized in the Data Gaps Work Plan submitted to ADEQ in November 2014. Supplemental data collection was proposed to address the potential antimony leaching pathway from soil to groundwater. The soil-to-groundwater leaching pathway will be fully evaluated once supplemental data is collected under the Data Gaps Work Plan (ARCADIS, 2014); therefore, it will not be further addressed in the BHHRA.

Comment #17:

As noted in Sierrita's response, please direct the VRP to the discussion of method detection limits that appear, "elsewhere in the Work Plan".

Sierrita Response: The BHHRA Work Plan has been revised to refer to Section 4.2.2 (Treatment of COIs Not Detected) for a discussion of how detection limits will be treated in the risk calculations.

Comment #19:

As discussed in Section 4.5.2 of the Quality Assurance Project Plan - Addendum prepared by URS, dated April 2008:

"A field duplicate is a second discrete sample volume collected at the same location as the original sample; homogenization is not performed between the original sample and the field duplicate ... The sample containers are assigned an identification number in the field such that they cannot be identified (blind duplicate) as duplicate samples by laboratory personnel performing the analysis."

Since the quality assurance project plan stipulated that the field duplicate would be submitted to the laboratory as a blind sample, it would be considered a quality control sample. The duplicates were intended to be quality control samples of the parent sample not samples intended to characterize the site. Therefore, the duplicate should not be used to replace the parent sample nor should the duplicate be averaged with the parent sample. The duplicate and parent samples should stand on their own for the purpose intended, i.e., the parent was intended to characterize the site and the duplicate was intended to address the quality of the parent.

Sierrita Response: Sierrita will use only the parent sample result to characterize conditions at the site. The duplicate sample result will not be used to replace the parent sample result nor will it be averaged with the parent sample result.

Comment #20:

See response to Comment 19. Parent and duplicate samples are not interchangeable. A parent sample with a higher detection limit does not necessarily have to be used in the quantification of risk. Such a sample can be omitted from the quantification as long as some discussion is provided to explain the handling of that sample. Therefore, a duplicate sample with a lower detection limit should not be used to replace a parent sample with a higher detection limit.

Sierrita Response: See response to Comment #19. Sierrita will defer to the parent sample as requested under Comment #19; however, in rare cases where there may be an elevated detection limit, Sierrita will carefully consider the use of a duplicate analysis if there are better detection limits and provide documentation if such a substitution is implemented for the analysis.

Comment #21:

See response to Comment 19. Parent and duplicate samples are not interchangeable. The parent sample should be handled as the result for that location whether a chemical of concern is detected in that sample or not and regardless of the analytical result for the duplicate. As discussed in the response to Comment 19, the duplicate sample addresses the quality of the parent; the duplicate should not be used to replace the parent.

Sierrita Response: See response to Comment #19.

Comment #34:

The VRP requests Sierrita provide a citation for site use factor (SUF). Since the SUF is typically "1", provide an explanation as to why Sierrita has chosen to utilize this factor in the risk assessment.


Sierrita Response: During development of the BHHRA Work Plan, the SUF was included in the algorithms for potential application in the event that the receptor exposure dose could be influenced by use/non-use of an area for work activities or influenced by seasonality (weather) considerations. However, after further

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review, the site use factor is expected to be 1 for the exposure pathways identified in the BHHRA Work Plan, and therefore the SUF has been omitted from the algorithms in the work plan.

Please do not hesitate to contact me if there are further comments or questions on the BHHRA Work Plan. Sierrita looks forward to ADEQ's approval of the work plan, and submitting a BHHRA report in the future.

Sincerely,



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**VOLUNTARY REMEDIATION
PROGRAM**

**BASELINE HUMAN HEALTH RISK
ASSESSMENT WORK PLAN**

Sierrita Mine
Green Valley, Arizona

February 1, 2013, Revised April 24, 2015



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**Baseline Human Health Risk
Assessment Work Plan**

Sierrita Mine
Green Valley, Arizona

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February 1, 2013, Revised April 24, 2015

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1-1	Site Location
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5-1	Human Health Conceptual Site Model

Acronyms and Abbreviations

ADD	average daily dose
ARCADIS	ARCADIS U.S., Inc.
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ALM	Adult Lead Methodology
amsl	above mean sea level
ATSDR	Agency for Toxic Substance and Disease Registry
bgs	below ground surface
BHHRA	baseline human health risk assessment
CalEPA	California Environmental Protection Agency
cm ² /day	square centimeter(s) per day
COI	constituent of interest
COPC	constituent of potential concern
cRfC	chronic reference concentration
cRfD	chronic reference dose
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency estimate
EA	exposure area
EC	exposure concentration
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
FCX	Freeport McMoRan Copper & Gold Inc.
ft	foot/feet
FS	feasibility study
GPL	Groundwater Protection Level

HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
kg	kilogram(s)
kg/mg	kilogram(s) per milligram
LADD	lifetime average daily dose
m ³ /kg	cubic meter(s) per kilogram
MDL	method detection limit
mg/cm ²	milligram(s) per square centimeter
mg/day	milligram(s) per day
mg/kg	milligram(s) per kilogram
mg/kg-day	milligram(s) per kilogram per day
mg/m ³	milligram(s) per cubic meter
MRLs	Minimal Risk Levels
ND	non-detect
nr – SRL	non-residential soil remediation level
PEF	particulate emission factor
PPRTVs	Provisional Peer-Reviewed Toxicity Values
RAGS	Risk Assessment Guidance for Superfund
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
RSL	Regional Screening Level

Sierrita	Freeport-McMoRan Sierrita Inc.
Site	Sierrita Mine, Green Valley, Arizona
sRfD	subchronic reference dose
SRLs	Soil Remediation Levels
STI	Sierrita Tailings Impoundment
URS	URS Corporation
UCL	upper confidence limit
$\mu\text{g}/\text{m}^3$	micrograms per cubic meter
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
VRP	Voluntary Remediation Program
work plan	Baseline Human Health Risk (BHHRA) Work Plan

1. Introduction

ARCADIS U.S., Inc. (ARCADIS) has prepared this Baseline Human Health Risk (BHHRA) Work Plan (work plan) on behalf of Freeport-McMoRan for the Freeport-McMoRan Sierrita Copper Mine, Green Valley, Arizona (Site; Figure 1-1) as part of the Arizona Department of Environmental Quality's (ADEQ) Voluntary Remediation Program (VRP). The results of the BHHRA will be used in the risk management decision making process for the Site, and the outcome of the work plan will be in compliance with Arizona Revised Statutes (A.R.S.) §49-175(B).

The BHHRA will focus solely on potential impacts associated with exposure to constituents of potential concern (COPCs; Site-related constituents) detected in soil and sediment in the following specific exposure areas (EAs) which are consistent with those assessed by URS in 2011 (URS Corporation [URS] 2011):

- Former CLEAR Plant Area, which is composed primarily of following subareas:
 - Former Clear Plant
 - Former E Pond
 - Former Evaporation Pond
 - Old D Pond
- Former Esperanza Mill Area, which is comprised primarily of following subareas:
 - Former Esperanza Mill
 - Former C Pond and C Pond Spoils
 - Former Laydown Yard
 - Former Raffinate Pond
- Former Rhenium Ponds, which is a subarea of the Tailing Impoundment Area.

The locations of these three EAs are presented on Figure 1-2. This work plan builds on the previous soil and sediment investigation conducted at the Site that is summarized in the following reports and related documents:

- VRP Soil and Sediment Characterization Report, Freeport-McMoRan, Sierrita Inc. Green Valley, Arizona. Final. December 2012 (URS 2012).

- Voluntary Remediation Program – VRP Site Code: 100073-03 Work Plan for Training Facility Soil Excavation Project, Freeport-McMoRan Sierrita Inc., Green Valley, AZ (ARCADIS 2012a)
- Response to Comments and Revised Work Plan for Training Facility Soil Excavation Project, Freeport Sierrita Mine, Green Valley, Arizona; Site Code: 100073-03 (ARCADIS 2012b)
- Voluntary Remediation Program – VRP Site Code: 100073-03 Former CLEAR Plant Soil Excavation and Tier I Screening Risk Evaluation Report , Sierrita Mine, Green Valley, AZ (ARCADIS 2012c)
- Voluntary Remediation Program – VRP Site Code: 100073-03 Addendum to the Soil and Sediment Characterization Report , Sierrita Mine, Green Valley, AZ (ARCADIS 2013a)

For this task, a BHHRA will evaluate an onsite outdoor commercial/industrial worker, a future onsite construction worker, a future onsite trespasser, and a future onsite child/adult resident for all identified complete and significant exposure pathways as described in the conceptual site model (CSM) under current and future land use scenarios (see Section 5). The BHHRA report, including text, tables, and figures, will be a stand-alone document. The results of the BHHRA will determine which, if any, areas of the Site and which COPCs need to be evaluated in the feasibility study (FS).

If the BHHRA identifies potential impacts that exceed agency thresholds, Sierrita will continue to work with the ADEQ under the VRP to prepare an FS that will evaluate potential remedial alternatives. The results of the risk characterization and source evaluation will be used in making risk management decisions to obtain regulatory closure for the Site.

1.1 Overall Approach

The approach for conducting the BHHRA for the Site was developed based on the results of previous investigations, evaluation of anticipated Site uses, including historical, current and long-term future land use, and applicable agency guidance and laws. Specifically regarding the latter, A.R.S 49-152(B,C) will be used to determine whether a “declaration of environmental use restriction” is required at the Site or whether unrestricted future land use can be suitable. For unrestricted future land use consideration, both residential and industrial/commercial worker exposures must be

evaluated. Therefore, the BHHRA will address both chronic and subchronic commercial/industrial worker exposure scenarios and a chronic residential exposure scenario for the purposes of evaluating future unrestricted land use of the property.

Based on the findings of the previous investigations (ARCADIS 2012a,b,c, 2013 and URS 2012), this work plan describes the approach for implementing the BHHRA. The BHHRA will follow applicable Arizona and USEPA guidance for conducting human health risk assessments (HHRAs). The key regulatory risk assessment guidance documents used are listed in the subsection below.

1.2 Guidance Documents Used to Conduct the Baseline Human Health Risk Assessment

The methods and approach for the BHHRA will be based primarily on the following (but not limited to) risk assessment guidance documents:

- Deterministic Risk Assessment Guidance (ADHS 2003)
- Guidance for Data Usability in Risk Assessment, Part A (USEPA. 1992a)
- Risk Assessment Guidance for Superfund (RAGS), Volume 1: Human Health Evaluation Manual, Part A (USEPA 1989)
- RAGS, Volume 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment (USEPA 2004)
- RAGS, Volume I: Human Health Evaluation Manual, Part F, Supplemental Guidance for Inhalation Risk Assessment (USEPA 2009a)
- RAGs, Volume III - Part A, Process for Conducting Probabilistic Risk Assessment (USEPA 2001a)
- Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002c)
- ProUCL Version 5.0.00 (5.0) User Guide (USEPA 2013)
- Guidelines for Exposure Assessment (USEPA 1992b)

- Exposure Factors Handbook (USEPA 1997b, 2011)
- Guidelines for Carcinogen Risk Assessment (USEPA 2005)
- Human Health Toxicity Values in Superfund Risk Assessments (USEPA 2003c)
- Soil Screening Guidance for Radionuclides: Technical Background Document (USEPA 2000)
- Preliminary Remediation Goals for Radionuclides. User's Guide (USEPA 2014).

1.3 Report Organization

The remainder of this work plan is organized as follows:

- **Section 2, Site Description** – provides background information on the Site, including existing facilities, regional geology, and hydrology.
- **Section 3, Previous Investigations and Remedial Activities** – describes previous Site investigations, summarizes the data collected, and presents relevant findings.
- **Section 4, Data Evaluation and Data Usability** – presents the data used to conduct the BHHRA and discusses the methods used to estimate exposure point concentrations (EPCs) for COPCs to which a human receptor might be exposed.
- **Section 5, Methods to Conduct the Baseline Human Health Risk Assessment** – which includes the Exposure Assessment, Toxicity Assessment, Risk Characterization, Uncertainty Assessment, and Results and Summary and Conclusions.
- **Section 6, References** – lists the literature cited in this report.

The report is followed by supporting tables and figures.

2. Site Description

Freeport-McMoRan Sierrita Inc. (Sierrita) is an operating open pit mine and mineral concentration facility, located approximately 6 miles northwest of Green Valley, in Pima County, Arizona (Figure 2-1). Green Valley lies approximately 25 miles south of Tucson, Arizona. The mine produces copper products and co-products of molybdenum and rhenium. The Sierrita property consists of three open pits (Sierrita-Esperanza pit, a molybdenum satellite pit, and the Ocotillo pit), a 115-ton per-day concentrator, two molybdenum roasting plants, a rhenium plant, an oxide and low-grade sulfide stockpile leaching operation, and a copper sulfate plant. The mine is capable of producing up to 250 million pounds of copper, and as a co-product, 25 million pounds of molybdenum, annually (ADEQ 2011).

2.1 Site Location and Physical Description

The mine is located on the southeast flank of the Sierrita Mountain Range, approximately 7 miles northwest of the Santa Cruz River. Elevations at the Site range from approximately 5000 feet above mean sea level (ft amsl) on the west side of the Site to approximately 3000 ft amsl on the east side, as shown on Figure 2-1. The mine is located in a desert environment with rainfall averaging 12 inches per year (U.S. Securities and Exchange Commission 2011).

2.2 Site Operations History

Mining in the area around Green Valley started in the late 1800s (Freeport McMoRan Copper & Gold Inc. (FCX) 2011b). At the Sierrita mine, underground mining began in 1907 and open-pit mining began in 1957 (FCX 2011a). The existing 3,614 acre Sierrita Tailings Impoundment (STI; Aquifer Protection Permit No. P-101679) has been used as a final tailings repository since the 1970s (FCX 2011b).

2.3 Facilities Overview

This work plan focuses on three facility areas at the mine: 1) the former CLEAR Plant; 2) the former Esperanza Mill, and 3) the STI. The facility locations are presented on Figure 1-2. A brief description of each facility is provided in the sections below. Information provided below was taken from the Final VRP Soil and Sediment Characterization Report (URS 2012).

2.3.1 Former CLEAR Plant

The former CLEAR Plant produced metallic copper from 1977 to 1983 and was demolished in 1995. Copper was initially leached from copper concentrate slurry which was produced from sodium and potassium chloride brines and sodium hydroxide and ferric chloride reagents. The leached solution was processed through two mixing reactors and a thickener before producing a pregnant solution. The pregnant solution was circulated in electrolytic tanks and the resulting precipitated copper was filtered, washed, dried, and stored until sold. The CLEAR plant had a number of impoundments that were associated with the plant, including the former Evaporation Pond, the Old D Pond, and the former E Pond.

The topography of the former CLEAR Plant area generally slopes eastward and is incised by east-west trending drainages. The western portion is cut into granodiorite bedrock, and the remaining area is covered with fill ranging from a few inches to approximately 25 ft in thickness. The easternmost portion of the plant area, near Demetrie Wash, is undisturbed and sparsely covered with native vegetation. A large portion of the plant area is covered with gravel or crushed rock, and buried concrete slabs are known to exist below the gravel.

The former CLEAR Plant area is currently used as 1) an asset recovery yard to store used equipment, machinery, and vehicles, 2) contractor offices and materials storage, 3) a metal fabrication shop, and 4) Sierrita's "Central Accumulation" building, currently used to store environmental sampling supplies and manage hazardous waste. The former CLEAR Plant building is currently used for storage of miscellaneous materials such as used computers and office equipment and as a training center. The Crystal Plant is located in the southernmost building, which manufactures copper sulfate pentahydrate, a product that may be sold as fertilizer, pesticide, foot bath, and animal feed.

Work Force at the Former CLEAR Plant

Workers (at the contractor offices) may be present in the former CLEAR Plant area for 8 hour days 5 days a week. Other activities such as workers storing supplies occur on an as-needed basis.

2.3.2 Former Esperanza Mill

The former Esperanza Mill is located in the central portion of the Sierrita property and includes the former C Pond, C Pond Spoils, former Raffinate Pond, and former Laydown Yard. The former Mill processed sulfide ore from 1959 through 1981 (Hydro Geo Chem Inc. 2008) and included a mill, two thickeners, and a raw water pond. Tailings from the mill were conveyed through a pipeline to the Esperanza Tailing Impound, located approximately one-half mile southeast of the former mill.

The topography of the former mill area slopes gently to the east-southeast. Amargosa Wash borders the mill area to the south and Demetrie Wash borders the mill area to the east. The Duval Canal Extension trends west to east along the north side of the former mill area. The northwestern portion of the area is cut into bedrock with fill extending eastward. A drainage channel extends from near the base of the former thickeners and trends southeast across the former mill area. Numerous work/storage shops, office buildings, and equipment storage areas are located in the northwest portion of the former mill area.

The former C Pond and C Pond Spoils are located within the easternmost portion of the former mill area, near the northwest corner of the confluence of Demetrie and Amargosa Washes. During operations, sediments that accumulated in the former C Pond were periodically dredged, and spoils were placed on the east and west sides of the current Duval Canal Extension (C Pond Spoils). The former C Pond was used to collect surface runoff from the former mill, overflow from the old Duval Canal during storm events, and runoff from the Sierrita crusher dust collector area, which had high concentrations of copper. Currently, the former C Pond area is being used by Sierrita for pilot water treatment plants.

The former Raffinate Pond is an inactive, unlined, and backfilled pond located within the central portion of the former mill. Use of the former Raffinate Pond was terminated when the current Raffinate Pond was constructed. The former Raffinate Pond is located in a low area, which collects some surface runoff from the western portion of the former mill.

The former Laydown Yard is located in the central portion of the former Esperanza Mill area and was used from the 1960s until the mill was demolished in 2005. During that time, the Laydown Yard was used to store equipment, new drums, and salvage materials from decommissioned Site facilities. A subcontractor removed and salvaged the drums and other equipment. The former Laydown Yard is currently used by a contractor for their mobile office and a few pieces of mobile equipment.

Work Force at the Former Esperanza Mill

Outdoor workers (general labor crew) are present in the former Esperanza Mill area for 8 hour days 5 days a week. Workers convene in the area in the morning and disperse throughout the site. A road maintenance crew may potentially work in the area performing grading, paving and other maintenance duties. These activities occur on an as-needed basis. Outdoor workers are also working in the laydown yard, rental yard, or other outdoor areas in the area. They will travel in and out of those areas on a daily basis.

2.3.3 Former Rhenium Ponds

Northwest of the STI is the Esperanza Tailing Impoundment, which contains the former Rhenium Ponds. The former Rhenium Ponds consisted of three impoundments excavated side by side into the surface of the Esperanza Tailings Impoundment. The ponds were used for storage and evaporation of process solutions from the Rhenium Plant (Montgomery Watson 1999). Each pond measured roughly 250 ft long, 65 ft wide, and 10 to 12 ft deep, and were lined with geosynthetic liner (MWH Americas, Inc. 2005). The ponds operated from 1981 until 1991. In 1998, Cyprus Amax closed the impoundments by excavating sediments from the cells and recycling the material on the heap leach stockpiles. The ponds were then backfilled with tailings. In 1999, the area was capped with 12 inches of growth medium and re-vegetated. Following the seeding, native vegetation typical of the Arizona Upland/Eastern Sonoran Basins ecoregion (e.g., grama grasses, creosote bush, bursage) (Griffith 2014) has become established in the former Rhenium Ponds area.

Work Force at the Former Rhenium Ponds

There are no buildings or on-going activities at the former Rhenium Ponds area and, therefore, no workers are present.

2.4 Environmental Features

The Site geology, hydrogeology, and surface water are described in the Groundwater Investigation Report (ARCADIS 2013b). The BHHRA Report will cite the most up-to-date description of environmental media, nature and extent of contamination, and CSM provided in ARCADIS (2013b) and any other documents that become available between the time of work plan approval and execution of the report itself.

3. Previous Investigations and Remedial Activities

On June 16, 2007, Sierrita submitted an application to enter the Arizona VRP administered by the ADEQ. The characterization goal for the VRP was to assess potential impacts to soil, groundwater, and sediment from historical and active mine operations. Sierrita retained URS Corporation (URS) to prepare and implement a site investigation work plan to characterize soil, sediment, and groundwater at the mine. The investigation activities were conducted by URS, in accordance with the VRP Investigation Work Plan (URS 2008a) and the Addendum to Sampling and Analysis Plan & Quality Assurance Project Plan (URS 2008b). Both plans were approved by the ADEQ VRP. URS (2012) reported the results of the soil and sediment investigation for metals; whereas, ARCADIS (2013a) reported the results of the soil and sediment investigation for radionuclides. Sierrita submitted a Groundwater Investigation Report which provided a conceptual site model for site geology, hydrogeology and groundwater data previously collected by URS (ARCADIS 2013b).

For soil and sediment, the investigation was conducted at three primary areas: 1) Former CLEAR Plant area, which consists of the Clear plant, Former E Pond, former Evaporation Pond, and the Old D pond; 2) Former Esperanza Mill Area, which consists of the Esperanza Mill area, former C Pond and C Pond Spoils, former Laydown Yard, former Raffinate Pond; and 3) the Sierrita Tailings Impoundment Area, which includes the former Rhenium Ponds. URS (2012) reported that 171 soil samples were analyzed from 54 soil borings advanced to the bedrock surface, and 36 sediment samples were collected and analyzed from 18 locations. Samples were analyzed for total metals and were compared to non-residential Soil Remediation Levels (nr-SRL; Arizona Administrative Code Title 18). Constituents of interest (COIs) were identified in the VRP Work Plan (URS 2008a) and include all the chemical constituents that are evaluated in the VRP. It is important to note, however, that the COPC selection process for the BHHRA (described in Section 4.3 of this work plan) is a separate and distinct process from the soil VRP screening. The BHHRA COPCs, therefore, may not necessarily be the same as determined in the soil VRP characterization.

Based on the comparison conducted in the soil VRP characterization, the most likely exposures to COIs in soil are through direct contact by site workers, specifically at: the Former CLEAR Plant, Former Esperanza Mill Area, Former C Pond and C Pond Spoils, Old D Pond, Former Raffinate Pond, and the Former Laydown Yard. Screening values (nr-SRLs) were exceeded in at least one sample at each of these sites:

- arsenic, copper and lead at the Former CLEAR Plant;

- arsenic at the Old D Pond; arsenic at the Former Esperanza Mill Area;
- arsenic and lead at the Former C Pond and C Pond Spoils;
- arsenic at the Former Raffinate Pond Subarea; and
- arsenic, lead and molybdenum at the Former Laydown Yard.

For these sites, the 95 percent upper confidence limit (UCL) value for the COIs was estimated, and arsenic was the only COI tentatively identified as a COPC for the former CLEAR plant sub-area, the former Esperanza Mill sub-area, the former Raffinate Pond sub-area, and the former Laydown Yard. This suggests that a sufficient range of data is represented by the samples collected and provides variability across a range of concentrations to characterize worker exposure. Most sampling locations were chosen based upon professional judgement and, therefore, biased to areas identified as source (except for the Former CLEAR Plant area which also has a systematic grid applied). In addition, ARCADIS (2013a) summarized results for the radiologic analysis and radionuclides were identified as COPCs.

Data quality objectives (DQOs) were evaluated and results presented in Table 4-1 (URS 2012). While a formal data usability evaluation ultimately will be included in the BHHRA report (see Section 4 herein), Sierrita did evaluate the appropriateness of locations, adequacy of site characterization (relative to nature and extent), and comprehensiveness of the data collected to date. As part of the exercise, Sierrita evaluated data needed for the forward risk assessment, constituents that may drive quantitative calculations of risk, and any potential gaps in the data collected to date as it relates to the ability to complete the BHHRA report. Potential data gaps include bioavailability data to assist with the analysis of arsenic as well as background samples to assist with the evaluation of arsenic and radionuclides.

Additionally, results were compared to the soil Groundwater Protection Levels (GPLs; ADEQ 2002). Antimony and lead were the only metals detected at concentrations greater than their respective GPLs. Antimony exceeded the GPL in the former CLEAR Plant and former Esperanza Mill sub-areas. Lead exceeded its GPL in the former CLEAR plant, the former C Pond and C Pond Spoils, former Raffinate Pond, and the former Laydown Yard sub-areas (URS 2012).

ARCADIS (2013) summarized the groundwater VRP characterization study which included:

- Installation of monitoring wells (15 monitoring wells in bedrock, and 14 temporary alluvial monitoring wells)
- Sampling and analysis of groundwater from 27 existing wells and the new monitoring wells (temporary and bedrock wells) for four consecutive quarters
- Installation of three tailings piezometers and sampling and analysis for one quarter
- Sampling and analysis of process solutions from 19 locations, including existing headwalls, impoundments, intercepts, and sumps, quarterly for four consecutive quarters
- Slug testing of 14 monitor wells and 2 piezometers
- Groundwater characterization activities conducted between July 2008 and July 2009.

ARCADIS (2013b) evaluated the nature and extent of contamination in groundwater and presented a CSM which included the fate and transport of constituents identified in sampled environmental media. None of the constituents of interest detected in groundwater are volatile, and since groundwater is not currently being used at the site nor is it expected to be used as a potable water source in the future, groundwater will not be quantitatively evaluated in the BHHRA Report. A comparison to relevant criteria was included in ARCADIS (2013b), however, as required by ADEQ, and a supplemental work plan for data gaps identified in ARCADIS (2013b) was submitted to ADEQ in 2014 (ARCADIS 2014). ARCADIS (2013b, 2014) meet the intent of the Site Investigation Guidance (ADEQ 2014), and the CSM discussed in Section 5 herein provides additional information on the exposure profile as recommended by ADEQ (2014). The BHHRA Report will further document recommended aspects of ADEQ (2014) as it relates specifically to exposures to soil and sediment. Section 5 will further document complete exposure pathways for human receptors to be evaluated in the BHHRA report.

4. Data Evaluation and Data Usability

This section provides a summary of the data quality review, defines the datasets considered in this BHHRA, describes methods used to confirm data usability for risk assessment purposes, discusses selection of COPCs, and describes the derivation of EPCs.

4.1 Media Considered and Evaluated in the BHHRA

The soil and sediment data collected by Hydro Geo Chem Inc. (HGC 2008) and URS (2012) through field activities in 2004 and 2008 will be evaluated in the BHHRA. As discussed in Section 3 and Section 5.1.1.5.2 of this work plan, groundwater will not be evaluated in the BHHRA.

For the purposes of this work plan, the following soil and sediment depths will be evaluated to conduct the BHHRA:

- The shallow soil and sediment interval (0 to 0.5 ft bgs or 0 to 2 ft bgs) dataset will be used to evaluate potential human health impacts assuming the continuation of current activities/operations at the Site. Only one shallow soil and sediment depth interval will be evaluated as discussed in more detail below.
- The deep soil and sediment interval (0 to 15 ft bgs) dataset developed to account for future soil and sediment construction activities that involve the redistribution of soils to the surface, consistent with ADEQ (2002) guidance in relation to considerations of future unrestricted land use for the property.

Prior to utilizing the data for risk assessment purposes, a data usability step will be implemented as discussed in the next section.

4.2 Data Usability

The BHHRA will evaluate the usability of data for risk assessment purposes. The data usability assessment considers both data quality and data applicability. The key components of the data usability assessment summarized below are consistent with USEPA (1989, 1992a) risk assessment guidance and include:

- Spatial – to ensure that the exposure area is adequately characterized and data are representative of potential current and future exposures
- Sample size and sample density – to ensure that EPCs calculated for an exposure area are sufficiently robust and representative of potential current and future exposures
- Temporal applicability – to ensure that data used in the risk assessment are representative of current conditions (e.g., very old data for volatile or biodegradable compounds may no longer be representative due to volatilization or degradation)
- Overall data quality – ascertained through a data review and data validation process
- Evaluation of data qualifiers – specifically with respect to data rejected by the analytical laboratory or during data validation

4.2.1 Analytical Methods and Detection Limits

For an analytical result to be usable for risk assessment, the sample collection, preparation, and analytical methods should appropriately identify the chemical, and the specified sample detection limit should be at or below a concentration that is associated with toxicologically relevant levels for the potentially exposed receptors at the Site, if readily achievable with laboratory instruments and standard analytical methods. The BHHRA will discuss the adequacy of the analytical detection limits to evaluate if analytical data are of sufficient quality to reach reasonable risk-based conclusions. This will include an evaluation of the adequacy of the detection limits relied upon in concluding that a chemical is not present at the Site and does not need to be included in the quantitative risk assessment. In some cases, it is not practical to achieve method detection limits (MDLs) lower than screening levels, or matrix interference from elevated concentrations of some COIs at specific locations may raise the MDLs of other COIs analyzed using the same analytical method. In these cases, the analytical chromatograms will be evaluated during the risk evaluation process to assess if Site-related COIs are likely to be present at concentrations above their respective screening values.

4.2.2 Treatment of COIs Not Detected

The BHHRA will use the USEPA-released statistical software ProUCL Version 5.0.00 (ProUCL 5.0) to calculate EPCs (USEPA 2013a, 2013b, 2013c). ProUCL 5.0 contains statistical methods to evaluate both full environmental datasets without not detected (ND) values and datasets with below detection limit or ND values (also known as left-censored datasets) without the use of proxy values. The methods for calculating EPCs are described in Section 4.4. If an analyte is detected in one or more samples in a dataset, EPCs for that analyte will be calculated as recommended by USEPA guidance (USEPA 2013a).

4.2.3 Treatment of Field Duplicate Data

In accordance with the Quality Assurance Project Plan – Addendum prepared for the Site (URS 2008b), any field duplicate collected as part of the site investigations will be treated as a quality control sample and not used to characterize the Site. Therefore, the parent analytical result will be considered representative of that sample and constituent. The only exception will be potential elevated detection limits in a parent sample where the duplicate has lower detection limits. In these special circumstances, Sierrita will carefully consider the use of a duplicate analysis if there are better detection limits and provide documentation if such a substitution is implemented for the analysis.

4.3 Selecting Constituents of Potential Concern

COPCs will be selected separately for each of the three EAs (Section 1; Figure 1-2) consistent with ADHS (2003) risk assessment guidelines. All constituents detected in at least one soil or sediment sample will be considered as COPCs for the BHHRA unless one of the following criteria is met:

- The highest detected concentration in soil and sediment is less than the applicable Arizona nr-SRL (Arizona Administrative Code Title 18). If no nr-SRL is available for a COI, a USEPA Regional Screening Level (RSL; USEPA 2015a) will be used for chemicals, when available, and a USEPA Preliminary Remediation Goal (PRG; USEPA 2014) for radionuclides, when available.
- The constituent is detected in less than 5 percent of the soil and sediment samples, and no “hotspots” are identified. ADHS (2003) defines “hotspots” as

areas that have one or more samples that contain concentrations of constituents that exceed the relevant nr-SRL by a factor of 10 or more.

- If detected concentrations of COIs are below ambient conditions¹

Any COIs in each EA not eliminated by these criteria will be selected as COPCs for evaluation in the BHHRA.

4.4 Exposure Point Concentrations

4.4.1 Soil/Sediment Exposure Point Concentrations

To estimate COPC exposure, the concentration term in the risk equation will be calculated as the average of the concentration that could be contacted at the exposure point or points over the exposure period (USEPA 1989, 1992b). The EPC is defined as “the arithmetic average of the concentration that is contacted over the exposure period” (USEPA 1989). To assure that the estimate of the arithmetic average is conservative and is not underestimated the lesser of the maximum detected concentration and the 95% upper confidence limit (UCL) on the mean concentration will be used as an estimate of the EPC (USEPA 1989, 1992b). The EPCs for the HHRA will be calculated over the Site as mentioned above. The software (ProUCL 5.0) and accompanying guidance (USEPA 2013a, 2013b, 2013c) introduce many refinements in calculating 95% UCLs, as discussed below.

USEPA recommends caution in the use of UCLs for small datasets (e.g., < 4 detects or 10 total samples) because the performance of the various methods may not be reliable in these cases (USEPA 2013b). Typically, at least five detected concentrations and ten total samples are necessary to calculate UCLs on the mean concentration (i.e., 95% UCLs) (USEPA 2013a). When these dataset criteria are not met, maximum concentrations may be selected as the EPC.

¹ An appropriate regional-specific ambient dataset will be used if available and, if not, a Site-specific ambient dataset may be developed and, if appropriate, hypothesis testing methods consistent with USEPA (2002b) will be implemented to conduct the ambient analysis.

The 95% UCL is defined as the value that, when calculated repeatedly for randomly drawn subsets of Site data, equals or exceeds the true mean 95% of the time (USEPA 1992b). Use of the 95% UCL (as representative of the average concentration) is recommended instead of the maximum concentration because it is highly unlikely that a receptor will be exposed to a single (e.g., maximum) concentration over the entire exposure duration. Rather, a receptor will likely be exposed to a range of concentrations in the exposure area, from not detected to the maximum concentration, over the entire exposure period.

In the event that a UCL exceeds the maximum detected concentration, the maximum concentration will be used to represent the EPC.

EPCs will be developed initially for three soil depth ranges (two shallow [0 to 0.5 and 0 to 2 ft bgs] and one deep [0 to 15 ft bgs]) for each receptor scenario, but only two soil depth ranges (one of the shallow ranges and the deep range) will be evaluated in the BHHRA. The rationale for calculating EPCs over multiple depth intervals is to capture the variable sampling depths of the soil data set, and to meet requirements of A.R.S. § 49-152, which identify up to 15 feet of soil as “surface soil”. As described in the overall approach, the BHHRA addresses a maximum 15 feet bgs to evaluate future unrestricted residential land use of the property. Evaluating a 0 to 15 ft bgs depth is consistent with ADEQ guidance (ADEQ 2002) and was also approved by ADEQ for the Former PureGro Facility located in Casa Grande, AZ (ADEQ 2012). As a conservative measure, only the shallow depth range (either 0 to 0.5 ft bgs or 0 to 2 ft bgs) with the highest COPC EPCs will be selected as the shallow soil depth range used in the BHHRA.

4.4.2 Air Exposure Point Concentrations

The inhalation of chemicals adsorbed to airborne soil dust particles is a potentially complete exposure pathway for all receptors evaluated in this work plan.

Potential exposure to non-volatile COPCs adsorbed to soil particles and released to air from wind erosion or during soil invasive activities will be evaluated using particulate emission factors (PEFs). For non-invasive soil scenarios, local ambient air conditions will be reviewed to derive a Site-specific PEF in accordance with the equations provided in the Soil Screening Guidance (USEPA 2002d). If local data are not available, default PEF values will be used (i.e., those used in calculating RSLs; USEPA, 2015a).

5. Baseline Human Health Risk Assessment Methodology

The purpose of a BHHRA is to evaluate the likelihood that COPCs in Site media could adversely impact human health under the assumed set of current and reasonable future land-use scenarios. This section describes the methodology for the HHRA that will be implemented to characterize risks and to make risk management decisions to ultimately obtain Site closure. The BHHRA approach described in this section is based on current USEPA and ADEQ guidance documents including, but not limited to, those listed in Section 1.3.

5.1 Exposure Assessment

Exposure assessment is the process of identifying potential receptors and estimating the magnitude of exposure to human receptors potentially exposed to constituents detected in environmental media. It includes information regarding the parameters and models necessary to estimate human exposure through dermal absorption, ingestion, and inhalation. The CSM (Figure 5-1) identifies the relationship between the fate and transport mechanisms of the COPCs identified in soil and the potentially complete human receptor exposure pathways.

5.1.1 Exposure Pathway Analysis

Complete exposure pathways for selected current and hypothetical future human receptors are discussed below. An exposure pathway is a mechanism by which receptors may come into contact with Site-related COPCs. USEPA (1989) describes a complete exposure pathway in terms of four components:

- A source and mechanism of release (e.g., accidental release of pesticides during mixing or in preparation for transport)
- A retention or transport medium (e.g., soil)
- A receptor at a point of potential exposure to an impacted medium (e.g., outdoor and indoor commercial/industrial workers)
- A complete exposure pathway (e.g., incidental ingestion of soil) to the receptor at the point of exposure.

If any of these four components is not present, a potential exposure pathway is incomplete and will not be evaluated further in this BHHRA. If all four components are present, that potential exposure pathway is considered complete and will be evaluated in the BHHRA. If a complete or partially complete exposure pathway cannot be quantified in the BHHRA, this pathway will be discussed in the uncertainty section. Each of the four components listed above are further discussed in the sections below.

5.1.1.1 Source and Mechanisms of Release

The sources and mechanisms of release at the Site are related to: mining and processing activities, which include:

- Excavation activities
- Hauling and dumping of overburden
- Historic processes to refine ore
- Storage of reagents and other solutions
- Accidental spills

5.1.1.2 Retention or Transport Media

All of the above listed processes in Section 5.1.1.1 have contributed to deposition of COIs onto surface soils. Constituents present in the surface may also migrate downward into deeper soils through leaching and to other locations onsite through transport of wind-blown dust and surface runoff. Additionally, constituent concentrations present between 0 and 15 ft bgs may be potentially redistributed across the three EAs during future construction/development activities.

5.1.1.3 Receptor Point of Potential Contact

Human receptors that will be evaluated in the BHHRA were chosen based on current and potential future uses of a Site, and evaluation of an unrestricted future land use of the property. Given that the Site is an active mine, the reasonable expected current and future receptors for the areas under consideration include onsite outdoor commercial/industrial workers, future onsite construction workers, and future onsite trespassers. Although extremely unlikely, future onsite child/adult residents will also be

evaluated for all three EAs specifically to address the possibility of future unrestricted land use of the property. Further description of each receptor point of potential contact and the basis for selection is discussed below.

5.1.1.3.1 Current and Future Onsite Outdoor Commercial/Industrial Worker

The onsite outdoor commercial/industrial worker receptor may be exposed to COPCs present in exposure media (shallow soil and particulates in air) when they are involved in activities that do not involve significant mining activities (non-intrusive activities). As noted earlier in Section 2.3, buildings (used in part for storage) currently exist in only one of the EAs (Former Clear Plant EA). An indoor commercial/industrial worker, however, will not be evaluated primarily because the vapor intrusion pathway (which could contribute significantly to indoor impacts) is incomplete for the three EAs as it is expected that only metals are COIs). If, however, radionuclides (i.e., radium and/or uranium) are identified as COPCs, then potential indoor-related exposures (exposure while in commercial buildings and residences) will be evaluated. If potential impacts estimated for an outdoor commercial/industrial worker (who is expected to be in contact with COPCs in soils/particulates in air throughout the duration of employment) are below agency threshold levels of concern, then they will be even lower for an indoor commercial/industrial worker due to the shielding effects of buildings. In the event impacts for an outdoor commercial/industrial worker exceed agency thresholds, then an indoor commercial/industrial worker may be evaluated in order to provide additional information for risk management purposes.

5.1.1.3.2 Future Onsite Construction Worker

A future onsite construction worker was selected because this worker may be exposed to COPCs in the unlikely event the Site is redeveloped.

5.1.1.3.3 Future Onsite Trespasser

A future onsite trespasser was selected because a person could illegally access the property and potentially be exposed to COPCs in soil. For the purpose of the BHHRA it is anticipated that if chronic trespassing were to occur at the Site, it would more likely involve an adolescent aged individual rather than an adult. Therefore, an adolescent trespasser will be evaluated.

5.1.1.3.4 Future Child/Adult Resident

Although it is extremely unlikely that the mining facility will be redeveloped for residential use, a future onsite child/adult resident will be evaluated for all three EAs specifically to evaluate potential unrestricted future land use for the property.

A.R.S. §49-152(B,C) will be used to determine whether a “declaration of environmental use restriction” is required for commercial/industrial land use, or whether unrestricted land use may be suitable for the Site. This citation is excerpted below for reference:

§49-152. Soil remediation standards; restrictions on property use

B. The owner of a property may elect to remediate the property to meet a site specific residential or nonresidential risk based remediation standard or a predetermined residential or nonresidential risk based remediation standard. The property is suitable for unrestricted use if it has been remediated without the use of engineering or institutional controls to meet either of the following:

- 1. The predetermined residential risk based remediation standard.*
- 2. A site specific risk based hazard index equal to or less than one or a risk of carcinogenic health effects that is less than or equal to the range of risk levels set forth in 40 Code of Federal Regulations section 300.430(e)(2)(i)(A)(2), based on residential exposure.*

C. If the owner has elected to use an engineering or institutional control to meet the standards prescribed in subsection B of this section, or if the owner has elected to leave contamination on the property that exceeds the applicable residential standard for the property, the owner shall record in each county where the property is located an institutional control that consists of a restrictive covenant that is labeled "declaration of environmental use restriction" pertaining to the area of the property necessary to protect the public health and the environment. A person who is conducting a remedial action, remediation, corrective action or response action that requires an institutional or engineering control and who is not the owner of the property shall obtain written consent from the owner before implementing the institutional control or constructing the engineering control. On implementation of the institutional or engineering control, the owner shall record a declaration of environmental use restriction in each county where the property is located. If the institutional control or engineering control will affect right-of-way that is owned, maintained or controlled by a public entity for public benefit, the person shall also obtain the public entity's written consent before implementing the institutional control or constructing the engineering control. The declaration of environmental use restriction shall limit by legal description:

- 1. The area of the property where the institutional control or engineering control shall be maintained.*
- 2. The area of the property to be restricted to nonresidential use, because contamination remains on the property above the standards prescribed in subsection B, paragraph 1 or 2 of this section.*

Some specific residential exposure assumptions are provided in ADEQ guidance (ADEQ 2002). The guidance considers “surface soil” as the interval between 0 to 15 feet bgs. The rationale behind selection of this depth interval, as described in the guidance, states:

“Within reason, a property owner may elect to construct a pool, play center, etc. In doing so, the depth of 15 feet typically can not be exceeded by use of common backhoe construction equipment. Soils at the reach of the backhoe may be brought to the surface where it will remain available for direct contact”

Therefore, the BHHRA will evaluate future child/adult resident exposure to a maximum soil depth of 15 ft bgs for the purposes of evaluating future unrestricted residential land use of the property. The results of the residential evaluation will be included in an appendix to the BHHRA report.

5.1.1.5 Exposure Pathways

For the purpose of assessing risks to current and future human receptors, several complete exposure pathways were identified; these pathways will be quantitatively evaluated in the HHRA. The exposure pathway analyses for the current and future onsite outdoor commercial/industrial worker, the future onsite construction worker, the future trespasser, and the future onsite child/adult resident are identical and are discussed together below.

5.1.1.5.1 Complete Exposure Pathways

Complete exposure pathways for the current and future onsite outdoor commercial/industrial worker, the future onsite construction worker, the future trespasser, and the future onsite child/adult resident exposed to COPCs in either the shallow or deep soils are incidental ingestion, dermal contact with soil, and inhalation of fugitive dust. These exposure pathways will be quantitatively evaluated in the BHHRA.

5.1.1.5.2 Incomplete Exposure Pathways

Incomplete exposure pathways for the current and future onsite outdoor commercial/industrial worker, the future onsite construction worker, the future trespasser, and the future child/adult resident include direct contact with groundwater and inhalation of COPCs in ambient air migrating from groundwater because:

- None of the COIs are volatile
- Groundwater is currently not being used at the Site, nor is it expected to be used as a potable source in the future.

For these reasons, groundwater is not an exposure medium to the human receptors identified in this work plan and, therefore, will not be evaluated in the BHHRA.

5.1.2 Reasonable Maximum Exposure

Consistent with ADHS (2003) guidance, potential human receptors will be evaluated under reasonable maximum exposure (RME) scenarios, which give risk estimates that exceed central tendency exposure scenarios in all cases. The “high end” exposure estimate or RME is defined as the highest exposure that is reasonably expected to occur at a site but that is still within the range of possible exposures (USEPA 1989). Focusing on RME scenarios provides an additional measure of health protectiveness.

5.1.3 Dose (Intake) Estimation

For incidental ingestion and dermal contact with soil, when evaluating exposure to potential carcinogens, lifetime average daily doses (LADDs) are calculated by averaging exposure over an expected 78-year lifespan. When evaluating exposure to noncarcinogens, doses are estimated as average daily doses (ADDs), calculated as the average exposure over the time the receptor is assumed to be exposed to the COPC. Exposures will be calculated with the algorithms recommended by USEPA (1992c, 2004) for the potentially complete pathways identified in the CSM (Figure 5-1) and considering the exposure parameters defined in Table 5-1. The exposure parameters provided in this table reflect ADHS and USEPA-recommended values for chronic and subchronic exposures.

The following sections describe the methods and inputs used to calculate LADDs for carcinogenic COPCs and ADDs for noncarcinogenic COPCs.

5.1.3.1 Carcinogenic Effects from Chemical COPCs

For chemical constituents with potential carcinogenic effects, the LADD is an estimate of potential daily intake over the course of a lifetime. In accordance with USEPA (1992c), the LADD is calculated by averaging the assumed exposure over the receptor's entire lifetime (assumed to be 78 years; USEPA 2011). For incidental

ingestion and dermal exposure, the LADD for each constituent via each route of exposure is multiplied by the cancer slope factor (CSF) to estimate the incremental lifetime cancer risk due to exposure to that constituent via that route of exposure. Consistent with USEPA RAGS Part F (2009a), an inhalation exposure concentration (EC) is calculated (in place of a LADD) to evaluate inhalation of fugitive dust particles.

5.1.3.2 Noncarcinogenic Effects from Chemical COPCs

The ADD is an estimate of a receptor's potential daily intake from incidental ingestion and dermal contact with constituents in soil with potential noncarcinogenic effects. The ADD does not represent a true average because the assumptions used to derive it do not represent "averages." In fact, they overestimate the average exposure. According to USEPA (1992c), the ADD should be calculated by averaging over the period of time for which the receptor is assumed to be exposed (averaging time = exposure duration for potential noncarcinogenic risk), not the lifetime. Consistent with USEPA RAGS Part F (2009a), an EC was calculated (in place of an ADD) to evaluate inhalation of fugitive dust particles.

In the BHHRA, chronic and subchronic exposures will be evaluated. Chronic exposures (e.g., commercial/industrial worker, future trespasser, hypothetical future resident) are long-term exposures ranging from 7 years to a lifetime. Subchronic exposures (e.g., short-term construction worker) are exposures over a period of 2 weeks to 7 years.

The following sections present the equations to be used for dose calculations in the BHHRA.

5.1.3.2.1 Incidental Ingestion of Soil

The doses of constituents associated with incidental ingestion of soil are calculated as follows:

Equation 5-1:

$$Dose = \frac{C_{soil} * CF * IR_{soil} * ABS_{in} * EF * ED}{AT_{n\ or\ c} * BW}$$

Where:

<i>Dose</i>	=	ADD or LADD (milligrams per kilogram per day [mg/kg-day])
<i>C_{soil}</i>	=	COPC EPC in soil (milligrams per kilogram [mg/kg])
<i>CF</i>	=	conversion factor (1 × 10 ⁻⁶ kilograms per milligram [kg/mg])
<i>IR_{soil}</i>	=	soil ingestion rate (milligrams per day [mg/day])
<i>ABS_{in}</i>	=	gastrointestinal absorption factor (unitless and often assumed to be “1”)
<i>EF</i>	=	exposure frequency (days per year)
<i>ED</i>	=	exposure duration (years)
<i>AT_n</i>	=	averaging time for noncarcinogens (days; ED (years) × 365 days per year)
<i>AT_c</i>	=	averaging time for carcinogens (days; lifetime (78 years) × 365 days per year)
<i>BW</i>	=	body weight (kilograms [kg]).

5.1.3.2.2 Dermal Contact with Soil

Absorbed doses of constituents associated with dermal contact with soil are calculated as follows:

Equation 5-2:

$$Dose = \frac{C_{soil} * CF * SA * AF * ABS_d * EF * ED}{AT_{n\ or\ c} * BW}$$

Where:

<i>Dose</i>	=	ADD or LADD (mg/kg-day)
<i>C_{soil}</i>	=	COPC EPC in soil (mg/kg)
<i>CF</i>	=	conversion factor (1 × 10 ⁻⁶ kg/mg)
<i>SA</i>	=	exposed skin surface area (square centimeters per day [cm ² /day])
<i>AF</i>	=	skin adherence factor (milligrams per square centimeter [mg/cm ²])
<i>ABS_d</i>	=	dermal absorption factor (unitless)
<i>EF</i>	=	exposure frequency (days per year)

<i>ED</i>	=	exposure duration (years)
<i>AT_n</i>	=	averaging time for noncarcinogens (days; ED (years) × 365 days per year)
<i>AT_c</i>	=	averaging time for carcinogens (days; lifetime (78 years) × 365 days per year)
<i>BW</i>	=	body weight (kg).

5.1.3.2.3 Inhalation of Fugitive Dust Particles

Doses associated with the inhalation of constituents associated with fugitive dust particles from ambient air are calculated as follows:

Equation 5-3:

$$EC = \frac{C_{air} * ABS_{inh} * ET * EF * ED}{AT_{n \text{ or } c}}$$

And:
$$C_{air} = \frac{C_{soil}}{PEF}$$

Where:

<i>EC</i>	=	exposure concentration (milligrams per cubic meter [mg/m ³])
<i>C_{air}</i>	=	COPC EPC in air (mg/m ³)
<i>ABS_{inh}</i>	=	inhalation absorption factor (unitless)
<i>ET</i>	=	exposure time (hours per day)
<i>EF</i>	=	exposure frequency (days per year)
<i>ED</i>	=	exposure duration (years)
<i>AT_c</i>	=	averaging time for carcinogens (hours; lifetime (78 years) × 365 days per year × 24 hours per day)
<i>AT_n</i>	=	averaging time for noncarcinogens (hours; ED (years) × 365 days per year × 24 hours per day)
<i>C_{soil}</i>	=	COPC EPC in soil (mg/kg)
<i>PEF</i>	=	particulate emission factor (cubic meters per kilogram [m ³ /kg]).

Toxicity values used along with the chemical doses estimated above are discussed in Section 5.3.

5.1.3.2.4 Radiological Assessment

As discussed in the addendum to the VRP Soil and Sediment Characterization Report, the unconsolidated deposits and bedrock complex at the Sierrita Mine contain natural levels of radioactivity at concentrations and activities consistent with a highly mineralized area. If in the event radionuclides (i.e., radium and/or uranium) are identified as COPCs, the BHHRA will estimate the potential risk from ionizing radiation.

Unlike chemicals, radionuclide exposure is typically expressed in units of activity per unit of the exposure medium, rather than mass per unit. Internal exposure is expressed for completed pathways using the following equation:

Equation 5-4:

$$Dose (pCi) = EC * CR * EF * ED$$

Where:

<i>Dose</i>	=	dose due to internal exposure (picocuries)
<i>EC</i>	=	Exposure concentration (picocuries per gram [pCi/g])
<i>CR</i>	=	Contact rate (grams per day)
<i>EF</i>	=	Exposure Frequency (days/year)
<i>ED</i>	=	Exposure Duration (years)

Toxicity values used along with the radiological doses estimated above are discussed in Section 5.3.

5.1.3.3 Lead Exposure

In the event that lead is selected as a COPC, USEPA's Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 2002a, 2012a) and the Adult Lead Methodology (ALM; USEPA 2003a,b; 2007b,c; 2009b) model will be used to evaluate the potential exposure to lead.

IEUBK will be used to evaluate lead exposures to the future onsite child resident between the ages of 0 and 84 months. The USEPA's (2003a,b; 2007b) ALM model will be used to assess exposure to the current and future onsite commercial/industrial worker, the future onsite construction worker, the future trespasser, and the future onsite adult resident by relating soil-lead intake in women of child-bearing age to blood-lead concentrations in a developing fetus. Default estimates will be used for the

statistical measures of blood lead, including the target 95th percentile blood-lead concentration in fetus, fetal/maternal blood-lead ratio ($R_{\text{fetal/maternal}}$), biokinetic slope factor, geometric standard deviation on the population mean blood-lead concentration (GSDi), and baseline blood-lead concentration. Default values will also be used for exposure parameters such as the lead absorption fraction and the averaging time.

USEPA-recommended methods (e.g., USEPA 2012a) will be used (e.g., arithmetic mean as the EPC) to run the most recent versions of IEUBK and ALM lead exposure models. Standard parameters will be used initially, but may be supplemented with site-specific information to reflect as accurately as possible the Site conditions.

5.2 Bioavailability of Metals

Oral bioavailability reflects the amount of a constituent that is absorbed into the body following ingestion. The typical assumption when calculating risks to humans is that oral bioavailability will typically be assumed to be 100%. At least in the case of lead and arsenic, however, numerous studies that have measured site-specific oral bioavailability, indicate that, especially for mine-related materials, the relative bioavailability of lead and arsenic is often much lower than 100% (e.g., Bradham et al. 2011; Drexler and Brattin 2007; USEPA 2010; Casteel et al. 1997; Freeman et al. 1993; etc.). Developing more site-specific bioavailability factors for at least these constituents is therefore becoming a more common component of risk calculations (USEPA 2007a). USEPA has developed an alternative bioavailability factor (USEPA 2007a) that reflects a conservative estimate of soil bioavailability, considering all types of soil materials and their mineralogies, and factoring those considerations into determination of a “default” bioavailability factor. Further refinements of site-specific bioavailability factors can be determined, and will be considered for this Site if needed, first by evaluating the site-specific mineralogy of the materials being addressed in the BHHRA and comparing the mineralogy to existing bioavailability studies of similar mining materials. In the event that site-specific bioavailability values are considered for use in the BHHRA, associated values and inputs will be discussed with ADEQ prior to submittal of the report.

5.3 Toxicity Assessment

USEPA derives numerical toxicity values for use in risk assessments. Because the impacts associated with exposure to carcinogens are assessed differently than the hazards associated with exposure to noncarcinogens, the toxicity values for

carcinogenic health effects and for noncarcinogenic health effects are derived using different assumptions and methods. The toxicity values used to assess potential carcinogenic risk and noncarcinogenic hazards for this BHHRA are described below.

5.3.1 Toxicity Values for Carcinogenic Health Effects of Chemicals

The current approach to carcinogenic risk assessment used by USEPA (2005) and other United States regulatory agencies assumes, without confirmatory studies, that exposure to any carcinogen poses a finite probability, however small, of producing a carcinogenic response. CSFs are used in the risk characterization to estimate potential cancer risk and represent the upper-bound probability of carcinogenic response per unit daily intake of a substance over a lifetime. CSFs are used to assess risks associated with oral and dermal exposures. Inhalation unit risks (IUR) are used in the risk characterization to estimate potential cancer risk for chemicals and represent the upper-bound probability of carcinogenic response per unit (1 microgram per cubic meter [$\mu\text{g}/\text{m}^3$] in air) of a substance over a lifetime. CSFs and IURs will be used in this BHHRA to assess the ELCR for each receptor. Consistent with USEPA (2005) guidelines, CSFs and IURs will be selected from the following sources, listed in order of priority:

- USEPA Integrated Risk Information System (IRIS; USEPA 2015b)
- USEPA Provisional Peer-Reviewed Toxicity Values (PPRTVs; USEPA 2015c)
- CalEPA Unit Risk and Cancer Potency Factors (OEHHA 2009)
- USEPA Health Effects Assessment Summary Tables (USEPA 1997a).

5.3.2 Toxicity Values for Noncarcinogenic Health Effects of Chemicals

Noncarcinogenic toxicity values are applied in the risk characterization to estimate the potential noncancer hazards associated with chemical exposure. In contrast to the default non-threshold assumption used for assessing carcinogenic risk, noncarcinogenic effects are assumed by most regulatory agencies, including USEPA, to exhibit a biological or toxicological threshold below which adverse effects are not expected.

Following USEPA (1989) guidance, chronic reference doses (cRfDs) are used in the risk characterization to assess potential noncarcinogenic hazard with exposure

durations greater than seven years. RfDs are used to assess hazards associated with oral and dermal exposures. Chronic inhalation reference concentrations (cRfCs) are used in the risk characterization to assess potential noncarcinogenic hazard by the inhalation route. Subchronic reference doses (sRfDs) are used in the risk characterization to assess potential noncarcinogenic hazard with exposure durations less than seven years, and subchronic inhalation RfCs (sRfCs) are used to assess potential inhalation noncarcinogenic hazards. Whenever a sRfD or sRfC is unavailable, the cRfD or cRfC, respectively will be used. cRfDs, sRfDs, cRfCs, and sRfCs to be used in this BHHRA will be obtained from the following sources, listed in order of priority:

- IRIS (USEPA 2015b)
- PPRTVs (USEPA 2015c)
- Agency for Toxic Substance and Disease Registry's (ATSDR) Minimal Risk Levels (MRLs; ATSDR 2012)
- CalEPA Reference Exposure Levels (OEHHA 2008)
- HEAST (USEPA 1997a).

5.3.3 Toxicity Values for Radionuclides

USEPA classifies all radionuclides as Group A carcinogens, based on their property of emitting ionizing radiation and on the extensive weight of evidence provided by epidemiological studies of radiogenic cancers in humans (USEPA 2001b; 2014). Human health risks are evaluated based on the radiotoxicity rather than on the chemical toxicity, of each radionuclide present (an exception is uranium, where both radiotoxicity and chemical toxicity are normally evaluated) (USEPA 2001b). Cancer slope factors for radionuclides are provided in the PRG Table developed by the USEPA (USEPA 2014).

In the event radionuclides (i.e., radium and/or uranium) are identified as COPCs, they will be evaluated using radionuclide CSFs obtained from the USEPA PRG Table (USEPA 2014).

5.4 Risk Characterization

Risk characterization integrates the exposure assessment and toxicity information. The cancer risk and/or noncancer hazard will be calculated for each COPC and for each medium and potentially complete exposure pathway. An ELCR will be calculated for constituents for which a valid CSF or IUR has been developed is available.

ELCR for incidental ingestion and dermal contact with soil will be estimated as shown in the following equation:

$$\text{Equation 5-4:} \quad \text{ELCR} = \text{CSF} \times \text{LADD}$$

For inhalation of fugitive dust exposures:

$$\text{Equation 5-5:} \quad \text{ELCR} = \text{IUR} \times \text{EC}$$

For radionuclide exposures:

$$\text{Equation 5-6:} \quad \text{ELCR} = \text{CSF} \times \text{Dose}$$

The total ELCR will be calculated by summing the ELCRs estimated for each carcinogen over all exposure media and exposure pathways.

An HQ will be calculated for all COPCs. The HQ is the ratio of the estimated dose from exposure to a compound in a particular medium to the dose that is not expected to result in adverse health effects, other than cancer.

The HQ for incidental ingestion and dermal contact is:

$$\text{Equation 5-7:} \quad \text{HQ} = \frac{\text{ADD}}{\text{RfD}}$$

For inhalation of fugitive dust exposures:

$$\text{Equation 5-8} \quad \text{HQ} = \frac{\text{EC}}{\text{RfC}}$$

If the HQ exceeds a value of one, the possibility exists for noncarcinogenic hazard. The HQ is not a mathematical prediction of the severity or incidence of the effects, but

rather is an indication that a hazard may exist. ADHS (2003) and USEPA (1989) recommend that the total HI (i.e., the sum of the individual HQs for all constituents) not exceed a value of one. If the resulting total HI is greater than one, it may be recalculated summing only HQs for constituents with a similar mechanism of action or toxic endpoints (USEPA 1989). This statement is consistent with ADHS risk assessment guidance, which describes this procedure in Section 6.1.2 of the guidance document (ADHS 2003): "If the initial screening level HI exceeds 1, it may be appropriate to segregate the compounds by effect and mechanism of action to derive separate HIs for each group."

Consistent with USEPA (1990, 1991) guidance and the Arizona Administrative Code R18-7-206, the BHHRA will be completed under the assumption that for cancer endpoints, the target risk range for cumulative ELCR considered health protective is 1×10^{-6} to 1×10^{-4} , and for noncancer endpoints the target HI is less than 1.

If necessary, site-specific health-based goals (HBGs) will be calculated for COPCs identified as risk drivers during the BHHRA using the exposure factors, toxicity values, and other chemical-specific parameters defined in the BHHRA.

The first step in developing HBGs will be to identify those environmental media (i.e., soil, sediment) that, in the BHHRA, present either a cumulative current or future potential ELCR greater than 1×10^{-4} or a noncancer mechanism of action/toxic endpoint HI greater than 1. The next step will be to identify those COPCs within each medium of concern that contribute to a potential ELCR greater than 1×10^{-6} or a potential HQ greater than 1. Following identification of media of concern and COPCs, the HBGs will be developed.

5.5 Probabilistic Risk Assessment Approach

A probabilistic risk assessment (PRA) relies on probability distributions to characterize variability and uncertainty in risk estimates, and provides results that represent receptor-specific probability distributions of risks. The general approach to PRA is outlined below. If a PRA is deemed necessary for the Site, specific input parameters will be provided to ADEQ for review 90 days prior to the submission of the BHHRA.

A probabilistic assessment tool (e.g., Monte Carlo Analysis [MCA] or Microexposure Event [MEE] analysis) may be used to refine the preliminary risks for environmental media, potential receptors, and Site-related constituents that have the greatest exceedance of risk benchmarks. The probabilistic approach uses the same

fundamental exposure estimation equations used in the conservative deterministic assessment but the former uses a distribution for most parameters (e.g., body weight, skin surface area, soil ingestion rate) whereas the deterministic assessment uses conservative point estimates for each exposure assumption. Distributions in a PRA can be used to characterize variability or uncertainty in the parameters. The exposure estimation equations are iterated several thousand times in a PRA to develop a distribution of a hypothetical receptor's potential excess lifetime cancer risk and non-cancer hazard. The distribution of risks and hazards is assumed to provide a better representation of potential risks and hazards at a site than the single point estimate provided by a deterministic assessment.

5.6 Uncertainties Associated with Baseline Human Health Risk Assessment

The BHHRA will include a discussion of uncertainties associated with the BHHRA. The goal of the BHHRA will be to evaluate the potential for unacceptable health effects associated with the Site. To this end, the assumptions used in this BHHRA will be based on upper-bound exposure (RME) estimates. Because standard default assumptions for the potential receptors will be used, the ELCRs and HIs that will be calculated in this assessment are not absolute and are very likely conservative overestimates of true risks. A list of the key uncertainties associated with conducting this BHHRA for the Site and a qualitative assessment of the potential impacts on the outcome will be presented as part of the BHHRA. Furthermore this section may also include an alternative set of results using USEPA PRA methods (USEPA, 2001a) as discussed above in Section 5.5.

5.7 Presentation of Results

The results of the BHHRA will be presented by EA and receptor. A discussion of "risk drivers" (those COPCs that contribute the most to ELCRs and/or HIs) will also be presented.

5.8 Summary of Work Plan

This work plan describes the approach that will be used to identify COI source(s) and select COPCs from the Site-related COIs, identifies potential human receptors and exposure pathways, and presents the methods to be used to characterize risk and hazard. The methods outlined in this work plan are consistent with the appropriate Arizona and federal guidance along with approved approaches used during previous investigations conducted by ARCADIS (2012a,b,c, 2013) and URS (2008a,b, 2012).



**Baseline Human Health
Risk Assessment Work
Plan**

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Sampling has been conducted at the Site to collect data to assess the nature and extent of impacts and to fulfill objectives of the BHHRA. The BHHRA for the three EAs will incorporate Site-specific parameters in the risk model wherever possible to reduce uncertainty that can arise from using literature-based values or assumptions.

The BHHRA will estimate both ELCRs and noncancer HIs for current and potential future human receptors identified at the Site. Consistent with USEPA (1990; 1991) guidance and the Arizona Administrative Code R18-7-206, the BHHRA will be completed under the assumption that for cancer endpoints, the target risk range for cumulative ELCR considered health protective is 1×10^{-6} to 1×10^{-4} , and for noncancer endpoints the target HI is less than 1. HBGs will be derived (if indicated) for the COPCs in each medium in which the calculated cancer risks exceed the target ELCR range and/or the calculated noncancer hazards exceed the target HI. The results of the BHHRA will be used in the risk management decision making process for the Site.

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**Table 5-1
Human Health Exposure Parameters
Baseline Human Health Risk Assessment Work Plan
Freeport-McMoran Sierrita Inc.
Sierrita Mine, Green Valley, Arizona**

Parameter ²⁵	Symbol	Units	Exposure Intake/Parameters				
			Commercial / Industrial Outdoor Worker (chronic exposure)	Construction Worker (subchronic exposure)	Trespasser - 6 to 16 years (chronic exposure)	Resident Adult (chronic exposure)	Resident Child (chronic exposure)
General Factors							
Averaging Time (cancer)	AT _c	days	28,470 ¹	28,470 ¹	28,470 ¹	28,470 ¹	28,470 ¹
Averaging Time (noncancer)	AT _n	days	9,125 ²	365 ²	3,650 ²	12,045 ²	2,190 ²
Body Weight	BW	kg	80 ³	80 ³	44 ⁴	80 ³	19 ⁵
Exposure Frequency	EF	days/yr	225 ⁶	250 ⁷	52 ⁸	350 ⁹	350 ⁹
Exposure Time	ET	hours/day	8 ¹⁰	8 ¹⁰	1 ⁸	24 ¹¹	24 ¹¹
Exposure Duration	ED	years	25 ¹²	1 ¹³	10 ⁸	27 ¹⁴	6 ¹⁵
Soil - Incidental Ingestion							
Incidental Soil Ingestion Rate	IR _{soil+dust}	mg/day	50 ^{16,17}	330 ¹⁸	50 ¹⁷	50 ¹⁶	200 ¹⁹
Gastrointestinal Absorption Factor	ABS _{in}	unitless	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸
Soil - Dermal Absorption							
Exposed Skin Surface Area	SA	cm ² /day	6,125 ²⁰	6,125 ²⁰	4,400 ²¹	6,125 ²⁰	2,350 ²²
Skin Adherence Factor	AF	mg/cm ²	0.15 ²³	0.19 ²⁴	0.07 ²⁵	0.15 ²³	0.19 ²⁶
Dermal Absorption factor	ABS _d	unitless	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸
Soil - Inhalation of Dust							
Particulate Emission Factor	PEF	m ³ /kg	1.396E +09 ²⁷	1.396E +09 ²⁷	1.396E +09 ²⁷	1.396E +09 ²⁷	1.396E +09 ²⁷
Inhalation Absorption Factor	ABS _{inh}	unitless	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸	chemical-specific ²⁸

Acronyms and Abbreviations:

kg = kilogram(s)
 yr = year(s)
 mg = milligram(s)
 cm² = square centimeter(s)
 m³ = cubic meter(s)
 ADEQ = Arizona Department of Environmental Quality
 ADHS = Arizona Department of Health Services
 USEPA = United States Environmental Protection Agency

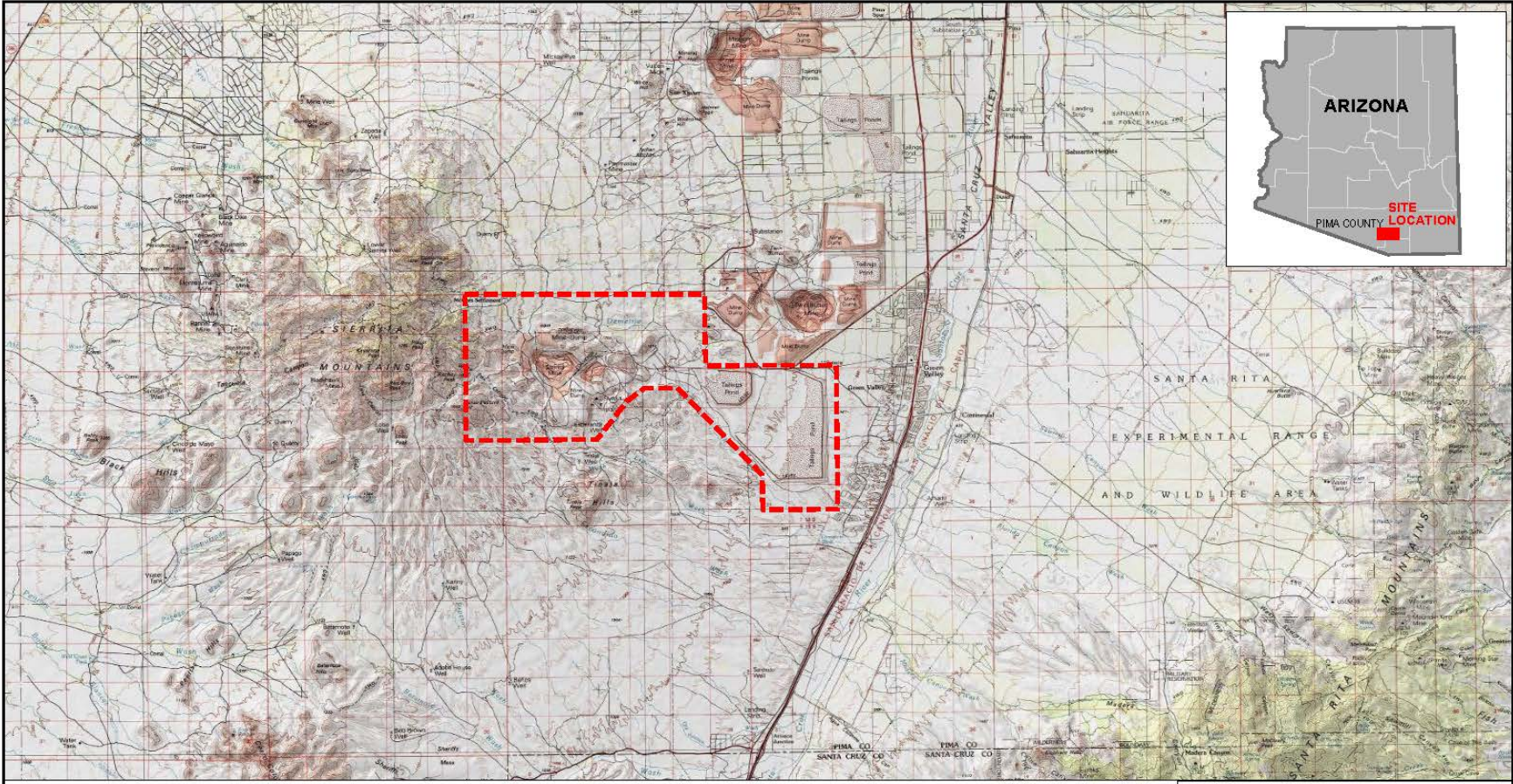
Footnotes:

- The averaging time for assessing cancer risk is the average expected lifespan of 78 years (Table 18-1, USEPA 2011) expressed in days.
- The averaging time for evaluating non-cancer health effects is the exposure duration expressed in days (e.g., 25 years x 365 days/year = 9,125 days) (USEPA 1989).
- Mean recommended body weight for adults (Table 8-1, USEPA 2011).
- Mean recommended body weight for adolescents age 6-16 (Table 8-1, USEPA 2011).
- Professional Judgment: Represents the age-weighted average of the mean body weights for boys and girls, ages 1 through 6 years (Table 8-1, USEPA 2011).
- Standard default occupational exposure frequency for an outdoor worker (ADHS 2003).
- Standard default occupational exposure frequency for a construction worker (ADHS 2003).
- Professional Judgment: Assumes trespassing occurs one day per week.
- Standard default residential exposure frequency (ADHS 2003; ADEQ 2002).
- Professional Judgment: Based on a typical 8-hour workday.
- Professional Judgment: Assumes continuous exposure.
- Standard default occupational exposure duration for an outdoor worker (ADHS 2003; ADEQ 2002).
- Standard default occupational exposure duration for a construction worker (ADHS 2003).
- The total exposure duration is 33 years, based on the 95th percentile residential occupancy period (Table 16-5, USEPA 2011). Cancer risks for the resident adult are calculated assuming 6 years at the child's rate of exposure and 27 years at the adult's rate of exposure.
- Standard default exposure duration for a resident child (ADHS 2003; ADEQ 2002).
- Recommended central tendency soil and dust ingestion rate for an adult (Table 5-1, USEPA 2011). There is no upper percentile soil and dust ingestion rate for an adult available in Table 5-1 (USEPA, 2011).
- Standard default occupational soil ingestion rate (ADEQ 2002).
- Standard default occupational soil ingestion rate for a construction worker (ADHS 2003).
- Recommended upper percentile soil and dust ingestion rate for an individual between the ages of 1 to <6 years (Table 5-1, USEPA 2011).
- Based on an age-weighted average of 95th percentile total skin surface areas for combined males and females, ages 18 to 60 (2.45 m² or 24,500 cm²) (Table 7-9; USEPA 2011). The exposed skin surface area was assumed to be 25% of the total skin surface area (ADEQ, 2002); 24,500 cm² x 0.25 = 6,125 cm².
- Assumes that a receptor 6 to 16 years old is wearing a short-sleeved shirt, shorts, and shoes therefore the SA is the time-weighted average of the surface area for the hands, forearms, and lower legs (USEPA 2011).
- Based on an age-weighted average of 95th percentile total skin surface areas for combined male and females, ages 1 through 6 (0.94 m² or 9,400 cm²) (Table 7-9; USEPA 2011). The exposed skin surface area was assumed to be 25% of the total skin surface area (ADEQ, 2002); 9,400 cm² x 0.25 = 2,350 cm².
- Average of recommended values for mean solids adherence to skin for adult hands (0.1595 mg/cm²) and feet (0.1393 mg/cm²), during "activities with soil" (Table 7-4, USEPA 2011).
- Average of recommended values for mean solids adherence to skin for adult face (0.0982 mg/cm²), arms (0.1859 mg/cm²), and hands (0.2763 mg/cm²) during "construction activities" (Table 7-4, USEPA 2011).
- The soil-to-skin adherence factor for the adolescent trespasser is based on the geometric mean adherence factor for gardeners (USEPA 2004).
- Average of recommended values for mean solids adherence to skin for children's hands (0.17 mg/cm²) and feet (0.20 mg/cm²), during "activities with soil" (Table 7-4, USEPA 2011).
- Standard default particulate emission factor (ADHS 2003; ADEQ 2002).
- Absorption factors are chemical specific (ADHS 2003; USEPA 2015). Default values equal 1.
- As noted in the text of the workplan, some parameters may be revised to address further site-specific information as available.


References:

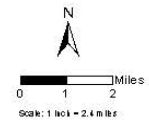
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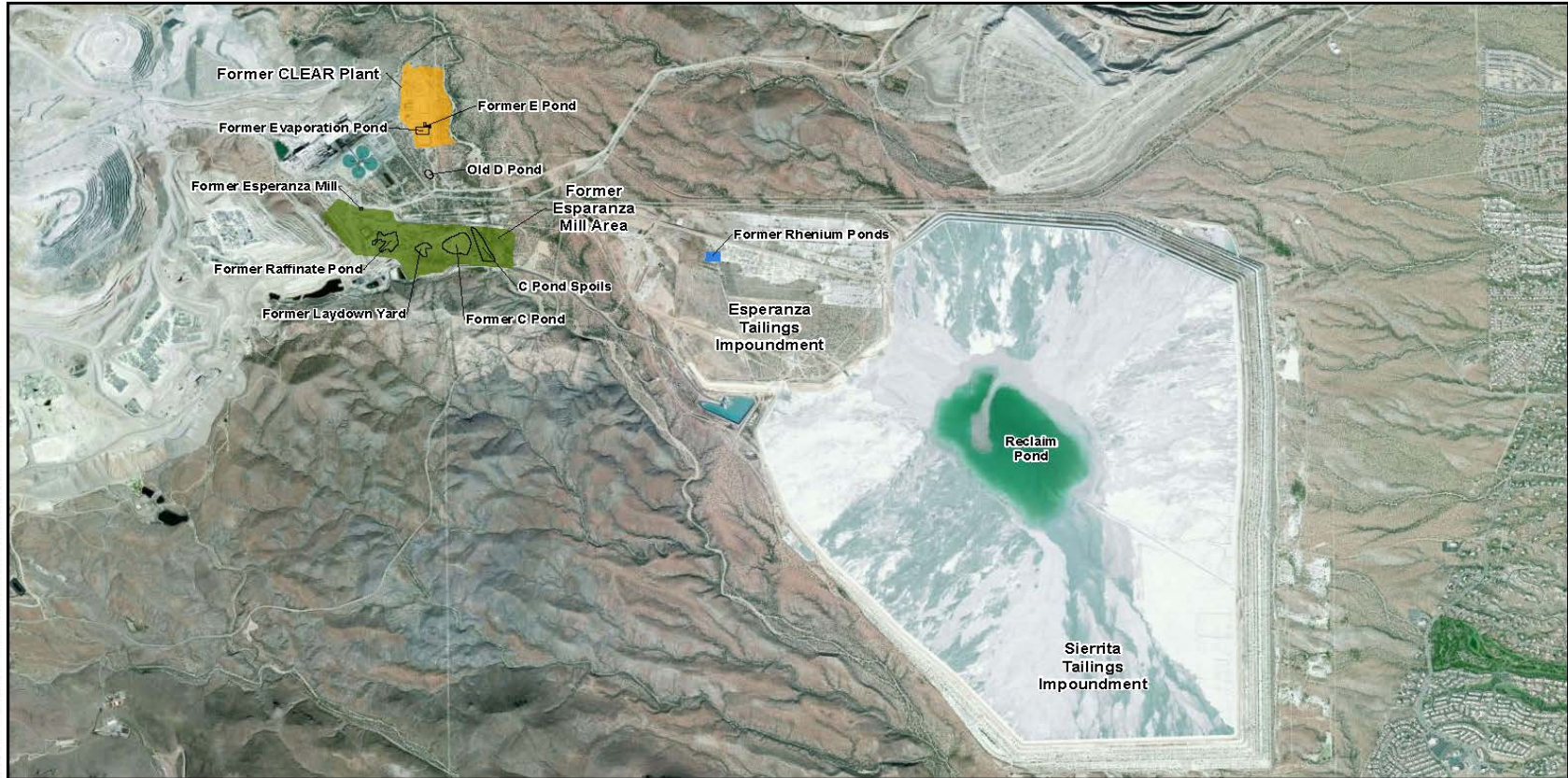


Source: US A Topo Maps, serviced by ESRI ArcGIS Online, accessed on 03/23/2012.

LEGEND
 Approximate Site Boundary



FREEPORT-MCMORAN SIERRITA INC. SIERRITA MINE, GREEN VALLEY, ARIZONA Baseline Human Health Risk Assessment Work Plan	
SITE LOCATION MAP	
	FIGURE 1-1



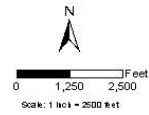
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Source: Bing Maps Aerial, serviced by ESRI ArcGIS Online, accessed on 03/23/2012.

LEGEND

- Footprint* of Former CLEAR Plant
- Footprint* of Former Esperanza Mill Area
- Footprint* of Former Rhenium Ponds
- Footprint* of other former ponds, Former Laydown Yard, and Former Esperanza Mill

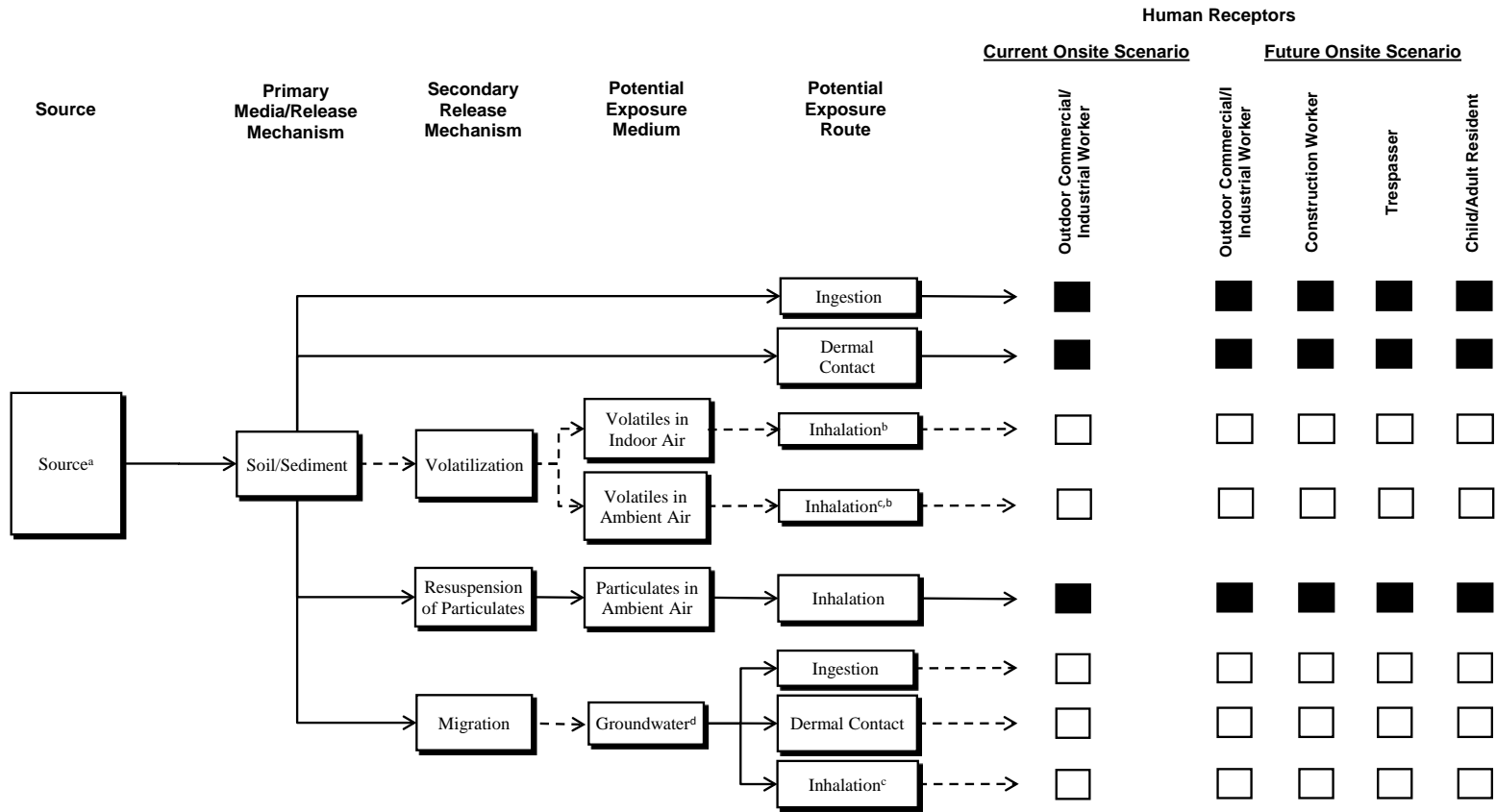
* These footprints of former site features are according to the Final Voluntary Remediation Program - Soil and Sediment Characterization Report, URS Corporation, March 2011, Freeport-McMoran Sierrita Inc.



FREEPORT-MCMORAN SIERRITA INC.
SIERRITAMINE, GREEN VALLEY, ARIZONA
Baseline Human Health Risk Assessment Work Plan

DETAILED SITE MAP

ARCADIS FIGURE
1-2



Notes:

- a Source is related to current and historical activities including: a) excavation; b) hauling and dumping of overburden; c) historic processes to refine ore; d) storage of reagents and other solutions; e) accidental spills.
- b In the event radionuclides are identified as COPCs then this pathway will be reassessed.
- c All COIs are metals (non volatile). As a result, this exposure pathway is incomplete.
- d Groundwater is not used at the facility nor does it discharge into any of the three exposure areas. For this reason it is not an exposure medium for this BHHRA.

Explanation:

--> Transport pathway incomplete; —> Transport pathway complete

□ Pathway/Exposure is not complete.

■ Pathway/Exposure is complete or potentially complete and will be quantitatively evaluated in the BHHRA.

DRAFT BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN
 FREEPORT-MCMORAN SIERRITA INC.
 SIERRITA MINE, GREEN VALLEY, ARIZONA

HUMAN HEALTH CONCEPTUAL SITE MODEL



FIGURE

5-1