FREEPORT-MCMORAN
COPPER & GOLD

Sierrita Operations
Environment, Land & Water Department
6200 West Duval Mine Road
PO Box 527
Green Valley, Arizona 85622-0527

February 22, 2013

Via Certified Mail # 7011 1150 0000 0283 7792
Return Receipt Requested

Ms. Danielle Taber
Project Manager
Voluntary Remediation Program
Arizona Department of Environmental Quality
1110 W. Washington St.
Phoenix, AZ 85007

Re: **Voluntary Remediation Program; Baseline Human Health Risk Assessment Work Plan; Freeport-McMoRan Sierrita Inc., Green Valley, AZ; VRP Site Code: 100073-03**

Dear Ms. Taber:

Please find the enclosed Baseline Human Health Risk Assessment Work Plan. This work plan was completed for Freeport-McMoRan Sierrita Inc. by ARCADIS, Inc. under the Voluntary Remediation Program. This Baseline Human Health Risk Assessment will focus solely on potential impacts associated with exposure to constituents of potential concern detected in soil and sediment as detailed in the work plan.

Please do not hesitate to contact me at (520) 393-2514 if you have any question regarding this submittal.

Sincerely,

Clinton D. Beck, E.I.T.
Environmental Engineer
Freeport-McMoRan Sierrita Inc.

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Stuart Brown, Freeport-McMoRan Copper & Gold

Imagine the result

Freeport-McMoRan Sierrita, Inc.

VOLUNTARY REMEDIATION PROGRAM

BASELINE HUMAN HEALTH RISK ASSESSMENT WORK PLAN

Sierrita Mine
Green Valley, Arizona

February 1, 2013

ARCADIS

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Baseline Human Health Risk Assessment Work Plan

Sierrita Mine
Green Valley, Arizona

Prepared for:
Freeport-McMoRan Sierrita, Inc.

Prepared by:
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Our Ref.:
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Date:
February 1, 2013

Table

Figures

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 Metholodgy
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
$\mu g/m^3$	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 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. March 2011 (URS 2011).

- 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)

For this task, a BHHRA will evaluate an onsite outdoor commercial/industrial worker, a future onsite construction worker, 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 the Arizona Administrative Code (AAC). Specifically regarding the latter, AAC R49-152(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 commercial/industrial workers and residential exposure scenarios for the purposes of evaluating future unrestricted land use of the property.

Based on the findings of the previous investigations (ARCADIS 2012a, b, c and URS 2011), 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 2001)
- Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002c)
- ProUCL Version 4.100. User Guidelines (USEPA 2010a)
- Guidelines for Exposure Assessment (USEPA 1992b)
- Exposure Factors Handbook (USEPA 1997b, 2011c)
- Guidelines for Carcinogen Risk Assessment (USEPA 2005)

- Human Health Toxicity Values in Superfund Risk Assessments (USEPA 2003c).

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 2011).

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.

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 rusted 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.

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.

2.4 Geology and Hydrology

This section summarizes the Site geology, hydrogeology, and surface water.

2.4.1 Site Geology

Four predominant bedrock formations are present at the Site: 1) Jurassic Harris Ranch quartz monzonite on the western side of the Site; 2) Cretaceous Demetrie Volcanics on the southern portion of the Site; 3) earliest Tertiary Ruby Star granodiorite in the northern portion of the Site, which intruded the Demetrie Volcanics and underlying Cretaceous and Jurassic formations; and 4) Tertiary Tinaja Peak formation on the southwestern corner of the Site (Spencer et al. 2003). Several faults are mapped near the southern property boundary.

Alluvial deposits at the Site are categorized as either alluvial stream channel deposits or as basin fill, which is piedmont alluvium deposited with relict alluvial fans. Basin fill deposits are present on the eastern half of the Site. Alluvial stream channel deposits are present mostly along Demetrie Wash and Esperanza Wash.

The ore body is a porphyry copper deposit that has oxide and secondary sulfide mineralization, and primary sulfide mineralization. The predominant oxide copper minerals are malachite, azurite, and chrysocolla. Chalcocite is the most important secondary copper sulfide mineral and chalcopyrite and molybdenite are the dominant sulfides (FCX 2011a).

2.4.2 Hydrogeology

Regionally, the Sierrita mine is located in the southwest end of the Upper Santa Cruz groundwater sub-basin of the Tucson Active Management Area. In the area of the mine, the sub-basin is bound on the southwest by the Sierrita Mountains, which provide mountain-front recharge to the basin. Groundwater flow in the basin fill aquifer typically follows the topography, with flow from the mountains toward the river, and then down valley to the north.

Groundwater at the Site is present in bedrock formations, alluvial deposits in drainages, and in basin fill deposits on the east side of the Site. The basin-fill aquifer provides the principal water source for the mine (URS 2008a). In bedrock formations, permeabilities are generally low and groundwater is present mainly within fractures (URS 2008a). Depth to water in bedrock formations varies from several feet below ground surface near drainages (such as in Demetrie Volcanics near Headwall No. 2 and Tinaja Peak formation near Headwall No. 5) to over 100 ft below ground surface (bgs) in other areas (such as Tinaja Peak formation on the western side of the Site) (URS 2011). Groundwater in the alluvium in drainages is shallow, with depths of several ft bgs. Groundwater in the basin fill deposits is deeper, especially on the east side of the STI where depths to water are approximately 400 ft bgs. The general direction of groundwater flow is from west to east.

2.4.3 Surface Water

Three principal drainages are present at the mine: 1) Amargosa Wash, which trends east from the waste rock piles and flows into Demetrie Wash; 2) Demetrie Wash, which trends southeast from the Sierrita mine-mill area across the southwest side of the STI to the confluence with the Santa Cruz River approximately seven miles southeast of the Sierrita Mill; and 3) Tinaja-Esperanza Wash, which trends southeast from the waste rock piles. The three washes are ephemeral tributaries to the Santa Cruz River (ADEQ 2007).

3. Previous Investigations and Remedial Activities

On June 16, 2007, Sierrita submitted an application to enter the Arizona VRP administered by the ADEQ. 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. The characterization goal for the VRP was to assess potential impacts to soil, groundwater, and sediment from historical and active mine operations.

The soil VRP characterization 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. 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). For sites where the 95 percent upper confidence value exceeded the nr-SRL, the parameter was tentatively identified as a COPC. Arsenic was 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. 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 subareas. 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 2011).

The groundwater VRP characterization study 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.

The results of the groundwater characterization have not been finalized yet (URS 2010).

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

Only relevant soil and sediment data collected by Hydro Geo Chem Inc. (HGC 2008) and URS (2011) through field activities in 2004 and 2008 will be used to conduct the BHHRA.

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

- 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

- Evaluation of detection limits – with respect to the range of detected concentrations.

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 constituents of interest (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 4.1.00 (ProUCL 4.1) to calculate EPCs (USEPA 2010a, 2010b, 2011a). ProUCL 4.100 contains statistical methods to evaluate both full environmental datasets without not detected (ND) values and datasets with 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 2010a).

4.2.3 Treatment of Field Duplicate Data and Data from Multiple Analytical Methods

For datasets with both parent and duplicate analytical results or with multiple analyses present, a single concentration will be selected that is representative of a sample and constituent, generally consistent with USEPA guidance regarding data verification, data validation, and data quality assessment (USEPA 1992a, 2002b). These procedures will include the following:

- In cases where a COI is detected in both the parent sample and the duplicate sample, then the COI concentrations for the parent and duplicate samples will be averaged.

- In cases where a COI is not detected in both the parent sample and the duplicate sample, then the lower of the two detection limits will be used to represent the detection limit for that sample and COI, and appropriate techniques for handling ND data will be applied in calculating statistics later in the data evaluation.

- In cases where a COI is detected in either the parent sample or the duplicate sample and is not detected in the other, the detected concentration will be selected to represent that sample COI concentration, and appropriate techniques for handling ND data will be applied in calculating statistics later in the data evaluation.

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 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 2011b) will be used, 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 conditions[1]

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 4.1.00) and accompanying

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[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.

guidance (USEPA 2010a, 2010b, 2011a) introduce many refinements in calculating 95% UCLs, as discussed below.

USEPA recommends caution in the use of UCLs for small datasets (e.g., < 4 to 6 detects or 8 to 10 total samples) because the performance of the various methods may not be reliable in these cases. Typically, at least five detected concentrations and eight total samples are necessary to calculate UCLs on the mean concentration (i.e., 95% UCLs). When these dataset criteria are not met, maximum concentrations may be selected as the EPC.

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. 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 0-15 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, 2011b).

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 and potentially significant 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 and significant exposure pathway (e.g., incidental ingestion) at the point of exposure.

If any of these four components is not present, a potential exposure pathway is incomplete/insignificant and is not evaluated further in this BHHRA.

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, and future onsite construction workers. 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 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.

AAC R49-152(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. <u>Soil remediation standards; restrictions on property use</u>

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…"

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.

5.1.1.4 Exposure Pathways

For the purpose of assessing risks to current and future human receptors, several complete and significant 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, and the future onsite child/adult resident are identical and are discussed together below.

5.1.1.4.1 Complete and Significant Exposure Pathways

Complete and significant exposure pathways for the current and future onsite outdoor commercial/industrial worker, the future onsite construction worker, 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.

5.1.1.4.2 Incomplete or Insignificant Exposure Pathways

Incomplete or insignificant exposure pathways for the current and future onsite outdoor commercial/industrial worker, the future onsite construction worker, 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. 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. However, site-specific considerations, such as site-use by commercial/industrial workers, may be developed as an alternative to these values if further review of site-specific exposure conditions suggests large variations from the values presented in Table 5-1.

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 COPCs

For 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 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.

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:

$$Dose = \frac{C_{soil} * CF * IR_{soil} * ABSin * EF * ED * SUF}{AT_{\mathrm{n\ or\ c}} * BW}$$

Where:

Dose = ADD or LADD (milligrams per kilogram per day [mg/kg-day])

C_{soil} = COPC EPC in soil (milligrams per kilogram [mg/kg])

CF = conversion factor (1×10^{-6} kilograms per milligram [kg/mg])

IR_{soil} = soil ingestion rate (milligrams per day [mg/day])

ABSin = gastrointestinal absorption factor (unitless and often assumed to be "1")

EF = exposure frequency (days per year)

ED = exposure duration (years)

SUF = site use factor (unitless)

AT_n = averaging time for noncarcinogens (days; ED (years) × 365 days per year)

AT_c = averaging time for carcinogens (days; lifetime (78 years) × 365 days per year)

BW = 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:

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

Where:

Dose = ADD or LADD (mg/kg-day)

C_{soil} = COPC EPC in soil (mg/kg)

CF = conversion factor (1×10^{-6} kg/mg)

SA = exposed skin surface area (square centimeters per day [cm^2/day])

AF = skin adherence factor (milligrams per square centimeter [mg/cm^2])

$ABSd$ = dermal absorption factor (unitless)

EF = exposure frequency (days per year)

ED = exposure duration (years)

SUF = site use factor (unitless)

AT_n = averaging time for noncarcinogens (days; ED (years) × 365 days per year)

AT_c = averaging time for carcinogens (days; lifetime (78 years) × 365 days per year)

BW = 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:

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

And:

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

Where:

EC = exposure concentration (milligrams per cubic meter [mg/m^3])

C_{air} = COPC EPC in air (mg/m^3)

ABS_{inh} = inhalation absorption factor (unitless)

ET = exposure time (hours per day)

EF = exposure frequency (days per year)

ED = exposure duration (years)

SUF = site use factor (unitless)

AT_c = averaging time for carcinogens (hours; lifetime (78 years) × 365 days per year × 24 hours per day)

AT_n = averaging time for noncarcinogens (hours; ED (years) × 365 days per year × 24 hours per day)

C_{soil} = COPC EPC in soil (mg/kg)

PEF = particulate emission factor (cubic meters per kilogram [m^3/kg]).

Toxicity values used along with the 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, 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 ($R_{fetal/maternal}$), 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, a 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 2010c; 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.

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

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 and represent the upper-bound probability of carcinogenic response per unit (1 microgram per cubic meter [µg/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 2012b)
- USEPA Provisional Peer-Reviewed Toxicity Values (PPRTVs; USEPA 2012d)
- 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

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

In the event radionuclides (i.e., radium and/or uranium) are identified as COPCs, they will be evaluated using radionuclide CSFs obtained from HEAST (USEPA 2012c).

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:

Equation 5-4: $ECLR = CSF \times LADD$

For inhalation of fugitive dust exposures:

Equation 5-5: $ECLR = IUR \times EC$

The total ECLR 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:

Equation 5-6: $$HQ = \frac{ADD}{RfD}$$

For inhalation of fugitive dust exposures:

Equation 5-7 $$HQ = \frac{EC}{RfC}$$

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).

Consistent with ADHS (2003) guidance and Arizona Administrative Code R18-7-206, it is assumed that ELCRs greater than the range of 1×10^{-6} to $1x10^{-4}$, or a noncancer HI of greater than one suggest that exposure to a COPC may pose a potential threat to human health.

5.5 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 probabilistic risk assessment (PRA) methods (USEPA, 2001). A PRA relies on probability distributions to characterize variability and uncertainty in risk estimates. PRA results represent receptor-specific probability distributions of risks.

5.6 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.

5.7 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 (2012) and URS (2011).

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 ECLRs and noncancer HIs for current and potential future human receptors identified at the Site. Consistent with the Arizona Department of Health Services guidance (ADHS 2003) and Arizona Administrative Code R18-7-206, it is assumed that an ELCR within the range of greater than $1x10^{-6}$ to $1x10^{-4}$, or a noncancer hazard index (HI) of greater than one suggest that exposure to Site-related COPCs may pose a threat to human health. The U.S. Environmental Protection Agency (USEPA 1990) also recommends a range of acceptable risks between one-in-ten thousand to one-in-one million ($1x10^{-4}$ to $1x10^{-6}$), within which risk management decisions may be made.

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Tables

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	Construction Worker	Resident Adult	Resident Child
General Factors						
Averaging Time (cancer)	AT_c	days	28,470 [1]	28,470 [1]	28,470 [1]	28,470 [1]
Averaging Time (noncancer)	AT_n	days	9,125 [2]	365 [2]	12,045 [2]	2,190 [2]
Body Weight	BW	kg	80 [3]	80 [3]	80 [3]	19 [4]
Exposure Frequency	EF	days/yr	225 [5]	250 [6]	350 [7]	350 [7]
Exposure Time	ET	hours/day	8 [8]	8 [8]	24 [9]	24 [9]
Exposure Duration	ED	years	25 [10]	1 [11]	27 [12]	6 [13]
Site Use Factor	SUF	unitless	1 [14]	1 [14]	1 [14]	1 [14]
Soil - Incidental Ingestion						
Incidental Soil Ingestion Rate	$IR_{soil+dust}$	mg/day	50 [15, 16]	330 [17]	50 [15]	200 [18]
Soil - Dermal Absorption						
Exposed Skin Surface Area	SA	cm^2/day	6,125 [19]	6,125 [19]	6,125 [19]	2,350 [20]
Skin Adherence Factor	AF	mg/cm^2	0.15 [21]	0.19 [22]	0.15 [21]	0.19 [23]
Soil - Inhalation of Dust						
Particulate Emission Factor	PEF	m^3/kg	1.396E +09 [24]	1.396E +09 [24]	1.396E +09 [24]	1.396E +09 [24]

Acronyms and Abbreviations:

kg = kilogram(s)

yr = year(s)

mg = milligram(s)

cm^2 = square centimeter(s)

m^3 = cubic meter(s)

ADEQ = Arizona Department of Environmental Quality

ADHS = Arizona Department of Health Services

USEPA = United States Environmental Protection Agency

Footnotes:

1. The averaging time for assessing cancer risk is the average expected lifespan of 78 years (Table 18-1, USEPA 2011) expressed in days.
2. 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).
3. Mean recommended body weight for adults (Table 8-1, USEPA 2011).
4. 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).
5. Standard default occupational exposure frequency for an outdoor worker (ADHS 2003).
6. Standard default occupational exposure frequency for a construction worker (ADHS 2003).
7. Standard default residential exposure frequency (ADHS 2003; ADEQ 2002).
8. Professional Judgment: Based on a typical 8-hour workday.
9. Professional Judgment: Assumes continuous exposure.
10. Standard default occupational exposure duration for an outdoor worker (ADHS 2003; ADEQ 2002).
11. Standard default occupational exposure duration for a construction worker (ADHS 2003).
12. The total exposure duration is 33 years, based on the 95^{th} 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.
13. Standard default exposure duration for a resident child (ADHS 2003; ADEQ 2002).
14. Default value in absence of site-specific information.
15. 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).
16. Standard default occupational soil ingestion rate (ADEQ 2002).
17. Standard default occupational soil ingestion rate for a construction worker (ADHS 2003).
18. Recommended upper percentile soil and dust ingestion rate for an individual between the ages of 1 to <6 years (Table 5-1, USEPA 2011).
19. Based on an age-weighted average of 95^{th} percentile total skin surface areas for combined males and females, ages 18 to 60 (2.45 m^2 or 24,500 cm^2) (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 cm^2 x 0.25 = 6,125 cm^2.
20. Based on an age-weighted average of 95^{th} percentile total skin surface areas for combined male and females, ages 1 through 6 (0.94 m^2 or 9,400 cm^2) (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 cm^2 x 0.25 = 2,350 cm^2.
21. Average of recommended values for mean solids adherence to skin for adult hands (0.1595 mg/cm^2) and feet (0.1393 mg/cm^2), during "activities with soil" (Table 7-4, USEPA 2011).
22. Average of recommended values for mean solids adherence to skin for adult face (0.0982 mg/cm^2), arms (0.1859 mg/cm^2), and hands (0.2763 mg/cm^2) during "construction activities" (Table 7-4, USEPA 2011).
23. Average of recommended values for mean solids adherence to skin for children's hands (0.17 mg/cm^2) and feet (0.20 mg/cm^2), during "activities with soil" (Table 7-4, USEPA 2011).
24. Standard default particulate emission factor (ADHS 2003; ADEQ 2002).
25. As noted in the text of the workplan, some parameters may be revised to address further site-specific information as available.

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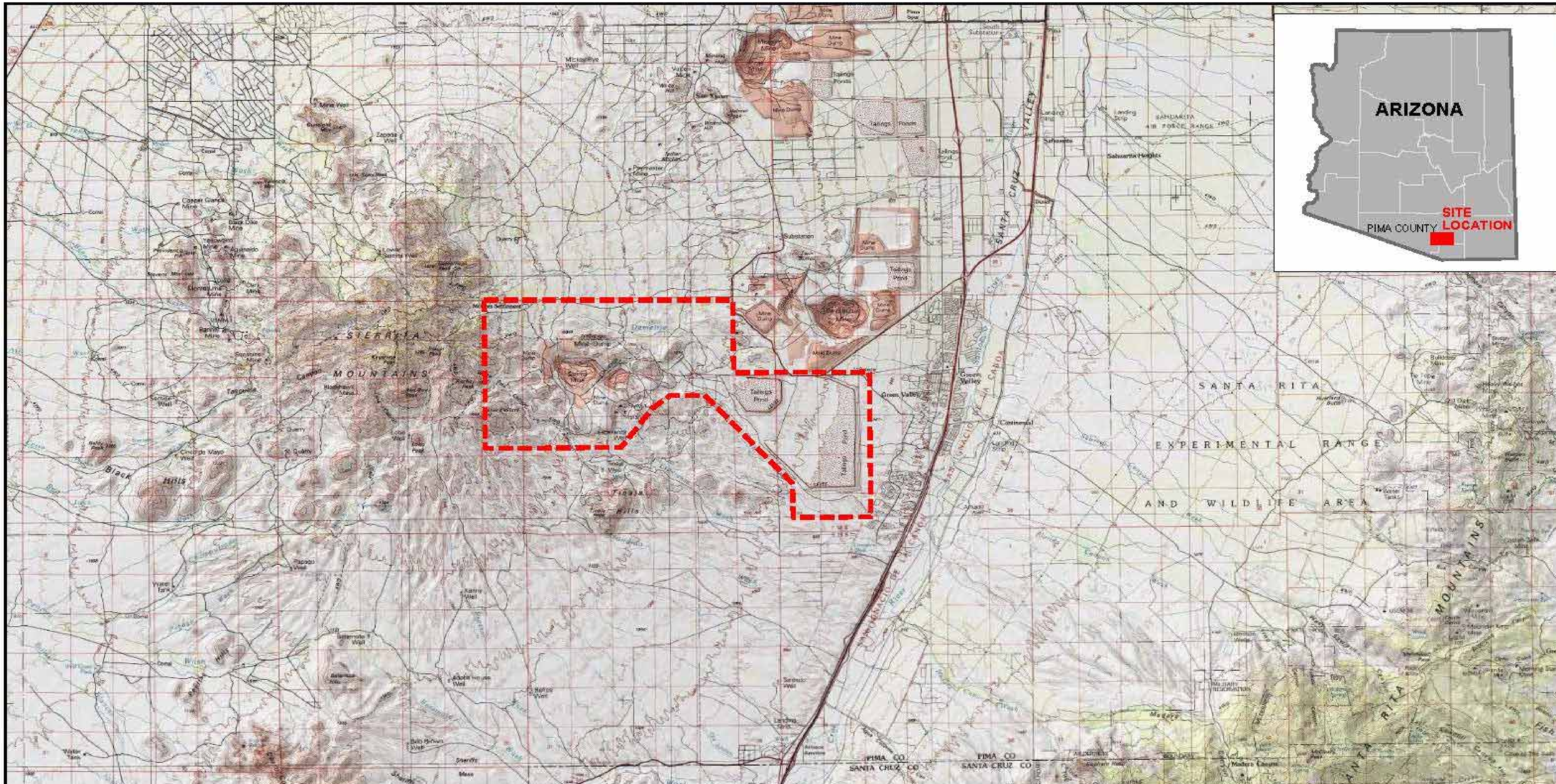
Figures



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

LEGEND

Approximate Site Boundary

N

Miles
0 1 2
Scale: 1 inch = 2.4 miles

FREEPORT-MCMORAN SIERRITA INC.
SIERRITA MINE, GREEN VALLEY, ARIZONA

Baseline Human Health Risk Assessment Work Plan

SITE LOCATION MAP

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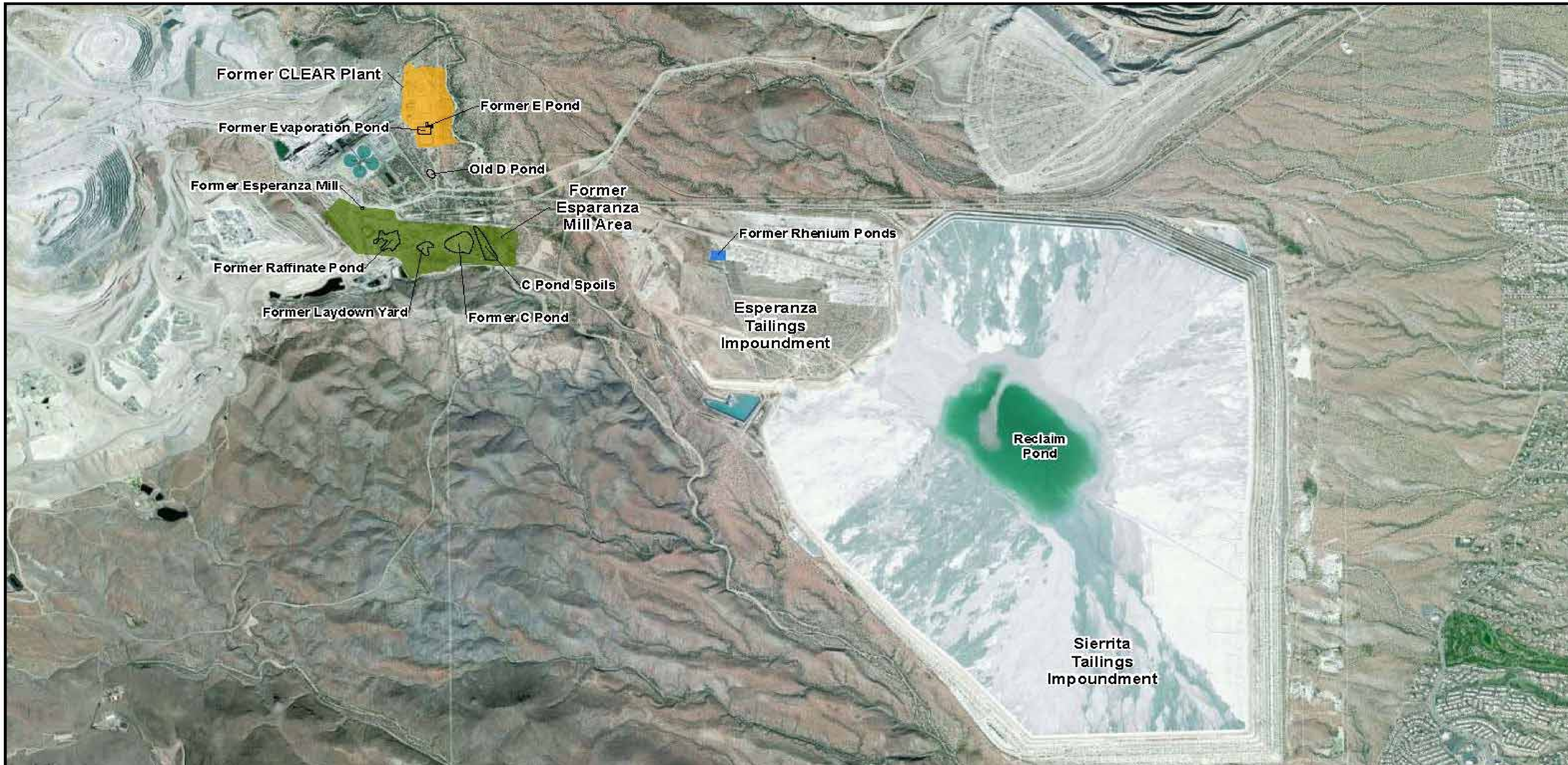
FIGURE
1-1



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

LEGEND

- Footprint* of Former CLEAR Plant
- Footprint* of Former Esparanza 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.

N

0 1,250 2,500 Feet

Scale: 1 inch = 2500 feet

FREEPORT-MCMORAN SIERRITA INC.
SIERRITA MINE, GREEN VALLEY, ARIZONA

Baseline Human Health Risk Assessment Work Plan

DETAILED SITE MAP

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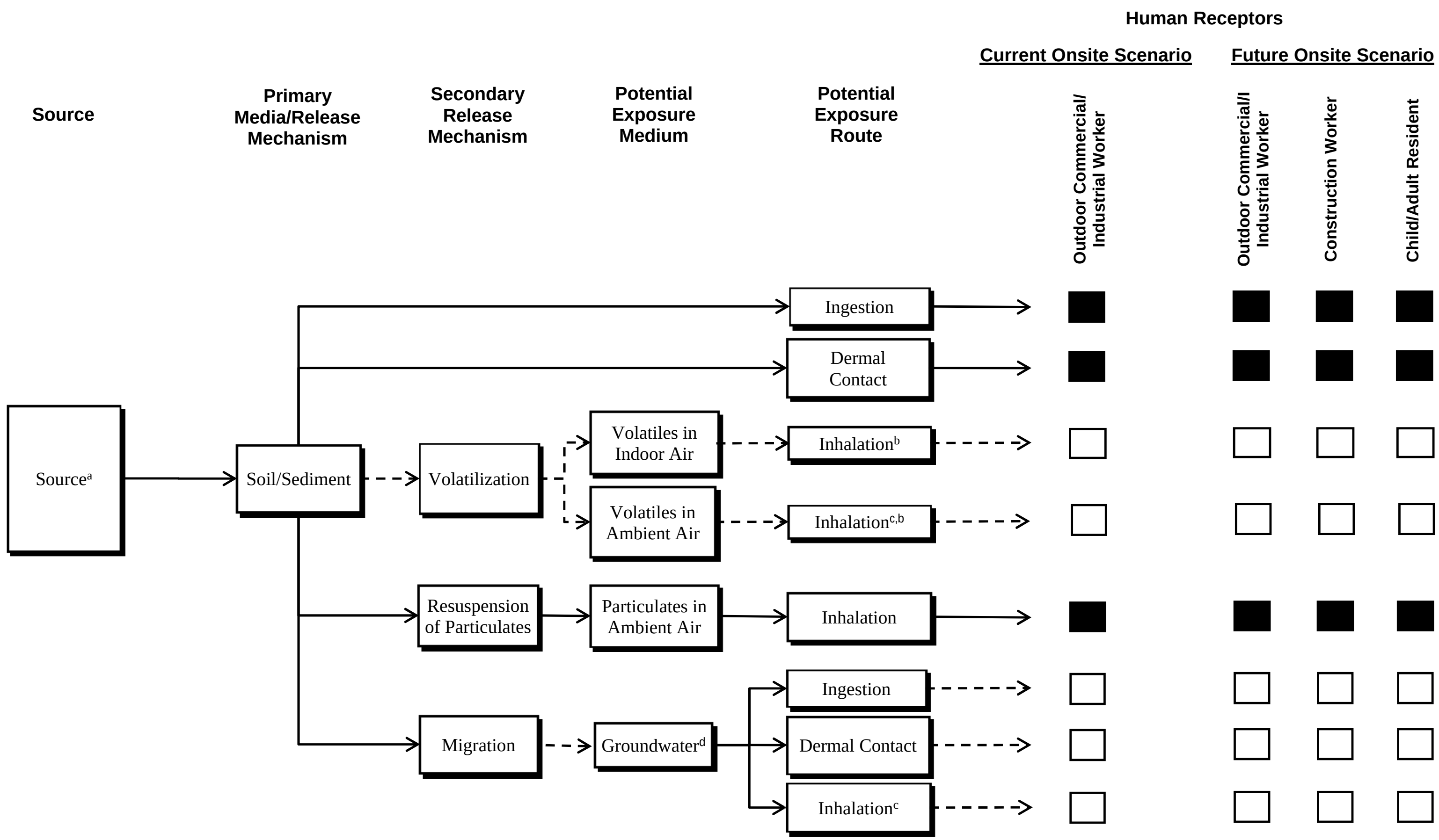
FIGURE **1-2**

Path: K:\Sierrita Risk Assessment\GIS\ArcMap_MXD\Figure 1-2 Detailed Site Map.mxd Date Saved: 3/23/2012 2:47:03 PM Author: JCiex @ Boulder, CO



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; d) 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.

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

HUMAN HEALTH CONCEPTUAL SITE MODEL

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FIGURE

5-1