PROBABILISTIC RISK ASSESSMENT FOR THE MORENCI SCHOOL COMPLEX
MORENCI, ARIZONA

Prepared for
Freeport Minerals Corporation

Prepared by
Ramboll US Consulting, Inc.
Seattle, WA

Date
February 17, 2021

CONTENTS

1.	**Introduction**	**1**
2.	**Background**	**2**
2.1	Site Location and History	2
2.2	PRA Methodology	2
2.3	Screening Level Assessment	3
2.4	Arsenic Data Analysis	4
3.	**Exposure Assessment**	**6**
3.1	Receptor Populations	6
3.2	Exposure Pathways	7
3.3	Exposure Assumptions	7
3.3.1	Exposure Duration	7
3.3.2	Body Weight	8
3.3.3	Exposure Frequency	8
3.3.4	Ingestion of Outdoor Soil and Indoor Dust	9
3.3.5	Oral Bioavailability of Arsenic in Soil	12
3.3.6	Dermal Exposure to Arsenic in Soil and Dust	12
3.3.7	Inhalation Exposure Time	14
3.3.8	Averaging Time	14
3.3.9	Arsenic Exposure Concentration	14
4.	**Toxicity Assessment**	**17**
5.	**Risk Characterization**	**18**
5.1	Cancer Risk Characterization Methods	18
5.2	Results and Discussion	20
6.	**Uncertainty Analysis**	**22**
7.	**Summary and Conclusions**	**24**
8.	**References**	**25**

TABLE OF TABLES

Table 1: Screening Summary
Table 2: Target Organ Hazard Indices (HIs)
Table 3: Arsenic Data
Table 4: UCLM Summary
Table 5: Probabilistic Risk Assessment Input Parameters
Table 6: Probabilistic Risk Assessment Results

TABLE OF FIGURES

Figure 1: Site Location Map
Figure 2: Morenci School Complex Property Map
Figure 3: 2020 Sample Locations by School
Figure 4: 2018 and 2019 Sample Locations
Figure 5: Analytical Results by Depth Interval

APPENDICES

Appendix A: ProUCL Output
Appendix B: Crystal Ball Report

ACRONYMS AND ABBREVIATIONS

95UCLM	Ninety-five percent upper confidence limit on the mean
A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department Health Services
A.R.S.	Arizona Revised Statute
CSF	cancer slope factor
cm^2	square centimeter
DTSC	Department of Toxic Substances Control
ED_{ca}	carcinogen exposure duration
EFH	Exposure Factors Handbook
HI	hazard index
HQ	hazard quotient
hr	hour
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
IUR	inhalation unit risk factor
kg	kilogram
m^3	cubic meter
mg	milligram
NHANES	National Health and Nutrition Examination Survey
ODEQ	Oregon Department of Environmental Quality
PRA	probabilistic risk assessment
QC	quality control
RBA	relative bioavailability of arsenic
Ramboll	Ramboll US Consulting, Inc.
RSL	regional screening level
SRLs	soil remediation levels
Site	Morenci School Complex, Morenci, Arizona
TRW	Bioavailability Technical Review Work Group
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
VRP	Voluntary Remediation Program
yr	year

1. INTRODUCTION

This probabilistic risk assessment (PRA) report was prepared by Ramboll US Consulting, Inc. (Ramboll, formerly Ramboll US Corporation) on behalf of Freeport Minerals Corporation to evaluate risks from potential exposures to arsenic in soil and tailings at the Morenci School Complex in Morenci, Arizona (school complex; schools; Site). A portion of the school complex is built on top of a former mine tailings storage facility (**Figure 1**), and tailings not covered by imported fill or topsoil have been observed in some locations. The Site was entered into the Arizona Department of Environmental Quality (ADEQ) Voluntary Remediation Program (VRP) in 2019 (Site Code 513333-00). This final PRA report incorporates revisions in accordance with approved resolutions to ADEQ's comments and additional direction from ADEQ (ADEQ 2020a,b,c, 2021; Ramboll, 2020a) on initial draft reports (Ramboll 2020b,c).

A Site Characterization Report completed in 2020 identified arsenic as the only chemical of potential concern at the Site. As shown in Table 8 of the Site Characterization Report, the other target constituents that were detected in soil and tailings samples collected from locations across the school complex where students, faculty, and staff may be present were below the ADEQ state-wide residential soil remediation levels (SRLs) (Arcadis 2020). An additional screening level assessment is presented in Section 2.3. The SRLs and other screening levels based on a residential scenario are protective of a school scenario. Of the potential receptors that may be present in a school scenario, children are the most sensitive. Assessment of risks to a child attending the schools and to an adult school staff member are evaluated in this PRA.

For arsenic concentrations at this Site, meeting the middle to lower end of the target risk range for carcinogenic effects will also meet the noncancer hazard criteria. For example, an arsenic concentration resulting in a cancer risk estimate of 1×10^{-5}, which has been used as a target cancer risk for cleanup level development at other Arizona VRP sites, will also result in a noncancer hazard estimate below one. This is demonstrated by a comparison of the cancer- and noncancer-based USEPA Regional Screening Levels (RSLs), where: the residential default soil RSL for arsenic based on a target cancer risk of 10^{-5} is 6.8 mg/kg, and the RSL based on a target noncancer hazard of 1 is 35 mg/kg. A similar relationship can be inferred for the school scenario. It is therefore not necessary to separately assess noncancer hazards when assessing cancer risks from arsenic at this target level. Consequently, this PRA focuses on potential cancer risks to Morenci school children and adults that could result from exposure to arsenic in soil and tailings across the school complex. Noncancer hazards are also addressed in the screening level assessment presented in Section 2.3.

The remainder of this report is organized as follows:

- Section 2 - Background
- Section 3 - Exposure Assessment
- Section 4 - Toxicity Assessment
- Section 5 - Risk Characterization
- Section 6 - Uncertainty Analysis
- Section 7 - Summary and Conclusions
- Section 8 - References

2. BACKGROUND

2.1 Site Location and History

A detailed description of the Site is provided in the Site Characterization Report (Arcadis 2020). Text from that report is duplicated or summarized in the following three paragraphs to provide background relevant to the PRA.

The Site is approximately 72 acres and is occupied by the Metcalf Elementary School and Early Childhood Center (hereinafter referred to as the Elementary School); Fairbanks Middle School; Morenci High School; the School District administration building; a bus barn; and parking lots, play areas, and sports fields associated with the schools (**Figure 2**). Based on information obtained during a January 9, 2020 meeting with Dr. Woodall, Morenci School Superintendent, approximately 1,400 students attend the Morenci Public Schools, with approximately 46 percent of the total student population attending preschool through fourth grade at the Elementary School, approximately 27 percent of the total student population attending fifth through eighth grade at Fairbanks Middle School, and approximately 27 percent of the total student population attending ninth through twelfth grade at Morenci High School. According to Dr. Woodall, approximately 225 full-time faculty and staff are employed at the three schools.

Copper mining in the vicinity of Morenci began in 1872 and is still occurring at the present time. Freeport-McMoRan Morenci Inc., a subsidiary of Freeport Minerals Corporation, is the current owner and operator of the Morenci Mine (the mine). The schools were built on a portion of a former tailings storage facility that was once operated as part of the mine. Dr. Woodall reported that 12 to 18 inches of imported fill was overlain on the tailings before construction of the school complex (prior to 1979) and imported topsoil was also used on landscaped areas. According to Dr. Woodall, some of the imported topsoil may have come from farm fields. Dr. Woodall also indicated that they routinely use (and have used in the past) commercially available fertilizer and herbicide mixtures on the sports fields.

Three stormwater ditches or washes incised into tailings and fill are present on and around the Site (**Figure 2**). Per a discussion with Dr. Woodall and as confirmed during the sampling program, the Site is fenced, and children do not have access to the drainages behind the Elementary School and Middle School. The East Ditch behind (east of) the High School is accessible (that is, not fenced over part of its reach); however, the ditch is located in an area that is not frequented by children during the school day.

2.2 PRA Methodology

This report utilizes PRA to assess potential risks at the Site. Unlike deterministic risk assessment methods, PRA methods use exposure assumptions that are expressed as statistical distributions rather than as a single value (i.e., a constant or "point estimate"). For example, instead of expressing arsenic bioavailability in soil as a single value, it may be expressed as a statistical distribution specified by a minimum value, various percentiles, and a maximum value. The advantage of PRA methods is that they incorporate the likely range of uncertainty or variability in exposure parameters into the final risk estimates. ADEQ regulatory guidance specifically permits the use of PRA methods (Arizona Administrative Code [A.A.C.] R18-7-206.B). The PRA methods used in this report are also consistent with United States Environmental Protection Agency (USEPA) guidance on PRA (Volume

III, Part A – Process for Conducting Probabilistic Risk Assessment [USEPA 2001]) and Oregon Department of Environmental Quality (ODEQ) PRA guidance (ODEQ 1998). The following section describes the exposure assumptions used to evaluate the health risks associated with arsenic in Site soil and tailings.

Oracle's Crystal Ball software (Release 11.1.2.4.850) was used to complete the PRA. This software utilizes Monte Carlo simulation methods to randomly select values from exposure parameter distributions, repeating the process over many iterations to produce a distribution of risk estimates that represents the range of possible outcomes. For this PRA, a maximum of 10,000 iterations was selected to create the arsenic cancer risk distributions.

2.3 Screening Level Assessment

As described above, prior to conducting risk assessments, the concentrations of chemicals present in environmental media are typically compared with risk-based screening levels, and only those chemicals exceeding the screening levels are carried forward in the risk assessment. Specifically, the site concentration is divided by the screening level to yield a hazard quotient (HQ). The Arizona SRLs are based on USEPA residential RSLs with a target HQ of 1 for most metals. Minor differences are likely due to revisions to RSL toxicity values and exposure parameters that have changed since the time the SRLs were issued. The exception is arsenic, for which the SRL is based on the State-wide background concentration rather than a risk-based value. Other than arsenic, which is a carcinogen, and lead, which is assessed by modeling blood lead levels, RSLs for metals detected in Morenci soil/tailings samples are derived using toxicity values for noncarcinogenic effects. As shown on Table 8 of the 2020 Site Characterization Report, the maximum concentrations of the analyzed metals, except for arsenic, are below their respective SRLs.

A screening level evaluation was conducted to assess the potential for cumulative noncancer health hazards, which are not accounted for in the chemical-specific SRLs. Because the RSLs have been updated since the SRLs were issued and represent current risk-based values, the RSLs based on noncancer hazards were used for this screening level evaluation. RSLs based on a target HQ of 1 were modified to account for potential additive effects that could result from exposure to multiple metals in soil. The target organ on which the toxicity value used to develop the noncancer RSL for each metal is based was identified. Metals with shared target organs were grouped, and the RSL for each metal was divided by the total number of metals in the corresponding target organ group. For example, if four detected chemicals had the nervous system as the toxicity value's target organ, then the associated RSLs were divided by 4 to account for this same target organ. Maximum concentrations of detected metals were compared to the target organ-adjusted RSLs, and these results are shown on **Table 1**.

If any metal had a maximum concentration greater than its target organ-adjusted RSL, cumulative noncancer hazards were estimated by summing screening level ratios for metals with shared target organs. The ratio of the maximum detected concentration of each metal to its RSL was calculated, and ratios were summed to estimate a hazard index (HI) for each group of metals sharing a target organ. Using the maximum concentration of each detected metal, rather than a 95 percent upper confidence limit (UCL) on the mean or similar statistic typically used to represent exposure concentrations, provides a conservative estimate of cumulative noncancer hazards. As shown in **Table 2**, the target organ specific HIs meet the target of 1. Therefore, only arsenic cancer risks were further evaluated in the PRA.

2.4 Arsenic Data Analysis

The arsenic concentrations are examined in more detail to examine differences between the tailings and the fill/topsoil/weathered native materials. As shown in **Table 3**, arsenic concentrations measured in soil samples from some locations were above the SRL of 10 mg/kg; however, arsenic concentrations greater than 10 mg/kg were limited to samples of imported topsoil. Arsenic concentrations measured in all samples that contained operations-related source material (i.e., mine tailings) were below the SRL. Arsenic in the combined soil/tailings materials was assessed further by estimating Site-wide exposure point concentrations using the USEPA's ProUCL software. Ninety-five percent upper confidence limits on the mean (95UCLMs) were calculated using all of the soil/tailings data collected in 2019 and 2020 from areas that may be accessed by school students and staff (i.e., the same data used for the PRA described in this report). A 95UCLM was also calculated using data collected from the 0 to 3 inch depth interval to estimate exposure concentrations in surface soil[1].

Additionally, separate 95UCLM concentrations were calculated using data collected from each individual school area (i.e., elementary, middle, and high schools), and from the sports fields where arsenic concentrations measured in soil tended to be higher compared to other areas of the Site (see Section 3.3.9). The ProUCL output is included in **Appendix A** and summarized in **Table 4**. Numerous UCLM calculation methods are available in ProUCL and potentially applicable 95UCLM concentrations are listed.[2] As shown in **Table 4**, the Site-wide mean and 95UCLM concentrations calculated for surface soil/tailings and for soil/tailings across sampled depths are below the SRL of 10 mg/kg. The mean and 95UCLM concentrations for each school are also less than 10 mg/kg. For the sports fields, seven of eight 95UCLMs are less than 10 mg/kg, while one value is just above 10 mg/kg (10.8 mg/kg). The sports fields dataset follows a lognormal distribution. The 95UCLM value identified by the ProUCL software as the "Suggested UCL to Use" for this dataset is 9.5 mg/kg, based on the lognormal H-UCL method. However, the USEPA notes included with the ProUCL output state that H-statistic based UCLMs are included for historical reasons only and should be avoided, contradicting the suggestion from ProUCL to use the 95UCLM based on this method. The USEPA notes further recommend the use of nonparametric methods to calculate 95UCLMs for skewed distributions that do not follow a gamma distribution (see ProUCL output in **Appendix A**). Based on this recommendation, additional values based on nonparametric calculation methods are also shown in **Table 4** for the sports fields. Six of the seven nonparametric 95UCLM concentrations, in addition to the ProUCL-recommended lognormal distribution-based value, are below 10 mg/kg and the mean concentration for the sports fields area is 6.9 mg/kg. The dataset collected from the sports fields area includes composite samples, which are collected to better approximate potential exposure from children playing across an entire use area rather than a single spatial point (USEPA 2003). This sampling approach better mimics students playing on the athletic fields. Also, the grid sampling approach used for the 2020 site characterization efforts often provides better precision (i.e., smaller confidence intervals, smaller standard errors of population estimates) and more complete coverage of the target population than random sampling. Finally, the USEPA recommends a sample size of at least 10 for calculating statistics to represent chemical concentrations in exposure media (USEPA 2009, 2015); a

[1] Data were collected in 2019 from a depth interval of 0 to 12 inches. Because these samples may not represent surface soil they were not included in the surface soil 95UCLM calculation. The range of concentrations detected in the 51 surface soil samples collected in 2020 encompasses the range of concentrations measured in the 13 samples from 2019 and the overall mean is higher based on the 2020 samples, so effects of excluding the 2019 samples from the surface soil dataset are expected to be minimal.

[2] Based on discussion with ADEQ (ADEQ 2020c), due to problems associated with the Chebyshev and Kaplan-Meier (KM) 95UCLM calculation methods in the ProUCL software, values based on these methods should not be used. Values calculated by ProUCL using these methods are therefore not presented.

total of 39 samples (including 30 composite and nine discrete samples) were collected from the sports fields area. Based on the number and type of samples collected from the sports fields area, the resulting dataset is considered sufficient to characterize the average soil concentration of arsenic in this area for risk assessment purposes. It is therefore reasonable to conclude that the average arsenic concentration in soil across the sports fields area is below the SRL and that further remedial investigation is not warranted.

3. EXPOSURE ASSESSMENT

The potentially impacted population (receptor population) at the Morenci school complex is made up of students, faculty, and staff. Arsenic is the only chemical of potential concern for this Site based on the results of the screening evaluation completed in the Site Characterization Report (Arcadis 2020). Exposure is via soil and tailings, not drinking water or surface water, so the relevant exposure pathways are limited to soil/tailings ingestion, dermal contact with soil/tailings, and inhalation of resuspended soil/tailings. Additional details and the basis for each exposure assumption used in this risk assessment are presented below.

3.1 Receptor Populations

The Morenci school complex includes preschool through grade 12 in four separate school buildings (Early Childhood Center and Elementary, Middle, and High Schools). Potential receptors include students, teachers, and other support staff such as coaches, groundskeepers, and indoor staff. Children can start preschool at age three, then attend a pre-K school at age four. In Arizona, students must be five years old to start kindergarten and six years old to start first grade. This PRA assumes attendance of all potential classes from preschool through 12th grade, resulting in an exposure period for students that could be as long as 15 years. Teachers and other staff may work at the school for up to 25 years or more.

Despite their potentially shorter exposure durations, several other factors are expected to result in greater overall potential exposure for children compared to adults. Children are likely to contact soil/tailings more frequently and intensively than adults as they engage in sports and other outdoor play activities. The combination of higher soil ingestion rates and lower body weights contributes to higher exposure estimates for children compared to adults. Because children are the most sensitive among the school receptor population, they are the focus of this PRA. The relevant receptor population consists of children ranging in age from three to 18 years. For this assessment, all receptors were assumed to be exposed beginning at age three, which conservatively incorporates early childhood exposure in all cancer risk estimates. In reality, some exposures could begin at a later stage of childhood. This results in the most conservative estimates of potential exposure and risk.

An adult staff member is also evaluated. This receptor is assumed to be a teacher or coach who supervises students during outdoor play or sporting activities. Evaluation of this receptor, who is likely to spend the most time contacting soil/tailings on the school grounds, is also expected to cover other potential school staff members such as a groundskeeper or maintenance staff member.

Recent exposure data for parameters such as soil ingestion rate enable distinction of exposure assumptions by age. For this PRA, student receptors are characterized using three age categories: 3 to <6 years, 6 to <12 years, and 12 to <18 years. Using exposure assumption distributions based on data for each age group enables modeling of exposures that may change as a child ages from preschool through high school graduation due to differences in activity patterns and physical characteristics between young children, preteens, and teenagers. Adult receptors are characterized as being 21 years or greater in age.

3.2 Exposure Pathways

Exposure to metals in soil/tailings may occur via ingestion, dermal contact and inhalation. Soil ingestion is assumed to occur when individuals incidentally transfer soil on the hands to the mouth. A portion of soil ingestion is assumed to consist of indoor dust ingestion (discussed in Section 3.3.4 below). Dermal absorption of metals from soil may also occur. Although dermal absorption of metals from soil is typically low, this pathway is evaluated where applicable information is available. Inhalation exposure to metals in soil occurs entirely via resuspension and subsequent inhalation of airborne dust since arsenic is non-volatile at ambient temperatures.

3.3 Exposure Assumptions

Numerous assumptions are used to calculate potential chemical exposure. These assumptions, which may be specified as single point estimates (i.e., constants), or as statistical distributions, describe the physical/physiological characteristics of the receptors (e.g., body weight, skin surface area, etc.), chemical-specific assumptions (e.g., oral bioavailability, dermal absorption efficiency) and receptor behavioral characteristics (e.g., number of days per year a child attends school). The assumptions used in this risk assessment and their basis are summarized in **Table 1** and described in detail below.

Where available and applicable, current data summaries and recommendations in the USEPA's *Exposure Factors Handbook* (EFH; USEPA 2011) were used as a primary reference for exposure parameter distributions in this PRA. For some parameters more recent data were available (i.e., soil ingestion rates and soil arsenic relative bioavailability). For several parameters, literature sources were obtained or distributions from the 1998 probabilistic risk assessment guidance published by the ODEQ were used. For some parameters, the ODEQ (1998) distributions represent the most current available data.

To enable incorporation of all potential values from a given distribution in risk estimate calculations, custom distributions defined by specified percentiles were entered as continuous distributions. In contrast, entering percentiles as discrete (weighted) values would result in only one of the discrete percentile values being selected for the specified exposure assumption in each model iteration. For example, a hypothetical exposure parameter distribution may have a 10th percentile of 15 and a 25th percentile of 40. Values between 15 and 40 exist within the distribution but are not included in the discrete percentile values. Using a continuous distribution allows, for example, a value of 30 to be selected for this hypothetical exposure parameter in one of the many iterations included in a particular model run. This approach results in a more complete characterization of the range of possible risk estimates.

3.3.1 Exposure Duration

Exposure duration is the number of years an individual is assumed to have contact with exposure media. For the student, a custom probability distribution of exposure duration for children aged 3 to <18 years was developed by averaging the percentiles provided in Table 16-109 of the EFH (USEPA 2011) for ages 3, 6, 9, 12, and 15 years. The resulting distribution was capped at a maximum exposure duration of 15 years, which conservatively assumes that a child lives in the Morenci school district throughout the entire duration of his/her preschool, elementary, middle, and high school years and attends the Morenci schools from preschool through high school graduation. Capping the exposure duration distribution at 15 years is conservative because greater weight is assigned to the maximum value in the distribution, resulting in a higher overall probability of selecting the maximum exposure duration relative to those less than 15 years in any given model iteration.

For the adult school worker, occupational tenure rather than residential occupancy period is the appropriate measure of exposure duration. The EFH provides median occupational tenure across all job categories based on January 1987 data from the U.S. Census Bureau (USEPA 2011). Burmaster (2000) reviewed more recent February 1996 U.S. Census Bureau data and projected occupational tenure percentiles by job category. The projected percentiles for male and female employees in the occupational category of "teachers, except college and university" were averaged to create one distribution. This distribution, which represents an update from the EFH specific to teachers (a job category not included in the EFH), provides a conservative exposure estimate because occupational tenure reflects the number of cumulative years that an individual is expected to work in a given occupation, rather than time spent working for a specific employer or at a specific location. It is not uncommon to have different jobs over the course of one's career working in the same occupation, so time spent at a specific job may be shorter (but cannot be longer) than the total amount of time spent working in the same occupation.

3.3.2 Body Weight

As a receptor ages over the length of the exposure duration, body weight increases. Body weights of very young children can be substantially different from those of older children. For this PRA, separate body weight distributions were defined for the three age groups identified in Section 3.1 for the student receptor and a single distribution was defined for the adult school worker receptor. The distributions are based on data presented in the EFH and are described below for each age category.

The USEPA used data collected between 1999 and 2006 as part of the National Health and Nutrition Examination Survey (NHANES) to develop distributions of body weight for different age categories. This information is presented for males and females combined in EFH Table 8-3 (USEPA 2011). Table 8-3 includes body weight distributions for children in age groups of 3 to < 6 years, 6 to <11 years, 11 to <16 years, and 16 to <21 years. Because the distributions for the 3 to < 6 and 6 to <11 year age groups closely approximate body weight for children in the 3 to < 6 and 6 to <12 year age categories, respectively, they are used directly to represent children in these respective age groups. For receptors aged 12 to <18, the weighted average of the values for each percentile provided for the 11 to <16 and 16 to <21 year age groups was calculated to provide one value for each percentile in the distribution representing students aged 12 to <18 years. For adult school worker, the average of the values for each percentile provided for the 21 to <30, 30 to <40, 40 to <50 and 50 to <60 year age groups was used.

3.3.3 Exposure Frequency

Exposure frequency is the number of days per year that a person is assumed to have contact with an exposure medium. The exposure medium evaluated in this PRA is soil/tailings in areas of the Site where students, faculty, and staff may be present. The distribution for students' and adult school workers' exposure frequency was developed based on the Morenci school calendar and Arizona state school attendance laws. A triangular distribution is supported for school exposure frequency because there are limits to the numbers of days within a year on which students may and may not attend schools. The school year in Morenci consists of 180 full or partial (e.g., early release) school days. It was therefore assumed that the most likely exposure frequency for a student is 180 days/year. Although the schools would be closed on weekends and holidays, it is possible that students could attend summer school, camps, or sports programs. According to the Morenci school calendars for the 2018-2019, 2019-2020, and 2020-2021 school years, summer breaks include an average of 45

weekdays. A maximum exposure frequency of 245 days/year was identified based on this information. Finally, according to Arizona state law, a child with excused or unexcused absences totaling more than 10 percent of school days may be considered incorrigible. Based on this information a minimum exposure frequency of 162 days/year was defined. While it is possible that a student or staff member could be present at school fewer than 162 days/year, this value is used as a conservative minimum estimate. These values conservatively assume that a child or worker contacts soil/tailings outdoors on school grounds every day that he or she is present at school. The USEPA (2002) central tendency and reasonable maximum exposure estimates for soil contact frequency, which include contact at all locations including school grounds/playgrounds, parks, at home (e.g., in the yard), and other locations, are 40 and 350 days/year, respectively. The amount of soil/tailings contact that is assumed to occur at school for this PRA therefore likely overestimates exposure and risk for students.

3.3.4 Ingestion of Outdoor Soil and Indoor Dust

The USEPA updated Chapter 5 of the EFH in 2017 to incorporate recent studies of soil and dust ingestion by children and adults in the general population. The term "soil" as applied by the USEPA when describing soil ingestion rates includes outdoor settled dust that may be ingested during incidental ingestion of soil. The term "dust" is used to describe indoor dust, for which separate ingestion rates are provided. Soil and dust ingestion rates recommended by the USEPA were updated as relevant based on the more recent studies. The recommended ingestion rates are point estimates representing central tendency and upper percentile values. These point estimates were derived by combining data distributions from multiple studies. The information reported in those studies was used in this PRA to develop soil and dust ingestion rate distributions, rather than using the point estimates presented in USEPA (2017).

Three new studies published since the 2011 EFH was completed were added to the assessment of soil and dust ingestion presented in the updated Chapter 5 (USEPA 2017). The three modeling studies used data from numerous studies for parameters such as time spent in different locations, microactivity data, surface/object soil/dust loading data, and other exposure factors (Ozkaynak et al. 2011); particle loading measures, particle fraction transferred to hands and the amount dissolved in saliva, hand surface areas and the fraction that may be mouthed or contact food, hand-to-mouth contact frequency, and exposure time (Wilson et al. 2013); and soil, dust, and child blood lead data and associated metadata from a Superfund site (von Lindern et al. 2016). These three studies were published within the last 10 years and represent the most recent assessments of available data. Additionally, the most recent tracer element-based mass-balance study (Davis & Mirick 2006) was considered. The data from these four studies were used to develop soil and dust ingestion rate distributions for the three student age groups and one adult age group evaluated in this PRA. The USEPA provides percentiles from two of the studies (Ozkaynak et al. 2011, von Lindern et al. 2016) in the updated EFH Chapter 5. For the other studies (Wilson et al. 2013, Davis & Mirick 2006), mean and standard deviations are provided. One distribution was generated from the data provided for each study as applicable for each age group. The distributions generated from each study were then combined to develop a single distribution for each age group. The methods used to generate and combine distributions for each age group are described below.

Values for each percentile (i.e., 5th, 10th, 25th, etc.) from the von Lindern et al. (2016) study for the two soil/dust partitioning scenarios that best fit blood lead levels predicted by the Integrated Exposure Uptake Biokinetic (IEUBK) model to observed blood lead levels (Table 5-16 of USEPA 2017)

were averaged across the years of age from 3 to <6 within each scenario, then the average values for each percentile were averaged between the two partitioning scenarios to create a single distribution (i.e., a single set of percentiles) based on this study. The single distribution provided in Table 5-12 of USEPA 2017 from the Ozkaynak et al. (2011) study for children aged 3 to <6 years was combined with the distribution generated from the von Lindern et al. (2016) study. Percentile values from the two distributions were averaged to develop a single soil/dust ingestion rate distribution for children in the 3 to <6 year age group. This resulting distribution is presented in the Assumptions section of **Appendix B**.

Data from the von Lindern et al. (2016) and Wilson et al. (2013) studies were used to develop a soil/dust ingestion rate distribution for the 6 to <12 year age group. As described above for the 3 to <6 year age group, the von Lindern et al. (2016) percentiles provided in USEPA (2017) Table 5-16 for ages 6 through <10 (oldest group included) were averaged across the relevant years of age and then between the two partitioning scenarios to create a single distribution based on that study. The EFH provides means and standard deviations, rather than percentiles, for the Wilson et al. (2013) study. To enable combination of the data from this study with the percentiles provided from the von Lindern et al. (2016) study, distributions were therefore defined using the parameters provided and then combined to generate percentiles. Mean and standard deviation values for soil ingestion and dust ingestion from the Wilson et al. (2013) data provided for children aged 5 to 11 years in Table 5-14 of USEPA (2017) were each assigned to a normal distribution and the two distributions were summed to develop a single distribution for the 6 to <12 year age group. This was done by generating a forecast distribution equal to the sum of soil and dust ingestion rate distributions. The soil and dust ingestion input distributions and the resulting combined forecast distribution, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix B** using graphs and associated statistics identified by study author, age group, and type (i.e., soil/dust ingestion) as applicable. [Because percentiles from the von Lindern et al. (2016) study are provided in the EFH, it was not necessary to define distributions and generate percentiles using Crystal Ball, and these distributions do not appear in **Appendix B**; rather, they are readily available in Table 5-16 of USEPA (2017).] In cases where lower percentiles resulted in negative soil ingestion rates, these values were replaced by zeros in the distribution, which is consistent with the USEPA (2017) approach, before combining the percentiles with those from other studies. Values for each percentile from the resulting distribution were then averaged with those from the combined distribution generated from the von Lindern et al. (2016) data, to develop the single soil/dust ingestion rate distribution for the 6 to <12 year age group presented in the Assumptions section of **Appendix B**. The data provided in USEPA (2017) do not correspond exactly to the age group used in this PRA but represent the closest available approximation, and were used by the USEPA to develop recommended soil/dust ingestion rates specific to children aged 6 to <12 years.

Data from Wilson et al. (2013) are provided in Table 5-14 of USEPA (2017) for teenagers aged 12 to 19 years. Using the same methods described above for the 6 to <12 year age group, the means and standard deviations for soil and dust ingestion were assigned to normal distributions that were combined to develop a single soil/dust ingestion rate distribution for teenagers. This distribution was then combined with the adult data from Davis & Mirick (2006) which are provided in Table 5-9 of USEPA (2017). While Davis & Mirick (2006) did not specifically evaluate the teenager age group, the adult data were used to represent this group, which is consistent with the approach USEPA (2017) used to develop recommended soil/dust ingestion rates for ages 12 and older. Similar to the Wilson et al. (2013) study, means and standard deviations from Davis & Mirick (2006), rather than

percentiles, are provided in the EFH. The mean and standard deviation values for mothers and fathers and aluminum and silicon tracer elements from Davis & Mirick (2006) were assigned to normal distributions, and the four resulting distributions were averaged to develop a single combined ingestion rate distribution for adults. The resulting forecast distribution based on the Davis & Mirick (2006) data was combined with the forecast distribution developed from the Wilson et al. (2013) data by averaging values for each percentile to develop a single soil ingestion rate distribution for teenagers aged 12 and older. As described for the younger age groups, the distributions were truncated at zero prior to being combined. The original input and combined forecast distributions from each study, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix B**. The final soil ingestion rate distribution defined for the 12 to <18 year age group is presented in the Assumptions section of **Appendix B**.

For the adult worker, data from Wilson et al. (2013) for adults aged 20 to 59 years and seniors aged 60+ years (applied here for adults aged 60 to 69 years) were used. Using the same methods described above for students, the means and standard deviations for soil and dust ingestion were assigned to normal distributions that were combined using a weighted average of the sums (based on the relative time represented by each age group) to develop a single soil/dust ingestion rate distribution to represent adults and seniors. The original Wilson et al. (2013) inputs and combined forecast distributions, respectively, are shown in the Soil Ingestion Rate Supporting Distributions and Soil Ingestion Rate Supporting Forecasts sections of **Appendix B**. This distribution was then combined with the adult distribution developed from Davis & Mirick (2006) as described above for the teenager. As described for the younger age groups, the distributions were truncated at zero prior to being combined. The final soil ingestion rate distribution defined for the adult worker is presented in the Assumptions section of **Appendix B**.

Of the total amount of soil and dust ingested each day, the USEPA assumes a composition of 45 percent soil and 55 percent dust (USEPA 1994, 2017). The contribution of arsenic in indoor dust from the outside soil/tailings was estimated using data from Tu et al. (2020) and Brattin and Griffin (2011). Both studies are primarily focused on lead, but Tu et al. (2020) also evaluated limited soil track-in data for arsenic, cadmium, and zinc. Both studies used ordinary linear regression and Bartlett's method to fit regression lines to soil and dust data collected from mining, smelting, and refining sites. The contribution of outdoor soil to indoor dust, which has numerous sources other than outdoor soil, is estimated based on the slope of the regression line. Tu et al. (2020) identified datasets with regression coefficients equal to or greater than 0.25 as indicating a good model fit. Twelve of the 22 datasets analyzed by Tu et al. (2020) and three of the nine analyzed by Brattin and Griffin (2011) met this criterion based on the ordinary linear regression analyses. Based on further communication (Tu 2020) two of the twelve datasets analyzed by Tu et al. (2020) were not included in this PRA due to numerous complicating factors that likely influence the slope estimates, leaving a total of 13 values with regression coefficients equal to or greater than 0.25. The Crystal Ball software requires at least 15 data points to define a distribution; two additional values from Brattin and Griffin (2011) with regression coefficients just below the Tu et al. (2020) criterion of 0.25 (0.23 and 0.24) were therefore added to the dataset, and the best-fit distribution of these values defined by the software was a logistic distribution with a mean of 0.25 and a scale of 0.08. The lower end of this distribution was truncated at zero.

The majority of available data used for estimating soil track-in are based on measurements of lead, which has more potential indoor sources than arsenic. While the data analysis completed by Tu et al.

(2020) showed lower estimates for arsenic, model fits for arsenic were generally poor. Relying primarily on lead data is considered to be conservative for arsenic because bias in lead estimates due to indoor sources likely overestimates the contribution of outdoor soil to indoor dust concentrations for other metals.

3.3.5 Oral Bioavailability of Arsenic in Soil

The Bioavailability Technical Review Work Group (TRW) at USEPA has reviewed available in vivo data for soil arsenic bioavailability to identify "key studies" (USEPA 2012a,b). The purpose of this review is to support a default soil arsenic relative bioavailability (RBA) value less than the previous default value of 100% that could be applied at sites lacking site-specific data. The new default is 60% based on analyses of 103 RBA estimates from a total of 88 samples of soils and waste materials tested in swine, monkeys, and mice. More than half of these RBA estimates (65 of 103) and 54 of 88 samples tested were from mining and/or smelting sites. The rest include samples from orchard soils, cattle dip sites, pesticide and other manufacturing sites, railroad corridors and miscellaneous sites such as volcanic soils. Data from all sites included in the TRW study (USEPA 2012a,b), not just smelter sites, are appropriate for this PRA because much of the soil present at the school complex, including the soil with the highest arsenic concentrations, is imported fill and weathered native material, not tailings.

The key studies included 64 RBA values from swine studies, 24 values from monkeys and 15 values for mice. Four test materials were tested in all three species. Seven additional test materials were tested in both swine and mice. The TRW used these RBA values to derive distributions for the swine dataset, the monkey dataset and the combined dataset. The combined dataset is summarized in two ways: 1) with each RBA value given equal weight, even if the sample was tested more than once (termed the "unweighted" dataset), and 2) with RBA values for the same sample averaged before generating summary statistics (termed the "weighted" dataset). The combined unweighted dataset has a minimum RBA of 4.1%, an arithmetic mean of 31%, a 50th percentile of 28.5% and a maximum value of 78%. The 95th percentile was 57%. The 95th percentile is highest for the swine dataset. The 95th percentile based on only the monkey data is substantially lower (33%). The 95th percentile for mouse data is 50%. For this PRA, the distribution presented in Table 3 of USEPA (2012a) for the unweighted dataset for all species and soil samples was used to define the arsenic RBA parameter. This distribution was selected because results from different species based on the same sample provide different estimates of bioavailability, and no species was considered more representative than another. Therefore, each sample result was given equal weight. As noted earlier in this section, all soil samples were included to best represent the mixture of imported fill, weathered native materials, and tailings present at the school complex.

3.3.6 Dermal Exposure to Arsenic in Soil and Dust

For inorganic substances in soil, very little absorption occurs via the dermal pathway; however, it is included in this PRA for completeness. The USEPA has assigned default ABS_d values for only arsenic and cadmium (USEPA 2004). For arsenic, the USEPA (2004) default ABS_d of 0.03 is highly conservative. This value is based on a 1993 study of rhesus monkeys that evaluated absorption of soluble arsenic in aqueous solution and soluble arsenic mixed with soil (Wester et al. 1993). However, this estimate is not representative of arsenic absorption from environmental media such as soil. Research on the geochemistry of arsenic suggests that for soils that are weathered in the environment, arsenic is likely to be present in more stable alteration phases that are tightly bound within the soil and would not be expected to behave like soluble arsenic (Lowney et al. 2005).

A 2007 *in vivo* mammalian study showed that dermal absorption of arsenic is negligible and highly overestimated by the USEPA default ABS_d value (Lowney et al. 2007). This study used the same animal model as the Wester et al. (1993) study with an "open-crossover" design that allowed the animals to serve as their own comparison controls. The abdomens of Rhesus monkeys were exposed to soil with elevated arsenic concentrations or to soluble arsenic. Specifically, soils with very high concentrations of arsenic were evaluated; one sample, containing 1,400 mg/kg arsenic, was collected adjacent to a pesticide production facility in New York and another sample, containing 1,230 mg/kg arsenic, was collected from a residential area in Denver, CO with a history of application of arsenical pesticides. Urine samples from the animals were collected 3 days prior to dosing to establish background and through day 7 after dosing. The results found that following application of wet and dry soil, urinary arsenic excretion could not be distinguished from background. For dermal absorption of arsenic in a variety of soil matrices, Lowney et al. (2007) estimated arsenic absorption to be 0.5 percent or less.

The findings of Lowney et al. (2007) of negligible dermal absorption of arsenic from soil are supported by a study by Wester et al. (2004) of dermal absorption of arsenic from copper chromated arsenic-treated wood residues showing that dermal absorption of arsenic could not be detected (i.e., does not result in urinary arsenic excretion above background levels). No additional *in vivo* studies of dermal arsenic absorption from soil have been identified. In vitro studies of dermal arsenic absorption (e.g., Abdel-Rahman et al. 1999, Abdel-Rahman et al. 2005, Hughes et al. 1995, Rahman and Hughes 1994) are not considered adequate to provide quantitative estimates for use in risk assessment.

For this PRA, the highest mean ABS_d value measured in the Lowney et al. (2007) study of 0.5 percent (0.005) and the associated standard deviation (0.44%, or 0.0044) were assigned to a normal distribution that was used to estimate dermal absorption of arsenic. The lower end of this distribution was truncated at zero.

The USEPA provides distributions for whole body skin surface area derived from their analysis of NHANES data from 1999-2006 for children and adults in Table 7-10 of the EFH (USEPA 2011). Distributions for specified age groups, including 3 to <6 years, 6 to <11 years, 11 to <16 years, and 16 to <21 years, are provided. The 3 to <6 and 6 to <11 year age group distributions were used directly to estimate skin surface area for students aged 3 to <6 and 6 to <12 years, respectively. For the 12 to <18 year student age group, a distribution was derived using the weighted averages of percentiles for the 11 to <16 and 16 to <21 year age groups.

Table 7-8 of the EFH provides information regarding the fraction of whole-body skin surface area represented by individual body parts. The fraction of whole-body area comprised of the head, legs, feet, lower arms, and hands was calculated using the data provided for male children of the specific ages included in the table that are relevant to each age category included in this PRA. Because males tend to be larger, this provides a conservative estimate for male and female children. The most conservative (i.e., highest) age-specific fraction for each age group was used to adjust the whole-body distributions to represent the skin surface area of the head, legs, feet, lower arms, and hands, which may be exposed to soil/tailings while playing outdoors.

The USEPA provides distributions of adult body part skin surface areas in Table 7-12 of the EFH (USEPA 2011). These distributions, which are based on USEPA 1985 and NHANES 2005-2006 data for

adult males, were used to represent both male and female school workers in this PRA. Because female adults tend to be smaller on average than males, this may slightly overestimate dermal exposure for female workers. A sum of the percentiles for head, hands, forearms, and lower legs was used in this PRA, which is consistent with the USEPA's recommendations stating that children are assumed to have more sensitive body parts (i.e. feet) exposed, whereas adults are not (USEPA 2002, 2014).

Skin surface area distributions for each age group were correlated with the body weight distributions for the same group using a correlation coefficient of one.

Point estimates were used to quantify the amount of soil or dust assumed to adhere to the skin. The USEPA (2004) default value of 0.2 milligrams per square centimeter (mg/cm^2) was used for children in the 3 to <6 year age group. The default value of 0.07 mg/cm^2 is specified in USEPA (2002) guidance for receptors aged seven to 31 years. This value was therefore used for the 6 to <12 and 12 to <18 year student age groups and the adult worker receptor.

3.3.7 Inhalation Exposure Time

The USEPA provides data reflecting the amount of time that children spend in various locations and performing certain activities. Time spent outdoors on school grounds/playgrounds is documented in Table 16-19 of the EFH (USEPA 2011). Students are most likely to contact soil/tailings, including dust generated from soil/tailings that could be inhaled, while playing outdoors during recess or sports, or while performing other activities outdoors on school grounds. The distributions provided in Table 16-19 of the EFH for children in the 3 to <6 and 6 to <11 year age categories were therefore used to define exposure time distributions for children in the 3 to <6 and 6 to <12 age groups for the PRA. A weighted average was calculated from the distributions for children aged 11 to <16 and 16 to <21 years to define the exposure time distribution for children aged 12 to <18 years. This distribution developed for students in the 12 to <18 year age group was also applied for the adult worker who is assumed to be coaching middle and high school students in outdoor team sports throughout the school year.

3.3.8 Averaging Time

The averaging time is the period of the lifetime over which the exposure is averaged. Averaging time was assumed to be a point estimate and no distribution was assumed for this exposure parameter. For carcinogenic risk evaluation, the standard averaging time is 70 years or 25,550 days (USEPA 1989). This value is also consistent with Arizona risk guidance (ADHS 2003).

3.3.9 Arsenic Exposure Concentration

Site characterization activities completed in 2019 and 2020 included collection of soil and exposed tailings samples from locations around the Site where students, faculty, and staff may be present. The 2020 sampling included 117 composite and 67 grab samples, and 13 samples were collected in 2019. Quality control (QC) samples were also collected. Tailings samples were also collected in 2018 from the three stormwater ditches/washes located behind the Elementary, Middle, and High Schools. As discussed in Section 2, the ditches/washes are located in areas that are either not accessible to, or not frequented by, children at the Site. Because the 2019 and 2020 sampling events included both soil and tailings, produced a sufficient number of samples for risk assessment, and targeted areas where students, faculty, and staff may be present, those data are considered most appropriate for estimating arsenic concentrations in potential exposure media. This dataset includes composite

samples, which are collected to better approximate potential exposure from children playing across an entire use area rather than a single spatial point (USEPA 2003). This sampling approach better mimics students playing on playgrounds or athletic fields and the inclusion of the 117 composite samples in addition to discrete samples achieves the overall goal of estimating an average soil concentration of arsenic for risk assessment purposes. The arsenic results from the 2019-2020 site characterization samples were therefore used to estimate potential exposure concentrations for arsenic; the 2018 data were not used for the PRA. It was assumed that students at each school may only be exposed to soil within the boundaries of the specific school during the time that they attend that school, to account for potential spatial differences in soil concentrations. According to the 2020 Site Characterization Report (Arcadis 2020), students attend elementary school from ages 3 to <10, middle school from ages 10 to <14 and high school from ages 14 to <18. The exposure concentration term was therefore age-adjusted to reflect exposure to arsenic concentrations in the distribution defined for each school area by students in the age group applicable to that school.

As a general rule of thumb, the USEPA recommends a sample size of at least 10 for calculating statistics to represent chemical concentrations in exposure media (USEPA 2009, 2015). Larger sample sizes may be needed if variability is high. The 197 primary samples were grouped to characterize the elementary school, middle school and high school areas according to **Figure 3**, which shows the 2020 samples, and **Figure 4** which shows the 2019 samples[3]. Six samples located along boundaries were conservatively included in both school groups (i.e. elementary school/middle school or middle school/high school). This resulted in 47 samples in the elementary school dataset, 72 samples in the middle school dataset, and 83 samples in the high school dataset. The grid sampling approach used for the 2020 site characterization efforts often provides better precision (i.e., smaller confidence intervals, smaller standard errors of population estimates) and more complete coverage of the target population than random sampling. The sample results for each dataset are evenly distributed across the range of detected values with relatively low variability. These datasets are therefore sufficient to define the distribution of arsenic concentrations in soil and tailings by school area at the Site and to estimate exposure concentrations for this PRA. These complete datasets (excluding QC samples) were used to characterize the distributions of arsenic concentrations in soil/tailings by school area at the Site. This approach most accurately represents the range of concentrations in soil/tailings that a student receptor could contact while attending the three schools at the Site.

The spatial distribution of arsenic levels measured in the 2019 and 2020 soil samples is shown on **Figure 5**. Further inspection of the data according to figures and tables of the 2020 Site Characterization Report found that some of the highest arsenic concentrations were located in the sports fields area of the Site. These included the surface soil interval of composite topsoil or fill samples MS-G035, MS-G043, MS-G048, MS-G050 and MS-G066, and discrete sample CSS-06. Tailings were not observed in these samples (Arcadis 2020). To evaluate the potential impact of subareas of higher arsenic concentrations, 39 samples from the sports fields area were grouped, and a distribution was developed for this dataset. It was assumed a student would encounter elementary school area soils while attending elementary school and the sports fields area soils while attending middle and high school. The adult staff member, evaluated as a coach, was also assumed to encounter the sports fields area soils.

[3] Figure 3, adapted from the Site Characterization Report (Arcadis 2020) shows the sample locations categorized by school area. The 2019 sample locations shown on Figure 4 were grouped based on the areas established on Figure 3.

The Crystal Ball software was used to generate a distribution for each of the four datasets representing the elementary school, middle school, high school and sports fields areas based on statistics calculated using ProUCL. For risk assessment, the exposure point concentration (EPC) term represents the average chemical concentration that a receptor is likely to encounter as they move around a site. A point estimate of the EPC, based on the 95UCLM, is typically used for deterministic risk assessment. For this PRA, rather than using the point estimates discussed in Section 2.4 to estimate EPCs, distributions of the average concentrations in each area were used to support a conservative probabilistic assessment of potential exposure concentrations. The average concentration within an exposure area should follow a normal distribution according to the Central Limit Theorem. The means and standard errors of the means calculated using ProUCL for each dataset were therefore assigned to a normal distribution in Crystal Ball. The ProUCL outputs can be found in **Appendix A** and the resulting arsenic EPC distributions can be found in the Assumptions section of **Appendix B**.

4. TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to present the toxicity criteria used to calculate health risks, as well as present basic information about the potential health effects related to exposure to the chemicals of concern. Toxicity criteria used to calculate cancer risks include oral cancer slope factors (CSFs) and inhalation unit risk factors (IURs). Toxicity criteria for arsenic were treated as point estimates or constants in this risk assessment; statistical distributions were not used for these parameters. Arsenic is considered by USEPA and other government agencies to be carcinogenic via both oral and inhalation routes of exposure (USEPA 2020). The arsenic CSF and IUR were obtained from the USEPA's Integrated Risk Information System (IRIS), an online database (USEPA 2020).

5. RISK CHARACTERIZATION

To characterize cancer risks, quantitative estimates of exposure and toxicity are combined to yield numerical estimates. This section discusses how cancer risk estimates were calculated for arsenic, and the resulting risk estimates.

5.1 Cancer Risk Characterization Methods

The cancer risk estimates derived using standard risk assessment methods are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to site-related chemicals resulting from the specific exposure scenarios that are going to be evaluated. The term "incremental" reflects the fact that the calculated risk associated with site-related exposure is in addition to the background risk of cancer experienced by all individuals. The USEPA refers to such estimates as lifetime excess cancer risk, or LECR, estimates.

Excess incremental lifetime cancer risks for ingestion/dermal and inhalation exposures, respectively, were calculated using the following equations:

$$Cancer\ Risk_{ingestion/dermal} = Intake\left({}^{mg}/_{kg\text{-}day}\right) \times SF\left({}^{mg}/_{kg\text{-}day}\right)^{-1}$$

$$Cancer\ Risk_{inhalation} = EC\left({}^{mg}/_{m^3}\right) \times URF\left({}^{mg}/_{m^3}\right)^{-1}$$

Where,

Intake	=	Estimated average daily intake of the chemical via the specified exposure route (mg/kg-day)
EC	=	Exposure concentration for the chemical (mg/m^3)
SF	=	Slope factor (mg/kg-day)$^{-1}$
URF	=	Inhalation unit risk factor (mg/m^3)$^{-1}$

Intake was calculated using age-adjusted factors as contact rates and certain exposure factors vary among the three student age groups evaluated (3 to <6, 6 to <12, and 12 to <18 years). For the adult worker, intake was calculated in a similar manner except age-adjusted factors were not needed.

The following equations were used for the ingestion pathway:

$$Intake_{ing} = C_{soil} \times \frac{IFS_{adj} \times (RBA \times FI_s + Dust\ Ratio \times RBA \times FI_d) \times EF \times CF1}{AT_{ca}}$$

If exposure duration (ED_{ca}) is greater than or equal to 9 years and less than 16 years:

$$IFS_{adj} = \frac{3\ yr \times IR_{3-6}}{BW_{3-6}} + \frac{6\ yr \times IR_{6-12}}{BW_{6-12}} + \frac{(ED_{ca} - 9\ yr) \times IR_{12-18}}{BW_{12-18}}$$

If exposure duration (ED_{ca}) is greater than or equal to 3 years and less than 9 years:

$$IFS_{adj} = \frac{3\ yr \times IR_{3-6}}{BW_{3-6}} + \frac{(ED_{ca} - 6\ yr) \times IR_{6-12}}{BW_{6-12}}$$

If exposure duration (ED_{ca}) is less than 3 years:

$$IFS_{adj} = \frac{ED_{ca} \times IR_{3-6}}{BW_{3-6}}$$

Where,

$Intake_{ing}$ = Estimated average daily intake of the chemical via ingestion (mg/kg-day)

C_{soil} = Concentration in soil and tailings (mg/kg)

IFS_{adj} = Age-adjusted ingested fraction of soil (mg-year/kg-day)

RBA = Relative bioavailability (unitless)

FI_s = Fraction of material ingested as soil (unitless)

FI_d = Fraction of material ingested as dust (unitless)

Dust ratio = Ratio of metal concentration in dust to metal concentration in soil (unitless)

EF = Exposure frequency (days/year)

CF1 = Conversion factor (10^{-6} kg/mg)

AT_{ca} = Cancer averaging time (days)

IR = Soil ingestion rate (mg/day)

BW = Body weight (kg)

ED_{ca} = Cancer exposure duration (years)

The following equations were used for the dermal pathway:

$$Intake_{derm} = C_{soil} \times \frac{DFS_{adj} \times ABS_{\ derm} \times EV \times EF \ \times CF1}{AT_{ca}}$$

If exposure duration (ED_{ca}) is greater than or equal to 9 years and less than 16 years:

$$DFS_{adj} = \frac{3\ yr\ \times\ SA_{3-6} \times AF_{3-6}}{BW_{3-6}} + \frac{6\ yr\ \times\ SA_{6-12} \times AF_{6-12}}{BW_{6-12}} + \frac{(ED_{ca} - 9\ yr)\ \times\ SA_{12-18} \times AF_{12-18}}{BW_{12-18}}$$

If exposure duration (ED_{ca}) is greater than or equal to 3 years and less than 9 years:

$$DFS_{adj} = \frac{3\ yr\ \times\ SA_{3-6} \times AF_{3-6}}{BW_{3-6}} + \frac{(ED_{ca} - 6\ yr)\ \times\ SA_{6-12} \times AF_{6-12}}{BW_{6-12}}$$

If exposure duration (ED_{ca}) is less than 3 years:

$$DFS_{adj} = \frac{ED_{ca}\ \times\ SA_{3-6} \times AF_{3-6}}{BW_{3-6}}$$

Where,

$Intake_{derm}$ = Estimated average daily intake of the chemical via dermal contact (mg/kg-day)

DFS_{adj} = Age-adjusted dermal fraction of soil (mg-year/kg)

ABS_{derm} = Chemical-specific dermal absorption factor (unitless)

EV = Events per day (day^{-1})

SA = Skin surface area (cm^2)

AF = Soil-to-skin adherence factor (mg/cm^2)

The following equations were used for the particulate inhalation pathway:

$$EC = (C_{soil} \times \frac{1}{PEF}) \times \frac{ET_{adj} \times EF \times ED_{ca}}{24\ hr/d \times AT_{ca}}$$

If exposure duration (ED_{ca}) is greater than or equal to 9 years and less than 16 years:

$$ET_{adj} = \frac{(3\ yr\ \times\ ET_{3-6}) + (6\ yr\ \times\ ET_{6-12)} + ((ED_{ca} - 9\ yr)\ \times\ ET_{12-18})}{ED_{ca}}$$

If exposure duration (ED_{ca}) is greater than or equal to 3 years and less than 9 years:

$$ET_{adj} = \frac{(3\ yr\ \times\ ET_{3-6}) + (ED_{ca} - 6\ yr)\ \times\ ET_{6-12}}{ED_{ca}}$$

If exposure duration (ED_{ca}) is less than 3 years:

$$ET_{adj} = ET_{3-6}$$

Where,

PEF = Particulate emission factor (m^3/kg)

ET = Exposure time (hrs/day)

ET_{adj} = Age-adjusted exposure time (hrs/day)

5.2 Results and Discussion

For known or suspected carcinogens, the National Oil and Hazardous Substances Pollution Contingency Plan established that acceptable exposure levels are generally concentration levels that represent an incremental upper-bound lifetime cancer risk in the range from 10^{-4} to 10^{-6} or less (29 CFR 1910.120, 40 CFR 300.430, USEPA 1991). The state of Arizona has adopted this lifetime cancer risk range in its VRP Statute, Arizona Revised Statute (A.R.S.) 49-175.B.2 & 49-152.B.2. For this PRA, the 95th percentile of the risk distribution is compared to the regulatory target. This discussion therefore focuses on the 95th percentile LECR estimates. The cumulative and pathway-specific risk estimates are shown in **Table 6**, and the complete LECR distributions are provided in **Appendix B**.

The combination of exposure parameter distributions, point estimates, and school-specific arsenic data used to develop the PRA model for the Site resulted in a cumulative 95th percentile LECR estimate of 4 x 10^{-7} for the student. As discussed in Section 3.3.9, the sports fields area was evaluated to account for subareas with higher concentrations. For this scenario, the 95th percentile LECR estimate was 4 x 10^{-7} for the student and 2 x 10^{-7} for the adult staff member. These values are below the range of LECR estimates considered acceptable by the USEPA and ADEQ. The PRA results therefore indicate that incremental excess lifetime cancer risks to students and staff members resulting from potential exposure to arsenic in soil/tailings at the Morenci School Complex are below acceptable target levels.

As a worst case scenario, risk estimates for the sports fields evaluation were added for the student and adult worker assuming the same receptor attends the Morenci School Complex schools as a child and later works at the Site as an adult throughout their entire occupational tenure. This assumption

resulted in a 95th percentile LECR estimate of 7 x 10^{-7}, which remains below the USEPA's and ADEQ's acceptable risk range.

6. UNCERTAINTY ANALYSIS

Uncertainty is an important component of risk assessment. Understanding uncertainty can help with interpretation of risk estimates and decision-making. Probabilistic risk assessment provides distributions of estimated risks that incorporate variability in exposure parameters and other assumptions and help to clarify the role of uncertainty in the risk assessment process. In deterministic risk assessment, uncertainty and variability are addressed by assigning conservative point estimates, usually from the upper end of available datasets. Including a more complete representation of the possible range of input parameters and risk estimates allows for a better understanding of the effects of uncertainty on the outcome of the assessment. Some of the factors contributing to uncertainty in the PRA model are discussed below.

For many exposure parameters, the USEPA breaks available data into specific age groups, which are not the same for every parameter. For this PRA, distributions provided by the USEPA for the age groups closest to those defined to characterize school receptors were used. In some cases the data used to characterize exposure for children in a particular age class correspond to children in a slightly younger class. For example, data for children aged 6 to <11 years were used to characterize exposure for children aged 6 to <12 years. These relatively minor differences are unlikely to have a large effect on outcomes, but may result in slight overestimates of exposure and risk.

Point estimates were used instead of distributions for some parameters, such as toxicity values. Point estimates are conservative, upper end values that do not incorporate the variability associated with the parameter. Toxicity values are particularly conservative because they incorporate numerous uncertainty and modifying factors. The use of point estimates for some parameters likely results in overestimation of risks.

The studies used by the USEPA to develop exposure parameter distributions include various types of uncertainty. Several studies used 24-hour diaries to extrapolate activity patterns to a longer timeframe, and in some cases survey questions had a limited set of potential responses that may not characterize the full range of actual activity patterns. Other studies used modeling to predict a pattern based on available data. For some parameters, such as RBA, all data reported in a study were considered applicable and used rather than only using a specific subset of data to ensure an adequately protective distribution was selected. The various types of uncertainty associated with the underlying data used to develop exposure parameter distributions for this PRA may result in under- or overestimation of exposure and risks.

As shown in **Table 6**, the ingestion pathway contributes most to the cumulative risk estimate for each receptor and scenario, followed in each case by the dermal pathway and lastly the inhalation pathway. **Appendix B** provides the Crystal Ball risk forecasts and sensitivity charts for each exposure pathway. The sensitivity chart displays the rankings of each input parameter assumption according to their contribution to variability in the risk forecast. The variability of each parameter is shown, with higher input parameter variability driving variability in the risk forecast. Because the soil ingestion pathway contributes most to the overall risk estimates for each receptor, the discussion of model sensitivity in this section focuses on the ingestion pathway.

The sensitivity charts for the ingestion pathway for both the student and adult worker risk forecasts show that exposure duration distributions have the greatest influence on the variability in risk estimates. Distributions for arsenic relative bioavailability and soil ingestion rate contribute most of the remaining variability in risk estimates for students and school workers. Exposure duration distributions are based on US census data and reflect the high variability in both residential occupancy and occupational tenure reported among the US population. The contribution of this parameter to variability in risk estimates is therefore a result of measured variability with relatively low uncertainty resulting from extrapolation from the US population to the Morenci, Arizona population. Arsenic relative bioavailability measurements can vary substantially between different soil types and between test species. Similar to the study used to develop the RBA distribution for this PRA, different soil types present at the Site are also likely to have variable levels of arsenic bioavailability. Including data measured in multiple test species provides a broader database, lowering the overall uncertainty by accounting for differences between species. Soil ingestion rate distributions likely add the greatest uncertainty to the PRA, due to limitations associated with the available methods to estimate ingestion. Incorporation of multiple studies that used different methods to estimate soil ingestion rates may reduce this uncertainty to some degree.

While uncertainty can only be reduced through further study, acknowledging uncertainties that exist within the available information is important for understanding and interpreting results. While the goal of using distributions is to better reflect available information, where uncertainty is greater the general trend leans toward more conservative assumptions. This is particularly true when underlying assumptions are considered. For example, while data are available to quantify the surface area of children’s bodies, assumptions must be made regarding body parts that are likely to be exposed to soil while playing outdoors at school. Where necessary such assumptions tend to be conservative, such as assuming the entire legs and head are always exposed to soil. Similarly, information is available to estimate the number of days per year that a child will be present at school, but the underlying assumption that a student will play outside and contact soil every day that the child is present at school is conservative. Such assumptions, when combined with available data, ensure a reasonable and health-protective characterization of risks.

7. SUMMARY AND CONCLUSIONS

Potential cancer risks to school children and school staff that could result from exposure to arsenic in soil and tailings across the Morenci School Complex property were assessed using probabilistic methods. For students, exposure data compiled by the USEPA, ODEQ, and others were combined with school-specific data to estimate exposures over the time spent in preschool/elementary school, middle school and high school. Exposure estimates were then combined with toxicity values to provide a distribution of risk estimates that takes into account both variability and uncertainty. The resulting 95th percentile risk estimate for students of 4×10^{-7} is below both the ADEQ and the USEPA acceptable risk range of 1×10^{-6} to 1×10^{-4}.

A scenario was also evaluated based on the observation that the highest arsenic concentrations were located in the sports fields between the middle school and high school. The 95th percentile risk estimate for a student based on this higher concentration exposure area during middle school and high school was 4×10^{-7}.

Potential risks for school staff assumed a teacher or coach was regularly exposed at the sports fields. The 95th percentile risk estimate for this adult worker was 2×10^{-7}.

As a worst case scenario, it was assumed that a student may return to the school as an adult worker, and the risk estimates were added for these two receptors. This assumption resulted in a 95th percentile risk estimate of 7×10^{-7}, which is still below the lower end of USEPA's and ADEQ's acceptable risk range.

It is also important to note that none of the arsenic concentrations in tailings at the Site exceeded the Arizona arsenic SRL of 10 mg/kg. Furthermore, the highest arsenic concentrations observed at the Site (in the sports fields area) are not associated with tailings. Additionally, with the exception of one of the eight 95UCLM method results for the sports fields, mean and 95UCLM arsenic concentrations across the Site and within the sports fields and school-specific areas are below the SRL.

8. REFERENCES

Abdel-Rahman, MS; Skowronski, GA; and Turkall, RM. 1999. Decreased dermal bioavailability of chemicals aged in soil: arsenic, nickel, and phenanthrene as models. In: Kostecki P.T., E.J. Calabrese, and M. Bonazountas (eds). Contaminated Soils, Vol 4. Amherst Scientific Publishers, Amherst, MA; 173–183.

Abdel-Rahman, MS; Skowronski, GA; and Turkall, RM. 2005. In vitro penetration of pig skin by heavy metals in soil. Soil Sediment Contam 14(2): 123–134.

Arcadis. 2020. Site Characterization Report, Morenci Schools Site, Morenci, Arizona, VRP Site Code: 513333-00. June 29.

Arizona Administrative Code (A.A.C.). 2009. Title 18, Chapter 7, Article 2. Supplement 09-1. March 31.

Arizona Department of Environmental Quality (ADEQ). 2020a. Review of Probabilistic Risk Assessment, Morenci School Site, 473 Stadium Drive, Morenci, Arizona 85540, Site Code: 513333-00. Memorandum from Nichole Osuch, ADEQ to Bryce Romig, Freeport Minerals Corporation. September 16.

ADEQ. 2020b. Review of Response to Comments: Morenci School Probabilistic Risk Assessment, Morenci School Site, 473 Stadium Drive, Morenci, Arizona 85540, Site Code: 513333-00. Memorandum from Nichole Osuch, ADEQ to Bryce Romig, Freeport Minerals Corporation. November 24.

ADEQ. 2020c. Personal Communication between Rosalind Schoof of Ramboll and Kurt Fehling of The Fehling Group, LLC (on behalf of ADEQ). December 8.

ADEQ. 2021. Review of revised PRA for Morenci Schools VRP site. Morenci School Site, 473 Stadium Drive, Morenci, Arizona 85540, Site Code: 513333-00. Email correspondence from Nichole Osuch, ADEQ to Bryce Romig, Freeport Minerals Corporation. January 5.

Arizona Department of Health Services (ADHS). 2003. Deterministic Risk Assessment Guidance. May 16.

Brattin, W and Griffin, S. 2011. Evaluation of the Contribution of Lead in Soil to Lead in Dust at Superfund Sites. Human and Ecological Risk Assessment: An International Journal 17(1): 236-244.

Burmaster, DE. 2000. Distributions of Total Job Tenure for Men and Women in Selected Industries and Occupations in the United States, February 1996. Risk Analysis. 20: 205-224. April.

Davis, S and Mirick, D. 2006. Soil ingestion in children and adults in the same family. J Exp Anal Environ Epidem 16:63−75.

Department of Toxic Substances Control (DTSC). 1994. Preliminary Endangerment Assessment Guidance Manual. Sacramento.

Hughes, MF; Mitchell, CT; Edwards, C; and Rahman, MS. 1995. In vitro percutaneous absorption of dimethylarsinic acid in mice. J Toxicol Environ Health 1995: 45: 279–290.

Lowney, YW; Ruby, MV; Wester, RC; Schoof, RA; Holm, SE; Hui, XY; Barbadillo, S; and Maibach, HI. 2005. Percutaneous absorption of arsenic from environmental media. Toxicol Ind Health 21:1-14.

Lowney, Y; Wester, R; Schoof, R; Cushing, C; Edwards, M; Ruby, M. 2007. Dermal Absorption of Arsenic from Soils as Measured in the Rhesus Monkey. Toxicological Sciences 100(2): 381-392.

Oregon Department of Environmental Quality (ODEQ). 1998. Guidance for Use of Probabilistic Analysis in Human Health Risk Assessments. Interim Final. Updated November 1998. Portland.

Özkaynak, H; Xue, J; Zartarian, VG; Glen, G; Smith, L. 2011. Modeled Estimates of Soil and Dust Ingestion Rates for Children. Risk Anal 31(4): 592−608.

Rahman, MS and Hughes, MF. 1994. In vitro percutaneous absorption of monosodium methanearsonate and disodium methanearsonate in female B6C3F1 mice. J Toxicol Environ Health 41(4): 421–433.

Ramboll. 2020a. Response to Comments: Morenci School Probabilistic Risk Assessment. Technical Memorandum from Rosalind A. Schoof and Amanda Bailey, Ramboll US Consulting, Inc. to Jennifer Laggan, Freeport Minerals Corporation. November 2.

Ramboll. 2020b. Probabilistic Risk Assessment for the Morenci School Complex, Morenci, Arizona. 1st Draft. June 26.

Ramboll. 2020c. Probabilistic Risk Assessment for the Morenci School Complex, Morenci, Arizona. 2nd Draft. December 24.

Tu, J. 2020. Personal communication between Julie Tu, Minti Patel, and Amanda Bailey of Ramboll, via email. May 20.

Tu, J; Fuller, W; Feldpausch, A; Van Landingham, C; Schoof, R. 2020. Objective Ranges of Soil-to-Dust Transfer Coefficients for Lead-Impacted Sites. Environmental Research 183(2020) 109349.

USEPA. 1985. Development of statistical distributions or ranges of standard factors used in exposure assessments. (EPA600885010). http://www.ntis.gov/search/product.aspx?A BBR=PB85242667.

USEPA. 1989. Risk Assessment Guidance for Superfund, Volume I, Part A – Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

USEPA. 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

USEPA. 1994. Guidance Manual for Integrated Exposure Uptake Biokinetic Model for Lead in Children. NTIS # PB93-963510, USEPA 9285.7-15-1.

USEPA. 2001. Risk Assessment Guidance for Superfund (RAGS), Volume III, Part A – Process for Conducting Probabilistic Risk Assessment. Office of Emergency and Remedial Response. EPA 540-R-02-002. Washington, D.C.

USEPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. Washington, D.C.

USEPA. 2003. Superfund Lead-Contaminated Residential Sites Handbook. Prepared by the Environmental Protection Agency Lead Site Workgroup (LSW). United States Environmental Protection Agency. Office of Emergency and Remedial Response. OSWER 9285.7-70. August.

USEPA. 2004. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final. EPA/540/R/99/005.

USEPA. 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guidance. Office of Resource Conservation and Recovery. EPA 530-R-09-007. March.

USEPA. 2011. "Exposure Factors Handbook" EPA/600/R-090/052F. September.

USEPA. 2012a. Compilation and Review of Data on Relative Bioavailability of Arsenic in Soil. U.S. Environmental Protection Agency, OSWER 9200.1-113, Washington, DC.

USEPA. 2012b. Recommendations for Default Value for Relative Bioavailability of Arsenic in Soil. U.S. Environmental Protection Agency, OSWER 9200.1-113, Washington, DC.

USEPA. 2015. ProUCL Version 5.1 Technical Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations: EPA/600/R-07/041. U.S. EPA, Office of Research and Development, Washington, DC, October.

USEPA. 2017. Update for Chapter 5 of the Exposure Factors Handbook – Soil and Dust Ingestion. EPA/600/R-17/384F. Washington, D.C.

USEPA. 2020. Integrated Risk Information System. Online database accessed May 2020. https://www.epa.gov/iris

USEPA. 2020. Regional Screening Levels (RSLs). November.

von Lindern, I; Spalinger, S; Stifelman, ML; Stanek, LW; Bartrem, C. 2016. Estimating Children's Soil/Dust Ingestion Rates Through Retrospective Analyses of Blood Lead Biomonitoring from the Bunker Hill Superfund Site in Idaho. Environ Health Perspect 124(9):1462−1470. DOI: 10.1289/ehp.1510144.

Wester, RC; Maibach, HI; Sedik, L; Melendres, J; and Wade, M. 1993. In vivo and in vitro percutaneous absorption and skin decontamination of arsenic from water and soil. Fundam. Appl. Toxicol. 20, 336–340.

Wester, RC; Xiaoying, H; Barbadillo, S; Maibach, HI; Lowney, YW; Schoof, RA; Holm, SE and Ruby, MV. 2004. In vivo percutaneous absorption of arsenic from water and CCA-treated wood residue. Toxicol Sciences 79:287-295.

Weston. 2019. Preliminary Assessment Report. Morenci Mine Tailings Area. Morenci, Greenlee County, AZ. EPA ID. No. AZN000905583. Weston Solutions, Inc. Concord, California. June.

Wilson, R; Jones-Otazo, H; Petrovic, S; Mitchell, I; Bonvalot, Y; Williams, D; Richardson, GM. 2013. Revisiting Soil and Dust Ingestion Rates Based on Hand-to-Mouth Transfer. Human Ecol Risk Assess 19:158−188.

TABLES

Table 1: Screening Summary

Target Constituent	USEPA RSL (mg/kg)	RSL Toxicity Value Target Organ (TO)	# of Metals with Shared TO	TO-Adjusted RSL (mg/kg)	Maximum Concentration (mg/kg)	Maximum > TO-Adjusted RSL?
Aluminum	77,000	Nervous System	3	25,667	15,300	No
Antimony	31	Hematological effects	3	10	7.11	No
Arsenic	35	Dermal	4	9	37.1	Yes
Barium	15,000	Urinary	4	3,750	295	No
Beryllium	160	Gastrointestinal	2	80	5.33	No
Cadmium	71	Urinary	4	18	8.35	No
Chromium	120,000	Other	1	120,000	103	No
Cobalt	23	Thyroid	1	23	14.8	No
Copper	3,100	Gastrointestinal	2	1,550	2,580	Yes
Lead	400	NA	NA	400	145	No
Manganese	1,800	Nervous System	3	600	2,040	Yes
Mercury	23	Immune/Urinary	4	6	0.206	No
Molybdenum	390	Urinary	4	98	135	Yes
Nickel	1,500	Decreased Body Weights	1	1,500	56.2	No
Selenium	390	Nervous System, Hematological, Dermal	4	98	1.86	No
Silver	390	Dermal	4	98	2.04	No
Vanadium	390	Dermal	4	98	63.4	No
Zinc	23,000	Hematological effects	3	7,667	436	No

Notes:
RSL: Regional Screening Level
USEPA: United States Environmental Protection Agency
USEPA RSLs are the default residential noncancer child screening levels at a target hazard quotient of 1; published November 2020.
NA: Not applicable; assessed by modeling blood lead levels

Table 2: Target Organ Hazard Indices (HIs)

Target Organ (TO)	Metals with Shared TO Toxicity	TO HI (sum of Max Conc/RSL Ratios)
Gastrointestinal	Beryllium, Copper	0.9
Nervous System	Aluminum, Manganese, Selenium	1
Urinary	Barium, Cadmium, Mercury, Molybdenum	0.5
Dermal	Arsenic, Selenium, Silver, Vanadium	1
Hematological	Antimony, Selenium, Zinc	0.3

Table 3: Arsenic Data

Location	Tailings in Boring (# / aliquots)	Sample ID	Sample Date	Sample Interval Depth (inches["])	Arsenic Result (mg/kg)	Qualifier	School Category	Sports Field Area
MS-G001	No	MS-G001-AC-C0001	1/12/2020	0 - 3"	9.1		ES and MS	No
MS-G001	No	MS-G001-BC-C0002	1/12/2020	6" - 12"	3.77		ES and MS	No
MS-G001	Yes (1 / 9)	MS-G001-CC-C0003	1/12/2020	12" - 18"	4.45		ES and MS	No
MS-G002	Yes (1 / 9)	MS-G002-AC-C0005	1/11/2020	0 - 3"	2.94		ES	No
MS-G002	Yes (3 / 9)	MS-G002-BC-C0006	1/11/2020	6" - 12"	2.68		ES	No
MS-G002	Yes (3 / 9)	MS-G002-CC-C0007	1/11/2020	12" - 18"	3.77		ES	No
MS-G002	Yes (5 / 9)	MS-G002-DC-C0008	1/11/2020	18" - 24"	3.08		ES	No
MS-G003	No	MS-G003-AC-C0009	1/11/2020	0 - 3"	1.21		ES	No
MS-G003	No	MS-G003-BC-C0010	1/11/2020	6" - 12"	1.01		ES	No
MS-G003	No	MS-G003-CC-C0011	1/11/2020	12" - 18"	1.41		ES	No
MS-G004	No	MS-G004-AC-C0013	1/11/2020	0 - 3"	6.16		MS	No
MS-G004	No	MS-G004-BC-C0014	1/11/2020	6" - 12"	6.22		MS	No
MS-G004	No	MS-G004-CC-C0015	1/11/2020	12" - 18"	5.14		MS	No
MS-G004	No	MS-G004-DC-C0016	1/11/2020	18" - 24"	5.7		MS	No
MS-G005	No	MS-G005-AC-C0017	1/11/2020	0 - 3"	0.938		MS	No
MS-G005	No	MS-G005-BC-C0018	1/11/2020	6" - 12"	1.67		MS	No
MS-G005	No	MS-G005-CC-C0019	1/11/2020	12" - 18"	3.27		MS	No
MS-G005	No	MS-G005-DC-C0020	1/11/2020	18" - 24"	6.3		MS	No
MS-G006	No	MS-G006-AC-C0021	1/12/2020	0 - 3"	8.26		MS	No
MS-G006	No	MS-G006-BC-C0022	1/12/2020	6" - 12"	8.88		MS	No
MS-G006	No	MS-G006-CC-C0023	1/12/2020	12" - 18"	9.27		MS	No
MS-G006	No	MS-G006-DC-C0024	1/12/2020	18" - 24"	**20.9**		MS	No
MS-G007	No	MS-G007-AC-C0025	1/12/2020	0 - 3"	4.23		MS	No
MS-G007	No	MS-G007-BC-C0026	1/12/2020	6" - 12"	7.07		MS	No
MS-G007	No	MS-G007-CC-C0027	1/12/2020	12" - 18"	6.54		MS	No
MS-G007	No	MS-G007-DC-C0028	1/12/2020	18" - 24"	**10.3**		MS	No
MS-G008	Yes (1 / 9)	MS-G008-AC-C0029	1/18/2020	0 - 3"	4.67		HS	No
MS-G008	Yes (1 / 9)	MS-G008-BC-C0030	1/18/2020	6" - 12"	4.09		HS	No
MS-G009	No	MS-G009-AC-C0033	1/18/2020	0 - 3"	5.26		HS	No
MS-G009	No	MS-G009-BC-C0034	1/18/2020	6" - 12"	5.64		HS	No
MS-G009	No	MS-G009-CC-C0035	1/18/2020	12" - 18"	6.44		HS	No
MS-G009	Yes (1 / 9)	MS-G009-DC-C0036	1/18/2020	18" - 24"	1.48		HS	No
MS-G010	No	MS-G010-AC-C0037	1/16/2020	0 - 3"	7.3		ES	No
MS-G010	No	MS-G010-BC-C0038	1/16/2020	6" - 12"	8.17		ES	No
MS-G010	No	MS-G010-CC-C0039	1/16/2020	12" - 18"	8.38		ES	No
MS-G010	Yes (1 / 9)	MS-G010-DC-C0040	1/16/2020	18" - 24"	6.6		ES	No
MS-G012	No	MS-G012-AC-C0041	1/13/2020	0 - 3"	3.96		ES	No
MS-G012	No	MS-G012-BC-C0042	1/13/2020	6" - 12"	4.89		ES	No
MS-G012	Yes (1 / 9)	MS-G012-CC-C0043	1/13/2020	12" - 18"	3.23		ES	No
MS-G012	Yes (2 / 9)	MS-G012-DC-C0044	1/13/2020	18" - 24"	2.92		ES	No
MS-G019	No	MS-G019-AC-C0045	1/14/2020	0 - 3"	5.51		MS	No
MS-G019	Yes (1 / 9)	MS-G019-BC-C0046	1/14/2020	6" - 12"	4.56		MS	No
MS-G019	Yes (2 / 9)	MS-G019-CC-C0047	1/14/2020	12" - 18"	4.29		MS	No
MS-G019	Yes (4 / 9)	MS-G019-DC-C0048	1/14/2020	18" - 24"	1.16		MS	No
MS-G020	No	MS-G020-AC-C0049	1/14/2020	0 - 3"	9.81		MS	No
MS-G020	No	MS-G020-BC-C0050	1/14/2020	6" - 12"	3.19		MS	No
MS-G020	Yes (1 / 9)	MS-G020-CC-C0051	1/14/2020	12" - 18"	3.54		MS	No
MS-G027	No	MS-G027-AC-C0057	1/14/2020	0 - 3"	6.16		MS	No
MS-G027	Yes (2 / 9)	MS-G027-BC-C0058	1/14/2020	6" - 12"	5.73		MS	No
MS-G027	Yes (2 / 9)	MS-G027-CC-C0059	1/14/2020	12" - 18"	5.49		MS	No
MS-G027	Yes (3 / 9)	MS-G027-DC-C0060	1/14/2020	18" - 24"	5.42		MS	No
MS-G028	No	MS-G028-AC-C0073	1/18/2020	0 - 3"	6.57		MS	No
MS-G028	Yes (3 / 9)	MS-G028-BC-C0074	1/18/2020	6" - 12"	6.63		MS	No
MS-G028	Yes (7 / 9)	MS-G028-CC-C0075	1/18/2020	12" - 18"	3.2		MS	No

Table 3: Arsenic Data

Location	Tailings in Boring (# / aliquots)	Sample ID	Sample Date	Sample Interval Depth (inches["])	Arsenic Result (mg/kg)	Qualifier	School Category	Sports Field Area
MS-G028	Yes (8 / 9)	MS-G028-DC-C0076	1/18/2020	18" - 24"	1.61		MS	No
MS-G035	No	MS-G035-AC-C0061	1/13/2020	0 - 3"	**18.1**		MS	Yes
MS-G035	No	MS-G035-BC-C0062	1/13/2020	6" - 12"	4.9		MS	Yes
MS-G035	No	MS-G035-CC-C0063	1/13/2020	12" - 18"	2.95		MS	Yes
MS-G039	Yes (1 / 9)	MS-G039-AC-C0069	1/16/2020	0 - 3"	6.04		HS	No
MS-G039	Yes (2 / 9)	MS-G039-BC-C0070	1/16/2020	6" - 12"	4.8		HS	No
MS-G039	Yes (2 / 9)	MS-G039-CC-C0071	1/16/2020	12" - 18"	4.62		HS	No
MS-G043	No	MS-G043-AC-C0065	1/16/2020	0 - 3"	**18.8**		MS	Yes
MS-G043	No	MS-G043-BC-C0066	1/16/2020	6" - 12"	3.89		MS	Yes
MS-G043	No	MS-G043-CC-C0067	1/16/2020	12" - 18"	6.04		MS	Yes
MS-G043	Yes (1 / 9)	MS-G043-DC-C0068	1/16/2020	18" - 24"	4.08		MS	Yes
MS-G046	Yes (2 / 9)	MS-G046-AC-C0053	1/18/2020	0 - 3"	2.75		HS	No
MS-G046	Yes (4 / 9)	MS-G046-BC-C0054	1/18/2020	6" - 12"	1.25		HS	No
MS-G046	Yes (5 / 9)	MS-G046-CC-C0055	1/18/2020	12" - 18"	1.33		HS	No
MS-G046	Yes (5 / 9)	MS-G046-DC-C0056	1/18/2020	18" - 24"	1.08		HS	No
MS-G048	No	MS-G048-AC-C0077	1/13/2020	0 - 3"	**13.8**		MS and HS	Yes
MS-G048	Yes (1 / 9)	MS-G048-BC-C0078	1/13/2020	6" - 12"	3.48		MS and HS	Yes
MS-G050	No	MS-G050-AC-C0081	1/13/2020	0 - 3"	**12.4**		HS	Yes
MS-G050	No	MS-G050-BC-C0082	1/13/2020	6" - 12"	**13**		HS	Yes
MS-G052	No	MS-G052-AC-C0085	1/17/2020	0 - 3"	9.13		HS	No
MS-G052	No	MS-G052-BC-C0086	1/17/2020	6" - 12"	**14.4**		HS	No
MS-G052	No	MS-G052-CC-C0087	1/17/2020	12" - 18"	4.08		HS	No
MS-G054	Yes (2 / 9)	MS-G054-AC-C0089	1/14/2020	0 - 3"	3.74		HS	No
MS-G054	Yes (7 / 9)	MS-G054-BC-C0090	1/14/2020	6" - 12"	1.49		HS	No
MS-G054	Yes (7 / 9)	MS-G054-CC-C0091	1/14/2020	12" - 18"	0.822		HS	No
MS-G054	Yes (7 / 9)	MS-G054-DC-C0092	1/14/2020	18" - 24"	0.977		HS	No
MS-G063	No	MS-G063-AC-C0093	1/17/2020	0 - 3"	4.87		HS	No
MS-G063	Yes (3 / 9)	MS-G063-BC-C0094	1/17/2020	6" - 12"	1.14		HS	No
MS-G063	Yes (3 / 9)	MS-G063-CC-C0095	1/17/2020	12" - 18"	0.885		HS	No
MS-G063	Yes (3 / 9)	MS-G063-DC-C0096	1/17/2020	18" - 24"	1.26		HS	No
MS-G066	No	MS-G066-AC-C0097	1/9/2020	0 - 3"	**37.1**		HS	Yes
MS-G066	No	MS-G066-BC-C0098	1/9/2020	6" - 12"	5.81		HS	Yes
MS-G066	No	MS-G066-CC-C0099	1/9/2020	12" - 18"	5.73		HS	Yes
MS-G066	No	MS-G066-DC-C0100	1/9/2020	18" - 24"	5.25		HS	Yes
MS-G068	No	MS-G068-AC-C0101	1/10/2020	0 - 3"	6.73		HS	Yes
MS-G068	No	MS-G068-BC-C0102	1/10/2020	6" - 12"	5.29		HS	Yes
MS-G068	No	MS-G068-CC-C0103	1/10/2020	12" - 18"	4.25		HS	Yes
MS-G070	Yes (1 / 9)	MS-G070-AC-C0105	1/17/2020	0 - 3"	5.09		HS	No
MS-G070	Yes (7 / 9)	MS-G070-BC-C0106	1/17/2020	6" - 12"	1.24		HS	No
MS-G070	Yes (7 / 9)	MS-G070-CC-C0107	1/17/2020	12" - 18"	1.28		HS	No
MS-G070	Yes (7 / 9)	MS-G070-DC-C0108	1/17/2020	18" - 24"	0.971		HS	No
MS-G078	Yes (1 / 9)	MS-G078-AC-C0117	1/16/2020	0 - 3"	2.61		HS	No
MS-G078	Yes (2 / 9)	MS-G078-BC-C0118	1/16/2020	6" - 12"	4.82		HS	No
MS-G081	No	MS-G081-AC-C0109	1/9/2020	0 - 3"	5.69		HS	Yes
MS-G081	Yes (2 / 9)	MS-G081-BC-C0110	1/9/2020	6" - 12"	3.91		HS	Yes
MS-G081	Yes (9 / 9)	MS-G081-CC-C0111	1/9/2020	12" - 18"	2.87		HS	Yes
MS-G081	Yes (9 / 9)	MS-G081-DC-C0112	1/9/2020	18" - 24"	0.867		HS	Yes
MS-G083	Yes (1 / 9)	MS-G083-AC-C0113	1/9/2020	0 - 3"	2.62		HS	No
MS-G083	Yes (5 / 9)	MS-G083-BC-C0114	1/9/2020	6" - 12"	2.43		HS	No
MS-G083	Yes (8 / 9)	MS-G083-CC-C0115	1/9/2020	12" - 18"	2.17		HS	No
MS-G083	Yes (9 / 9)	MS-G083-DC-C0116	1/9/2020	18" - 24"	1.24		HS	No
MS-G088	No	MS-G088-AC-C0121	1/10/2020	0 - 3"	7.27		HS	Yes
MS-G088	Yes (3 / 9)	MS-G088-BC-C0122	1/10/2020	6" - 12"	3.6		HS	Yes
MS-G088	Yes (7 / 9)	MS-G088-CC-C0123	1/10/2020	12" - 18"	2.09		HS	Yes

Table 3: Arsenic Data

Location	Tailings in Boring (# / aliquots)	Sample ID	Sample Date	Sample Interval Depth (inches["])	Arsenic Result (mg/kg)	Qualifier	School Category	Sports Field Area
MS-G088	Yes (8 / 9)	MS-G088-DC-C0124	1/10/2020	18" - 24"	0.712	J	HS	Yes
MS-G089	Yes (1 / 9)	MS-G089-AC-C0129	1/10/2020	0 - 3"	5.5		HS	Yes
MS-G089	Yes (4 / 9)	MS-G089-BC-C0130	1/10/2020	6" - 12"	2.57		HS	Yes
MS-G089	Yes (9 / 9)	MS-G089-CC-C0131	1/10/2020	12" - 18"	1.41		HS	Yes
MS-G089	Yes (9 / 9)	MS-G089-DC-C0132	1/10/2020	18" - 24"	0.659	J	HS	Yes
MS-G095	Yes (1 / 9)	MS-G095-AC-C0125	1/9/2020	0 - 3"	2.2		HS	No
MS-G095	Yes (7 / 9)	MS-G095-BC-C0126	1/9/2020	6" - 12"	1.8		HS	No
MS-G095	Yes (8 / 9)	MS-G095-CC-C0127	1/9/2020	12" - 18"	1.65		HS	No
MS-G095	Yes (8 / 9)	MS-G095-DC-C0128	1/9/2020	18" - 24"	1.27		HS	No
MS-G106	No	MS-G106-AG-G0001	1/11/2020	0 - 3"	0.75	J	ES	No
MS-G106	No	MS-G106-BG-G0002	1/11/2020	6" - 12"	0.567	J	ES	No
MS-G106	No	MS-G106-CG-G0003	1/11/2020	12" - 18"	0.999		ES	No
MS-G106	No	MS-G106-DG-G0004	1/11/2020	18" - 24"	1.62		ES	No
MS-G107	No	MS-G107-AG-G0005	1/11/2020	0 - 3"	1.96		ES	No
MS-G107	No	MS-G107-BG-G0006	1/11/2020	6" - 12"	2.15		ES	No
MS-G107	No	MS-G107-CG-G0007	1/11/2020	12" - 18"	3.21		ES	No
MS-G107	No	MS-G107-DG-G0008	1/11/2020	18" - 24"	3.67		ES	No
MS-G108	No	MS-G108-AG-G0009	1/11/2020	0 - 3"	2.18		ES	No
MS-G108	No	MS-G108-BG-G0010	1/11/2020	6" - 12"	2.63		ES	No
MS-G108	No	MS-G108-CG-G0011	1/11/2020	12" - 18"	4.04		ES	No
MS-G109	No	MS-G109-AG-G0013	1/12/2020	0 - 3"	2.67		ES	No
MS-G109	No	MS-G109-BG-G0014	1/12/2020	6" - 12"	2.99		ES	No
MS-G110	No	MS-G110-AG-G0017	1/12/2020	0 - 3"	0.661	J	ES	No
MS-G110	No	MS-G110-BG-G0018	1/12/2020	6" - 12"	1.08		ES	No
MS-G110	No	MS-G110-CG-G0019	1/12/2020	12" - 18"	2.37		ES	No
MS-G110	No	MS-G110-DG-G0020	1/12/2020	18" - 24"	3.4		ES	No
MS-G111	No	MS-G111-AG-G0021	1/12/2020	0 - 3"	0.706	J	ES	No
MS-G111	No	MS-G111-BG-G0022	1/12/2020	6" - 12"	0.664	J	ES	No
MS-G111	No	MS-G111-CG-G0023	1/12/2020	12" - 18"	1		ES	No
MS-G112	No	MS-G112-AG-G0025	1/12/2020	0 - 3"	0.648	J	ES	No
MS-G112	No	MS-G112-BG-G0026	1/12/2020	6" - 12"	0.556	J	ES	No
MS-G112	No	MS-G112-CG-G0027	1/12/2020	12" - 18"	0.833		ES	No
MS-G113	No	MS-G113-AG-G0029	1/12/2020	0 - 3"	0.604	J	ES	No
MS-G113	No	MS-G113-BG-G0030	1/12/2020	6" - 12"	0.597	J	ES	No
MS-G113	No	MS-G113-CG-G0031	1/12/2020	12" - 18"	0.645	J	ES	No
MS-G113	No	MS-G113-DG-G0032	1/12/2020	18" - 24"	1.1		ES	No
MS-G114	No	MS-G114-AG-G0033	1/12/2020	0 - 3"	0.804		MS	No
MS-G114	No	MS-G114-BG-G0034	1/12/2020	6" - 12"	0.756	J	MS	No
MS-G114	No	MS-G114-CG-G0035	1/12/2020	12" - 18"	0.991		MS	No
MS-G114	No	MS-G114-DG-G0036	1/12/2020	18" - 24"	1.16		MS	No
MS-G115	No	MS-G115-AG-G0037	1/12/2020	0 - 3"	0.776		MS	No
MS-G115	No	MS-G115-BG-G0038	1/12/2020	6" - 12"	0.683	J	MS	No
MS-G115	No	MS-G115-CG-G0039	1/12/2020	12" - 18"	0.883		MS	No
MS-G115	No	MS-G115-DG-G0040	1/12/2020	18" - 24"	1.04		MS	No
MS-G116	No	MS-G116-AG-G0041	1/12/2020	0 - 3"	4		MS	No
MS-G116	No	MS-G116-BG-G0042	1/12/2020	6" - 12"	4.3		MS	No
MS-G116	No	MS-G116-CG-G0043	1/12/2020	12" - 18"	**14.6**		MS	No
MS-G116	No	MS-G116-DG-G0044	1/12/2020	18" - 24"	7.25		MS	No
MS-G117	No	MS-G117-AG-G0045	1/12/2020	0 - 3"	2.83		MS	No
MS-G117	No	MS-G117-BG-G0046	1/12/2020	6" - 12"	4.91		MS	No
MS-G117	No	MS-G117-CG-G0047	1/12/2020	12" - 18"	5.33		MS	No
MS-G117	No	MS-G117-DG-G0048	1/12/2020	18" - 24"	9.7		MS	No
MS-G118	No	MS-G118-AG-G0049	1/12/2020	0 - 3"	2.48		MS	No
MS-G118	No	MS-G118-BG-G0050	1/12/2020	6" - 12"	4.32		MS	No

Table 3: Arsenic Data

Location	Tailings in Boring (# / aliquots)	Sample ID	Sample Date	Sample Interval Depth (inches["])	Arsenic Result (mg/kg)	Qualifier	School Category	Sports Field Area
MS-G118	No	MS-G118-CG-G0051	1/12/2020	12" - 18"	3.87		MS	No
MS-G118	No	MS-G118-DG-G0052	1/12/2020	18" - 24"	9.62		MS	No
MS-G119	No	MS-G119-AG-G0053	1/14/2020	0 - 3"	**10.7**		MS	No
MS-G119	No	MS-G119-BG-G0054	1/14/2020	6" - 12"	8.98		MS	No
MS-G119	No	MS-G119-CG-G0055	1/14/2020	12" - 18"	9.55		MS	No
MS-G119	No	MS-G119-DG-G0056	1/14/2020	18" - 24"	5.97		MS	No
MS-G120	No	MS-G120-AG-G0057	1/17/2020	0 - 3"	6.92		HS	Yes
MS-G120	No	MS-G120-BG-G0058	1/17/2020	6" - 12"	7.55		HS	Yes
MS-G120	No	MS-G120-CG-G0059	1/17/2020	12" - 18"	7.39		HS	Yes
MS-G120	No	MS-G120-DG-G0060	1/17/2020	18" - 24"	5.21		HS	Yes
MS-G121	No	MS-G121-AG-G0061	1/17/2020	0 - 3"	5.31		HS	No
MS-G121	Yes (1 / 1)	MS-G121-BG-G0062	1/17/2020	6" - 12"	3.47		HS	No
MS-G121	No	MS-G121-CG-G0063	1/17/2020	12" - 18"	4.81		HS	No
MS-G121	No	MS-G121-DG-G0064	1/17/2020	18" - 24"	2.55		HS	No
MS-G122	No	MS-G122-AG-G0065	1/19/2020	0 - 3"	5.35		HS	No
MS-G122	No	MS-G122-BG-G0066	1/19/2020	6" - 12"	7.56		HS	No
MS-G122	No	MS-G122-CG-G0067	1/19/2020	12" - 18"	7.88		HS	No
MS-G122	No	MS-G122-DG-G0068	1/19/2020	18" - 24"	7.12		HS	No
MS-G123	No	MS-G123-AG-G0069	1/19/2020	0 - 3"	7.86		HS	No
MS-G123	No	MS-G123-BG-G0070	1/19/2020	6" - 12"	7.33		HS	No
MS-G123	No	MS-G123-CG-G0071	1/19/2020	12" - 18"	5.84		HS	No
MS-G123	No	MS-G123-DG-G0072	1/19/2020	18" - 24"	5.82		HS	No
CSS-01	No	CSS-01-0.5	7/25/2019	0 - 12"	1.08	J	HS	No
CSS-02	No	CSS-02-0.5	7/25/2019	0 - 12"	2.76		NA	No
CSS-03	No	CSS-03-0.5	7/25/2019	0 - 12"	5.69		HS	Yes
CSS-04	No	CSS-04-0.5	7/25/2019	0 - 12"	4.38		HS	Yes
CSS-05	No	CSS-05-0.5	7/25/2019	0 - 12"	3.41		HS	Yes
CSS-06	No	CSS-06-0.5	7/25/2019	0 - 12"	**15.7**		HS	Yes
CSS-07	No	CSS-07-0.5	7/25/2019	0 - 12"	2.56		MS and HS	Yes
CSS-08	Yes (0.5-1 ft)	CSS-08-0.5	7/25/2019	0 - 12"	3.54		ES	No
CSS-09	No	CSS-09-0.5	7/25/2019	0 - 12"	2		MS	No
CSS-10	No	CSS-10-0.5	7/25/2019	0 - 12"	4.02		MS	No
CSS-11	No	CSS-11-0.5	7/25/2019	0 - 12"	4.67		MS	No
CSS-12	No	CSS-12-0.5	7/25/2019	0 - 12"	3.61		ES	No
CSS-13	No	CSS-13-0.5	7/25/2019	0 - 12"	3.2		MS	No

Notes:
ADEQ: Arizona Department of Environmental Quality
ES: primary and elementary school; MS: middle school; HS: high school
NA: Not applicable; sample collected from community softball fields adjacent to school
Arsenic results greater than the ADEQ residential soil remediation level of 10 mg/kg are bolded.

Table 4: UCLM Summary

Dataset	Number of Samples	Min	Max	Mean	UCLM(s)[a]	UCLM Method[b]
		(mg/kg)				
Surface Soil/Tailings (0-3" bgs)	51	0.604	37.1	5.955	7.378	95% Approximate Gamma UCL
All Soil/Tailings	197	0.556	37.1	4.616	5.113	95% CLT UCL
					5.104	95% Standard Bootstrap UCL
					5.256	95% Hall's Bootstrap UCL
					5.203	95% BCA Bootstrap UCL
					5.224	95% Bootstrap-t UCL
					5.147	95% Percentile Bootstrap UCL
Elementary School	47	0.556	9.1	2.773	3.402	95% Adjusted Gamma UCL
Middle School	72	0.683	20.9	5.681	6.589	95% Approximate Gamma UCL
High School	83	0.659	37.1	4.872	5.656	95% Approximate Gamma UCL
Sports Fields	39	0.659	37.1	6.86	8.624	95% CLT UCL
					8.624	95% Standard Bootstrap UCL
					10.84	95% Hall's Bootstrap UCL
					9.346	95% BCA Bootstrap UCL
					8.668	95% Jackknife UCL
					9.538	95% Bootstrap-t UCL
					8.716	95% Percentile Bootstrap UCL
					9.575	95% H-UCL[c]

Notes:
bgs: below ground surface
UCLM: upper confidence limit on the mean
[a] 95UCLM values were calculated using the USEPA's ProUCL software. Values recommended by the ProUCL software based on distribution goodness of fit and calculated using valid statistical methods are included in the table.
[b] Based on discussion with ADEQ (ADEQ 2020c), 95UCLMs based on the Chebyshev and Kaplan-Meier (KM) calculation methods should not be used due to problems with these methods in ProUCL; values calculated using these methods are therefore not included in the table.
[c] The sports fields dataset follows a lognormal distribution. The 95UCLM value identified by the ProUCL software as the "Suggested UCL to Use" for this dataset is based on the lognormal H-UCL method. However, the USEPA notes included with the ProUCL output state that H-statistic based UCLMs are included for historical reasons only and should be avoided, contradicting the suggestion from ProUCL to use the 95UCLM based on this method. The USEPA notes further recommend the use of nonparametric methods to calculate 95UCLMs for skewed distributions that do not follow a gamma distribution (see **Appendix A**). Based on this recommendation, nonparametric UCLM values are also included in the table.

Table 5: Probabilistic Risk Assessment Input Parameters

Parameter	Abbreviation	Value or Distribution Type	Description	Reference
Exposure Frequency (d/y)	EF	162, 180, 225	Triangular distribution (minimum, most likely, maximum)	Morenci school calendar; Arizona school attendance regulations
Cancer Exposure Duration Student ages 3 to <18 (y)	ED_c	Custom	Distributions for ages 3, 6, 9, 12, and 15 truncated at 15 years from Table 16-109	USEPA 2011 (subreference Johnson & Capel 1992)
Cancer Exposure Duration Staff age 21+ (y)	ED_c	Custom	Distributions for men and women for teacher job category from Tables IX and X	Burmaster 2000
Soil Ingestion Rate Student ages 3 to <6 (mg/d)	IR	Custom	Distributions for ages 3 to < 6 from Tables 5-12 and 5-16	USEPA 2017 (subreference Ozkaynak et al. 2011 and von Lindern et al. 2016)
Soil Ingestion Rate Student ages 6 to <12 (mg/d)	IR	Custom	Distributions for ages 6 to < 12 from Tables 5-14 and 5-16	USEPA 2017 (subreference von Lindern et al. 2016 and Wilson et al. 2013)
Soil Ingestion Rate Student ages 12 to <18 (mg/d)	IR	Custom	Distributions for ages 12 to < 19 from Tables 5-14 and 5-9	USEPA 2017 (subreference Wilson et al. 2013 and Davis & Mirick 2006)
Soil Ingestion Rate Staff age 21+ (mg/d)	IR	Custom	Distributions for ages 20+ from Tables 5-14 and 5-9	USEPA 2017 (subreference Wilson et al. 2013 and Davis & Mirick 2006)
Fraction Ingested soil (unitless)	FI_s	0.45	Fixed value	USEPA 2007
Fraction Ingested dust (unitless)	FI_d	0.55	Fixed value	USEPA 2007
Bioavailability of arsenic in soil and dust (unitless)	RBA	Custom	Distribution from Table 3	USEPA 2012
Ratio of concentration in dust to soil (unitless)	Dust-Ratio	Custom	Distribution derived from datasets with good regression model fit; truncated at 0	Brattin & Griffin 2011; Tu et al. 2020
Skin Surface Area Student ages 3 to <6 (cm^2)	SSA	Custom	Distribution for ages 3 to < 6 from Table 7-10, adjusted by mean percentage of total SSA from Table 7-8	USEPA 2011
Skin Surface Area Student ages 6 to <12 (cm^2)	SSA	Custom	Distribution for ages 6 to < 11 from Table 7-10, adjusted by mean percentage of total SSA from Table 7-8	USEPA 2011
Skin Surface Area Student ages 12 to <18 (cm^2)	SSA	Custom	Distribution for ages 11 to < 16 and 16 to < 21 from Table 7-10, adjusted by mean percentage of total SSA from Table 7-8	USEPA 2011
Skin Surface Area Staff age 21+ (cm^2)	SSA	Custom	Sum of distributions for head, forearms, hands, and lower legs from Table 7-12	USEPA 2011
Dermal absorption fraction of arsenic (unitless)	ABS_{dermal}	0.005 (0.0044)	Mean ± standard deviation of dataset with highest absorption; truncated at 0	Lowney et al. 2007
Dermal Adherence Factor Student ages 3 to <6 (mg/cm^2)	AF	0.2	Fixed value	USEPA 2004
Dermal Adherence Factor Student ages 6 to <18 and Staff age 21+ (mg/cm^2)	AF	0.07	Fixed value	USEPA 2004
Body Weight Student ages 3 to <6 (kg)	BW	Custom	Distribution for ages 3 to < 6 from Table 8-3	USEPA 2011
Body Weight Student ages 6 to <12 (kg)	BW	Custom	Distribution for ages 6 to < 11 from Table 8-3	USEPA 2011
Body Weight Student ages 12 to <18 (kg)	BW	Custom	Distribution for ages 11 to < 16 and 16 to < 21 from Table 8-3	USEPA 2011
Body Weight Staff age 21+ (kg)	BW	Custom	Distribution for ages 21 to < 60 from Table 8-3	USEPA 2011
Exposure Time (particulate) Student ages 3 to <6 (h/d)	ET	Custom	Distribution for ages 3 to < 6 from Table 16-19	USEPA 2011
Exposure Time (particulate) Student ages 6 to <12 (h/d)	ET	Custom	Distribution for ages 6 to < 11 from Table 16-19	USEPA 2011
Exposure Time (particulate) Student ages 12 to <18 and Staff age 21+ (h/d)	ET	Custom	Distribution for ages 11 to < 16 and 16 to < 21 from Table 16-19	USEPA 2011
Conversion Factor (kg/mg)	CF1	0.000001	Fixed value	NA
Cancer Averaging Time (d)	AT_c	25550	Fixed value	ADHS 2003; USEPA 2014
Particulate Emission Factor (m^3/kg)	PEF	1396000000	Fixed value	ADHS 2003
Event per day (event/d)	EV	1	Fixed value	USEPA 2004
Arsenic oral slope factor ($(mg/kg/d)^{-1}$)	SF_o	1.5	Fixed value	USEPA 2020
Arsenic gastrointestinal absorption (unitless)	ABS_{GI}	1	Fixed value	USEPA 2004
Arsenic dermal slope factor ($(mg/kg/d)^{-1}$)	SF_{derm}	1.5	Fixed value	USEPA 2020
Arsenic inhalation unit risk factor ($(mg/m3)^{-1}$)	IUR	4.3	Fixed value	USEPA 2020
Arsenic Exposure Concentration Elementary School (mg/kg)	C_{soil}	2.773 (0.321)	Normal distribution of averages of 2019-2020 dataset	Arcadis 2020; AECOM 2019
Arsenic Exposure Concentration Middle School (mg/kg)	C_{soil}	5.681 (0.494)	Normal distribution of averages of 2019-2020 dataset	Arcadis 2020; AECOM 2019
Arsenic Exposure Concentration High School (mg/kg)	C_{soil}	4.872 (0.531)	Normal distribution of averages of 2019-2020 dataset	Arcadis 2020; AECOM 2019
Arsenic Exposure Concentration Sports Fields (mg/kg)	C_{soil}	6.86 (1.072)	Normal distribution of averages of 2019-2020 dataset	Arcadis 2020; AECOM 2019

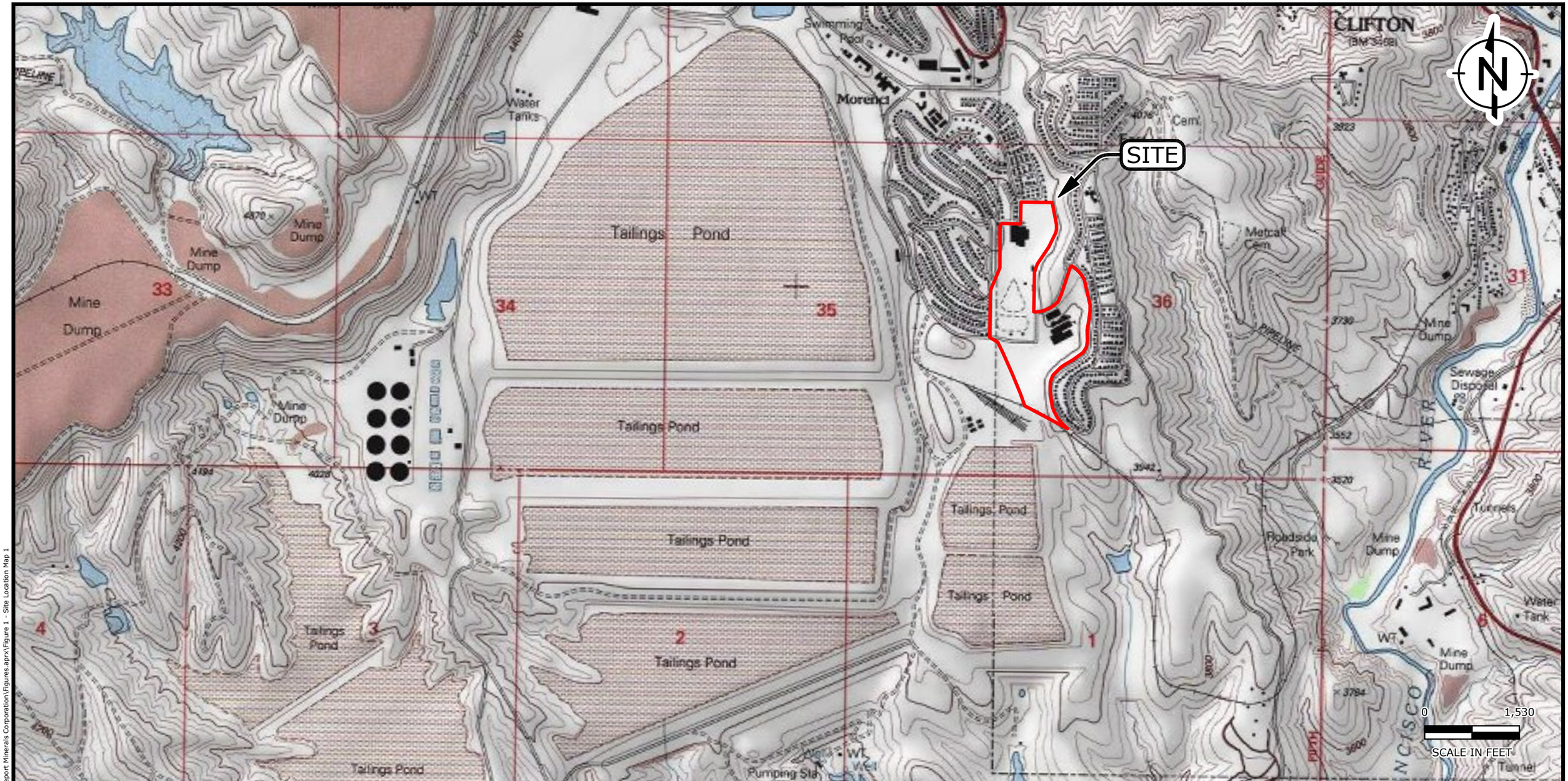
Notes:
ADHS: Arizona Department of Health Services
USEPA: United States Environmental Protection Agency
NA: not applicable

Table 6: Probabilistic Risk Assessment Results

Exposure Scenario	95th Percentile LECR Estimate			
	Ingestion	**Dermal**	**Inhalation**	**Cumulative**
Student (school-specific)	3E-07	8E-08	1E-10	4E-07
Student (sports fields)	4E-07	8E-08	1E-10	4E-07
Adult Coach (sports fields)	2E-07	7E-08	3E-10	2E-07
Student and Coach (sports fields sum)	6E-07	2E-07	4E-10	7E-07

Notes:
LECR: Lifetime Excess Cancer Risk

FIGURES



Legend

Site Boundary

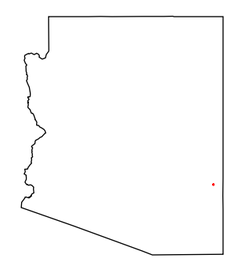
Source: Modified from Arcadis (2020)

0 1

Scale in Miles

0 4,000 8,000

Scale in Feet



KEY MAP

Site Location Map

Freeport Minerals Corporation
Morenci, Arizona

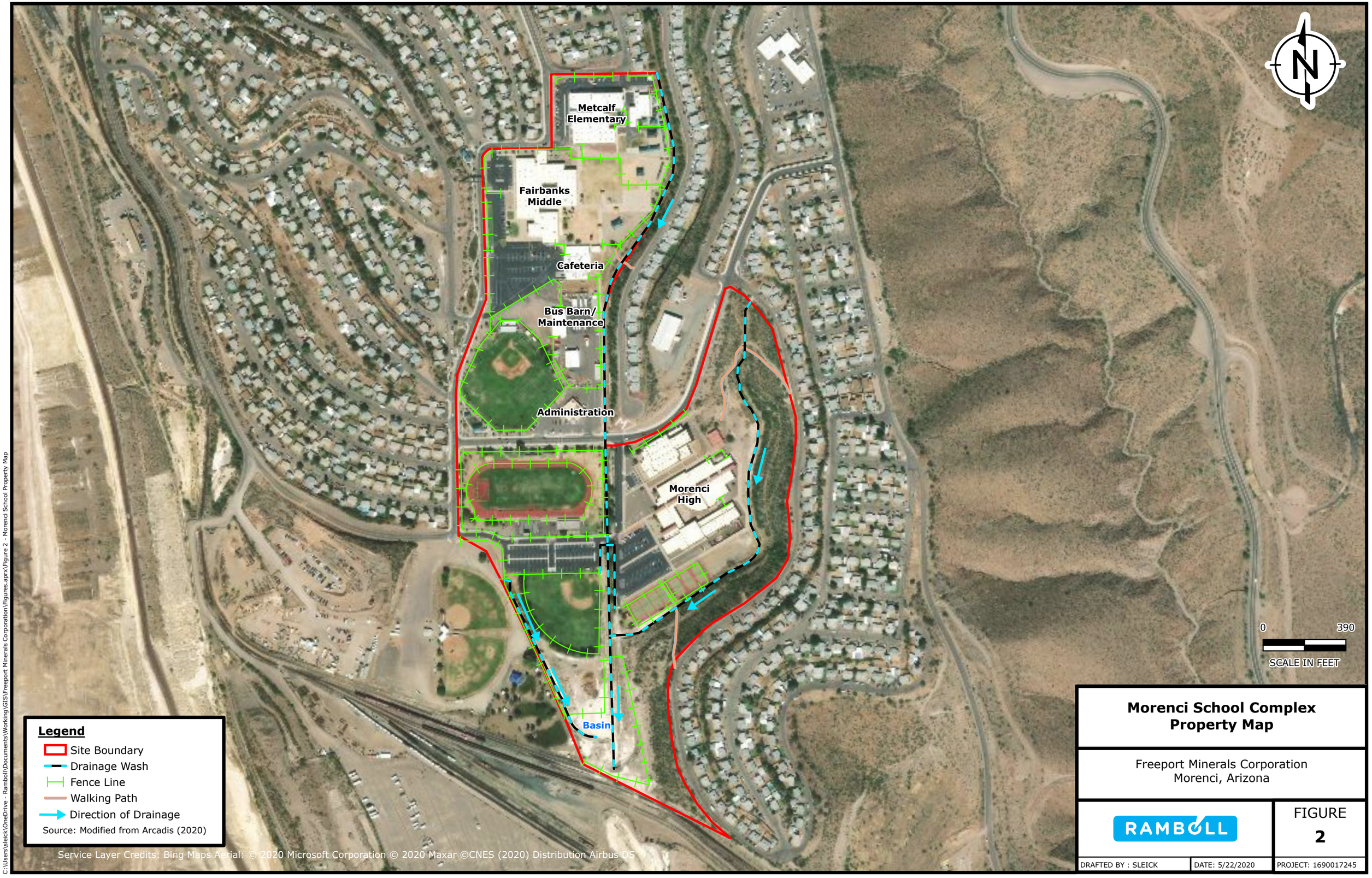
RAMBOLL

FIGURE
1

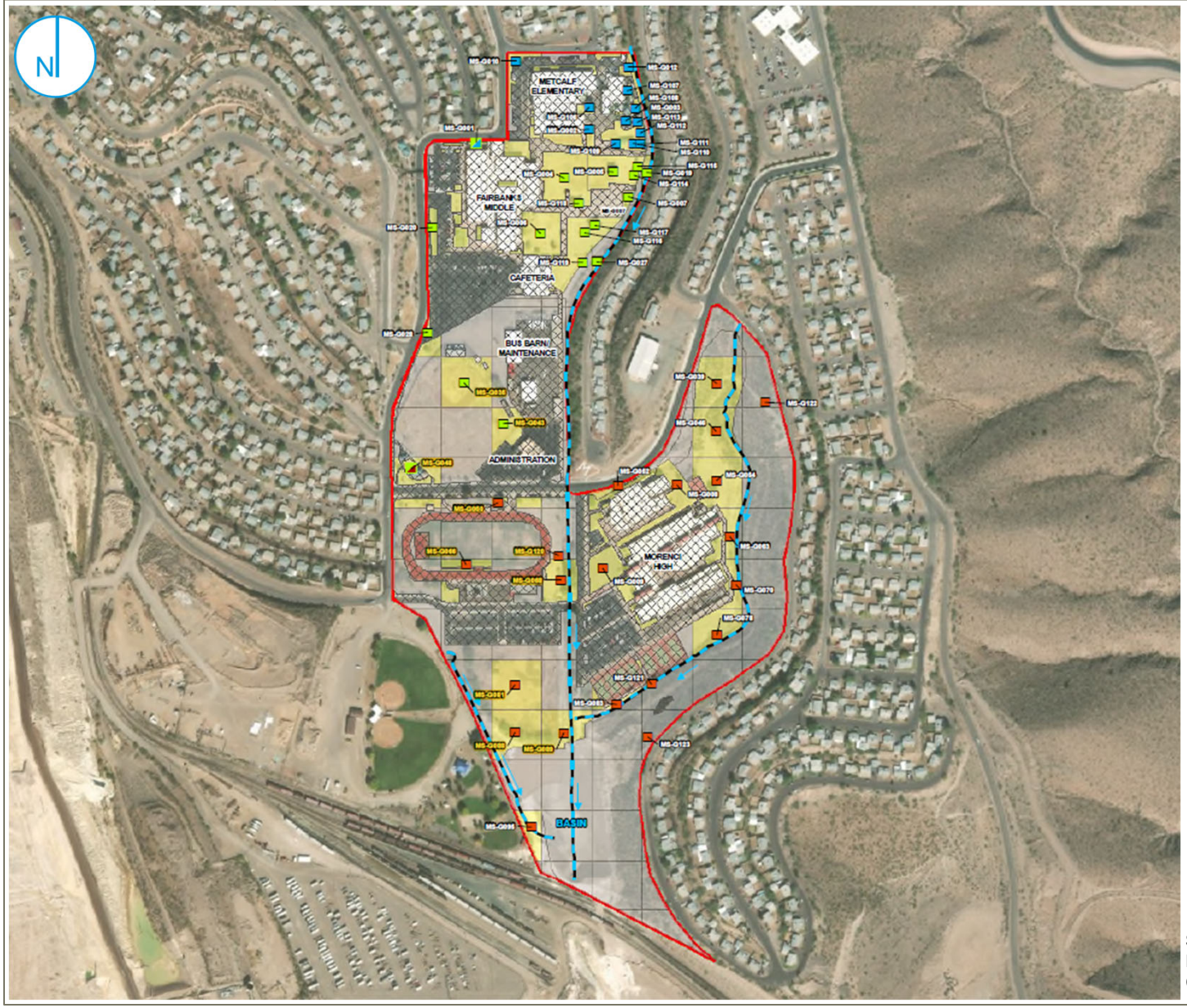
DRAFTED BY : SLEICK | DATE: 6/26/2020 | PROJECT: 1690017245

SOURCE:
Copyright:© 2013 National Geographic Society, i-cubed.
Map Scale: 1:; Spatial Reference: NAD 1983 UTM Zone 14N;
Map Center:

C:\Users\sleick\OneDrive - Ramboll\Documents\Working\GIS\Freeport Minerals Corporation\Figures.aprx\Figure 1 - Site Location Map 1



C:\Users\sleick\OneDrive - Ramboll\Documents\Working\GIS\Freeport Minerals Corporation\Figures.aprx\Figure 2 - Morenci School Property Map



LEGEND:

- ELEMENTARY (ES)
- MIDDLE (MS)
- HIGH SCHOOL (HS)
- ELEMENTARY (ES) AND MIDDLE (MS)
- MIDDLE (MS) AND HIGH SCHOOL (HS)
- DRAINAGE WASH
- DIRECTION OF DRAINAGE
- GRID SELECTED SAMPLING
- NOT SELECTED FOR SAMPLING
- SITE BOUNDARY
- BUILDING/IMPERVIOUS AREA

0 400 800 Feet

Notes:

1. Yellow-highlighted sample locations represent the sports fields dataset.
2. Borings advanced on the grounds of Metcalf Elementary School are designated ES.
3. Borings advanced on the grounds of Fairbanks Middle School are designated MS.
4. Borings advanced on the grounds of Morenci High School are designated HS.
5. Two borings straddled the grounds of more than one school. These data were applied to both schools as indicated.

Source: Modified from Arcadis. 2020. Site Characterization Report, Morenci Schools Site, Morenci, Arizona, VRP Site Code: 513333-00. April 17.

2020 Sample Locations by School

Freeport Minerals Corporation
Morenci, Arizona

FIGURE 3

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL

C:\Users\sleick\Ramboll\PNW GIS - Documents\PROJECTS\Morenci/Figure 4.pptx

PROJECT: 1690017245 | DATED: 1/18/2021 | DESIGNER: SLEICK

School Property Boundary

Soil Sample Location – October 2018

Soil Sample Location – July 2019

Notes:

1. GPS coordinates obtained via: Trimble R-1 (Submeter accuracy) My GPS Coordinates – iPhone Application.
2. **SOURCE**: AECOM. 2019. Morenci Schools Complex Sampling Report – Version 1. AECOM. Tucson, Arizona. September 13.

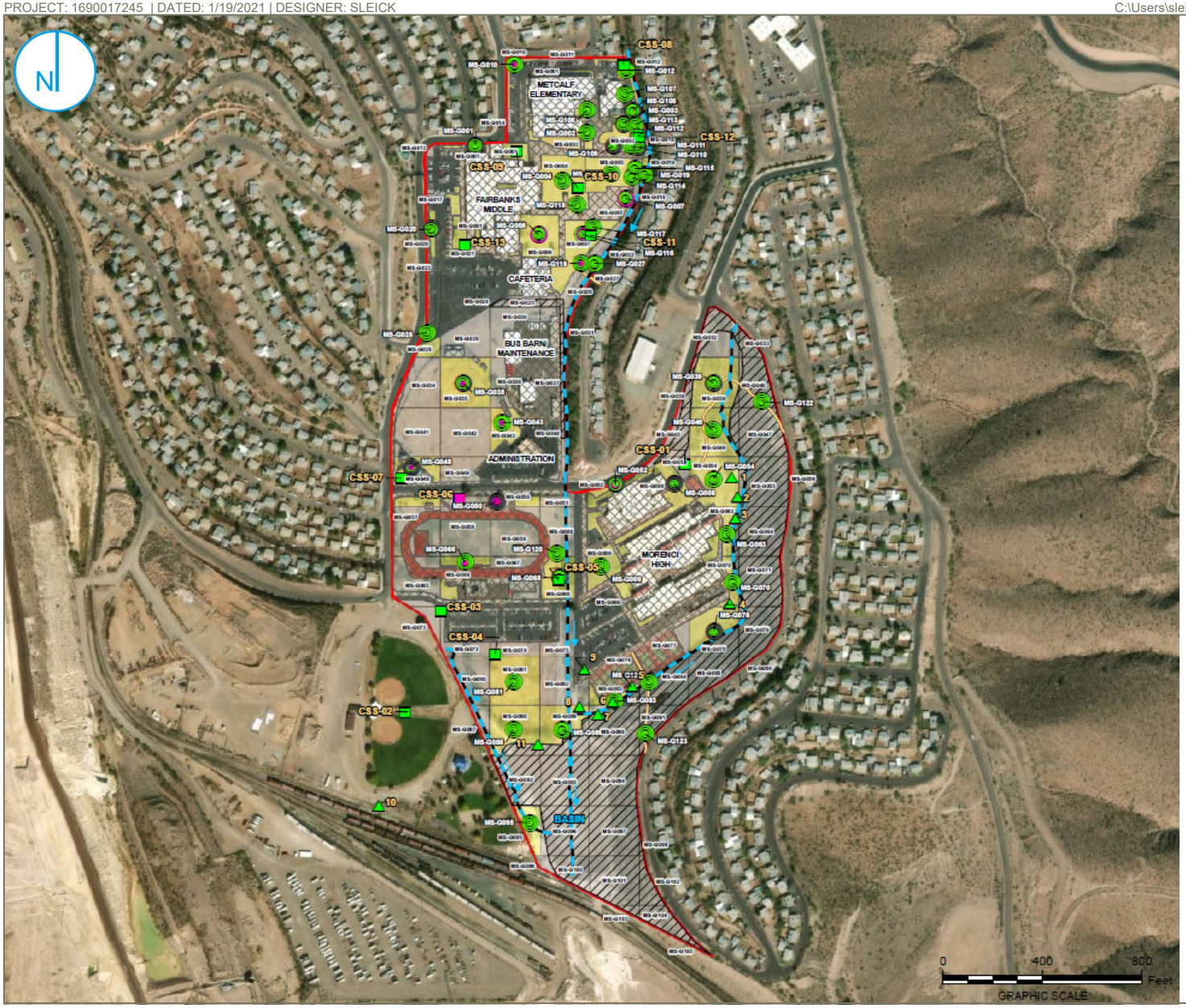
2018 and 2019 Sample Locations

Freeport Minerals Corporation
Morenci, Arizona

FIGURE 4

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL



LEGEND:

- AECOM SAMPLE LOCATION ANALYTICAL RESULT BELOW ADEQ RESIDENTIAL SOIL REMEDIATION LEVEL (OCTOBER 2018 - SAMPLE DEPTH 0-6 IN. FT)
- AECOM SAMPLE LOCATION ANALYTICAL RESULT ABOVE ADEQ RESIDENTIAL SOIL REMEDIATION LEVEL (JULY 2019) - SAMPLE DEPTH 0-6 IN. FT)
- AECOM SAMPLE LOCATION ANALYTICAL RESULT ABOVE ADEQ RESIDENTIAL SOIL REMEDIATION LEVEL (JULY 2019 - SAMPLE DEPTH 0-6 IN. FT)
- ANALYTICAL RESULT BELOW ADEQ RESIDENTIAL SOIL REMEDIATION LEVEL
- ANALYTICAL RESULT ABOVE ADEQ RESIDENTIAL SOIL REMEDIATION LEVEL
- SOIL SAMPLE FROM THAT DEPTH INTERVAL NOT COLLECTED DUE TO REFUSAL
- DRAINAGE WASH
- WALKING PATH
- DIRECTION OF DRAINAGE
- UNSAMPLEABLE AREA
- GRID SELECTED SAMPLING
- NOT SELECTED FOR SAMPLING
- SITE BOUNDARY
- BUILDING/IMPERVIOUS AREA
- MS-G122 - ARCADIS SAMPLE ID
- CS-007 - AECOM SAMPLE ID

0 - 3"
6" - 12"
12" - 18"
18" - 24"

Arcadis Sample ID	Sample Type	Sample Depth In.	As Result (mg/kg)	Tailings Observed
MS-G006	Composite Area	18" - 24"	20.9	No
MS-G007	Composite Area	18" - 24"	10.3	No
MS-G010	Composite Area	0 - 3"	11.0	No
MS-G035	Composite Area	0 - 3"	18.1	No
MS-G043	Composite Area	0 - 3"	18.8	No
MS-G048	Composite Area	0 - 3"	13.8	No
MS-G050	Composite Area	0 - 3"	12.4	No
MS-G050	Composite Area	6" - 12"	13.0	No
MS-G052	Composite Area	6" - 12"	14.4	No
MS-G066	Composite Area	0 - 3"	37.1	No
MS-G116	Discrete Grab	12" - 18"	14.6	No
MS-G119	Discrete Grab	0 - 3"	10.7	No

AECOM Sample ID	Sample Type	Sample Depth In.	As Result (mg/kg)	Tailings Observed
CSS-06	Discrete Grab	0 – 6"	15.7	No

The ADEQ Residential Soil Remediation Level for arsenic (As) is 10 mg/kg

Source: Arcadis. 2020. Site Characterization Report, Morenci Schools Site, Morenci, Arizona, VRP Site Code: 513333-00. June 29.

Analytical Results by Depth Interval

Freeport Minerals Corporation
Morenci, Arizona

FIGURE 5

RAMBOLL US CONSULTING, INC.
A RAMBOLL COMPANY

RAMBOLL

APPENDIX A
PROUCL OUTPUT

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.112/14/2020 5:24:49 PM
From File	Arsenic_data_All.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic (mg/kg) (0 - 3")

General Statistics

Total Number of Observations	51	Number of Distinct Observations	50
		Number of Missing Observations	0
Minimum	0.604	Mean	5.955
Maximum	37.1	Median	5.09
SD	6.062	Std. Error of Mean	0.849
Coefficient of Variation	1.018	Skewness	3.123

Normal GOF Test

Shapiro Wilk Test Statistic	0.72	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	4.543E-12	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.197	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.123	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	7.378	95% Adjusted-CLT UCL (Chen-1995)	7.748
		95% Modified-t UCL (Johnson-1978)	7.44

Gamma GOF Test

A-D Test Statistic	0.544	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.771	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0824	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.127	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.371	k star (bias corrected MLE)	1.304
Theta hat (MLE)	4.343	Theta star (bias corrected MLE)	4.568
nu hat (MLE)	139.9	nu star (bias corrected)	133
MLE Mean (bias corrected)	5.955	MLE Sd (bias corrected)	5.216
		Approximate Chi Square Value (0.05)	107.3
Adjusted Level of Significance	0.0453	Adjusted Chi Square Value	106.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	7.378	95% Adjusted Gamma UCL (use when n<50)	7.424

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.946	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.0343	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.117	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.123	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.504	Mean of logged Data	1.377
Maximum of Logged Data	3.614	SD of logged Data	0.963

Assuming Lognormal Distribution

95% H-UCL	8.59	90% Chebyshev (MVUE) UCL	9.162
95% Chebyshev (MVUE) UCL	10.49	97.5% Chebyshev (MVUE) UCL	12.34
99% Chebyshev (MVUE) UCL	15.97		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	7.352	95% Jackknife UCL	7.378
95% Standard Bootstrap UCL	7.321	95% Bootstrap-t UCL	7.958
95% Hall's Bootstrap UCL	10.13	95% Percentile Bootstrap UCL	7.482
95% BCA Bootstrap UCL	7.858		
90% Chebyshev(Mean, Sd) UCL	8.502	95% Chebyshev(Mean, Sd) UCL	9.656
97.5% Chebyshev(Mean, Sd) UCL	11.26	99% Chebyshev(Mean, Sd) UCL	14.4

Suggested UCL to Use

95% Approximate Gamma UCL	7.378

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.112/14/2020 5:23:06 PM
From File	Arsenic_data_All.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic (mg/kg)

General Statistics

Total Number of Observations	197	Number of Distinct Observations	183
		Number of Missing Observations	0
Minimum	0.556	Mean	4.616
Maximum	37.1	Median	3.87
SD	4.243	Std. Error of Mean	0.302
Coefficient of Variation	0.919	Skewness	3.247

Normal GOF Test

Shapiro Wilk Test Statistic	0.765	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.169	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.0635	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	5.116	95% Adjusted-CLT UCL (Chen-1995)	5.188
		95% Modified-t UCL (Johnson-1978)	5.127

Gamma GOF Test

A-D Test Statistic	1.211	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.77	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0708	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.0656	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.587	k star (bias corrected MLE)	1.566
Theta hat (MLE)	2.909	Theta star (bias corrected MLE)	2.947
nu hat (MLE)	625.3	nu star (bias corrected)	617.1
MLE Mean (bias corrected)	4.616	MLE Sd (bias corrected)	3.688
		Approximate Chi Square Value (0.05)	560.5
Adjusted Level of Significance	0.0488	Adjusted Chi Square Value	560.1

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	5.082	95% Adjusted Gamma UCL (use when n<50)	5.086

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	8.0181E-6	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0836	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.0635	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.587	Mean of logged Data	1.183
Maximum of Logged Data	3.614	SD of logged Data	0.871

Assuming Lognormal Distribution

95% H-UCL	5.422	90% Chebyshev (MVUE) UCL	5.786
95% Chebyshev (MVUE) UCL	6.253	97.5% Chebyshev (MVUE) UCL	6.901
99% Chebyshev (MVUE) UCL	8.174		

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	5.113	95% Jackknife UCL	5.116
95% Standard Bootstrap UCL	5.104	95% Bootstrap-t UCL	5.224
95% Hall's Bootstrap UCL	5.256	95% Percentile Bootstrap UCL	5.147
95% BCA Bootstrap UCL	5.203		
90% Chebyshev(Mean, Sd) UCL	5.523	95% Chebyshev(Mean, Sd) UCL	5.934
97.5% Chebyshev(Mean, Sd) UCL	6.504	99% Chebyshev(Mean, Sd) UCL	7.624

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	5.934

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.112/14/2020 5:25:46 PM
From File	Arsenic_data_All.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic (mg/kg) (es)

General Statistics

Total Number of Observations	47	Number of Distinct Observations	46
		Number of Missing Observations	0
Minimum	0.556	Mean	2.773
Maximum	9.1	Median	2.63
SD	2.2	Std. Error of Mean	0.321
Coefficient of Variation	0.794	Skewness	1.318

Normal GOF Test

Shapiro Wilk Test Statistic	0.843	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.157	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	3.312	95% Adjusted-CLT UCL (Chen-1995)	3.367
		95% Modified-t UCL (Johnson-1978)	3.322

Gamma GOF Test

A-D Test Statistic	0.917	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.765	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.124	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.131	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.735	k star (bias corrected MLE)	1.638
Theta hat (MLE)	1.598	Theta star (bias corrected MLE)	1.693
nu hat (MLE)	163.1	nu star (bias corrected)	154
MLE Mean (bias corrected)	2.773	MLE Sd (bias corrected)	2.166
		Approximate Chi Square Value (0.05)	126.3
Adjusted Level of Significance	0.0449	Adjusted Chi Square Value	125.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	3.381	95% Adjusted Gamma UCL (use when n<50)	3.402

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.921	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.946	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.134	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.128	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.587	Mean of logged Data	0.705
Maximum of Logged Data	2.208	SD of logged Data	0.832

Assuming Lognormal Distribution

95% H-UCL	3.728	90% Chebyshev (MVUE) UCL	3.994
95% Chebyshev (MVUE) UCL	4.521	97.5% Chebyshev (MVUE) UCL	5.251
99% Chebyshev (MVUE) UCL	6.686		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	3.301	95% Jackknife UCL	3.312
95% Standard Bootstrap UCL	3.317	95% Bootstrap-t UCL	3.418
95% Hall's Bootstrap UCL	3.348	95% Percentile Bootstrap UCL	3.337
95% BCA Bootstrap UCL	3.329		
90% Chebyshev(Mean, Sd) UCL	3.736	95% Chebyshev(Mean, Sd) UCL	4.172
97.5% Chebyshev(Mean, Sd) UCL	4.777	99% Chebyshev(Mean, Sd) UCL	5.966

Suggested UCL to Use

95% Adjusted Gamma UCL 3.402

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Arsenic (mg/kg) (hs)

General Statistics

Total Number of Observations	83	Number of Distinct Observations	80
		Number of Missing Observations	0
Minimum	0.659	Mean	4.872
Maximum	37.1	Median	4.25
SD	4.836	Std. Error of Mean	0.531
Coefficient of Variation	0.993	Skewness	4.003

Normal GOF Test

Shapiro Wilk Test Statistic	0.679	Shapiro Wilk GOF Test
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.192	Lilliefors GOF Test
5% Lilliefors Critical Value	0.0974	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	5.756	95% Adjusted-CLT UCL (Chen-1995)	5.995
		95% Modified-t UCL (Johnson-1978)	5.794

Gamma GOF Test

A-D Test Statistic	1.027	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.769	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0938	Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value	0.0997	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.648	k star (bias corrected MLE)	1.597
Theta hat (MLE)	2.956	Theta star (bias corrected MLE)	3.052
nu hat (MLE)	273.6	nu star (bias corrected)	265
MLE Mean (bias corrected)	4.872	MLE Sd (bias corrected)	3.856
		Approximate Chi Square Value (0.05)	228.3
Adjusted Level of Significance	0.0471	Adjusted Chi Square Value	227.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	5.656	95% Adjusted Gamma UCL (use when n<50)	5.67

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.958	Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk P Value	0.029	Data Not Lognormal at 5% Significance Level

Lilliefors Test Statistic	0.114	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.0974	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.417	Mean of logged Data	1.251
Maximum of Logged Data	3.614	SD of logged Data	0.83

Assuming Lognormal Distribution

95% H-UCL	5.962	90% Chebyshev (MVUE) UCL	6.426
95% Chebyshev (MVUE) UCL	7.117	97.5% Chebyshev (MVUE) UCL	8.077
99% Chebyshev (MVUE) UCL	9.961		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	5.746	95% Jackknife UCL	5.756
95% Standard Bootstrap UCL	5.743	95% Bootstrap-t UCL	6.13
95% Hall's Bootstrap UCL	7.198	95% Percentile Bootstrap UCL	5.829
95% BCA Bootstrap UCL	5.897		
90% Chebyshev(Mean, Sd) UCL	6.465	95% Chebyshev(Mean, Sd) UCL	7.186
97.5% Chebyshev(Mean, Sd) UCL	8.188	99% Chebyshev(Mean, Sd) UCL	10.15

Suggested UCL to Use

95% Approximate Gamma UCL	5.656

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Arsenic (mg/kg) (ms)

General Statistics

Total Number of Observations	72	Number of Distinct Observations	69
		Number of Missing Observations	0
Minimum	0.683	Mean	5.681
Maximum	20.9	Median	4.785
SD	4.193	Std. Error of Mean	0.494
Coefficient of Variation	0.738	Skewness	1.592

Normal GOF Test

Shapiro Wilk Test Statistic	0.859	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	3.2582E-9	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.16	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	6.505	95% Adjusted-CLT UCL (Chen-1995)	6.593
		95% Modified-t UCL (Johnson-1978)	6.52

Gamma GOF Test

A-D Test Statistic	0.622	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.764	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0794	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.932	k star (bias corrected MLE)	1.861
Theta hat (MLE)	2.941	Theta star (bias corrected MLE)	3.053
nu hat (MLE)	278.2	nu star (bias corrected)	267.9
MLE Mean (bias corrected)	5.681	MLE Sd (bias corrected)	4.165
		Approximate Chi Square Value (0.05)	231
Adjusted Level of Significance	0.0467	Adjusted Chi Square Value	230.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	6.589	95% Adjusted Gamma UCL (use when n<50)	6.608

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.935	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.00136	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.122	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.104	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.381	Mean of logged Data	1.457
Maximum of Logged Data	3.04	SD of logged Data	0.815

Assuming Lognormal Distribution

95% H-UCL	7.315	90% Chebyshev (MVUE) UCL	7.883
95% Chebyshev (MVUE) UCL	8.762	97.5% Chebyshev (MVUE) UCL	9.981
99% Chebyshev (MVUE) UCL	12.38		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	6.494	95% Jackknife UCL	6.505
95% Standard Bootstrap UCL	6.502	95% Bootstrap-t UCL	6.659
95% Hall's Bootstrap UCL	6.669	95% Percentile Bootstrap UCL	6.546
95% BCA Bootstrap UCL	6.619		
90% Chebyshev(Mean, Sd) UCL	7.163	95% Chebyshev(Mean, Sd) UCL	7.835

97.5% Chebyshev(Mean, Sd) UCL	8.767	99% Chebyshev(Mean, Sd) UCL	10.6

Suggested UCL to Use

95% Approximate Gamma UCL	6.589

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Arsenic (mg/kg) - Sports Fields

General Statistics

Total Number of Observations	39	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	0.659	Mean	6.86
Maximum	37.1	Median	5.25
SD	6.695	Std. Error of Mean	1.072
Coefficient of Variation	0.976	Skewness	2.839

Normal GOF Test

Shapiro Wilk Test Statistic	0.71	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.939	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.279	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.14	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	8.668	95% Adjusted-CLT UCL (Chen-1995)	9.145
		95% Modified-t UCL (Johnson-1978)	8.749

Gamma GOF Test

A-D Test Statistic	0.907	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.764	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.17	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.144	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.613	k star (bias corrected MLE)	1.506
Theta hat (MLE)	4.253	Theta star (bias corrected MLE)	4.555
nu hat (MLE)	125.8	nu star (bias corrected)	117.5
MLE Mean (bias corrected)	6.86	MLE Sd (bias corrected)	5.59
		Approximate Chi Square Value (0.05)	93.45
Adjusted Level of Significance	0.0437	Adjusted Chi Square Value	92.6

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	8.624	95% Adjusted Gamma UCL (use when n<50)	8.703

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.959	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.939	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.125	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.14	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-0.417	Mean of logged Data	1.585
Maximum of Logged Data	3.614	SD of logged Data	0.853

Assuming Lognormal Distribution

95% H-UCL	9.575	90% Chebyshev (MVUE) UCL	10.14
95% Chebyshev (MVUE) UCL	11.59	97.5% Chebyshev (MVUE) UCL	13.6
99% Chebyshev (MVUE) UCL	17.55		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	8.624	95% Jackknife UCL	8.668
95% Standard Bootstrap UCL	8.624	95% Bootstrap-t UCL	9.538
95% Hall's Bootstrap UCL	10.84	95% Percentile Bootstrap UCL	8.716
95% BCA Bootstrap UCL	9.346		
90% Chebyshev(Mean, Sd) UCL	10.08	95% Chebyshev(Mean, Sd) UCL	11.53

97.5% Chebyshev(Mean, Sd) UCL	13.56	99% Chebyshev(Mean, Sd) UCL	17.53

Suggested UCL to Use

95% H-UCL	9.575

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

APPENDIX B
CRYSTAL BALL REPORT

Crystal Ball Report - Full
Simulation started on 2/10/2021 at 3:06 PM
Simulation stopped on 2/10/2021 at 3:07 PM

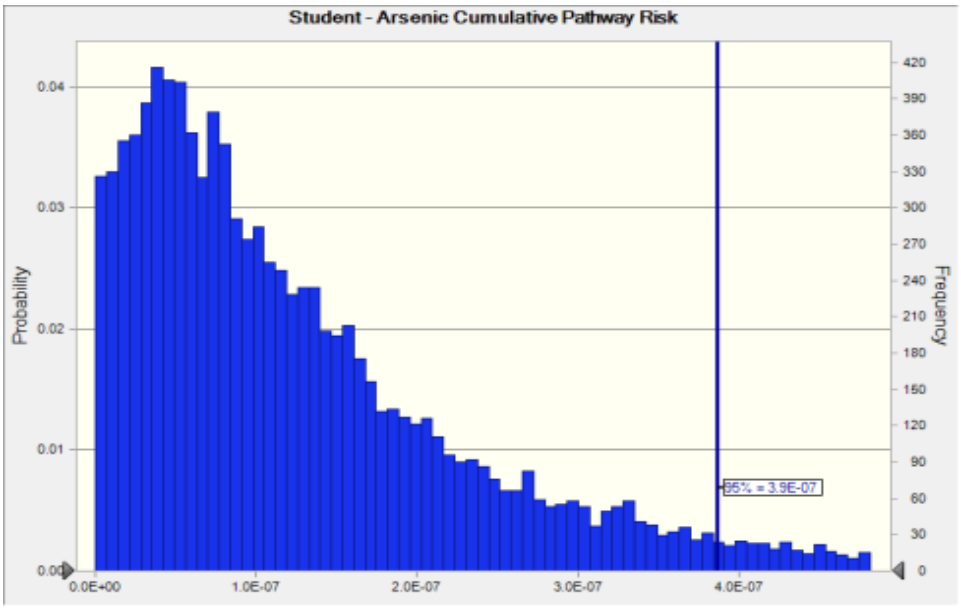
Run preferences:	
Number of trials run	10,000
Monte Carlo	
Random seed	
Run statistics:	
Total running time (sec)	26.17
Trials/second (average)	382
Random numbers per sec	15,283
Crystal Ball data:	
Assumptions	40
Correlations	4
Correlation matrices	4
Decision variables	0
Forecasts	17

Forecasts

School Specific Area Scenario Risks (student only)

Forecast: Student - Arsenic Cumulative Pathway Risk **Cell: K20**

Summary:
Entire range is from 9.9E-11 to 1.0E-06
Base case is 1.2E-07
After 10,000 trials, the std. error of the mean is 1.2E-09



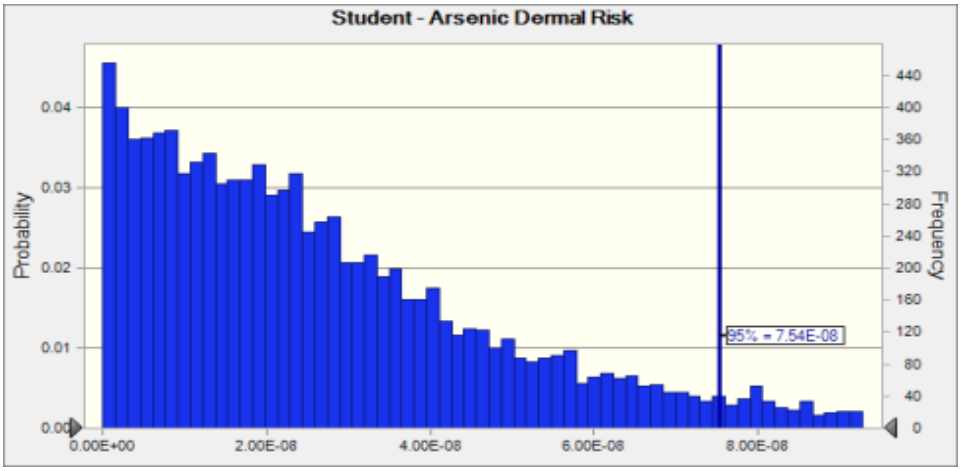
Statistics:	Forecast values
Trials	10,000
Base Case	1.2E-07
Mean	1.3E-07
Median	9.9E-08
Mode	---
Standard Deviation	1.2E-07
Variance	1.5E-14
Skewness	1.83
Kurtosis	7.36
Coeff. of Variation	0.92
Minimum	9.9E-11
Maximum	1.0E-06
Range Width	1.0E-06
Mean Std. Error	1.2E-09

Forecast: Student - Arsenic Cumulative Pathway Risk (cont'd) **Cell: K20**

Percentiles:	Forecast values
0%	9.9E-11
10%	2.1E-08
20%	3.9E-08
30%	5.6E-08
40%	7.6E-08
50%	9.9E-08
60%	1.3E-07
70%	1.6E-07
80%	2.1E-07
90%	3.0E-07
100%	1.0E-06

Forecast: Student - Arsenic Dermal Risk **Cell: K16**

Summary:
Entire range is from 2.58E-12 to 1.65E-07
Base case is 2.54E-08
After 10,000 trials, the std. error of the mean is 2.32E-10



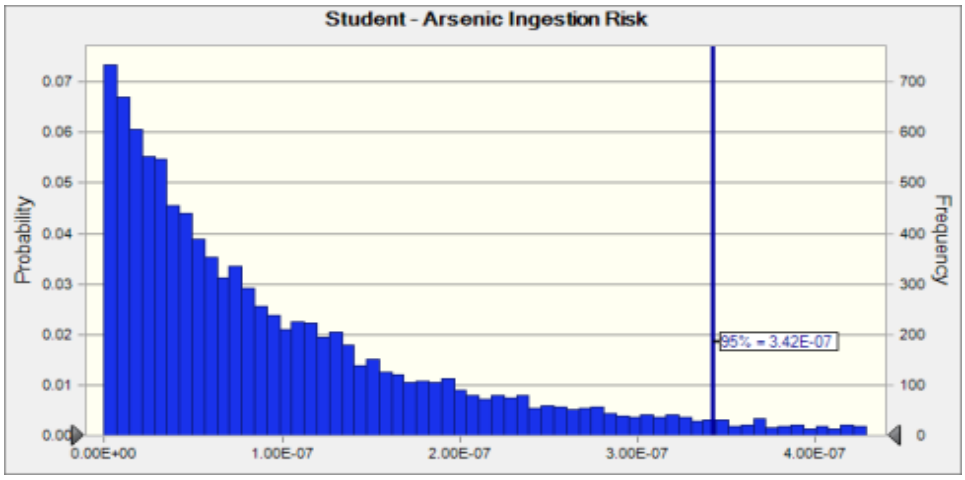
Statistics:	Forecast values
Trials	10,000
Base Case	2.54E-08
Mean	2.77E-08
Median	2.21E-08
Mode	---
Standard Deviation	2.32E-08
Variance	5.40E-16
Skewness	1.32
Kurtosis	4.95
Coeff. of Variation	0.84
Minimum	2.58E-12
Maximum	1.65E-07
Range Width	1.65E-07
Mean Std. Error	2.32E-10

Forecast: Student - Arsenic Dermal Risk (cont'd) **Cell: K16**

Percentiles:	Forecast values
0%	2.58E-12
10%	3.58E-09
20%	7.84E-09
30%	1.23E-08
40%	1.71E-08
50%	2.21E-08
60%	2.75E-08
70%	3.46E-08
80%	4.42E-08
90%	6.05E-08
100%	1.65E-07

Forecast: Student - Arsenic Ingestion Risk **Cell: K14**

Summary:
Entire range is from 3.36E-12 to 9.49E-07
Base case is 9.94E-08
After 10,000 trials, the std. error of the mean is 1.15E-09



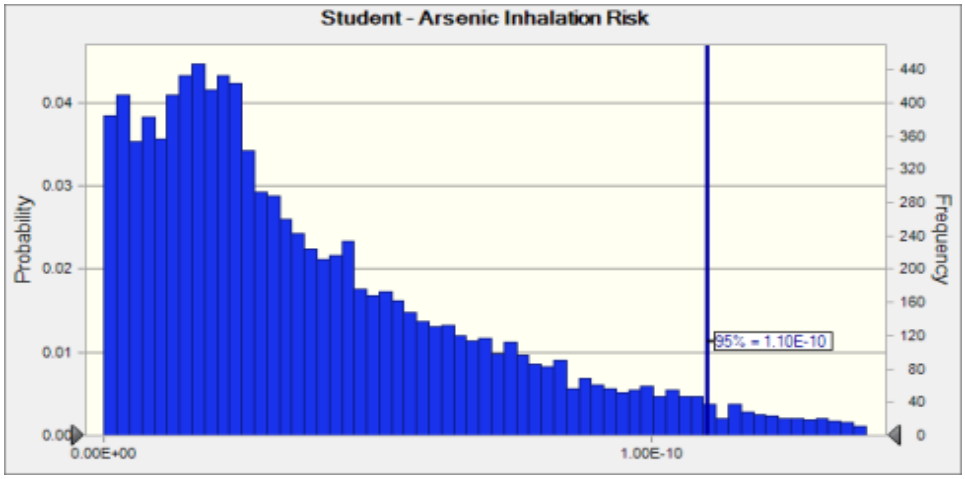
Statistics:	Forecast values
Trials	10,000
Base Case	9.94E-08
Mean	1.07E-07
Median	6.89E-08
Mode	---
Standard Deviation	1.15E-07
Variance	1.32E-14
Skewness	2.03
Kurtosis	8.30
Coeff. of Variation	1.07
Minimum	3.36E-12
Maximum	9.49E-07
Range Width	9.49E-07
Mean Std. Error	1.15E-09

Forecast: Student - Arsenic Ingestion Risk (cont'd) **Cell: K14**

Percentiles:	Forecast values
0%	3.36E-12
10%	9.68E-09
20%	2.10E-08
30%	3.37E-08
40%	4.91E-08
50%	6.89E-08
60%	9.30E-08
70%	1.26E-07
80%	1.72E-07
90%	2.58E-07
100%	9.49E-07

Forecast: Student - Arsenic Inhalation Risk **Cell: K18**

Summary:
Entire range is from 3.10E-14 to 3.30E-10
Base case is 3.45E-11
After 10,000 trials, the std. error of the mean is 3.54E-13



Statistics:	Forecast values
Trials	10,000
Base Case	3.45E-11
Mean	3.99E-11
Median	2.89E-11
Mode	---
Standard Deviation	3.54E-11
Variance	1.25E-21
Skewness	1.66
Kurtosis	6.93
Coeff. of Variation	0.89
Minimum	3.10E-14
Maximum	3.30E-10
Range Width	3.30E-10
Mean Std. Error	3.54E-13

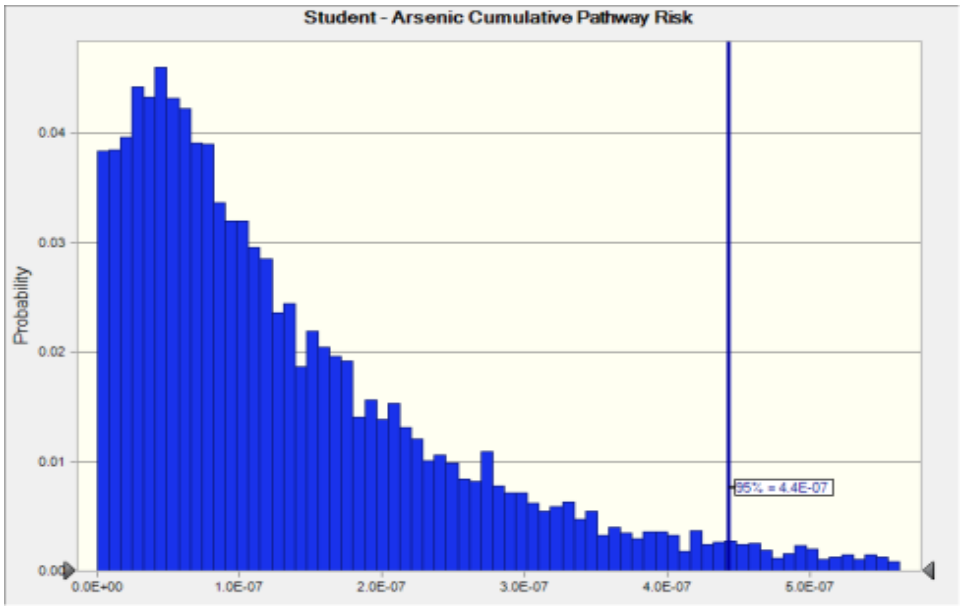
Forecast: Student - Arsenic Inhalation Risk (cont'd) **Cell: K18**

Percentiles:	Forecast values
0%	3.10E-14
10%	5.90E-12
20%	1.20E-11
30%	1.74E-11
40%	2.27E-11
50%	2.89E-11
60%	3.77E-11
70%	4.87E-11
80%	6.41E-11
90%	8.81E-11
100%	3.30E-10

Sports Fields Area Scenario Risks (student and adult worker)

Forecast: Student - Arsenic Cumulative Pathway Risk **Cell: K20**

Summary:
Entire range is from 1.8E-10 to 1.5E-06
Base case is 1.3E-07
After 10,000 trials, the std. error of the mean is 1.5E-09



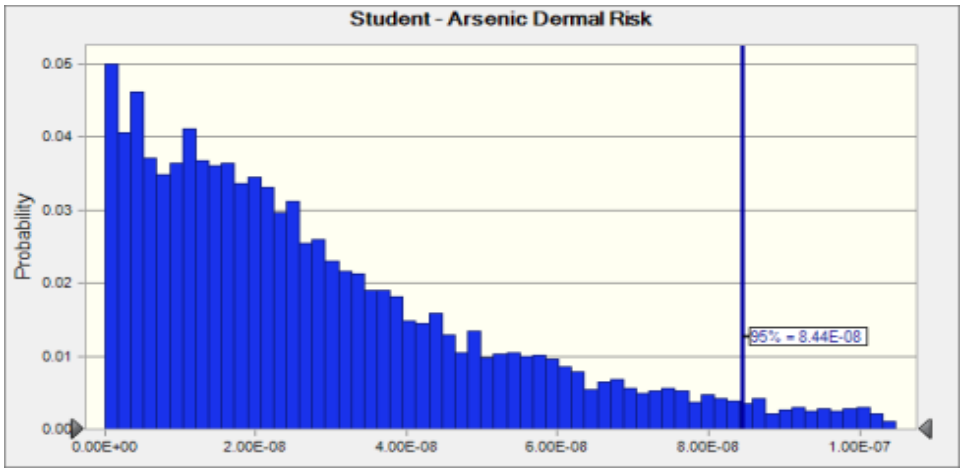
Statistics:	Forecast values
Trials	10,000
Base Case	1.3E-07
Mean	1.5E-07
Median	1.0E-07
Mode	---
Standard Deviation	1.5E-07
Variance	2.2E-14
Skewness	2.30
Kurtosis	11.04
Coeff. of Variation	1.00
Minimum	1.8E-10
Maximum	1.5E-06
Range Width	1.5E-06
Mean Std. Error	1.5E-09

Forecast: Student - Arsenic Cumulative Pathway Risk (cont'd) **Cell: K20**

Percentiles:	Forecast values
0%	1.8E-10
10%	2.2E-08
20%	4.0E-08
30%	5.9E-08
40%	7.9E-08
50%	1.0E-07
60%	1.3E-07
70%	1.7E-07
80%	2.3E-07
90%	3.3E-07
100%	1.5E-06

Forecast: Student - Arsenic Dermal Risk **Cell: K16**

Summary:
Entire range is from 8.14E-13 to 2.29E-07
Base case is 2.61E-08
After 10,000 trials, the std. error of the mean is 2.67E-10



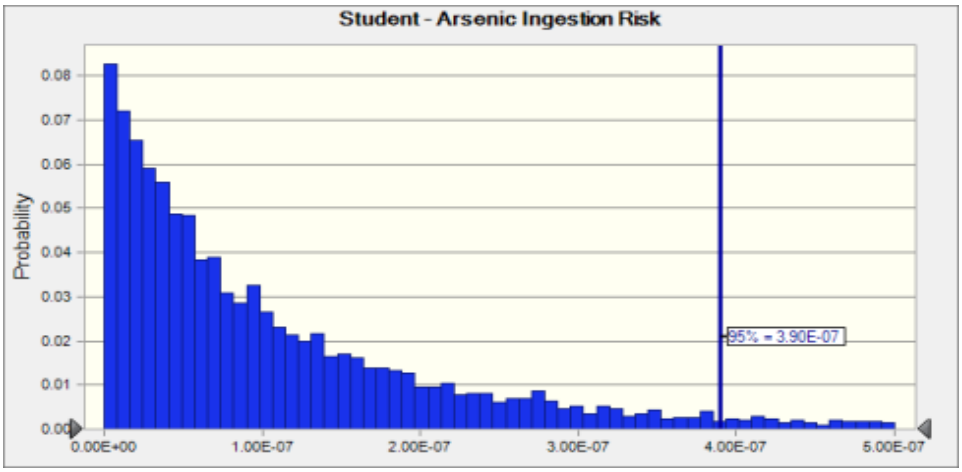
Statistics:	Forecast values
Trials	10,000
Base Case	2.61E-08
Mean	3.00E-08
Median	2.26E-08
Mode	---
Standard Deviation	2.67E-08
Variance	7.13E-16
Skewness	1.55
Kurtosis	6.03
Coeff. of Variation	0.89
Minimum	8.14E-13
Maximum	2.29E-07
Range Width	2.29E-07
Mean Std. Error	2.67E-10

Forecast: Student - Arsenic Dermal Risk (cont'd) **Cell: K16**

Percentiles:	Forecast values
0%	8.14E-13
10%	3.75E-09
20%	8.10E-09
30%	1.26E-08
40%	1.74E-08
50%	2.26E-08
60%	2.86E-08
70%	3.67E-08
80%	4.82E-08
90%	6.70E-08
100%	2.29E-07

Forecast: Student - Arsenic Ingestion Risk **Cell: K14**

Summary:
Entire range is from 6.23E-13 to 1.43E-06
Base case is 1.02E-07
After 10,000 trials, the std. error of the mean is 1.36E-09



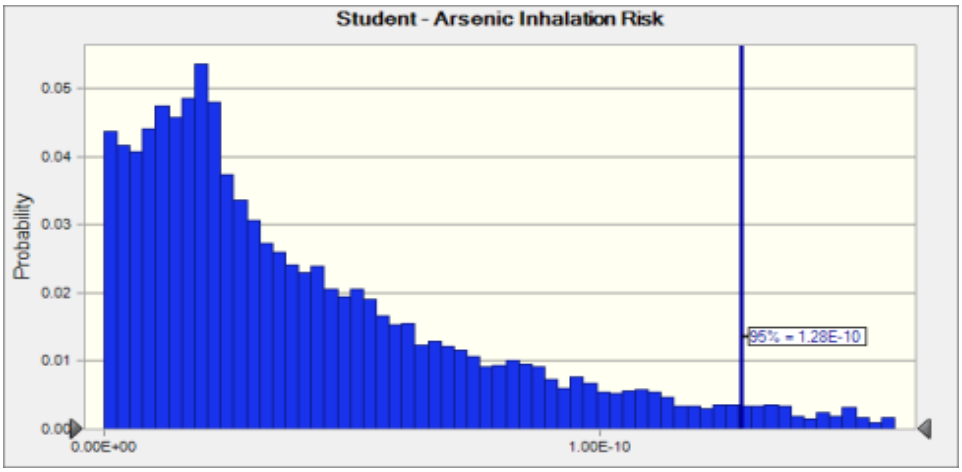
Statistics:	Forecast values
Trials	10,000
Base Case	1.02E-07
Mean	1.18E-07
Median	7.20E-08
Mode	---
Standard Deviation	1.36E-07
Variance	1.86E-14
Skewness	2.54
Kurtosis	12.69
Coeff. of Variation	1.15
Minimum	6.23E-13
Maximum	1.43E-06
Range Width	1.43E-06
Mean Std. Error	1.36E-09

Forecast: Student - Arsenic Ingestion Risk (cont'd) **Cell: K14**

Percentiles:	Forecast values
0%	6.23E-13
10%	1.00E-08
20%	2.18E-08
30%	3.58E-08
40%	5.23E-08
50%	7.20E-08
60%	9.84E-08
70%	1.35E-07
80%	1.87E-07
90%	2.83E-07
100%	1.43E-06

Forecast: Student - Arsenic Inhalation Risk **Cell: K18**

Summary:
Entire range is from 5.06E-14 to 3.67E-10
Base case is 3.55E-11
After 10,000 trials, the std. error of the mean is 4.13E-13



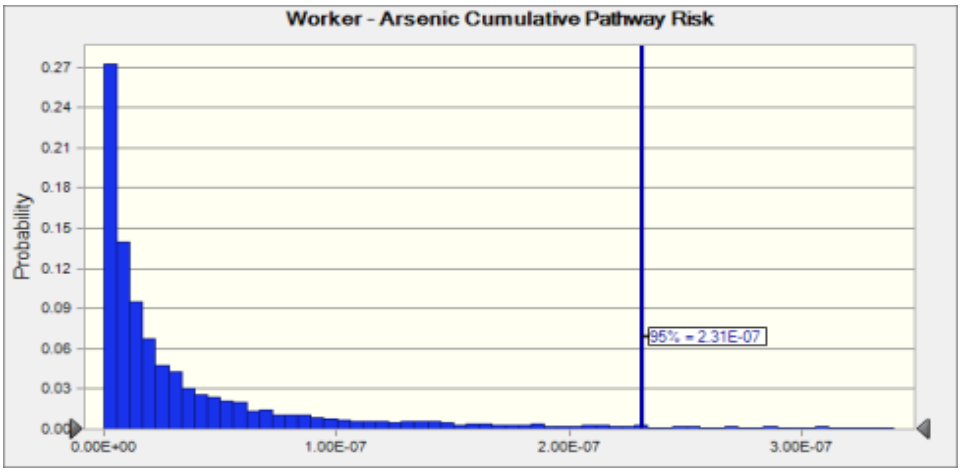
Statistics:	Forecast values
Trials	10,000
Base Case	3.55E-11
Mean	4.37E-11
Median	3.01E-11
Mode	---
Standard Deviation	4.13E-11
Variance	1.71E-21
Skewness	1.83
Kurtosis	7.53
Coeff. of Variation	0.94
Minimum	5.06E-14
Maximum	3.67E-10
Range Width	3.67E-10
Mean Std. Error	4.13E-13

Forecast: Student - Arsenic Inhalation Risk (cont'd) **Cell: K18**

Percentiles:	Forecast values
0%	5.06E-14
10%	6.16E-12
20%	1.21E-11
30%	1.78E-11
40%	2.28E-11
50%	3.01E-11
60%	4.01E-11
70%	5.23E-11
80%	7.00E-11
90%	9.93E-11
100%	3.67E-10

Forecast: Worker - Arsenic Cumulative Pathway Risk **Cell: K49**

Summary:
Entire range is from 4.05E-12 to 1.31E-06
Base case is 5.34E-08
After 10,000 trials, the std. error of the mean is 1.02E-09



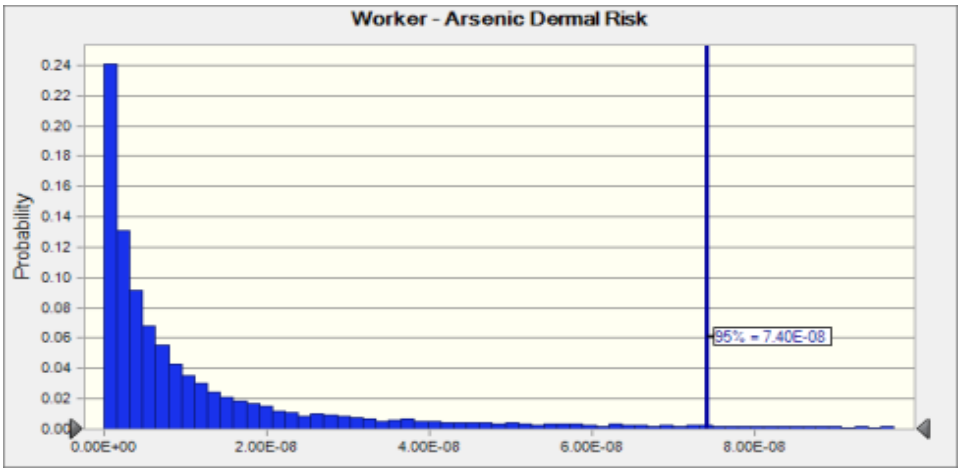
Statistics:	Forecast values
Trials	10,000
Base Case	5.34E-08
Mean	5.28E-08
Median	1.62E-08
Mode	---
Standard Deviation	1.02E-07
Variance	1.05E-14
Skewness	4.45
Kurtosis	30.57
Coeff. of Variation	1.94
Minimum	4.05E-12
Maximum	1.31E-06
Range Width	1.31E-06
Mean Std. Error	1.02E-09

Forecast: Worker - Arsenic Cumulative Pathway Risk (cont'd) **Cell: K49**

Percentiles:	Forecast values
0%	4.05E-12
10%	1.52E-09
20%	3.62E-09
30%	6.41E-09
40%	1.05E-08
50%	1.62E-08
60%	2.52E-08
70%	4.00E-08
80%	6.77E-08
90%	1.40E-07
100%	1.31E-06

Forecast: Worker - Arsenic Dermal Risk **Cell: K45**

Summary:
Entire range is from 8.44E-13 to 3.34E-07
Base case is 1.66E-08
After 10,000 trials, the std. error of the mean is 2.88E-10



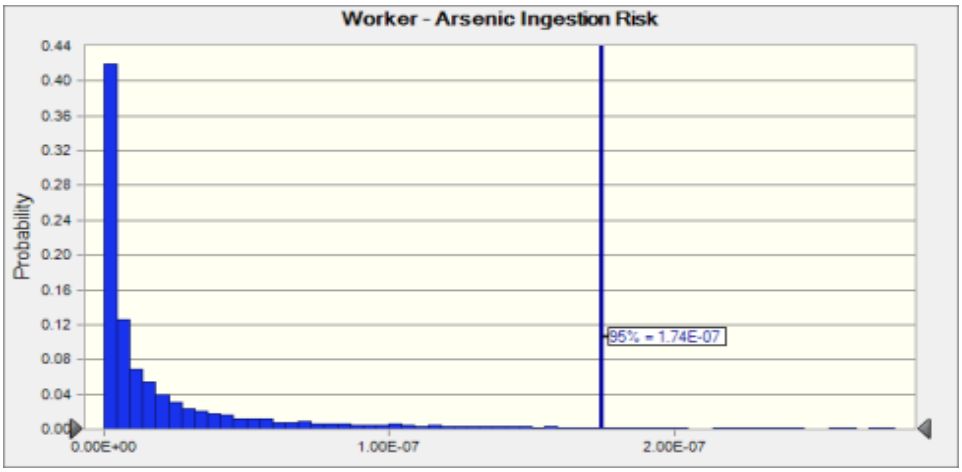
Statistics:	Forecast values
Trials	10,000
Base Case	1.66E-08
Mean	1.64E-08
Median	5.57E-09
Mode	---
Standard Deviation	2.88E-08
Variance	8.29E-16
Skewness	3.56
Kurtosis	19.56
Coeff. of Variation	1.75
Minimum	8.44E-13
Maximum	3.34E-07
Range Width	3.34E-07
Mean Std. Error	2.88E-10

Forecast: Worker - Arsenic Dermal Risk (cont'd) **Cell: K45**

Percentiles:	Forecast values
0%	8.44E-13
10%	4.83E-10
20%	1.20E-09
30%	2.21E-09
40%	3.62E-09
50%	5.56E-09
60%	8.48E-09
70%	1.31E-08
80%	2.21E-08
90%	4.55E-08
100%	3.34E-07

Forecast: Worker - Arsenic Ingestion Risk **Cell: K43**

Summary:
Entire range is from 2.96E-13 to 1.21E-06
Base case is 3.68E-08
After 10,000 trials, the std. error of the mean is 8.60E-10



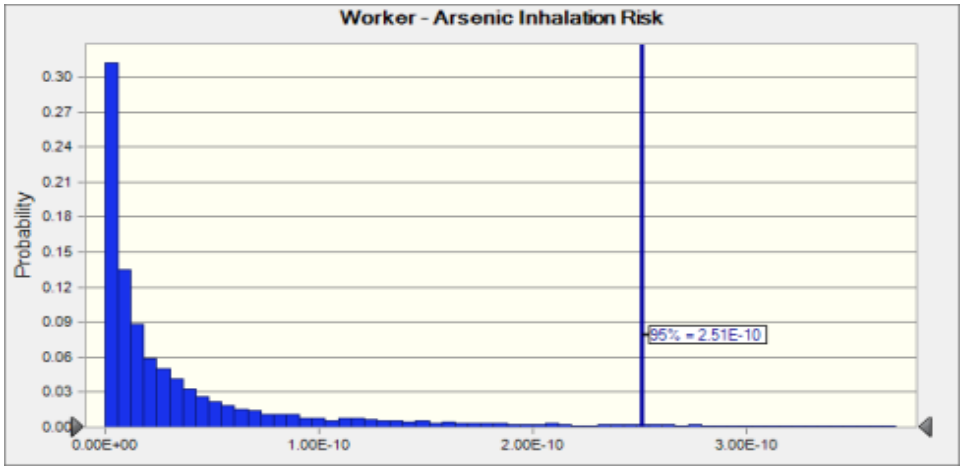
Statistics:	Forecast values
Trials	10,000
Base Case	3.68E-08
Mean	3.63E-08
Median	7.18E-09
Mode	---
Standard Deviation	8.60E-08
Variance	7.40E-15
Skewness	5.28
Kurtosis	41.39
Coeff. of Variation	2.37
Minimum	2.96E-13
Maximum	1.21E-06
Range Width	1.21E-06
Mean Std. Error	8.60E-10

Forecast: Worker - Arsenic Ingestion Risk (cont'd) **Cell: K43**

Percentiles:	Forecast values
0%	2.96E-13
10%	2.73E-10
20%	8.69E-10
30%	2.01E-09
40%	4.07E-09
50%	7.18E-09
60%	1.27E-08
70%	2.18E-08
80%	4.10E-08
90%	9.48E-08
100%	1.21E-06

Forecast: Worker - Arsenic Inhalation Risk **Cell: K47**

Summary:
Entire range is from 7.01E-15 to 2.03E-09
Base case is 5.58E-11
After 10,000 trials, the std. error of the mean is 1.13E-12



Statistics:	Forecast values
Trials	10,000
Base Case	5.58E-11
Mean	5.41E-11
Median	1.55E-11
Mode	---
Standard Deviation	1.13E-10
Variance	1.27E-20
Skewness	5.71
Kurtosis	56.95
Coeff. of Variation	2.08
Minimum	7.01E-15
Maximum	2.03E-09
Range Width	2.03E-09
Mean Std. Error	1.13E-12

Forecast: Worker - Arsenic Inhalation Risk (cont'd) **Cell: K47**

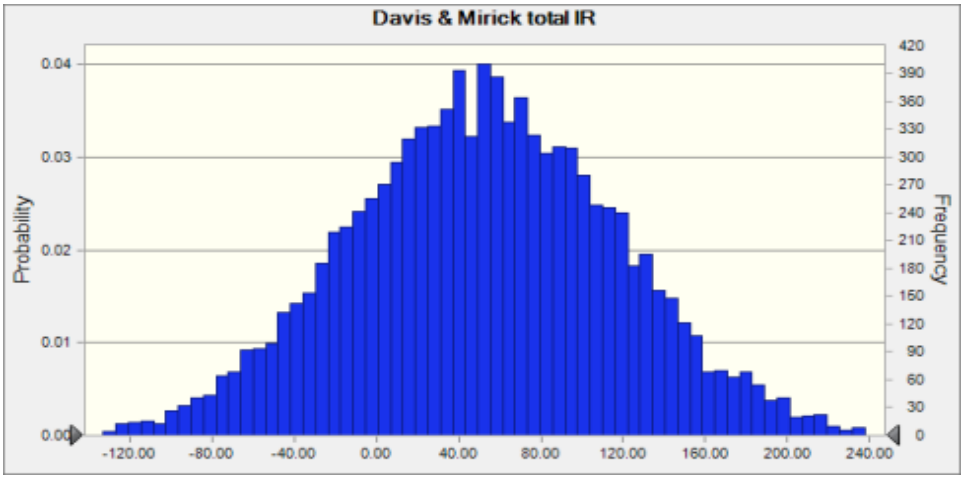
Percentiles:	Forecast values
0%	7.01E-15
10%	1.21E-12
20%	2.90E-12
30%	5.65E-12
40%	9.64E-12
50%	1.55E-11
60%	2.51E-11
70%	3.90E-11
80%	6.77E-11
90%	1.44E-10
100%	2.03E-09

Soil Ingestion Rate Supporting Forecasts

Worksheet: [REH MC_Morenci_HRA_playfields_20210108.xlsx]4-14 App B IR

Forecast: Davis & Mirick total IR (mg/kg) **Cell: E305**

Summary:
Entire range is from -192.51 to 364.55
Base case is 52.25
After 10,000 trials, the std. error of the mean is 0.66



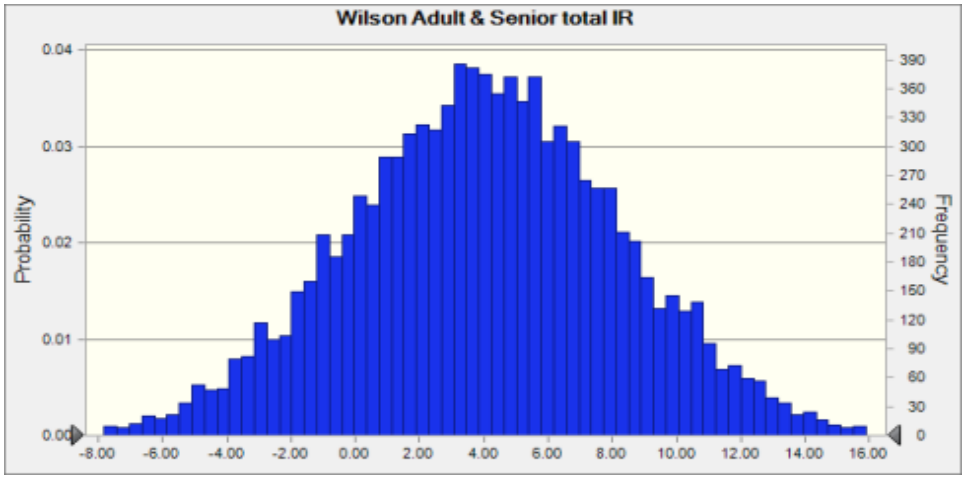
Statistics:	Forecast values
Trials	10,000
Base Case	52.25
Mean	52.30
Median	52.20
Mode	---
Standard Deviation	66.15
Variance	4,376.18
Skewness	0.0591
Kurtosis	3.04
Coeff. of Variation	1.26
Minimum	-192.51
Maximum	364.55
Range Width	557.06
Mean Std. Error	0.66

Forecast: Davis & Mirick total IR (cont'd) **Cell: E305**

Percentiles:	Forecast values
0%	-192.51
10%	-32.80
20%	-3.91
30%	17.56
40%	35.48
50%	52.18
60%	68.37
70%	87.11
80%	108.15
90%	136.35
100%	364.55

Forecast: Wilson et al. Adult & Senior total IR (mg/kg) **Cell: F349**

Summary:
Entire range is from -11.82 to 19.75
Base case is 4.12
After 10,000 trials, the std. error of the mean is 0.04



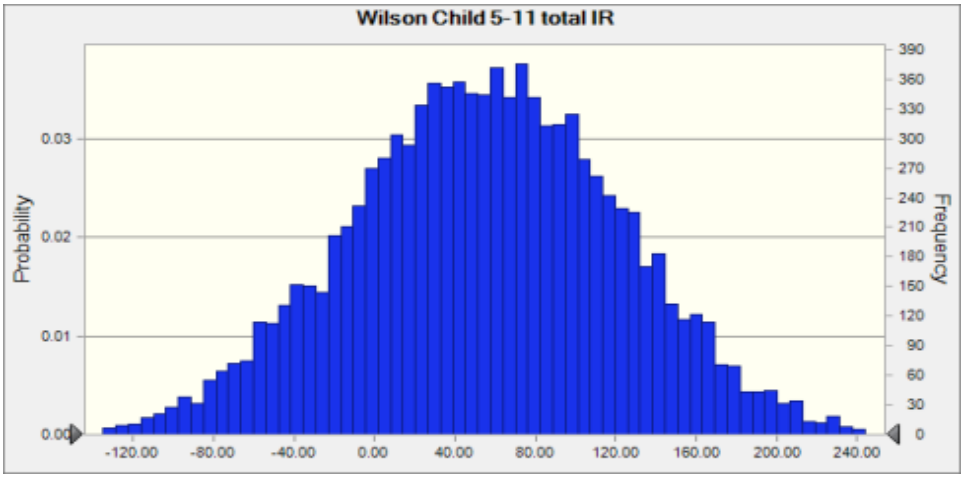
Statistics:	Forecast values
Trials	10,000
Base Case	4.12
Mean	4.03
Median	4.02
Mode	---
Standard Deviation	4.23
Variance	17.88
Skewness	0.0020
Kurtosis	2.96
Coeff. of Variation	1.05
Minimum	-11.82
Maximum	19.75
Range Width	31.57
Mean Std. Error	0.04

Forecast: Wilson et al. Adult & Senior total IR (cont'd) **Cell: F349**

Percentiles:	Forecast values
0%	-11.82
10%	-1.38
20%	0.47
30%	1.82
40%	3.02
50%	4.02
60%	5.10
70%	6.25
80%	7.58
90%	9.54
100%	19.75

Forecast: Wilson et al. Child 5-11 total IR (mg/kg) **Cell: F233**

Summary:
Entire range is from -201.21 to 310.27
Base case is 55.00
After 10,000 trials, the std. error of the mean is 0.68



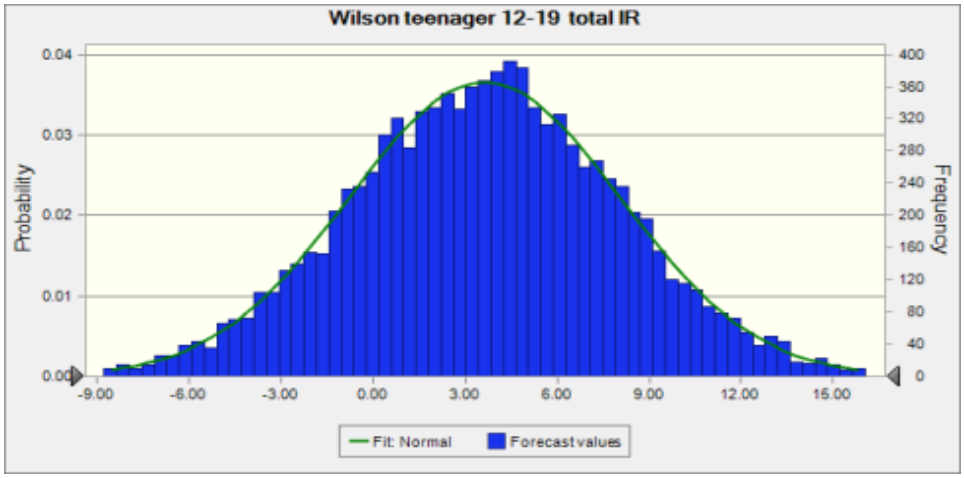
Statistics:	Forecast values
Trials	10,000
Base Case	55.00
Mean	54.41
Median	54.94
Mode	---
Standard Deviation	67.60
Variance	4,569.23
Skewness	-0.0507
Kurtosis	2.93
Coeff. of Variation	1.24
Minimum	-201.21
Maximum	310.27
Range Width	511.48
Mean Std. Error	0.68

Forecast: Wilson et al. Child 5-11 total IR (cont'd) **Cell: F233**

Percentiles:	Forecast values
0%	-201.21
10%	-34.14
20%	-2.29
30%	19.27
40%	37.30
50%	54.94
60%	72.72
70%	91.12
80%	111.97
90%	140.59
100%	310.27

Forecast: Wilson et al. teenager 12-19 total IR (mg/kg) **Cell: F343**

Summary:
Entire range is from -12.78 to 20.61
Base case is 3.70
After 10,000 trials, the std. error of the mean is 0.04



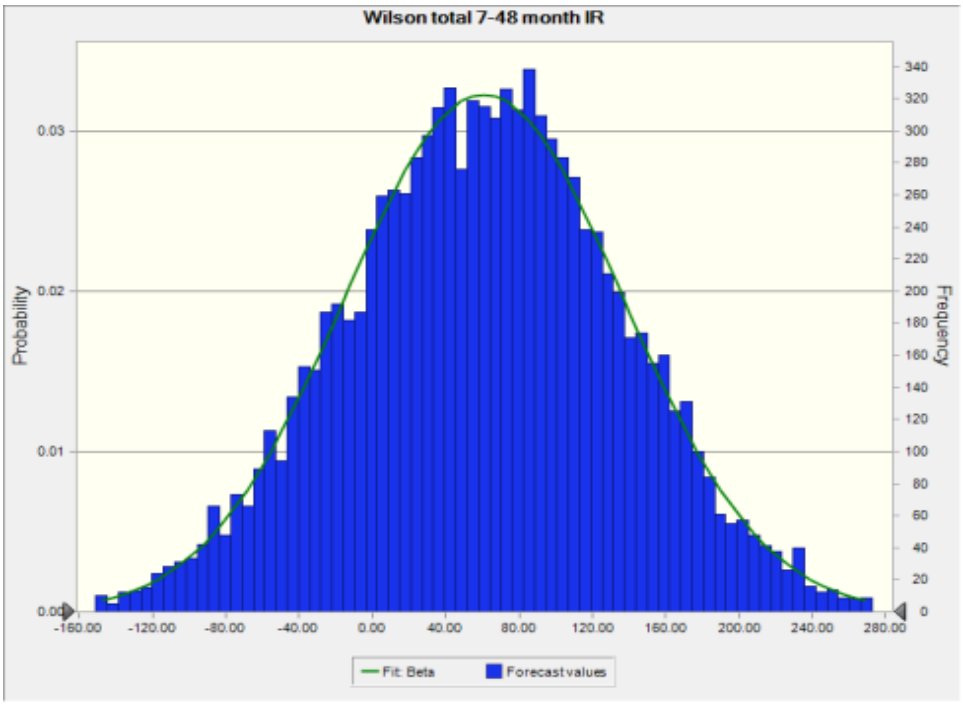
Statistics:	Forecast values
Trials	10,000
Base Case	3.70
Mean	3.63
Median	3.69
Mode	---
Standard Deviation	4.43
Variance	19.60
Skewness	-0.0018
Kurtosis	3.00
Coeff. of Variation	1.22
Minimum	-12.78
Maximum	20.61
Range Width	33.39
Mean Std. Error	0.04

Forecast: Wilson et al. teenager 12-19 total IR (cont'd) **Cell: F343**

Percentiles:	Forecast values
0%	-12.78
10%	-2.06
20%	-0.09
30%	1.32
40%	2.52
50%	3.69
60%	4.75
70%	5.93
80%	7.37
90%	9.21
100%	20.61

Forecast: Wilson et al. total toddler 7-48 month IR (mg/kg) **Cell: F101**

Summary:
Entire range is from -314.72 to 368.95
Base case is 61.00
After 10,000 trials, the std. error of the mean is 0.76



Statistics:	Forecast values
Trials	10,000
Base Case	61.00
Mean	60.77
Median	61.82
Mode	---
Standard Deviation	75.66
Variance	5,723.93
Skewness	-0.0156
Kurtosis	3.02
Coeff. of Variation	1.24
Minimum	-314.72
Maximum	368.95
Range Width	683.67
Mean Std. Error	0.76

Forecast: Wilson et al. total toddler 7-48 month IR (cont'd) **Cell: F101**

Percentiles:	Forecast values
0%	-314.72
10%	-36.86
20%	-3.05
30%	21.13
40%	41.73
50%	61.82
60%	81.01
70%	100.54
80%	124.44
90%	158.02
100%	368.95

End of Forecasts

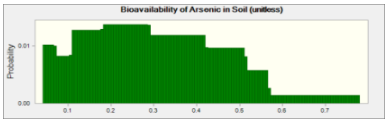
Assumptions

Worksheet: [REH MC_Morenci_HRA_playfields_20201203.xlsx]REH HRA

Assumption: Bioavailability of Arsenic in Soil (unitless) **Cell: E17**

Custom distribution with parameters:

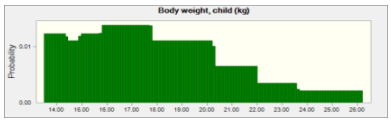
Min	Max	Percentile
0.041	0.071	5
	0.108	10
	0.18	25
	0.291	50
	0.42	75
	0.515	90
	0.568	95
	0.78	100



Assumption: Body Weight Student age 3 to 6 (kg) **Cell: E30**

Custom distribution with parameters:

Min	Max	Percentile
13.5	14.4	10
	14.9	15
	15.8	25
	17.8	50



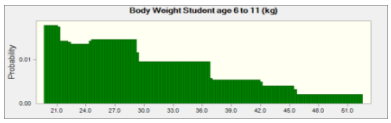
20.3	75
22	85
23.6	90
26.2	95

Correlated with:	Coefficient
Skin Surface Area Student age 3 to 6 (cm2) (E20)	1.00

Assumption: Body Weight Student age 6 to 11 (kg) **Cell: E31**

Custom distribution with parameters:

Min	Max	Percentile
19.7	21.3	10
	22.3	15
	24.4	25
	29.3	50
	36.8	75
	42.1	85
	45.6	90
	52.5	95

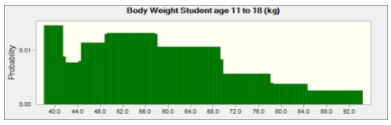


Correlated with:	Coefficient
Skin Surface Area Student age 6 to 11 (cm2) (E21)	1.00

Assumption: Body Weight Student age 11 to 18 (kg) **Cell: E32**

Custom distribution with parameters:

Min	Max	Percentile
38.1	41.4	10
	44.6	15
	48.8	25
	58.0	50
	69.5	75
	78.1	85
	84.6	90
	94.3	95

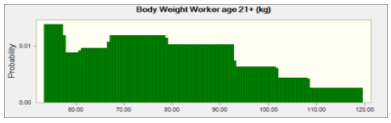


Correlated with:	Coefficient
Skin Suface Area Student age 11 to 18 (cm2) (E22)	1.00

Assumption: Body Weight Worker age 21+ (kg) **Cell: E33**

Custom distribution with parameters:

Min	Max	Percentile
53.39	57.55	10
	60.80	15
	66.79	25
	78.92	50
	92.89	75
	101.96	85
	108.56	90
	119.54	95



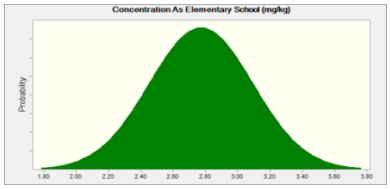
Correlated with:	Coefficient
Skin Suface Area Worker (cm2) (E23)	1.00

Assumption: Conc Arsenic Elementary School (mg/kg) **Cell: E3**

Normal distribution with parameters:

Mean	2.77
Std. Dev.	0.32

Selected range is from 0.00 to ∞

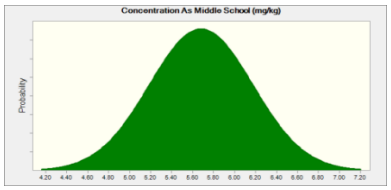


Assumption: Conc Arsenic Middle School (mg/kg) **Cell: E5**

Normal distribution with parameters:

Mean	5.68
Std. Dev.	0.49

Selected range is from 0.00 to ∞

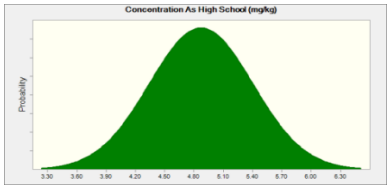


Assumption: Conc Arsenic High School (mg/kg) **Cell: E7**

Normal distribution with parameters:

Mean	4.87
Std. Dev.	0.53

Selected range is from 0.00 to ∞

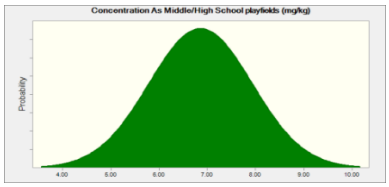


Assumption: Conc Arsenic Middle/High School sports fields (mg/kg) **Cell: E5**

Normal distribution with parameters:

Mean	6.86
Std. Dev.	1.07

Selected range is from 0.00 to ∞

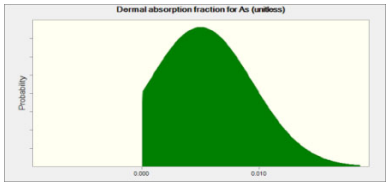


Assumption: Dermal absorption fraction for Arsenic (unitless) **Cell: E24**

Normal distribution with parameters:

Mean	0.005
Std. Dev.	0.004

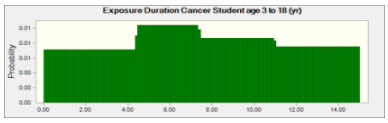
Selected range is from 0.000 to ∞



Assumption: Exposure Duration Cancer Student age 3 to 18 (yr) **Cell: E9**

Custom distribution with parameters:

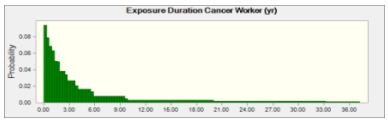
min	max	percentile
0.01	4.4	25
	7.4	50
	11	75
	15	90
	15	95
	15	99



Assumption: Exposure Duration Cancer Worker (yr) **Cell: E10**

Custom distribution with parameters:

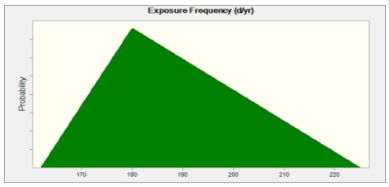
min	max	percentile
0.01	0.34	10
	0.74	20
	1.23	30
	1.85	40
	2.66	50
	3.83	60
	5.73	70
	9.64	80
	19.99	90
	28.52	95
	33.33	97.5
	37.2	99



Assumption: Exposure Frequency (d/yr) **Cell: E7**

Triangular distribution with parameters:

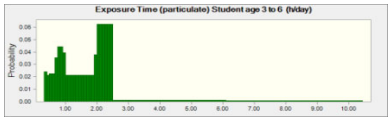
Minimum	162
Likeliest	180
Maximum	225



Assumption: Exposure Time (particulate) Student age 3 to 6 (h/day) **Cell: E27**

Custom distribution with parameters:

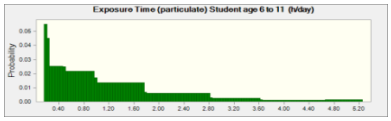
min	max	percentile
0.33	0.37	1
	0.40	2
	0.52	5
	0.70	10
	0.98	25
	1.97	50
	2.30	75
	2.50	90
	6.07	95
	8.68	98
	9.55	99
	10.42	100



Assumption: Exposure Time (particulate) Student age 6 to 11 (h/day) **Cell: E28**

Custom distribution with parameters:

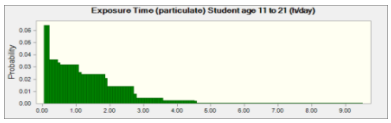
min	max	percentile
0.17	0.17	1
	0.25	10
	0.50	25
	0.98	50
	1.77	75
	2.82	90
	3.62	95
	4.67	98
	4.97	99
	5.25	100



Assumption: Exposure Time (particulate) Student age 11 to 21 (h/day) **Cell: E29**

Custom distribution with parameters:

min	max	percentile
0.05	0.10	1
	0.11	2
	0.12	5
	0.15	10
	0.47	25
	1.08	50
	1.90	75
	2.73	90
	3.57	95
	4.57	98
	6.50	99
	9.50	100

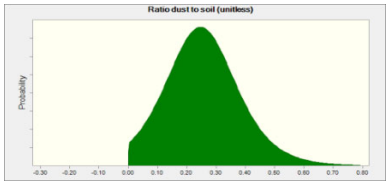


Assumption: Ratio dust to soil (unitless) **Cell: E18**

Logistic distribution with parameters:

Mean	0.25
Scale	0.08

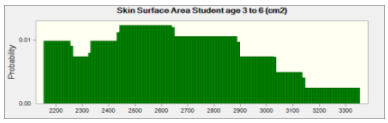
Selected range is from 0.00 to ∞



Assumption: Skin Surface Area Student age 3 to 6 (cm2) **Cell: E20**

Custom distribution with parameters:

Min	Max	Percentile
2153.3	2259.2	10
	2329.8	15
	2435.7	25
	2647.5	50
	2894.6	75
	3035.8	85
	3141.7	90
	3353.5	95

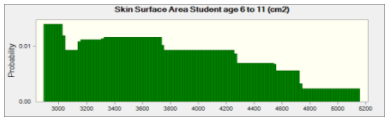


Correlated with:	Coefficient
Body Weight Student age 3 to 6 (kg) (E30)	1.00

Assumption: Skin Surface Area Student age 6 to 11 (cm2) **Cell: E21**

Custom distribution with parameters:

Min	Max	Percentile
2895	3036	10
	3142	15
	3318	25
	3742	50
	4271	75
	4554	85
	4730	90
	5154	95

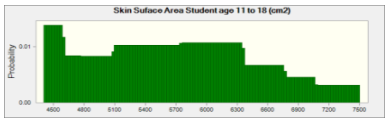


Correlated with:	Coefficient
Body Weight Student age 6 to 11 (kg) (E31)	1.00

Assumption: Skin Suface Area Student age 11 to 18 (cm2) **Cell: E22**

Custom distribution with parameters:

Min	Max	Percentile
4405.4	4599.7	10
	4760.0	15
	5085.4	25
	5741.1	50
	6367.7	75
	6770.9	85
	7067.1	90
	7499.4	95

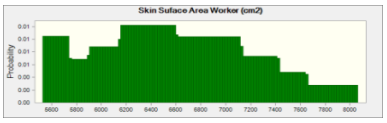


Correlated with:	Coefficient
Body Weight Student age 11 to 18 (kg) (E32)	1.00

Assumption: Skin Suface Area Worker (cm2) **Cell: E23**

Custom distribution with parameters:

Min	Max	Percentile
5530.0	5740	10
	5900	15
	6150	25
	6600	50
	7130	75
	7430	85
	7660	90
	8060	95

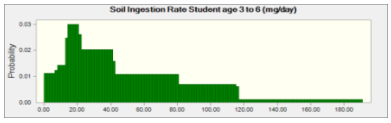


Correlated with:	Coefficient
Body Weight Worker age 21+ (kg) (E33)	1.00

Assumption: Soil Ingestion Rate Student age 3 to 6 (mg/day) **Cell: E11**

Custom distribution with parameters:

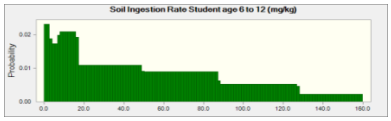
min	max	Percentile
0.01	7.37	5
	13.17	10
	21.48	25
	41.90	50
	80.60	75
	116.67	90
	191.08	95



Assumption: Soil Ingestion Rate Student age 6 to 12 (mg/kg) **Cell: E12**

Custom distribution with parameters:

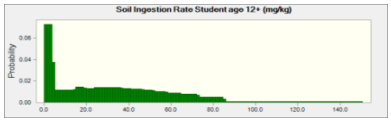
min	max	Percentile
0.01	3.00	5
	7.00	10
	15.90	25
	48.47	50
	87.35	75
	128.29	90
	159.75	95



Assumption: Soil Ingestion Rate Student age 12+ (mg/kg) **Cell: E13**

Custom distribution with parameters:

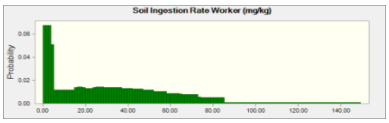
min	max	percentile
0	4.06	25
	9.44	30
	14.25	35
	19.00	40
	23.25	45
	27.94	50
	32.06	55
	36.56	60
	41.30	65
	46.52	70
	51.73	75
	57.76	80
	64.30	85
	72.78	90
	85.73	95
	192.58	100



Assumption: Soil Ingestion Rate Worker (mg/kg) **Cell: E14**

Custom distribution with parameters:

min	max	percentile
0	4.33	25
	9.69	30
	14.50	35
	19.25	40
	23.44	45
	28.10	50
	32.24	55
	36.74	60
	41.45	65
	46.68	70
	51.84	75
	57.86	80
	64.41	85
	72.94	90
	85.75	95
	192.15	100



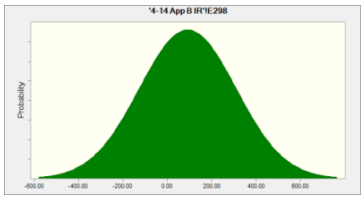
Soil Ingestion Rate Supporting Distributions

Worksheet: [REH MC_Morenci_HRA_playfields_20201203.xlsx]4-14 App B IR

Assumption: Davis & Mirick 2006 Mother Aluminum IR (mg/kg) **Cell: E298**

Normal distribution with parameters:

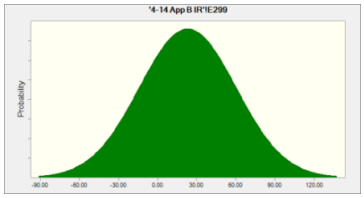
Mean	92.00
Std. Dev.	218.00



Assumption: Davis & Mirick 2006 Mother Silicon IR (mg/kg) **Cell: E299**

Normal distribution with parameters:

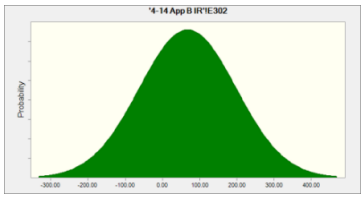
Mean	23.00
Std. Dev.	37.00



Assumption: Davis & Mirick 2006 Father Aluminum IR (mg/kg) **Cell: E302**

Normal distribution with parameters:

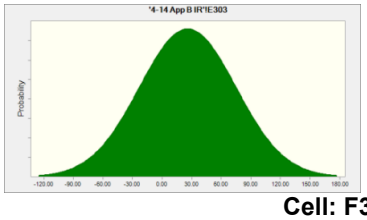
Mean	68.00
Std. Dev.	130.00



Assumption: Davis & Mirick 2006 Father Silicon IR (mg/kg) **Cell: E303**

Normal distribution with parameters:

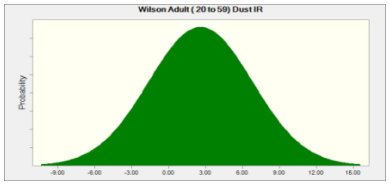
Mean	26.00
Std. Dev.	49.00



Assumption: Wilson et al. Adult (20 to 59) Dust IR (mg/kg) **Cell: F346**

Normal distribution with parameters:

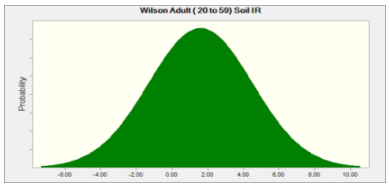
Mean	2.60
Std. Dev.	4.20



Assumption: Wilson et al. Adult (20 to 59) Soil IR (mg/kg) **Cell: F345**

Normal distribution with parameters:

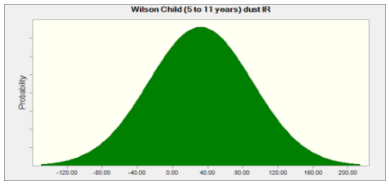
Mean	1.60
Std. Dev.	2.90



Assumption: Wilson et al. Child (5 to 11 years) Dust IR (mg/kg) **Cell: F232**

Normal distribution with parameters:

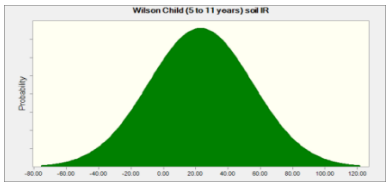
Mean	32.00
Std. Dev.	59.00



Assumption: Wilson et al. Child (5 to 11 years) Soil IR (mg/kg) **Cell: F231**

Normal distribution with parameters:

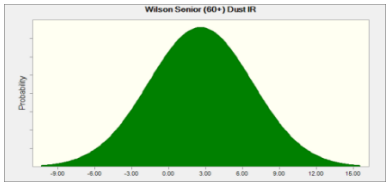
Mean	23.00
Std. Dev.	32.00



Assumption: Wilson et al. Senior (60+) Dust IR (mg/kg) **Cell: F348**

Normal distribution with parameters:

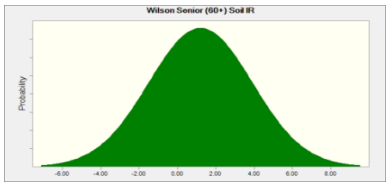
Mean	2.60
Std. Dev.	4.20



Assumption: Wilson et al. Senior (60+) Soil IR (mg/kg) **Cell: F347**

Normal distribution with parameters:

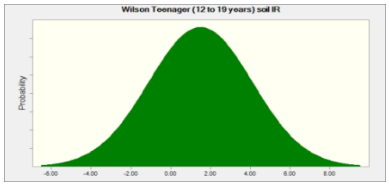
Mean	1.20
Std. Dev.	2.70



Assumption: Wilson et al. Teenager (12 to 19 years) soil IR (mg/kg) **Cell: F341**

Normal distribution with parameters:

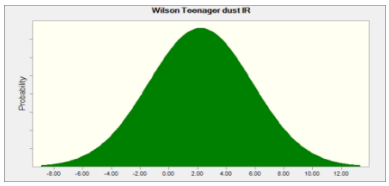
Mean	1.50
Std. Dev.	2.60



Assumption: Wilson et al. Teenager (12 to 19 years) dust IR (mg/kg) **Cell: F342**

Normal distribution with parameters:

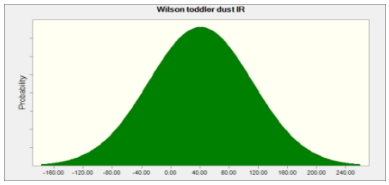
Mean	2.20
Std. Dev.	3.60



Assumption: Wilson et al. toddler Dust IR (mg/kg) **Cell: F99**

Normal distribution with parameters:

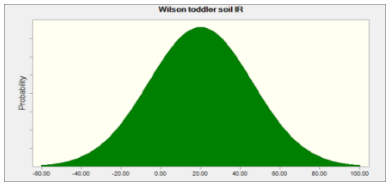
Mean	41.00
Std. Dev.	71.00



Assumption: Wilson et al. toddler Soil IR (mg/kg) **Cell: F100**

Normal distribution with parameters:

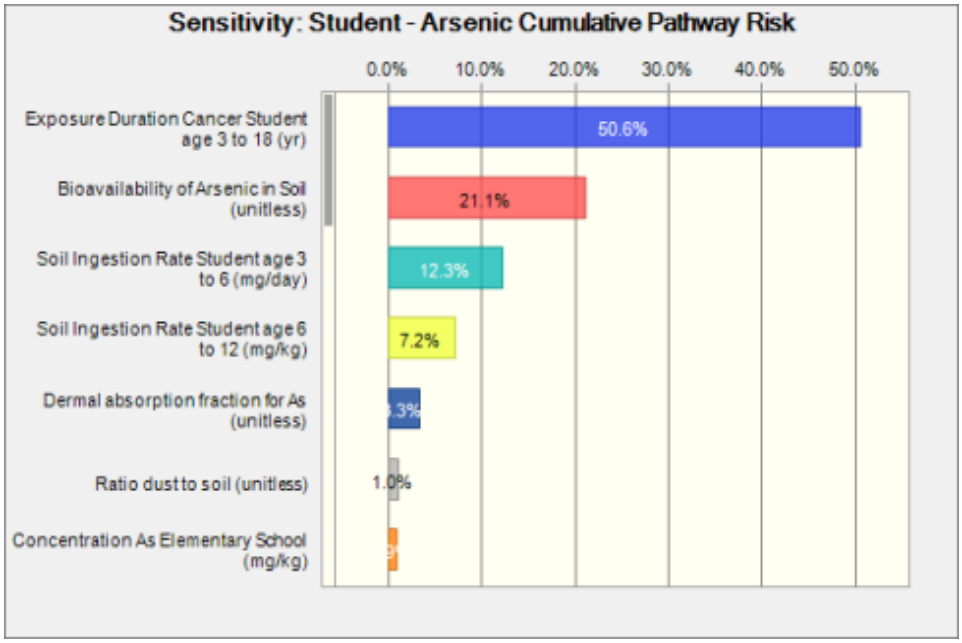
Mean	20.00
Std. Dev.	26.00

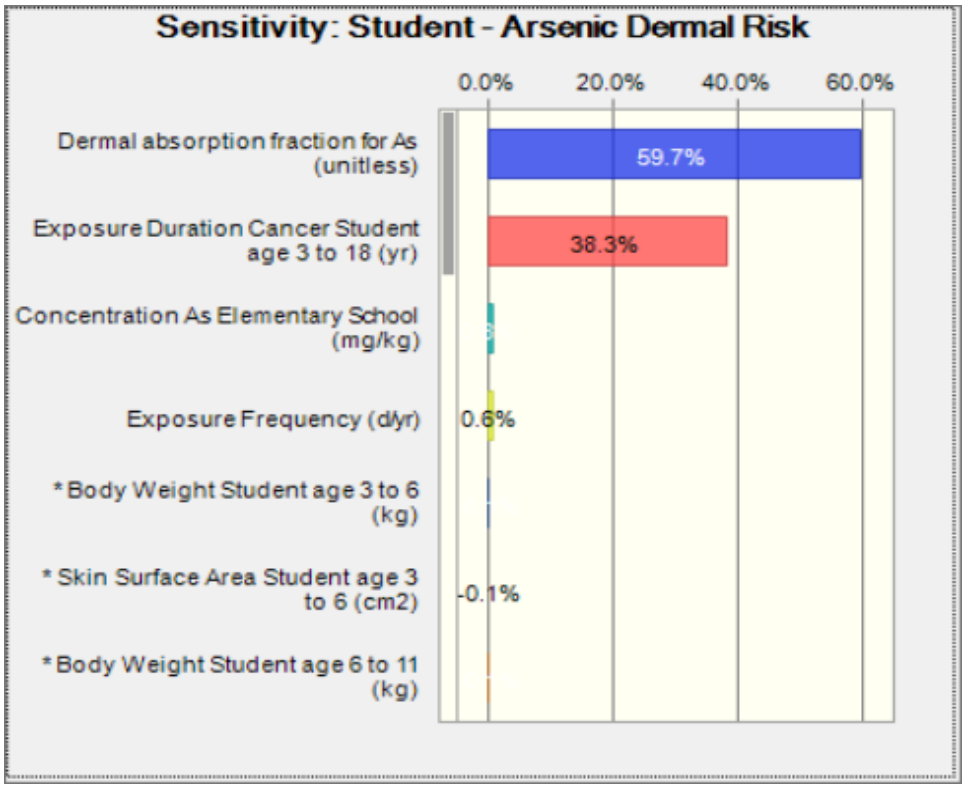


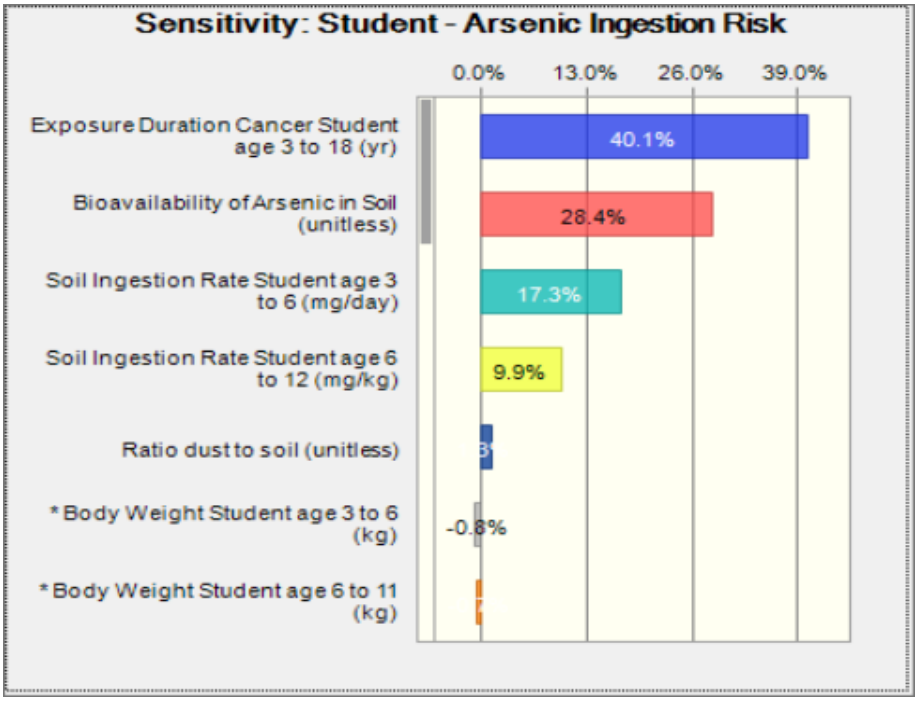
End of Assumptions

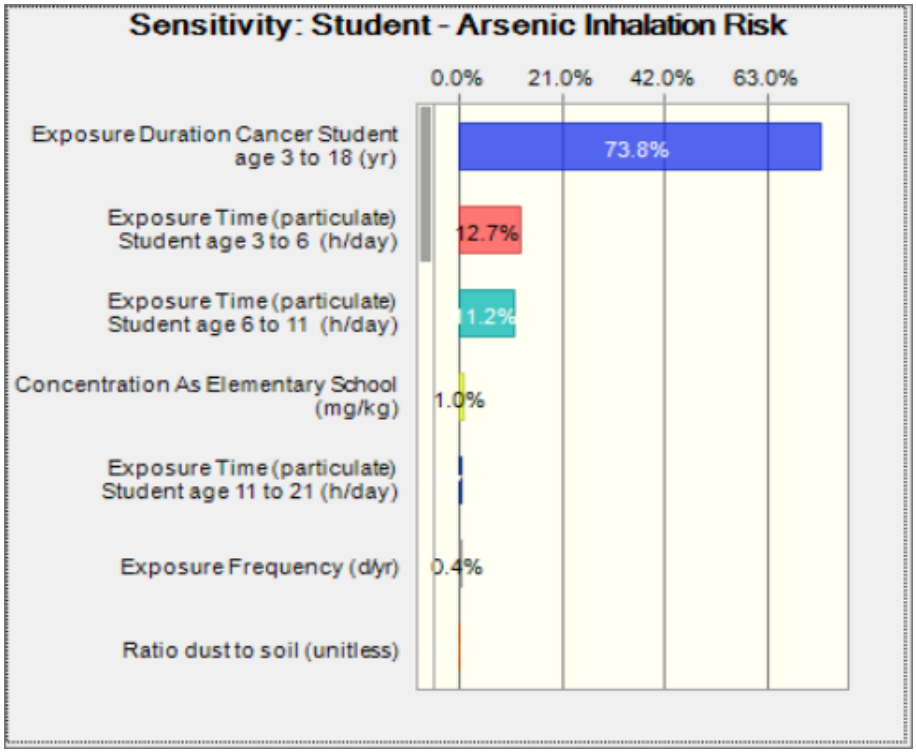
Sensitivity Charts

School Specific Area Scenario Sensitivity (student only)

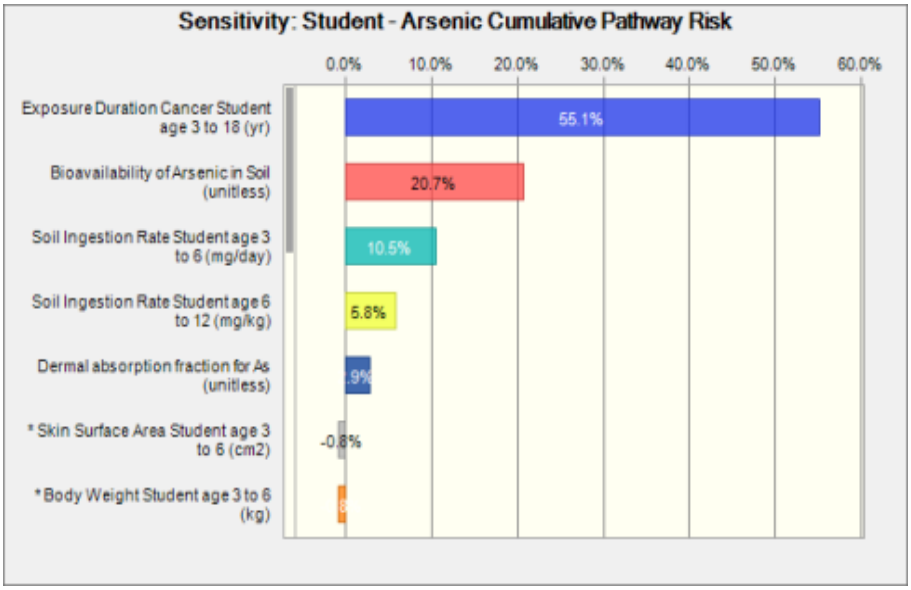


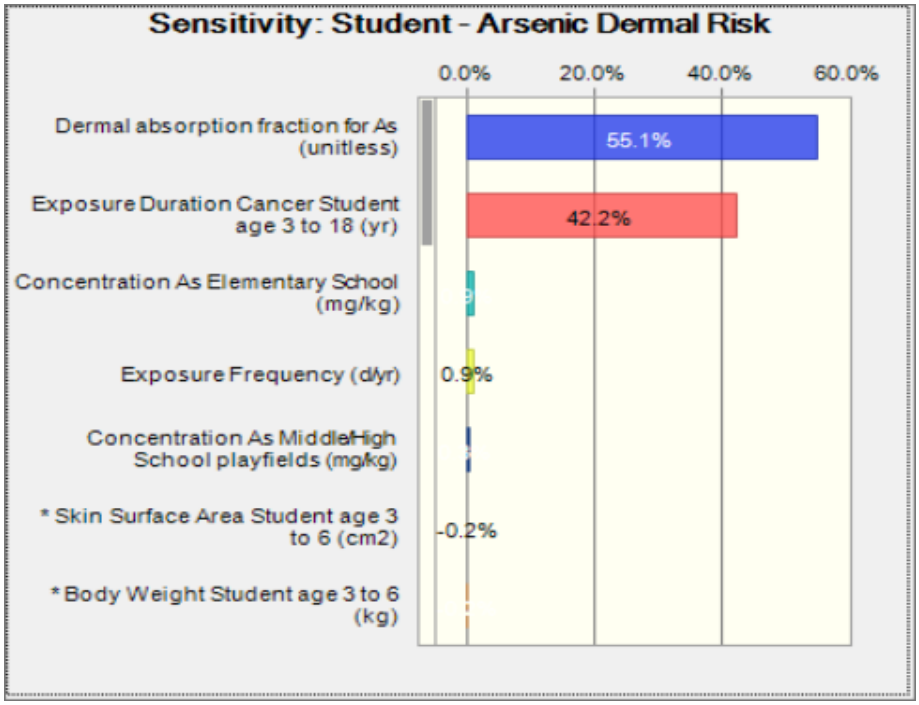


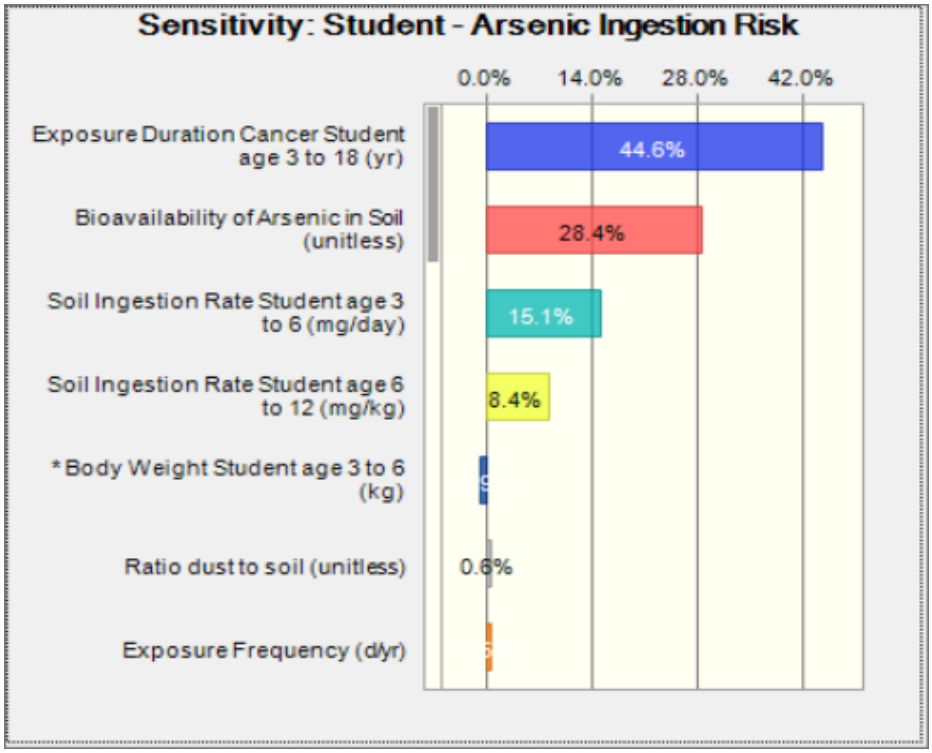

Sensitivity: Student - Arsenic Ingestion Risk
0.0%
13.0%
26.0%
39.0%
Exposure Duration Cancer Student age 3 to 18 (yr)
40.1%
Bioavailability of Arsenic in Soil (unitless)
28.4%
Soil Ingestion Rate Student age 3 to 6 (mg/day)
17.3%
Soil Ingestion Rate Student age 6 to 12 (mg/kg)
9.9%
Ratio dust to soil (unitless)
* Body Weight Student age 3 to 6 (kg)
-0.8%
* Body Weight Student age 6 to 11 (kg)

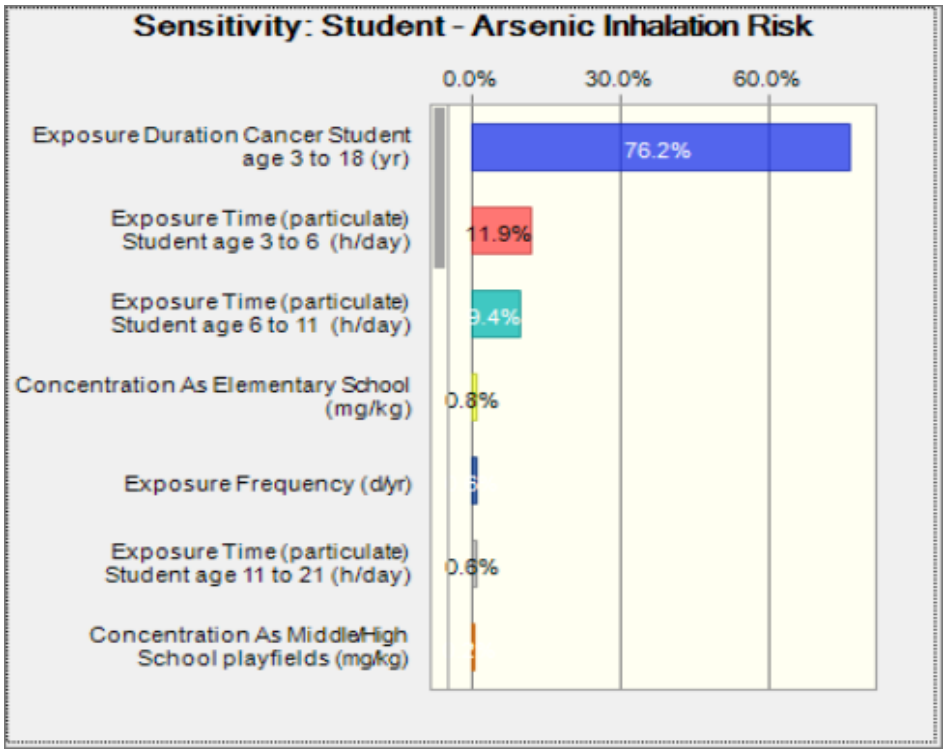

Sensitivity: Student - Arsenic Inhalation Risk
0.0%
21.0%
42.0%
63.0%
Exposure Duration Cancer Student age 3 to 18 (yr)
73.8%
Exposure Time (particulate) Student age 3 to 6 (h/day)
12.7%
Exposure Time (particulate) Student age 6 to 11 (h/day)
11.2%
Concentration As Elementary School (mg/kg)
1.0%
Exposure Time (particulate) Student age 11 to 21 (h/day)
Exposure Frequency (d/yr)
0.4%
Ratio dust to soil (unitless)

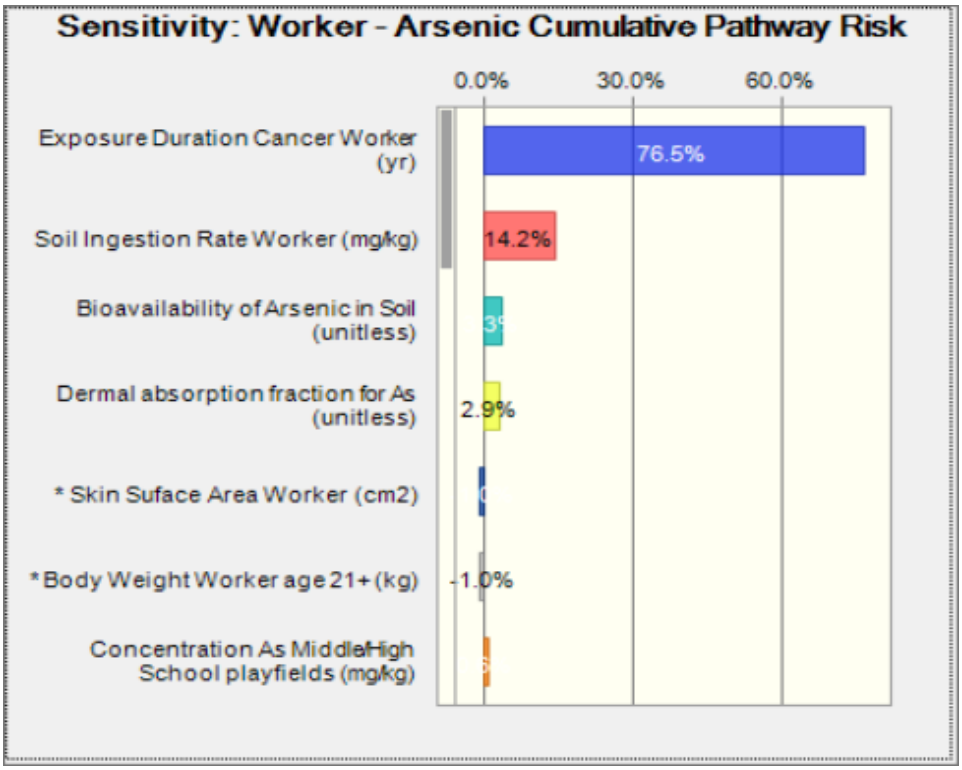
Sports Fields Area Scenario Sensitivity (student and adult worker)

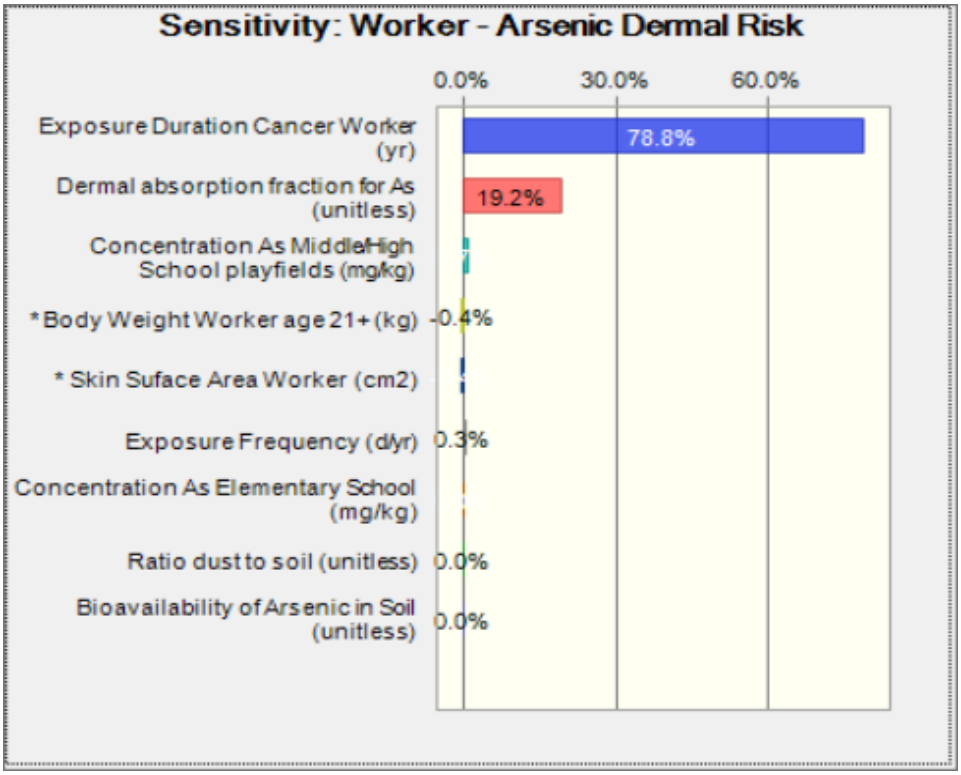


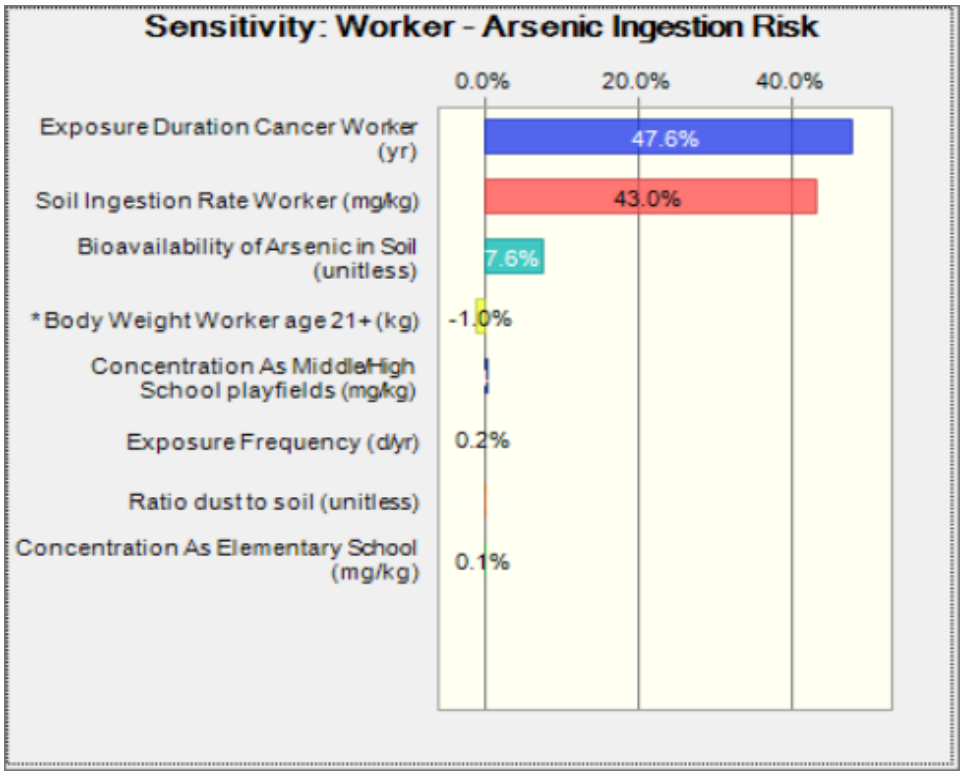


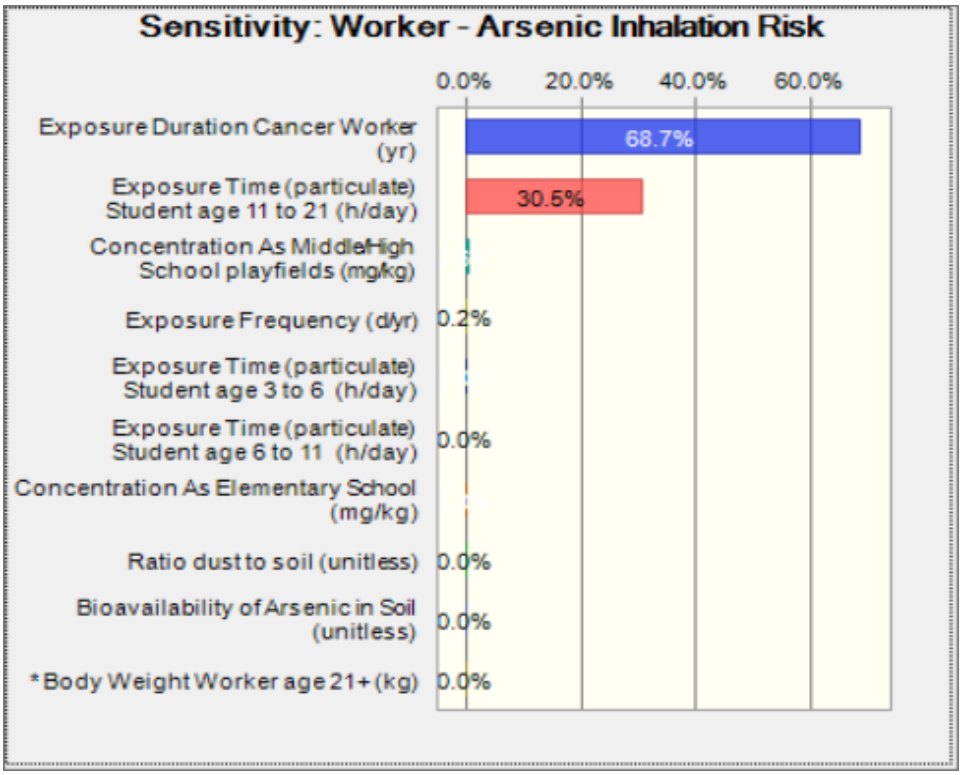

Sensitivity: Student - Arsenic Ingestion Risk
0.0%
14.0%
28.0%
42.0%
Exposure Duration Cancer Student age 3 to 18 (yr)
44.6%
Bioavailability of Arsenic in Soil (unitless)
28.4%
Soil Ingestion Rate Student age 3 to 6 (mg/day)
15.1%
Soil Ingestion Rate Student age 6 to 12 (mg/kg)
8.4%
*Body Weight Student age 3 to 6 (kg)
Ratio dust to soil (unitless)
0.6%
Exposure Frequency (d/yr)


Sensitivity: Student - Arsenic Inhalation Risk
0.0%
30.0%
60.0%
Exposure Duration Cancer Student age 3 to 18 (yr)
76.2%
Exposure Time (particulate) Student age 3 to 6 (h/day)
11.9%
Exposure Time (particulate) Student age 6 to 11 (h/day)
9.4%
Concentration As Elementary School (mg/kg)
0.8%
Exposure Frequency (d/yr)
Exposure Time (particulate) Student age 11 to 21 (h/day)
0.6%
Concentration As Middle/High School playfields (mg/kg)


Sensitivity: Worker - Arsenic Cumulative Pathway Risk
0.0%
30.0%
60.0%
Exposure Duration Cancer Worker (yr)
76.5%
Soil Ingestion Rate Worker (mg/kg)
14.2%
Bioavailability of Arsenic in Soil (unitless)
Dermal absorption fraction for As (unitless)
2.9%
* Skin Suface Area Worker (cm2)
* Body Weight Worker age 21+ (kg)
-1.0%
Concentration As Middle/High School playfields (mg/kg)


Sensitivity: Worker - Arsenic Dermal Risk
0.0%
30.0%
60.0%
Exposure Duration Cancer Worker (yr)
78.8%
Dermal absorption fraction for As (unitless)
19.2%
Concentration As Middle/High School playfields (mg/kg)
* Body Weight Worker age 21+ (kg)
-0.4%
* Skin Suface Area Worker (cm2)
Exposure Frequency (d/yr)
0.3%
Concentration As Elementary School (mg/kg)
Ratio dust to soil (unitless)
0.0%
Bioavailability of Arsenic in Soil (unitless)
0.0%


Sensitivity: Worker - Arsenic Ingestion Risk
0.0%
20.0%
40.0%
Exposure Duration Cancer Worker (yr)
47.6%
Soil Ingestion Rate Worker (mg/kg)
43.0%
Bioavailability of Arsenic in Soil (unitless)
7.6%
*Body Weight Worker age 21+ (kg)
-1.0%
Concentration As Middle/High School playfields (mg/kg)
Exposure Frequency (d/yr)
0.2%
Ratio dust to soil (unitless)
Concentration As Elementary School (mg/kg)
0.1%


Sensitivity: Worker - Arsenic Inhalation Risk
0.0%
20.0%
40.0%
60.0%
Exposure Duration Cancer Worker (yr)
68.7%
Exposure Time (particulate) Student age 11 to 21 (h/day)
30.5%
Concentration As Middle/High School playfields (mg/kg)
Exposure Frequency (d/yr)
0.2%
Exposure Time (particulate) Student age 3 to 6 (h/day)
Exposure Time (particulate) Student age 6 to 11 (h/day)
0.0%
Concentration As Elementary School (mg/kg)
Ratio dust to soil (unitless)
0.0%
Bioavailability of Arsenic in Soil (unitless)
0.0%
*Body Weight Worker age 21+ (kg)
0.0%