Bureau of Land Management
AZ Magma Mine

Magma Consulting

Preliminary Assessment & Site Inspection

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List of Abbreviations

AA	Atomic Absorption
ADMA	Administrative Assistant
ADMMR	Arizona Department of Mines and Mineral Resources
ADWR	Arizona Department of Water Resources
ASOS	Arizona Secretary of State
BLM	Bureau of Land Management
COC	Contaminant of Concern
CDI	Chronic Daily Intake
EHS	Environmental Health and Safety
ENG	Engineer
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
ICP	Inductively Coupled Plasma
IDW	Investigation Derived Wastes
INT	Intern
LAB	Lab Technician
NAU	Northern Arizona University
PA	Preliminary Assessment
PPE	Personal Protective Equipment
SAP	Sampling and Analysis Plan
SENG	Senior Engineer
SI	Site Inspection
SOP	Standard Operating Procedures
XRF	X-ray Fluorescence

Acknowledgements

1.0 Project Description

1.1 Project Purpose

The purpose of this project is to provide a preliminary assessment and site inspection (PA/SI) of the AZ Magma Mine near Chloride, Arizona for contaminated soil. Mine tailings have been identified at the mine's location and there is evidence of contaminant migration. Potential contaminants of concern (COC) include lead and arsenic. After the inspection, it will be determined whether additional, more in-depth analysis of the mine is necessary from the Bureau of Land Management (BLM).

1.2 Project Background

The AZ Magma Mine (Latitude N 35°25'00" Longitude W114°13'27") is located approximately one mile west of Chloride, Arizona and 28 miles north of Kingman (ADMMR, 1995). Figure 1-1 below shows the mine's location in reference to both towns and Figure 1-2 shows its proximity to Chloride.
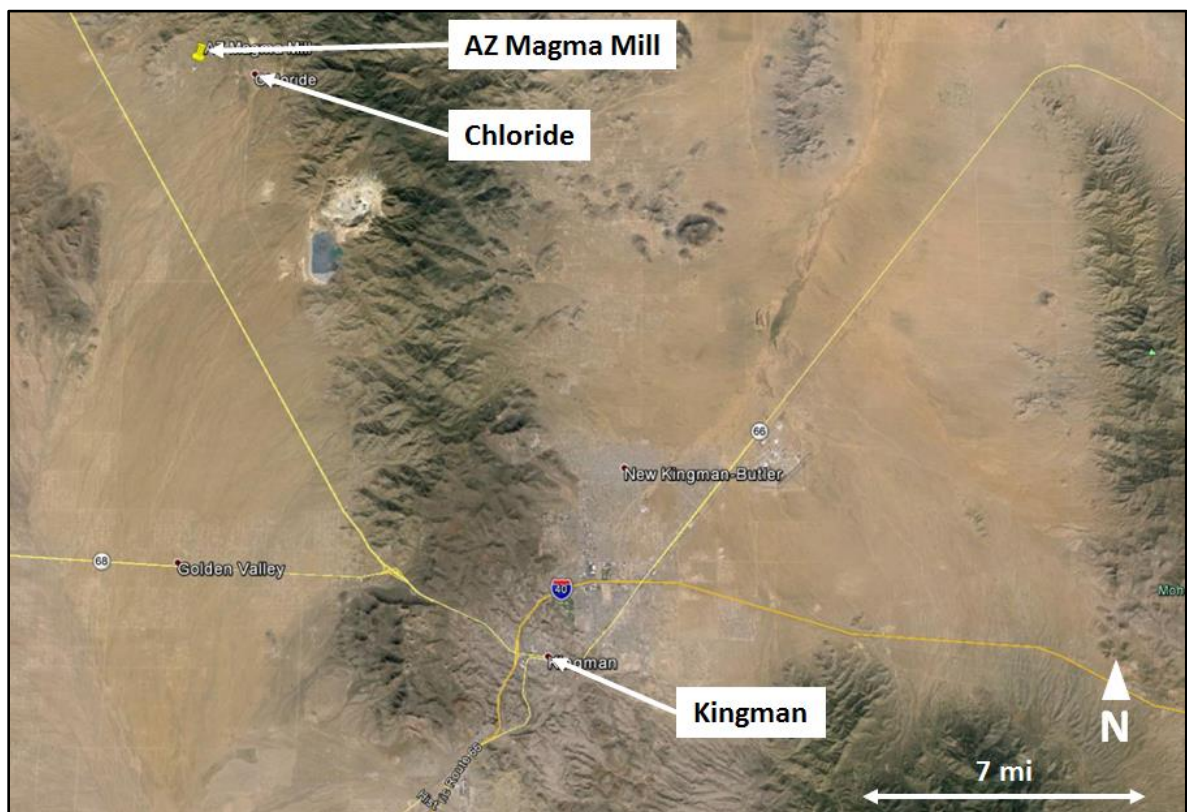
Figure 1-1. AZ Magma Mine in Reference to Chloride and Kingman (Google Earth, 2016)

Figure 1-2. AZ Magma Mine's Proximity to Chloride (Google Earth, 2016)

Chloride has a population of approximately 250 residents and is considered one of the oldest mining towns in America because of its proximity to over 70 mines (McNeely, 2016).

Mining began at this site, originally called Arizona Diana Mine, in the 1890's. It experienced a period of inactivity until the 1920's where its commodities were primarily silver, gold, and lead (ADMMR, 1995). The mine closed again in the 1920's and was reopened and named after its new operating company, Magma Mine, in 1934 (ADMMR, 1995). For the mine's reopening, a new mill was built that was initially reported to provide a steady stream of revenue for years to come. However, after an investigation in 1940, it was found to be run down and in need of repair (ADMMR, 1995). A high-grade ore with ruby silver was mined at the site in its early years, while a low-grade ore with zinc and lead was its primary export in its later years. The mine was reviewed several times from 1940 to 1945 due to lack of funding and difficulty in extracting anything lucrative. As a result of these site investigations, AZ Magma Mine was advised to close in 1945.

Currently, the site belongs to the BLM and is considered open and accessible to the public. While mine operations shut down in the early 1940's, tailings about 10 feet deep are still present on the site (Zielske, 2016). These tailings may contain lead or arsenic (Zielske, 2016). Photos of the tailings can be seen in Figures 1-3 and 1-4.

Figure 1-3. Current Condition of Tailings (Zielske, 2016)

Figure 1-4. Landscape Photo of Entire Tailings Pile (Szaro, 2017)

The tailings have also washed down into the nearby wash (Figure 1-5) and onto Old Chloride Road, which connects the mine to Chloride (Figure 1-6).

Figure 1-5. Tailings in the Wash (Zielske, 2016)

Figure 1-6. Tailings on the Road (Zielske, 2016)

The site is also located near several water wells, as seen in Figure 1-7. Wells are signified by red dots on the map.
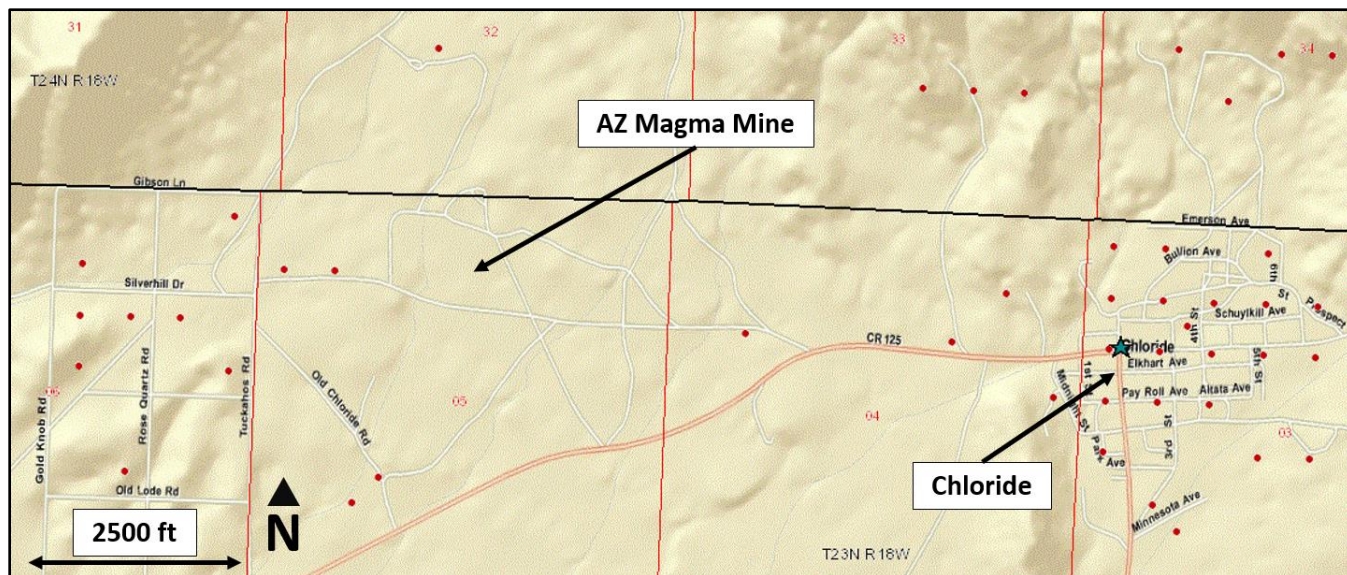
Figure 1-7. Wells near AZ Magma Mine (ADWR, 2016)

The depth to groundwater for these wells varies from 100 to 150 feet and may be at risk for contamination from the mine (ADWR, 2016). Magma Consulting did not take any water samples for this project.

1.3 Scope of Services

The scope of services included all activities necessary to fulfill the project purpose. Major tasks included the development of a Work Plan, training, site sampling, laboratory analysis, risk assessment, and the development of the PA/SI document.

The team did not sample to depth at the site; only surface samples were taken. An additional drainage area was identified on the east side of the tailings pile; additional hotspot samples were taken downgradient in this area. No recommendations for remedial actions following the PA/SI are made.

2.0 Work Plan

The Work Plan outlines all procedures and safety considerations for all field and laboratory activities. The Work Plan includes the Sampling and Analysis Plan (SAP) and Health and Safety Plan (HASP). The Work Plan, SAP, and HASP are found in Appendices A, B, and C, respectively.

3.0 Field Activities

All sampling procedures, documentation procedures, storage methods, quality assurance and control measures, and chain of custody procedures followed those outlined in the SAP (Appendix B) unless otherwise noted. Deviations from the SAP are detailed below.

Field sampling was conducted between January 20th (Day 1) and January 21st (Day 2). With a mixture of heavy rain, wind, and clouds, conditions during Day 1 were unfavorable. This resulted in deviations from the SAP. First, with dust no longer a concern at the site on Day 1, mouth covers and Tyvek suits were not worn. Team members wore shoe covers and nitrile gloves as their only means of personal protective equipment (PPE). Second, the initial plan was to collect 25 samples on the tailings pile, 66 samples on the wash and road south of the tailings pile, 4 background samples, and 5 hotspot samples for a total of 100 samples. Due to the poor conditions on Day 1, with anticipated improved conditions on Day 2, it was decided by the Northern Arizona University (NAU) person-in-charge, Dr. Bridget Bero, that the tailings pile would be sampled on Day 1, with the wash, road, background, and any observed hotspots sampled on Day 2.

For Day 1, coordinates for node 21 were initially planned to be used as reference coordinates. Due to cloud cover, the accuracy of the team's GPS was compromised. To find node 21, the team used unique geographical identifiers from aerial maps included in the SAP to more accurately plant the stake flag for node 21. Despite technical issues, coordinates for the location of node 21's stake flag were recorded in the GPS. To the team's judgement, the coordinates recorded in the GPS for node 21 appeared to be about 10 feet north of where the team had anticipated the node to be. From here, two people from the team used measuring tape to stake out the other nodes on the tailings pile, each located 100 feet from one another, per the SAP. At each stake flag on the tailings pile, coordinates were recorded in the GPS. Soon after two people from the team began staking out flags, two other people from the team began collecting soil samples. Sampling and decontamination procedures outlined in the SAP were followed. However, due to rain, trowels used for sampling were unable to be dried following decontamination.

Additionally, due to the poor weather conditions on Day 1, some nodes were eliminated from the grid on the tailings pile. This included nodes 8, 12, 14, and 18. This decision was made by the NAU person-in-charge. The assumption was that contaminant concentrations on the tailings pile would be fairly homogenous. At the end of Day 1, 21 grid samples in total were collected at the site, all of which were on or near the tailings pile. Figure 3-1 shows the location of the 21 samples collected on Day 1.
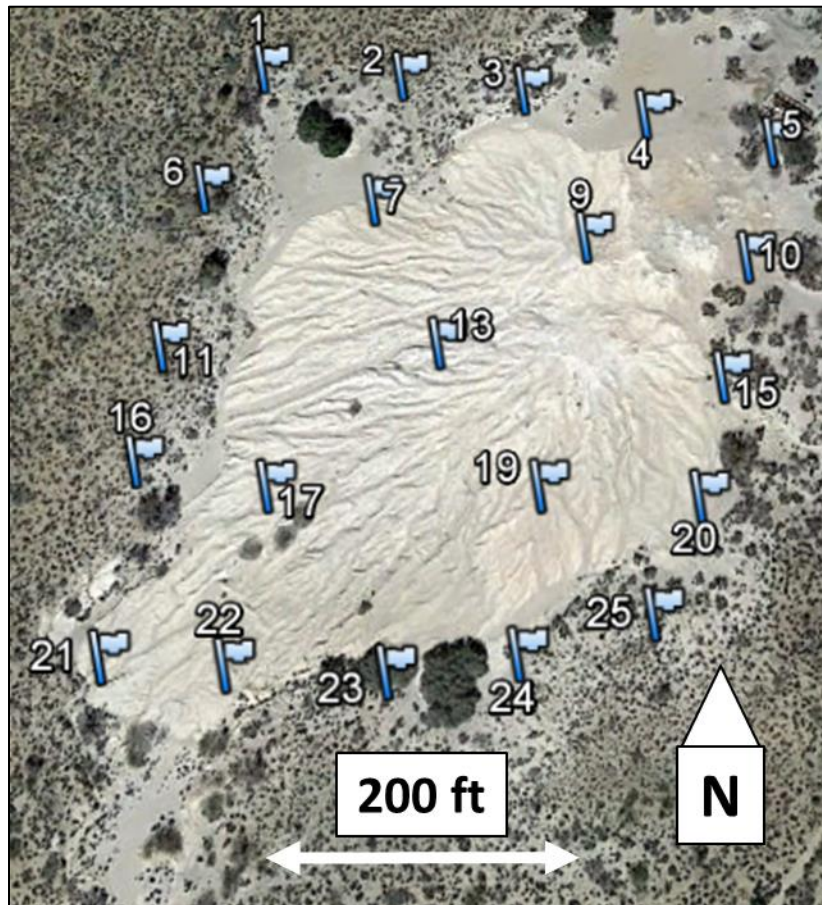
Figure 3-1. Samples Collected on Day 1

For Day 2, weather conditions improved. Because soil at the site was still damp, a reduced outfit of PPE was still used, with only shoe covers and nitrile gloves being worn by team members. All staking and sampling procedures mirrored those used on Day 1. However, with clearer weather, trowels used for sampling were able to be dried following decontamination.

Due to observed deviations in terrain south of the tailings pile, as compared to the terrain anticipated from maps in the SAP, some samples were eliminated from the grid. This included nodes 26-29, 46, 51, 52, 56, 64, 70, and 75-91. However, some sample locations were added to the grid, as decided by the NAU person-in-charge. This included nodes 55A, 69A, and 69B. Figure 3-2 shows the location of the 42 samples collected in the wash and road on Day 2.
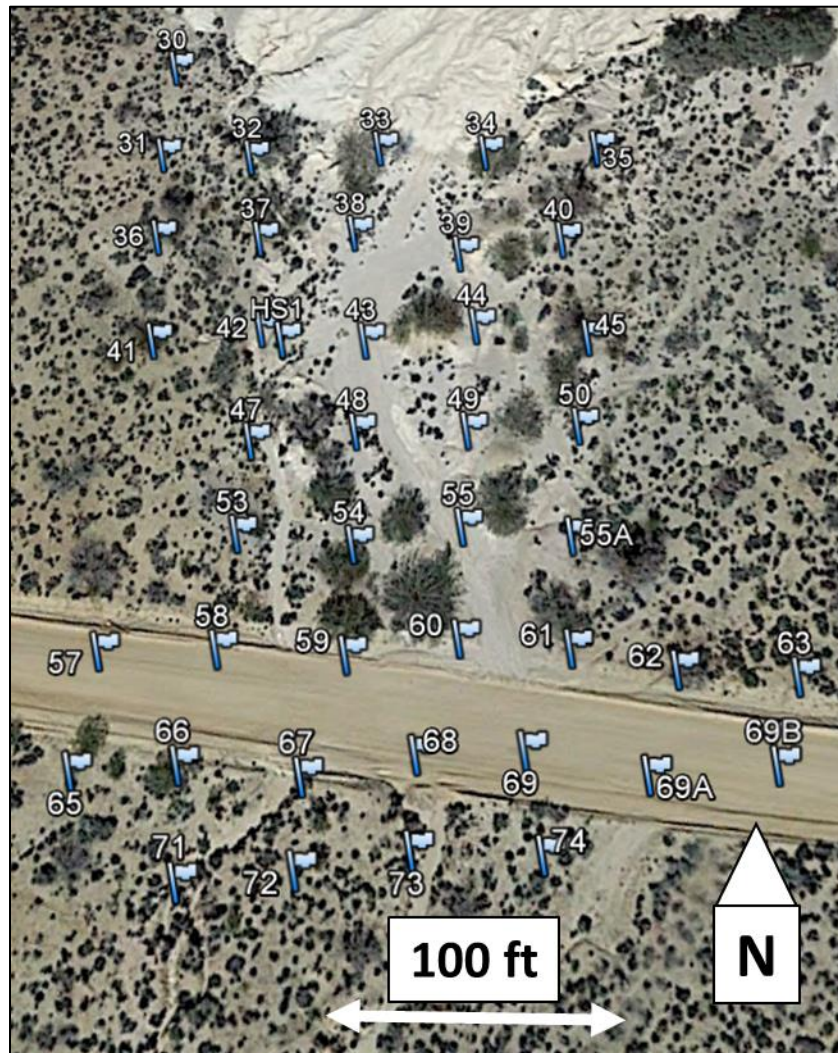
Figure 3-2. Samples Collected in Wash and Road on Day 2

Additionally, background and hotspot samples were collected on Day 2. A total of 3 background samples were collected, all located west of the site. A total of 8 hotspot samples were collected, with their locations being chosen by the NAU person-in-charge. The location of hotspot 1 can be seen in Figure 3-2, between sample 42 and 43. The locations of all other hotspot and background samples can be seen in Figure 4-3. In total, the team collected 74 samples at the site, in comparison to the 100 samples it projected to collect.

In storing the samples from Day 1 and Day 2, there were a few deviations from the chain of custody procedures outlined in the SAP. Although samples were properly labeled with their sample ID and placed into a total of three plastic crates, chain of custody forms indicating which samples were in which crate were not created or stored with the samples. Additionally, the crates were not sealed with tape after being closed with a lid. After sample collection was completed at the end of Day 2, the team drove the samples from the site to NAU, where the crates were stored in the Engineering Building on campus.

4.0 Laboratory Analysis

All sample preparation procedures, laboratory analyses, quality assurance and control methods, and analytical methods followed those outlined in the SAP (Appendix A-2) unless otherwise noted. A brief discussion of each analysis and deviations from the SAP are detailed in the sections below.

4.1 Sample Preparation

Following EPA Method 6200 for X-ray fluorescence (XRF) analysis, each sample was dried at 105°C ± 5°C for 24 ± 2 hours. After the samples were dried, they were placed into new, labeled plastic gallon bags. Following drying, all soil samples were sieved to material passing a #60 sieve (250 μm) for 10 minutes (rather than a #200 sieve [74 μm] for 5 minutes as intended in the SAP) and placed back into the plastic bags. Some of the samples were only sieved to a #35 sieve (500 μm) due to difficulty in obtaining enough sample to analyze with XRF. Samples that were sieved to a #35 sieve are indicated in Table 4-1. Before beginning XRF analysis, each plastic bag was labeled with 9 equal squares, as shown in Figure 4-1.
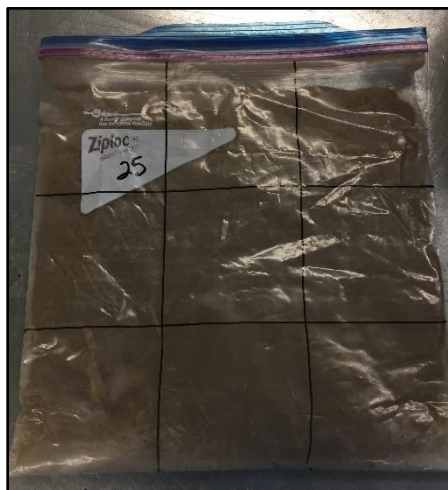
Figure 4-1. Sample Ready for XRF Analysis

4.2 XRF Analysis

For XRF analysis, all samples were analyzed using EPA Method 6200, with some exceptions (EPA A, 2007). Due to difficulty in obtaining enough sieved soil, some samples were analyzed with 3 shots (rather than 9 shots, then excluding the highest and lowest values), and an average was developed from those 3 readings. In one case, only 1 XRF reading could be made for a soil sample. Samples that were analyzed with XRF once or 3 times are indicated in Table 4-1. Figure 4-2 shows the XRF process.

Figure 4-2. XRF Analyzer

Following XRF analysis, all chemical concentrations were compared to Arizona's residential and non-residential soil remediation standards (ASOS). Arsenic was found to exceed its residential and non-residential standard (10 mg/kg) in 74 of 74 samples. The standard for arsenic is identical for residential and non-residential due to the high toxicity of arsenic. Manganese was found to exceed its residential standard (3300 mg/kg) in 31 of 74 samples. Vanadium was found to exceed its residential standard in 42 of 74 samples (78 mg/kg). The chemical concentrations of arsenic, manganese, and vanadium for each sample are presented in Table 4-1. All individual XRF readings can be seen in Appendix F.

Table 4-1. Chemical Concentrations in Soil Samples

Sample ID	Arsenic Concentration (mg/kg)	Manganese Concentration (mg/kg)	Vanadium Concentration (mg/kg)
Res Std.	10	3300	78
1[ab]	197	1245	78
2[d]	151	1211	110
3[ab]	1185	4173	54
4[b]	926	3022	87
5[b]	1027	3370	51
6[ab]	910	3254	71
7[ac]	46	661	161
9[ab]	787	2679	56
10[ab]	1223	4182	65
11[bd]	521	3187	105
13[d]	383	2536	113

15[ab]	311	1958	96
16	1276	5310	65
17	910	3963	59
19[b]	540	3766	90
20[ab]	539	3070	86
21	308	1842	110
22[b]	1051	4420	57
23	1158	2826	72
24[ab]	233	1416	95
25	680	3210	67
30[d]	581	2888	95
31	794	3956	52
32[ab]	58	1038	154
33	1098	4522	73
34	457	2753	85
35	1014	6187	60
36[d]	982	4322	73
37[bd]	1372	4664	83
38	250	1694	104
39[bd]	51	835	166
40[b]	1179	3059	58
41[bd]	261	1761	110
42[b]	271	2030	120
43	1019	4829	52
44[b]	775	6331	60
45	634	3379	87
47	298	1520	89
48	716	3409	87
49[d]	124	1138	117
50	707	3205	85
53	439	2277	92
54[b]	361	1985	94
55	574	3116	88
55A	898	4203	54
57[b]	41	774	164
58[bd]	2090	7779	106
59	785	3937	80
60[d]	1213	5508	54
61[b]	194	1206	95

62[abd]	2720	11350	89
63	678	2941	90
65	591	3597	50
66	875	3983	80
67	967	5839	46
68	1369	5217	71
69[d]	753	4283	61
69A	255	1781	113
69B	199	983	101
71	830	4112	67
72	545	1953	58
73[b]	644	3967	67
74	1070	4724	54
BG1	1251	5773	56
BG2	603	4047	78
BG3	959	3140	59
HS1[d]	456	2607	91
HS2[b]	65	1065	152
HS3[b]	55	1013	148
HS4[ab]	31	1018	146
HS5[ab]	395	1923	84
HS6[ab]	417	1945	93
HS7[ab]	286	1863	88
HS8	747	3065	51

a = Sieved to #35 sieve, rather than #60 sieve
b = 3 XRF shots
c = 1 XRF shot
d = Acid digested in preparation for ICP analysis

Once the XRF data was found, the concentrations for arsenic, manganese, and vanadium were input into a Geographic Information Systems (GIS) map to observe the spatial distribution of contaminant concentrations at the site. Figures 4-3, 4-4, and 4-5 present the spatial distribution of concentrations for arsenic, manganese, and vanadium, respectively.
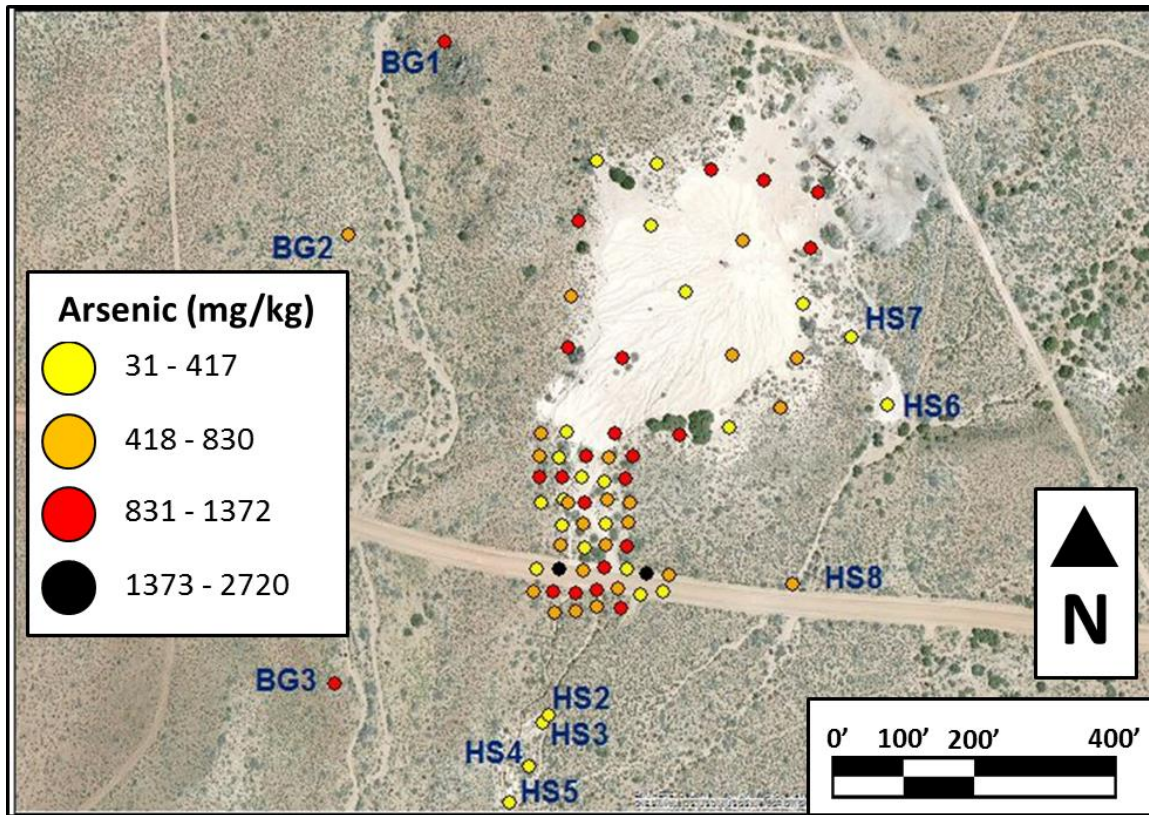
Figure 4-3. Arsenic GIS Map
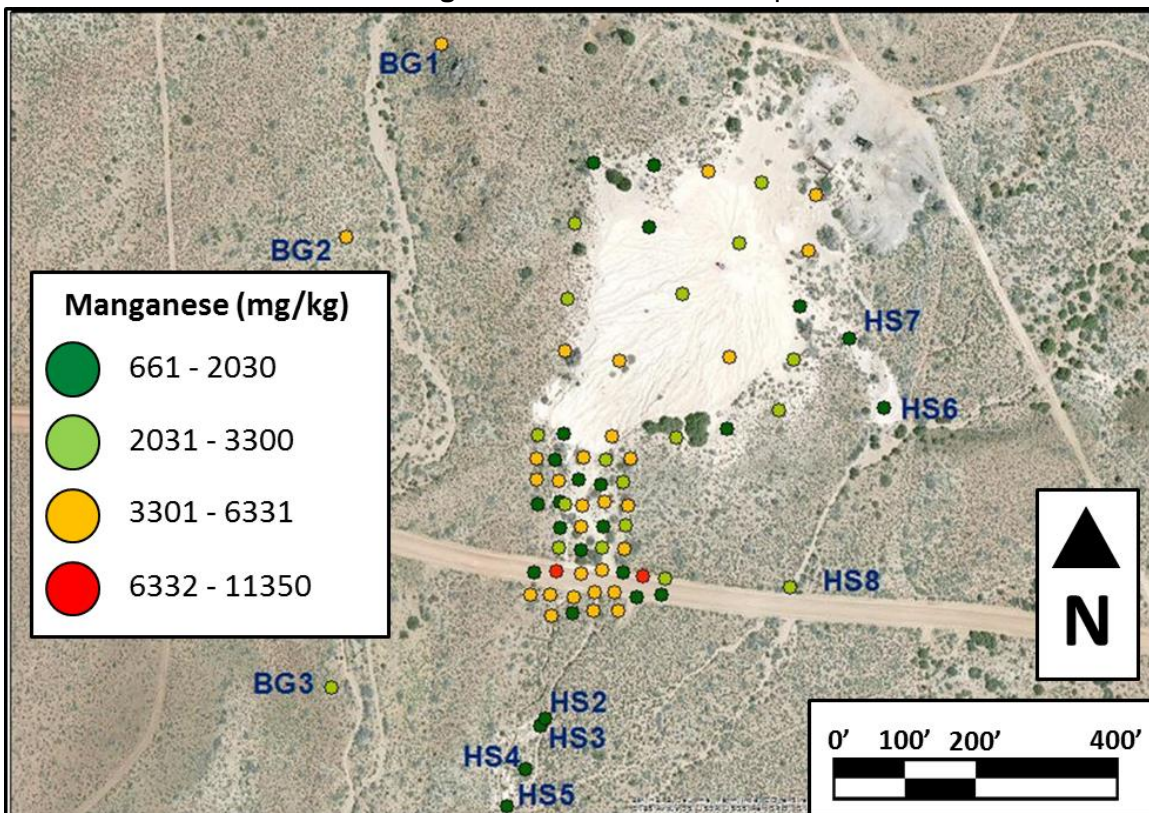
Figure 4-4. Manganese GIS Map
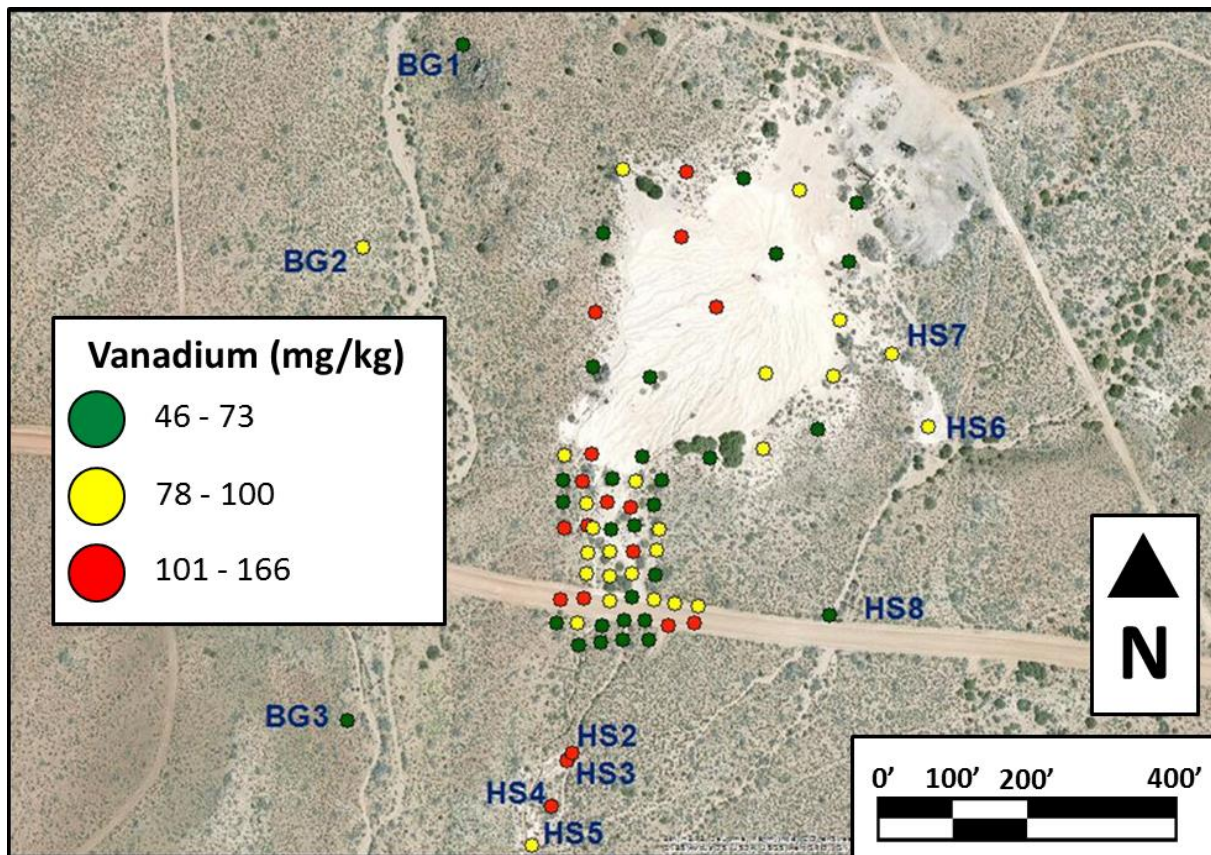
Figure 4-5. Vanadium GIS Map

Upon observation of the GIS maps, there is no logical trend within the XRF data for any of the COCs. The tailings pile seems to have lower concentrations than the wash and the road, suggesting the soil increases in concentration as it moves away from the tailings pile. The road is also a high point in the concentrations of all COCs and this is especially concerning because the road connects directly to houses west of the mine. Another anomaly in the data is with background samples having higher arsenic concentration than hotspots. This most likely means that the hotspots chosen during sampling were misidentified.

4.3 Acid Digestion

Following XRF analysis, some samples were acid digested following EPA Method 3050B (Acid Digestion of Sediments, Sludges, and Soils) to prepare them for inductively coupled plasma (ICP) mass spectrometric analysis of arsenic. As detailed in the SAP, approximately 20% of the samples were chosen and digested. To decide which samples to include, the XRF data was ordered from lowest to highest arsenic concentration and approximately each fifth sample was chosen. This allowed for an even spread of data to be represented in the subset sent off for ICP analysis. Sixteen total samples were chosen for digestion and are indicated in the XRF table in Table 4-1. EPA Method 3050B was followed exactly as it is stated in the SAP, with 16 samples and 1 blank being digested in one day. Figure 4-6 shows the digestion process.

Figure 4-6. Acid Digestion

Once all steps presented in the SAP were completed, the supernatants from the digested samples were refrigerated until they were ready for transport. During this time, some samples fell out of the refrigerator, causing the centrifuge tubes holding the samples to dent and one to shatter. Samples within any dented centrifuge tubes were pipetted into new tubes and thus only 15 samples could be sent off for ICP analysis.

Although manganese and vanadium were found as COCs from the XRF data, these contaminants were not chosen for digestion or ICP analysis. Manganese and vanadium are non-carcinogenic and require a different method of acid digestion. Thus, due to time constraints, arsenic is the only contaminant in which the XRF concentrations were confirmed with ICP.

4.4 Inductively Coupled Plasma (ICP) Mass Spectrometry

The digested samples were placed in a cooler with a chain of custody form and a document with exact masses of soil used for each sample during digestion. This cooler was given to Dr. Paul Gremillion who then passed it on to Dr. Michael Ketterer on March 24, 2017. Dr. Ketterer transported the samples back to his lab in Denver, Colorado where he performed ICP analysis to determine the arsenic concentrations of each digest. Dr. Ketterer's results can be seen in Appendix G.

4.4.1 XRF and ICP Correlation of Arsenic

As mentioned in the SAP, in order to use XRF data in a screening level risk assessment, it must be confirmed by ICP analysis with a correlation of 0.7 or greater. Table 4-2 shows the arsenic concentrations found by both XRF and ICP analysis.

Table 4-2. XRF vs. ICP Arsenic Concentrations

Sample ID	XRF (mg/kg)	ICP (mg/kg)	Relative Percent Difference (%)
2	151	2980	181
11	521	1120	73
13	383	2090	138
30	581	410	35
36	982	181	138
37	1372	2340	52
39	51	4910	196
41	261	614	81
49	124	1940	176
58	2090	762	93
60	1213	939	25
62	2720	370	152
69	753	704	7
HS1	456	1820	120

Figure 4-7 displays the data and what the ideal correlation should be. It is clear by comparing the concentrations in Table 4-2 and viewing the graph, there is no significant correlation between the XRF and ICP data. The ICP data were double checked by Dr. Ketterer and confirmed, so it can be considered a more accurate representation of the arsenic concentrations in AZ Magma's soil.
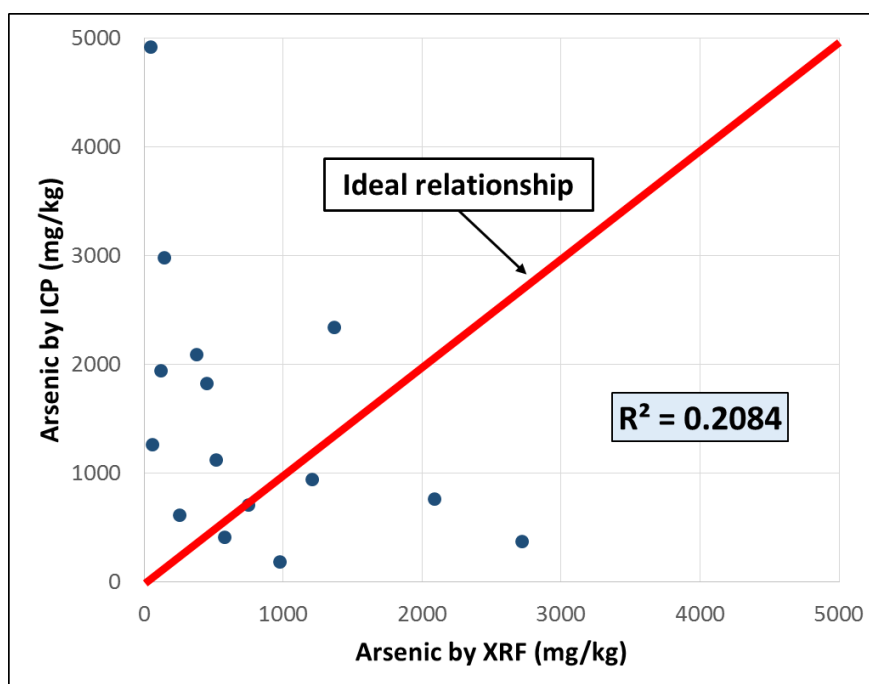
Figure 4-7. XRF and ICP Correlation

Figures 4-8 and 4-9 show GIS maps of arsenic concentrations determined by XRF and ICP.
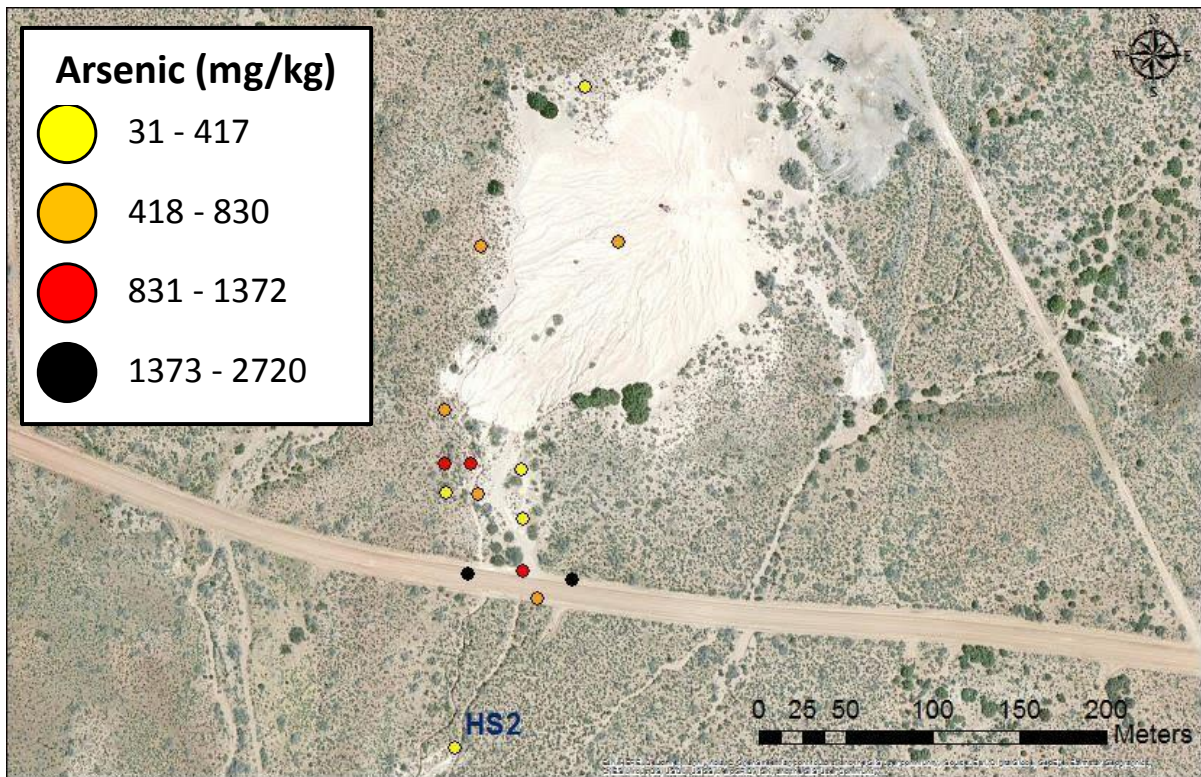
Figure 4-8. XRF Arsenic GIS Map of Samples chosen for ICP
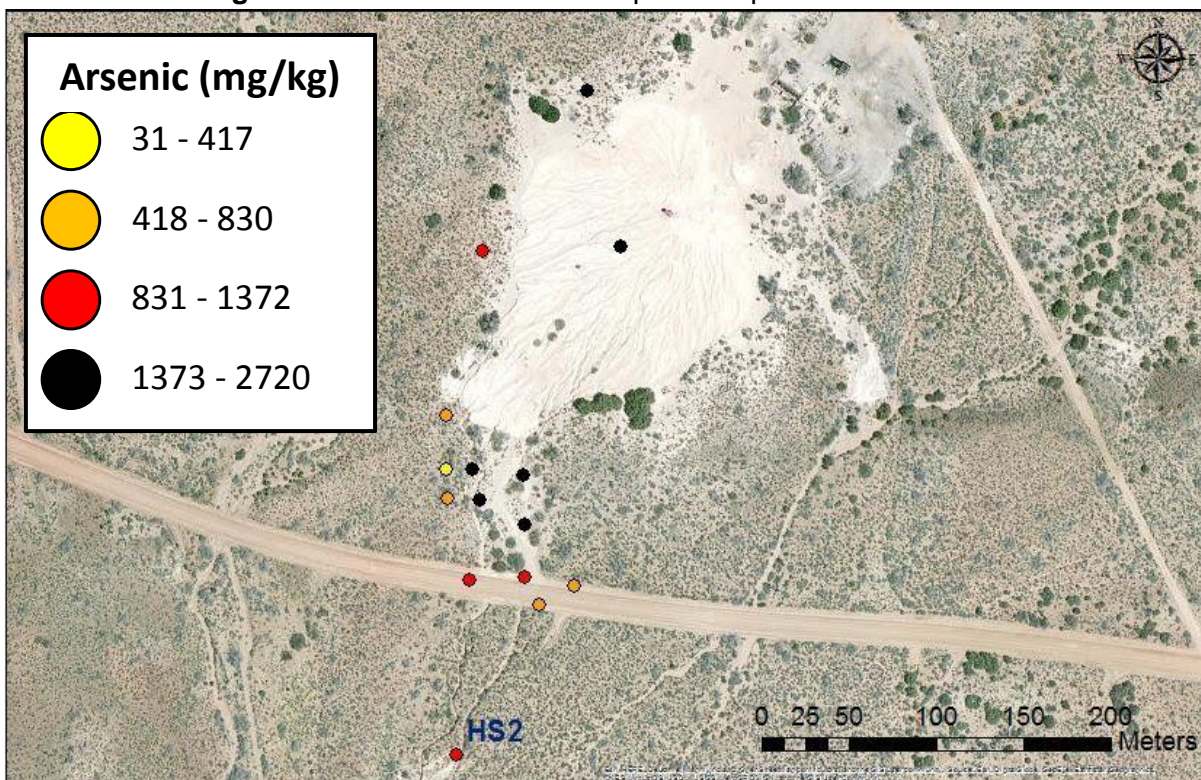
Figure 4-9. ICP Arsenic GIS Map

As the ICP results are more accurate than the XRF results, Figure 4-9 shows a more realistic view of the site. The ICP data shows a more logical trend of higher concentrations in the tailings pile and a gradual decrease further away from the tailings pile. The samples taken in the road are still well above the residential standard as well, which may directly impact those who live close to the mine.

4.4.2 Potential Causes for XRF Inaccuracy

For arsenic, the other BLM team performed similar XRF and ICP analyses. However, the other BLM team's correlation between XRF and ICP was nearly perfect. Because of this, potential problems within Magma Consulting's analysis had to be considered.

One possible cause for XRF inaccuracy is soil moisture. As detailed in Section 3.0, the soils were sampled during intense rain and sleet and were excessively wet before analysis began. However, this should not have impacted the results significantly as Magma Consulting dried the samples for 24 ± 2 hours. In addition, soil moisture typically results in XRF readings that are lower than the actual concentrations. This is not accurate for Magma's data, as some samples the XRF read as low were actually high (sample 39) and some the XRF read as high were actually low (sample 62). There is no consistent trend, so soil moisture is most likely not the cause.

Another possible cause for XRF inaccuracy is soil homogeneity. The larger the particle size, the fewer the X-rays will hit the sample resulting in possibly skewed data. Again, this should not have impacted the results because all samples were sieved to finer than a #60 sieve. Although a deviation was made by sieving to a #35 sieve, only one of these samples was chosen for ICP analysis and removing it from the data set does not improve the correlation. In fact, removing all deviations (6 samples sieved to #35 down or 3 XRF shots) from the data set does not improve the correlation, suggesting Magma Consulting's deviations are not the problem.

The last possible cause is also the most probable: spectral interference within the soil. It is possible that high concentrations of manganese, vanadium, and even iron might skew XRF data due to their similar wavelengths to arsenic. As manganese and vanadium were above residential soil remediation standards, those concentrations might be considered high enough to impact the XRF. For the BLM's consideration, the average concentration of iron in the soil samples was 17,066 mg/kg. Also, when compared to the other BLM team, they did not have high concentrations of these metals, so spectral interference would not have occurred for their samples.

Despite the poor correlation between the XRF and ICP data, Magma Consulting completed a screening level risk assessment for arsenic, manganese, and vanadium. Although the arsenic concentrations may not be accurate, the ICP data still shows concentrations of arsenic above the non-residential and residential remediation standards, suggesting this site is still a risk.

5.0 Screening Risk Assessments

5.1 EPA's Risk Assessment Technique

The EPA has standard approaches for both human and ecological risk assessment. The subsections below describe the process for both risk assessment techniques.

5.1.1 Human Health Risk Assessment

The following four-step procedure outlined by the EPA was used to characterize human health risk (EPA B):

- Planning
- Step 1: Hazard Identification
- Step 2: Dose-Response Assessment
- Step 3: Exposure Assessment
- Step 4: Risk Characterization

5.1.1.1 Planning

The AZ Magma Mine is located about 2 miles from Chloride, Arizona, and about 20 miles from Kingman, Arizona. Surrounding populations are at risk of being exposed to fugitive dust as well as potential ingestion of mine tailings. As of 2014, Chloride has a population of 197 (Table 5-1). As of 2014, Kingman has a population of 28,201 (Table 5-1).

Table 5-1. Population Distribution Data for Chloride, AZ and Kingman, AZ
(USA A, USA B)

Age Group	Chloride, AZ	% of Total in Chloride	Kingman, AZ	% of Total in Kingman
Under 5	6	3.05%	1779	6.31%
5 – 9	0	0%	1346	4.77%
10 – 14	0	0%	1880	6.67%
15- 19	7	3.55%	1661	5.89%
20 - 24	6	3.05%	1702	6.04%
25 - 34	0	0%	3245	11.51%
35 – 44	5	2.54%	2962	10.50%
45 – 54	7	3.55%	4254	15.08%
55 – 64	51	25.89%	3300	11.70%
65 – 74	83	42.13%	3281	11.63%
75 – 84	0	0%	1831	6.49%
85 and Over	32	16.24%	960	3.40%
Total	197	100%	28201	100%

Adults in Chloride are the primary group at risk, with 96.95% of the population falling into this category. The remaining 3.05% are children. Adults in Kingman are the primary group at risk, with 82.25 % of the population falling into this category. The remaining 17.75% are people under the age of 15. No medical data for people living near the site was found.

This risk assessment was conducted quantitatively for soil ingestion, but qualitatively for air inhalation. This is because there is insufficient data to compute dust contaminant concentrations in the air. In addition, this risk assessment did not consider drinking water exposure because water sampling was excluded from the project.

5.1.1.2 Hazard Identification

As identified by the chemical analysis, the contaminants of concern on the AZ Magma Mine are arsenic, manganese, and vanadium. Arsenic exposure may cause the following carcinogenic and non-carcinogenic health effects (WHO):

- Cancer (skin, bladder, lung)
- Nerve damage
- Cardiac disease
- Birth defects

Oral exposure to arsenic may cause non-carcinogenic health impacts, while oral, drinking water, and inhalation exposure may lead to carcinogenic health effects (EPA E). Manganese, unlike other contaminants, is considered a toxic micronutrient (Lenntech A). Manganese exposure may cause the following non-carcinogenic health effects:

- Birth defects
- Nerve damage
- Glucose intolerance

Oral and inhalation exposure to manganese may cause non-carcinogenic health effects (EPA F). Manganese is considered to be non-carcinogenic in humans. Vanadium exposure may cause the following non-carcinogenic health effects (Lenntech B):

- Cardiac and vascular disease
- Nerve damage
- Skin rash
- Kidney and liver bleeding
- Behavioral change

Oral exposure to vanadium can cause non-carcinogenic health effects. Table 5-2 shows the Arizona Soil Remediation Standards for arsenic, manganese, and vanadium.

Table 5-2. Arizona Soil Remediation Standards (ASOS, 2017)

Contaminant	Residential Level (mg/kg)	Non-residential Level (mg/kg)
Arsenic	10	10
Manganese	3300	3200
Vanadium	78	1000

Table 5-3 below shows the contaminant concentrations present at the AZ Magma Mine.

Table 5-3. Average and Maximum Concentrations at Site

	Arsenic		Manganese		Vanadium	
Concentration	Avg	Max	Avg	Max	Avg	Max
(mg/ kg)	939	3752	3205	6152	85	151

Average contaminant concentrations were determined using a function in Excel that computed the 50th percentile. Maximum contaminant concentrations were determined using a function in Excel that computed the 95th percentile. Arsenic concentrations are reported using ICP values, while manganese and vanadium data are reported using XRF values.

Under an average exposure scenario, arsenic and vanadium exceed the Arizona Soil Remediation Standards, but manganese does not. However, under a maximal exposure scenario, arsenic, manganese, and vanadium exceed the Arizona Soil Remediation Standards. Therefore, this site is considered hazardous for people who come in contact with the soil.

5.1.1.3 Dose-Response Assessment

Table 5-4 shows the dose-response data for arsenic, manganese, and vanadium.

Table 5-4. Dose-response Data
(EPA E, F, & G)

	Non-carcinogenic		Carcinogenic		
	RfD [mg/(kg*day)]	RfC [mg/(kg*day)]	Oral slope factor [mg/(kg*day)]$^{-1}$	Drinking water unit risk (ug/L)$^{-1}$	Inhalation Unit Risk (ug/m3)$^{-1}$
Arsenic	3.00e-4	Not assessed under IRIS	1.5	5.00e-5	4.30e-3
Manganese	1.40e-1	5.00e-5	Not assessed under IRIS		
Vanadium	9.00e-3	Not assessed under IRIS	Not assessed under IRIS		

Toxicity scores are values used to rank the risk that a contaminant poses solely based on maximum concentration as well as reference dose/slope factor (LaGrega, Buckingham, and Evans). Toxicity scores independent of each other do not reflect how toxic a contaminant is. Rather, toxicity scores are used to rank contaminants from greatest to least risk. Equation 5-1 and Equation 5-2 are used to assess the toxicity of non-carcinogens and carcinogens (LaGrega, Buckingham, and Evans).

Equation 5-1: *Non-carcinogens*

$$TS = Cmax/RfD$$

TS = toxicity score
Cmax = maximum concentration
RfD = reference dose

Equation 5-2: *Carcinogens*

$$TS = SF * Cmax$$

SF = slope factor (carcinogen potency factor)

Table 5-5 shows the non-carcinogenic and carcinogenic toxicity scores for arsenic, manganese, and vanadium.

Table 5-5. Toxicity Scores

Toxicity Score	Arsenic	Manganese	Vanadium
Non-carcinogenic	1.25E+7	4.39E+4	1.68E+4
Carcinogenic	5628	N/A	N/A

Based on Equations 5-1 and 5-2, arsenic poses the greatest non-carcinogenic risk while vanadium poses the lowest non-carcinogenic risk.

This is because vanadium is found at the lowest concentrations. Manganese and vanadium are not considered carcinogens. Therefore, a carcinogenic toxicity score was not computed for either chemical.

5.1.1.4 Exposure Assessment

Five exposure scenarios have been developed for this site. They are: residential, recreational day use (off-roading), recreational camping, visiting, and remediation worker. Three populations were considered for the risk assessment. They are: adult, child aged 6 – 12, and child aged 2 – 6.

It is assumed under the residential scenario that adults are exposed for 350 days of the year and 30 years for a total of 10500 days. For children aged 6 – 12, it is assumed that they are exposed for 350 days of the year and 6 years for a total of 2100 days. For children aged 2 – 6, it is assumed that they are exposed for 350 days of the year and 4 years for a total of 1400 days. This is because it is assumed that they take a 2 week vacation every year.

It is assumed under a recreational day use scenario that users are on the site for 4 hours per month. It is assumed that adults uses the site for ten years resulting in a total exposure duration of 20 days. It is assumed that children aged 6 – 12 use the site for 6 years resulting in a total exposure duration of 12 days. It is assumed that children aged 2 – 6 use the site for 4 years resulting in a total exposure duration of 8 years.

It is assumed under a recreational camping exposure scenario that users are on site for 40 hours per year. In addition, it is assumed that the people camping use the site once in their lives. Therefore, the total exposure duration for them is 1.67 days.

Under a visiting scenario, it is assumed that adults would visit family and friends in Chloride for 15 days per year and for a total of 30 years. This results in an exposure duration of 450 days. It is assumed that children aged 6 – 12 visit family and friends for 15 days per year for 6 years resulting in a total exposure duration of 90 days. It is assumed that children aged 2 – 6 visit family and friends for 15 days per year for 4 years resulting in a total exposure duration of 60 days.

It is assumed that the remediation worker works for 8 hours per day, 5 days per week, 50 weeks per year, for a total of 1 year. In addition, it is assumed that the worker is given 2 weeks of vacation. Therefore, the total exposure duration for the remediation worker is 83.33 days. The remediation worker is assumed to be an adult only.

Table 5-6 shows the exposure duration and exposure frequency for each exposure scenario.

Table 5-6. Exposure Durations and Frequencies

	Residential	Recreational day use	Recreational camping	Visiting	Remedial Worker
Exposure Frequency (days/year)	350	4 hr/month	40 hr/year	15	8 hr/day
Adult Exposure Duration (years)	30	10	1	30	1
Child aged 6 – 12 Exposure Duration (years)	6	6	1	6	-
Child aged 2 – 6 Exposure Duration (years)	4	4	1	4	-

Chronic daily intake is computed assuming soil ingestion only. No risk calculations are computed for inhalation exposure. In addition, this risk assessment excludes drinking water as an exposure scenario. Chronic daily intake is computed assuming an average contaminant exposure (50th percentile of concentration data), and maximal contaminant exposure (95th percentile of concentration data).

Equation 5-3 is used to calculate chronic daily intake (CDI) (LaGrega, Buckingham, and Evans).

Equation 5-3: *Chronic daily intake*

$$I = C*CR*EF*ED/(BW*AT)$$

I = intake (milligram soil/kilogram of bodyweight - day)
C = concentration at exposure point (milligram of contaminant/kg soil)
CR = contact rate (mg/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = bodyweight (kg)
AT = averaging time (days)

Table 5-7 shows the average contact rate and body weight of adults, children aged 6 - 12, and children aged 2 - 6 for soil (LaGrega, Buckingham, and Evans).

Table 5-7. Average Body Weight and Ingestion Rates for Adults and Children

Parameter	Adult	Child aged 6-12	Child aged 2-6
Body weight (kg)	70	29	16
Soil ingestion rate (mg/day)	100	100	200

Averaging time for non-carcinogens is taken as the exposure duration, while averaging time for carcinogens is 70 years (LaGrega, Buckingham, and Evans). Table 5-8 shows non-carcinogenic chronic daily intake values.

Table 5-8. Chronic Daily Intake for Non-carcinogenic Risk Calculations

		Arsenic			Manganese			Vanadium		
	Exposure	Adult	Child aged 6 - 12	Child aged 2 - 6	Adult	Child aged 6 - 12	Child aged 2 - 6	Adult	Child aged 6 - 12	Child aged 2 - 6
Residential	Avg	1.29e-3	3.10e-3	1.13e-2	4.39e-3	1.06e-2	3.84e-2	1.16e-4	2.81e-4	1.02e-3
	Max	5.14e-4	1.24e-5	4.50e-2	8.43e-3	2.03e-2	7.37e-2	2.07e-4	4.99e-4	1.81e-3
Recreational day use	Avg	7.35e-6	1.77e-5	6.43e-5	2.51e-5	6.06e-5	2.20e-4	6.65e-7	1.61e-6	5.82e-6
	Max	2.94e-5	7.09e-5	2.57e-4	4.82e-5	1.16e-4	4.21e-4	1.18e-6	2.85e-6	1.03e-5
Recreational camping	Avg	6.13e-6	1.48e-5	5.36e-5	2.09e-5	5.05e-5	1.83e-4	5.54e-7	1.34e-6	4.85e-6
	Max	2.45e-5	5.91e-5	2.14e-4	4.01e-5	9.69e-5	3.51e-4	9.85e-7	2.38e-6	8.62e-6
Visiting	Avg	5.51e-5	1.33e-4	4.82e-4	1.88e-4	4.54e-4	1.65e-3	4.99e-6	1.20e-5	4.37e-5
	Max	2.20e-4	5.32e-4	1.93e-3	3.61e-4	8.72e-4	3.16e-3	8.86e-6	2.14e-5	7.76e-5
Remedial Worker	Avg	3.06e-4	-	-	1.05e-3	-	-	2.77e-5	-	-
	Max	1.22e-3	-	-	2.01e-3	-	-	4.92e-5	-	-

Table 5-9 shows the carcinogenic chronic daily intake values.

Table 5-9. Chronic Daily Intake for Cancer Risk Calculations

		Arsenic		
	Exposure	Adult	Child aged 6 - 12	Child aged 2 - 6
Residential	Avg	5.51e-4	2.66e-4	6.43e-4
	Max	2.20e-3	1.06e-3	2.57e-3
Recreational day use	Avg	1.05e-6	1.52e-6	3.68e-6
	Max	4.20e-6	6.08e-6	1.47e-5
Recreational camping	Avg	8.75e-8	2.11e-7	7.66e-7
	Max	3.50e-7	8.44e-7	3.06e-6
Visiting	Avg	2.36e-5	1.14e-5	2.76e-5
	Max	9.44e-5	4.56e-5	1.10e-4
Remedial Worker	Avg	4.38e-6	-	-
	Max	1.75e-5	-	-

5.1.1.5 Risk Characterization

Non-carcinogenic risk and carcinogenic risk are considered incremental. Unlike other risks, non-carcinogenic and carcinogenic risk increases over time with repeated exposure. Carcinogenic risk was assessed using Equations 5-4.

Equation 5-4: *Carcinogenic risk* (LaGrega, Buckingham, and Evans)

$$Risk = I * SF$$

Equation 5-4 shows the risk of excess lifetime cancer due to exposure to the specified chemical. The regulatory goal for excess cancer risk is 1 in a million (10^{-6}) (LaGrega, Buckingham, and Evans). However, for the purposes of this site, an acceptable cancer risk was defined as 1 in 10,000 people.

Equation 5-5 is used to calculate non-carcinogenic risk (LaGrega, Buckingham, and Evans).

Equation 5-5: *Non-carcinogenic risk* (LaGrega, Buckingham, and Evans)

$$HI = I/RfD$$

$HI = hazard\ index$

Hazard indices cannot simply be added together to calculate cumulative hazard index. If possible, they should be summed up by an organ specific basis. A hazard index below 1.0 is deemed acceptable (LaGrega, Buckingham, and Evans). However, for the purposes of this risk assessment, the risk calculations do not discriminate between organs. Therefore, individual hazard indices were summed to compute a cumulative hazard index.

Table 5-10 shows the hazard indices for each exposure scenario and contaminant. Hazard indices greater than 1.0 are highlighted in yellow.

Table 5-10. Hazard Indices

		Manganese HI			Vanadium HI		
	Exposure	Adult	Child aged 6 - 12	Child aged 2 - 6	Adult	Child aged 6 - 12	Child aged 2 - 6
Residential	Avg	0.031	0.076	0.274	0.013	0.031	0.113
	Max	0.060	0.145	0.527	0.023	0.055	0.201
Recreational day use	Avg	0.000	0.000	0.002	0.000	0.000	0.001
	Max	0.000	0.001	0.003	0.000	0.000	0.001
Recreational camping	Avg	0.000	0.000	0.001	0.000	0.000	0.001
	Max	0.000	0.001	0.003	0.000	0.000	0.001
Visiting	Avg	0.001	0.003	0.012	0.001	0.001	0.005
	Max	0.003	0.006	0.023	0.001	0.002	0.009
Remedial Worker	Avg	0.007	-	-	0.003	-	-
	Max	0.014	-	-	0.005	-	-
		Arsenic HI			Cumulative HI		
	Exposure	Adult	Child aged 6 - 12	Child aged 2 - 6	Adult	Child aged 6 - 12	Child aged 2 - 6
Residential	Avg	4.288	10.350	37.517	4.332	10.457	37.904
	Max	17.132	41.354	149.909	17.215	41.554	150.637
Recreational day use	Avg	0.025	0.059	0.214	0.025	0.059	0.217
	Max	0.098	0.236	0.857	0.098	0.237	0.861
Recreational camping	Avg	0.020	0.049	0.179	0.020	0.049	0.181
	Max	0.082	0.197	0.714	0.082	0.198	0.718
Visiting	Avg	0.184	0.444	1.608	0.186	0.448	1.625
	Max	0.734	1.772	6.425	0.738	1.780	6.457
Remedial Worker	Avg	1.021	-	-	1.031	-	-
	Max	4.079	-	-	4.098	-	-

Table 5-11 shows the arsenic cancer risk for each exposure scenario. Cancer risks greater than 1 in 10,000 are highlighted in yellow.

Table 5-11. Cancer Risk

	Exposure	Adult	Child aged 6 - 12	Child aged 2 - 6	
Residential	Avg	8.27e-4	3.99e-4	9.65e-4	**Arsenic Cancer Risk**
	Max	33.0e-4	16.0e-4	38.5e-4	
	Avg	8	4	10	**People in 10000 at risk**
	Max	33	16	39	
Recreational day use	Avg	0.015e-4	0.022e-4	0.055e-4	**Arsenic Cancer Risk**
	Max	0.063e-4	0.091e-4	0.220e-4	
	Avg	0	0	0	**People in 10000 at risk**
	Max	0	0	0	
Recreational camping	Avg	0.001e-4	0.003e-4	0.012e-4	**Arsenic Cancer Risk**
	Max	0.005e-4	0.0127e-4	0.046e-4	
	Avg	0	0	0	**People in 10000 at risk**
	Max	0	0	0	
Visiting	Avg	0.354e-4	0.171e-4	0.413e-4	**Arsenic Cancer Risk**
	Max	1.42e-4	0.68E-4	1.65e-4	
	Avg	0	0	0	**People in 10000 at risk**
	Max	1	1	2	
Remedial Worker	Avg	0.066e-4	-	-	**Arsenic Cancer Risk**
	Max	0.026e-4	-	-	
	Avg	0	-	-	**People in 10000 at risk**
	Max	0	-	-	

5.1.1.6 Non-cancer Risk Interpretation

Individually, manganese and vanadium do not contribute a significant amount to the hazard indices. Under a residential exposure scenario, all exposed populations are at risk due to arsenic exposure (average and maximum). Children aged 2 – 6 are at the greatest risk, while adults are at the lowest risk. No recreational exposure scenarios put any exposed populations at non-carcinogenic risk. Under a visiting scenario, children aged 6 -12 exposed maximally to arsenic are at risk, while children aged 2 – 6 exposed to arsenic (average and maximum) are at risk. Remedial workers are at risk strictly due to arsenic exposure (average and maximum).

5.1.1.7 Cancer Risk Interpretation

Under a residential exposure scenario, all exposed populations (average and maximum) are at risk of developing cancer due to arsenic exposure. Children

aged 2 – 6 are at the greatest risk, while children aged 6 -12 are at the lowest risk. This is because a children aged 6 – 12 weigh more than children aged 2 – 6, but are exposed for a shorter period of time than adults. No recreational exposure scenarios put exposed populations at an elevated cancer risk. Under a visiting scenario, all populations are at risk if exposed maximally to arsenic. A child aged 2 – 6 is at the greatest risk. Remedial workers are not at an elevated risk of cancer under average or maximal exposure.

5.1.2 Ecological Risk Assessment

The following four-step procedure outlined by the EPA was used to characterize human health risk (EPA C, 2015):

- Planning and Scoping
- Problem Formation (Phase I)
- Analysis (Phase II)
- Risk Characterization (Phase III)

5.1.2.1 Planning and Scoping

The contaminants of concern on-site are arsenic, manganese and vanadium. No wildlife with the exception of an unidentified bird were at the site during the sampling trip. Unidentified animal foot prints and droppings were also observed on site. Flora could be identified on site based off photographs. However, fauna were identified using online sources.

The primary source of contaminants are the uncapped mine tailings. However, background concentrations for arsenic were found to be high. Therefore, background arsenic also poses a risk to the flora and fauna. As the contaminants are found in the soil phase, soil ingestion presents the primary exposure route for the wildlife on site. In addition, wildlife are also at risk of inhaling contaminated soil. Plants on site are assumed to uptake arsenic, manganese, and vanadium. Therefore, plant ingestion presents an additional exposure scenario for wildlife on site.

Data were insufficient in order to quantitatively determine harmful dosages for each contaminant. Therefore, this risk assessment is presented qualitatively.

5.1.2.2 Mammalian Contaminant Exposure Symptoms

Arsenic exposure in mammals can cause the following health effects (EPA D):

- cancer
- embryo malformation (teratogen)
- mutations
- fatigue
- gastrointestinal disease
- neuropathy
- skin lesions
- skin cancer
- anemia.

The EPA did not specify the animals that these symptoms were expressed in.

Manganese exposure in mammals can cause the following health effects (EPA D):

- brain chemical alterations
- gastric irritation,
- delayed testicular development,
- low birth weights
- behavioral changes
- muscular weakness

The EPA did not specify the animals that these symptoms were expressed in.

Vanadium exposure in mammals can cause the following health effects (Domingo):

- reproductive and developmental toxin
- decreased fertility
- embryolethality
- fetotoxin
- teratogen

Vanadium toxicity data was taken from tests conducted on rats, mice, and hamsters.

5.1.2.3 Bird Contaminant Exposure Symptoms

Arsenic exposure in birds can cause the following health effects (EPA D):

- blood-cell damage
- gut-blood vessel destruction
- slowness
- jerkiness
- seizures
- growth and behavioral problems
- immobility

The EPA did not specify the animals that these symptoms were expressed in. However, these symptoms are known to occur in birds of prey such as the barn owl and sparrow hawk (Koivula).

Toxicological studies suggest that arsenic tolerance in birds depends on the species.

Manganese exposure in birds can cause the following health effects (EPA D):

- decreased hemoglobin
- anemia
- reduced growth

The EPA did not specify the animals that these symptoms were expressed in.

Vanadium exposure in birds can cause the following health effects (Koivula):

- histopathological changes in mallards and geese found in intestine, kidney, heart, and liver.
- Blood chemistry changes
- intestinal hemorrhaging
- liver lesions
- kidney congestion found in chronic exposure
- diminished egg production
- altered metabolic rates

Vanadium toxicity data was taken from studies conducted on mallards and Canada geese.

5.1.2.4 Reptile Contaminant Exposure Symptoms

No toxicological data was found for reptile exposure to arsenic, manganese, or vanadium. However, contaminant exposure data were found for desert tortoises. Arsenic exposure in desert tortoises has been associated with diseased tortoises (Berry, 2001). Exosore to arsenic may cause shell disease, mycoplasmosis, and upper respiratory tract disease. Manganese and vanadium has been found in elevated in ill or dying tortoises (Homer, 1996). However, no data was present to indicate what health effects these contaminants have on desert tortoises. Desert tortoises are considered completely herbivorous in the wild (Arizona Game and Fish). However, they are known to ingest soil and stones (Esque, 1991). Desert tortoises are at risk of arsenic exposure due to ingestion and inhalation (Berry, 2001). In addition, desert tortoise habitats extend into and near mining sites.

5.1.2.5 Plant Contaminant Exposure Symptoms

Arsenic exposure in plants can cause the following health effects (EPA D):

- wilting
- chlorosis
- browning
- dehydration
- mortality
- light activation inhibition

The EPA did not specify the plants that these symptoms were expressed in.

Manganese exposure in plants can cause the following health effects (Fernando):

- possibly disrupts photosynthetic electron flow in chloroplasts, may depend on light availability
- photo-oxidative stress
- may compete with other cations in metabolism and transport. Can cause nutrient deficiencies.

Light and temperature may impact manganese toxicity in plants. The manganese toxicity data was not specific to any plants.

There are no indications that vanadium exposure under natural conditions is toxic to plants (USGS). However, under laboratory conditions, vanadium exposure is toxic to germinating seeds, can cause extreme chlorosis and dwarfing. As little as 0.5 ppm may be toxic to plants in nutrient solutions.

5.1.2.6 Problem Formation

Table 5-12 shows the plants and animals being considered for the ecological risk assessment.

Table 5-12. Plants and Animals Native to Mohave Desert
(Planet Oz Kids, Pollen Library)

Mammals	Birds	Reptiles	Plants
Coyote	Raven	Desert tortoise*	Creosote bush
Jackrabbit	Hummingbird	Rattlesnake	Yucca
Cougar	Red-tailed hawk	Desert horned-lizard	
*Note: The desert tortoise is considered an endangered species.			

Because plants are considered primary producers, they are considered to be at a lower risk. Herbivorous animals are considered to be at medium risk. Animals at high trophic levels are considered to be at the greatest risk. This is because there is potential for contaminants to bioaccumulate (Newman, 2010). However, trophic studies consistently show little evidence for biomagnification of metals and metalloids. In spite of this, some studies have found evidence for arsenic biomagnification. Table 5-13 outlines the trophic position that each plant and animal occupy.

Table 5-13. Trophic Level for Plants and Animals
(Journey North, Fauser, CK-12, Desert Tortoise, HLCS, Sammi)

Primary Producer	Yucca	Creosote	-	-	-
Primary Consumer	Hummingbird	Desert tortoise	-	-	-
Secondary Consumer	Rattlesnake	Jackrabbit	Coyote	Raven	Desert horned-lizard[1]
Tertiary Consumer	Red-tailed hawk	Coyote[2]	Cougar	-	-
1. Trophic position of the desert horned-lizard was estimated					
2. Coyotes may occupy the trophic level of secondary or tertiary consumer.					

5.1.2.3 Analysis and Risk Characterization

Due to insufficient data availability, a quantitative analysis and risk characterization cannot be completed. However, minimal plant life was found growing on the tailings pile. This indicates that the contaminants found in the tailings are hazardous to plant life. Because the desert tortoise is listed as

endangered, it is suggested that remediation efforts are aimed at preserving its habitat.

For the purposes of this risk assessment, it is assumed that arsenic poses the greatest risk to wildlife due to its high concentration and limited potential for trophic transfer. Manganese and vanadium are considered to pose a risk to wildlife. However, they are not assumed to biomagnify. Therefore, manganese and vanadium pose a risk to wildlife strictly due to contaminant exposure.

For the purposes of this risk assessment, tertiary consumers are considered to be at the greatest risk due to arsenic biomagnification. In addition, the desert tortoise is considered to be at the highest risk as well. This is because the desert tortoise is considered an endangered species, not because of its trophic position. Secondary consumers (rattlesnake, jackrabbit, coyote, raven, desert horned-lizard) are considered at high risk due to arsenic biomagnification. The hummingbird is a primary consumer, meaning that it is at medium risk due to minimal arsenic biomagnification. The primary consumers (creosote bush, yucca) are considered to be at low risk because there is no potential for them to be exposed to biomagnified arsenic.

6.0 Summary and Conclusions

Using the Work Plan as a guide, Magma Consulting took samples from the AZ Magma Mine and analyzed them using XRF and ICP analysis to determine possible contaminants of concern. These contaminants included arsenic, manganese, and vanadium. For arsenic, a human health risk assessment was completed to reveal the site as a risk to residents of Chloride and visitors near the site. An ecological risk assessment revealed the high levels of arsenic within the soil to be a risk to the desert tortoise, in particular. The XRF data did not correlate with the ICP data.

Magma Consulting recommends further analysis into the site be made. A review of the XRF soil sample data taken by Magma Consulting should be completed to confirm these PA/SI results.

7.0 Project Management

7.1 Project Schedule

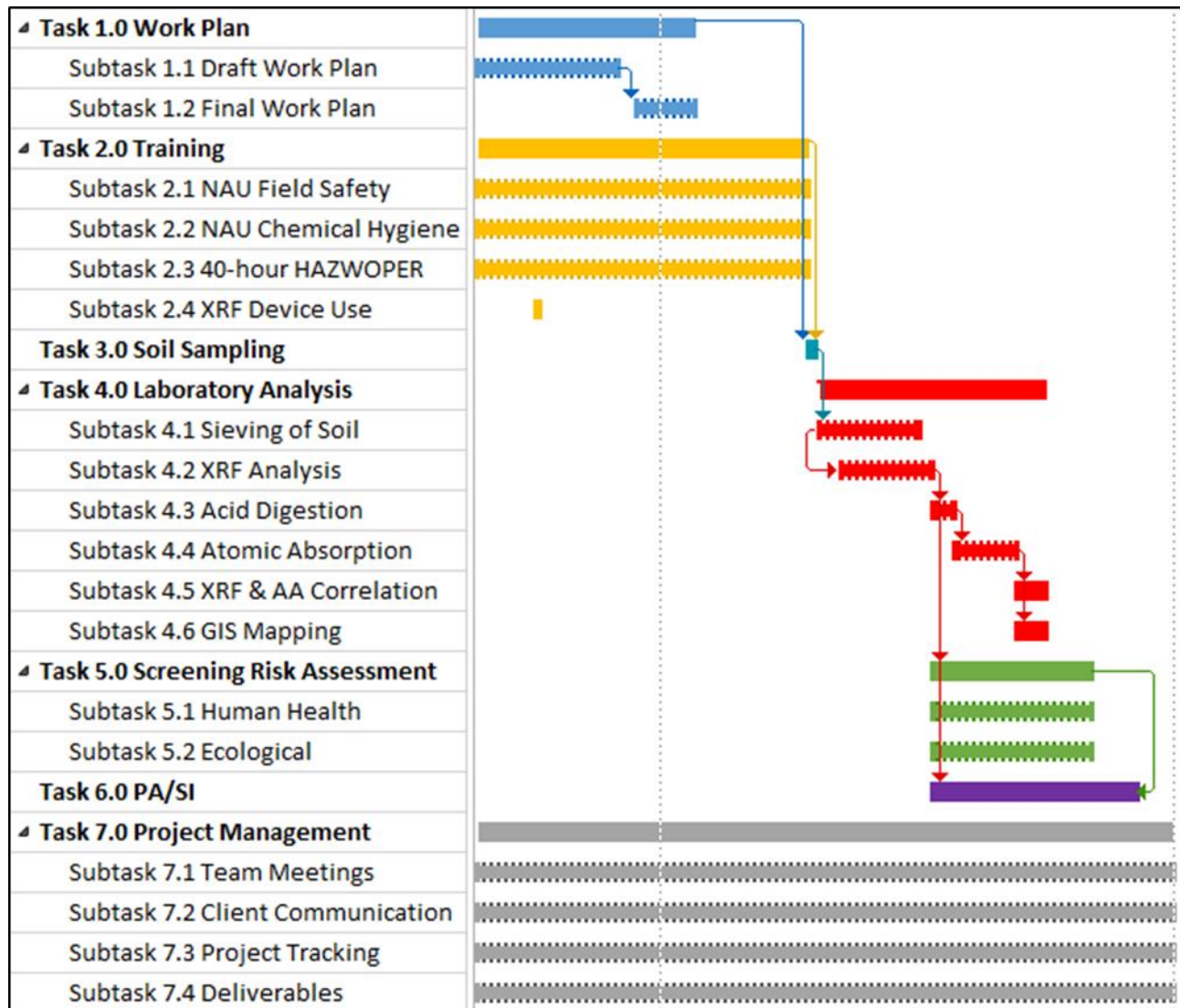The Gantt chart from Magma Consulting's project proposal in December, 2016 is presented in Figure 7-1.

Figure 7-1. Project Proposal Gantt Chart

Table 7-1 provides a comparison between Magma Consulting's projected completion dates and its actual completion dates. Tasks in green were completed ahead of schedule or on-time, while tasks in red were completed after the projected completion date.

Table 7-1. Projected vs. Actual Completion Dates

Task	Projected	Actual
1.0 Work Plan	12/15/2016	12/15/2016
2.0 Training	1/19/2017	1/19/2017
3.0 Soil Sampling	1/21/2017	1/21/2017
4.0 Lab Analysis		
4.1 Drying and Sieving	2/22/2017	2/11/2017
4.2 XRF Analysis	2/26/2017	2/19/2017
4.3 Acid Digestion	3/5/2017	3/4/2017
4.4 ICP Analysis	3/24/2017	4/6/2017
4.5 XRF and ICP Correlation	4/2/2017	4/10/2017
4.6 GIS Mapping	4/2/2017	4/10/2017
5.0 Screening Risk Assessment	4/16/2017	4/19/2017
6.0 PA/SI	4/30/2017	5/9/2017
7.0 Project Management	5/9/2017	5/9/2017

Magma Consulting was late to complete its ICP analysis largely because it had difficulty in finding a laboratory capable of analyzing arsenic. Once the ICP analysis was complete, the team slowly caught back up to its projected schedule.

7.2 Staffing and Cost of Services

Table 7-2 shows Magma Consulting's projected person-hour breakdown of tasks for the project.

Table 7-2. Project Person-Hour Breakdown of Project Tasks

Task	SENG (hrs)	ENG (hrs)	LAB (hrs)	INT (hrs)	ADMA (hrs)
1.0 Work Plan	26	26	-	-	-
2.0 Training	-	-	-	-	-
2.1 Field Safety	-	1	2	1	-
2.2 Chemical Hygiene	-	1	2	1	-
2.3 XRF	-	-	6	6	-
2.4 HAZWOPER	-	40	80	40	-
3.0 Soil Sampling	-	16	32	16	-
4.0 Lab Analysis	-	-	-	-	-
4.1 Sieving of Soil Samples	-	-	60	60	-
4.2 XRF Analysis	-	-	36	36	-
4.3 Acid Digestion	-	-	16	-	-
4.4 AA Analysis	-	-	-	-	-
4.5 XRF vs AA Correlation	-	8	-	-	-
4.6 GIS Mapping	-	8	-	-	-
5.0 Screening Risk Assessment	-	-	-	-	-
5.1 Human Health	20	20	-	-	-
5.2 Ecological Risk	10	10	-	-	-
6.0 PA/SI	22	22	-	-	-
7.0 Project Management	-	-	-	-	-
7.1 Team Meetings	15	15	15	15	15
7.2 Client Meetings	6	-	-	6	6
7.3 Technical Advisor Meetings	7	7	7	7	7
7.4 Website	-	-	-	-	20
7.5 Presentations	6	6	-	6	-
Subtotals	**112**	**180**	**256**	**194**	**48**
TOTAL	**790**				

Table 7-3 shows Magma Consulting's actual person-hour breakdown of tasks for the project. Tasks that required less hours than projected are highlighted in green, tasks that matched the projected hours are not highlighted, and tasks that required more hours than projected are highlighted in red.

Table 7-3. Actual Person-Hour Breakdown of Project Tasks

Task	SENG (hrs)	ENG (hrs)	LAB (hrs)	INT (hrs)	ADMA (hrs)
1.0 Work Plan	22.5	21.5	-	-	-
2.0 Training	-	-	-	-	-
2.1 Field Safety	-	1	1	1	-
2.2 Chemical Hygiene	-	1	1	1	-
2.3 XRF	-	-	6	6	-
2.4 HAZWOPER	-	40	80	40	-
3.0 Soil Sampling	-	20	40	20	-
4.0 Lab Analysis	-	-	-	-	-
4.1 Sieving of Soil Samples	-	-	38.5	35	-
4.2 XRF Analysis	-	-	15	12	-
4.3 Acid Digestion	-	-	35	-	-
4.4 AA Analysis	-	-	-	-	-
4.5 XRF vs AA Correlation	-	7	-	-	-
4.6 GIS Mapping	-	9.5	-	-	-
5.0 Screening Risk Assessment	-	-	-	-	-
5.1 Human Health	2.5	2.5	-	-	-
5.2 Ecological Risk	3	2.5	-	-	-
6.0 PA/SI	12.5	10	-	-	-
7.0 Project Management	-	-	-	-	-
7.1 Team Meetings	1.5	1.5	0	0	1.5
7.2 Client Meetings	0	-	-	0	0
7.3 Technical Advisor Meetings	9.5	9	0	0	8.5
7.4 Website	-	-	-	-	1.5
7.5 Presentations	8.5	7.5	-	5.5	-
7.6 Project Management	-	-	-	-	26.5
Subtotals	**60**	**136**	**156**	**141**	**38**
TOTAL	531				

The primary reason for the differences in Magma Consulting's projected and actual hours is the fact that the team went from 4 people to 3 people in late December, 2016. Nonetheless, the hours per person still fell below the team's projection. This is due to lab analyses, for the most part, taking less time than projected.

Table 7-4 provides a breakdown of Magma Consulting's projected and actual costs for the project.

Table 7-4. Projected vs. Actual Hours and Costs

	Projected Hours	Actual Hours	Projected Cost	Actual Cost
1.0 Personnel				
SENG	112	60	$ 18,816	$ 10,080
ENG	180	136	$ 16,200	$ 12,240
LAB	260	156	$ 17,940	$ 10,764
INT	190	141	$ 5,130	$ 3,807
ADMA	48	38	$ 2,520	$ 1,995
Total Hours	**790**	**531**	**$ 60, 606**	**$ 38,886**
2.0 Subcontracted Analysis			$ 194	$ 233
3.0 Materials			$ 315	$ 392
4.0 Travel			$ 985	$ 985
5.0 Lab Rental			$ 2,400	$ 2,400
Total Project Cost			**$ 64,500**	**$ 42,900**

The actual cost for the project was approximately two-thirds of what was projected. This is due to the large difference in projected and actual hours spent on the project. The cost of all other items were fairly close to what was projected.

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