Tyro Mill PA/SI Report

ACGM. Engineering & Consulting
Est. 2014

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List of Abbreviations

ASTM: American Society for Testing and Materials
BLM: Bureau of Land Management
COC: Contaminant of Concern
CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act of 1980
GPS: Global Positioning System
LOD: Level of Detection
PPE: Personal Protection Equipment
PPM: Parts Per Million
PA/SI: Preliminary Assessment and Site Investigation
XRF: X-Ray Fluorescence
FAAS: Flame Atomic Absorption Spectroscopy

List of Equations

Acknowledgements

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1.0 Project Introduction

ACGM Engineering has developed this Preliminary Assessment and Site Investigation Report (PA/SI) to provide the Bureau of Land Management with information on the contaminants present on the site, where the current contamination is located on the Tyro Mill site, and information on the potential human health and environmental hazards that these contaminants present for the Tyro Mill site located in Mohave County, Arizona.

The purpose of this report is to provide the Bureau of Land Management with the information to determine if further remediation of the site is necessary based on requirements of the Environmental Protection Agency and the CERCLA process.

1.1 Site Location

Tyro Mill is located at 3°13’ 29.68” N and 114° 27’ 32.22” W and can be accessed from the Katherine Mine Road exit of AZ Highway 68 [1]. Katherine Mine Road turns into an unmarked dirt road at the edge of the existing housing development and the access road to the Tyro Mill site is on the right approximately 3.5 miles down this dirt road. Figure 1-1 shows the Tyro Mill site on a large-scale map of the State of Arizona. Figure 1-2 shows the site located in reference to AZ Highway 68, Katherine Mine Road (and the 3.5 mile dirt extension road), and the access road to the site. Figure 1-3 shows a satellite image of the Tyro Mill Site with the access road and mine tailings repositories labeled.

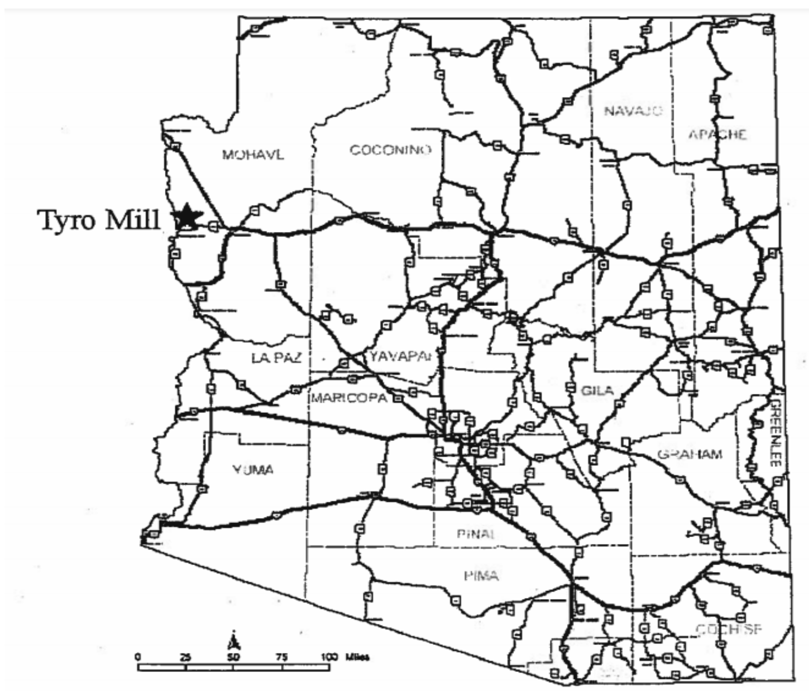

Figure 1-1. Tyro Mill Location on Arizona Map [1].

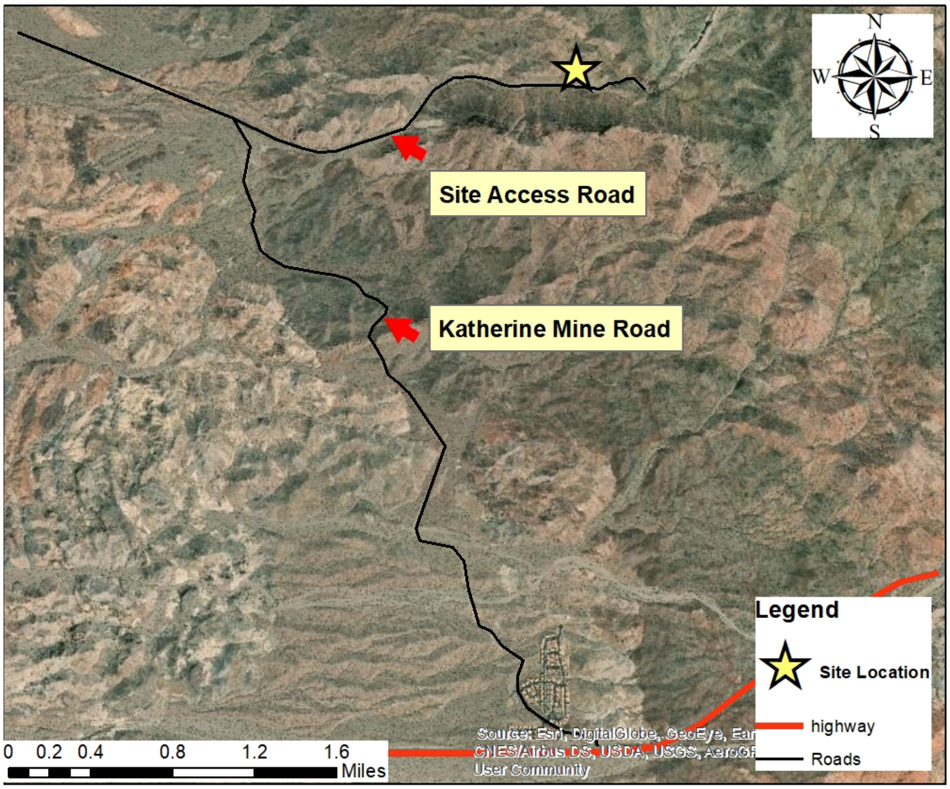

Figure 1-2. Tyro Mill Site Location Showing Route to Site from AZ Highway 68.

1.2 Site Background

Tyro Mill consisted of a cyanide mill that processed precious metal ores (primarily gold and silver) from local mines, the exact start date of the mill is unknown along with the owners/operators of the mill however it is known that the mine never submitted its paperwork to BLM which caused BLM to close down the milling operation in the 1970s [1]. The Tyro Mine and Mill site then continued to operated illegally for approximately 20 years, beginning illegal operations in the early 1980s and was abandoned in 1999 [1]. Figure 1-3 below displays the old Tyro Mill with the labeling and locations of the old buildings and the tailings piles that were in place when the mill was in operation. There were also four tailing ponds that were located in the dry wash and supported by dam embankments which were also constructed of the tailings. Throughout the operation of Tyro Mill these dams and tailings piles were actively eroding. When the mill was abandoned, approximately 70,000 cubic yards of tailings between the four dry ponds were left and all of the buildings were demolished [1].

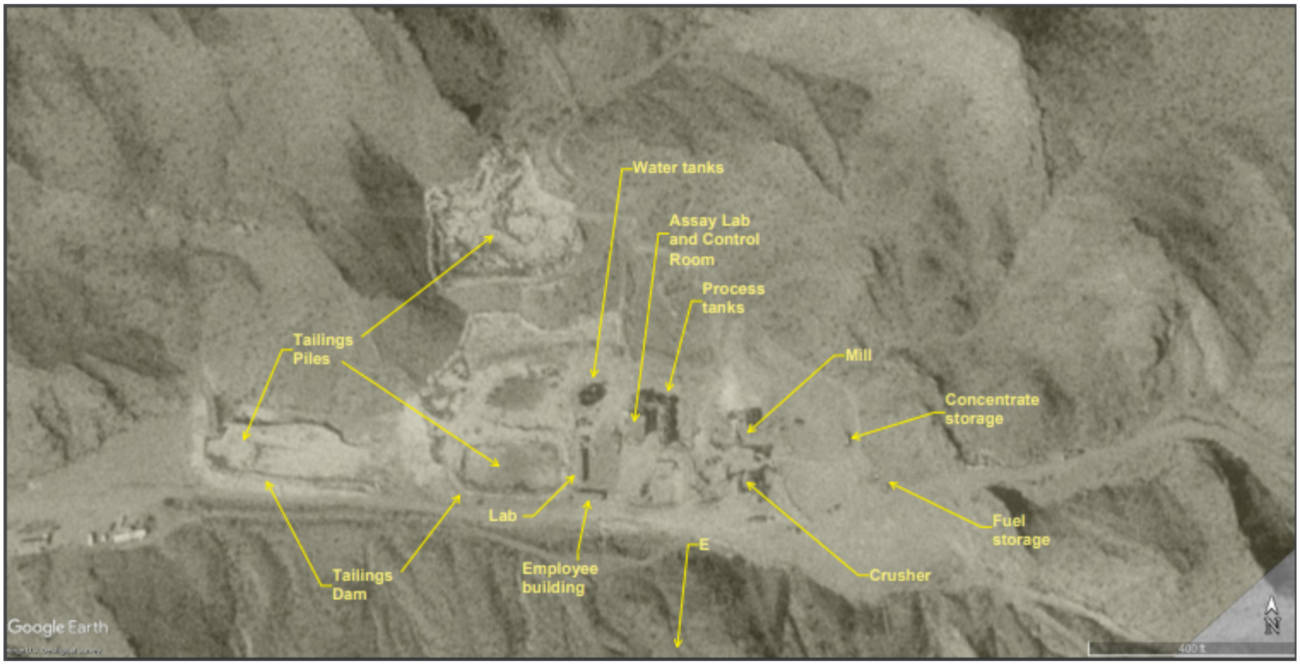

Figure 1-3. Tyro Mill Historic Operations [1]..

A repository to contain the mine and mill tailings was constructed by Red J Environmental in 2004 to contain the leftover mine tailings on the site [1]. The cover of the repository that contains the mine tailings is held in place by large boulders. Some of these boulders have been moved, allowing the mine tailings to escape from the repository. Figure 1-4 shows the site in its current condition.

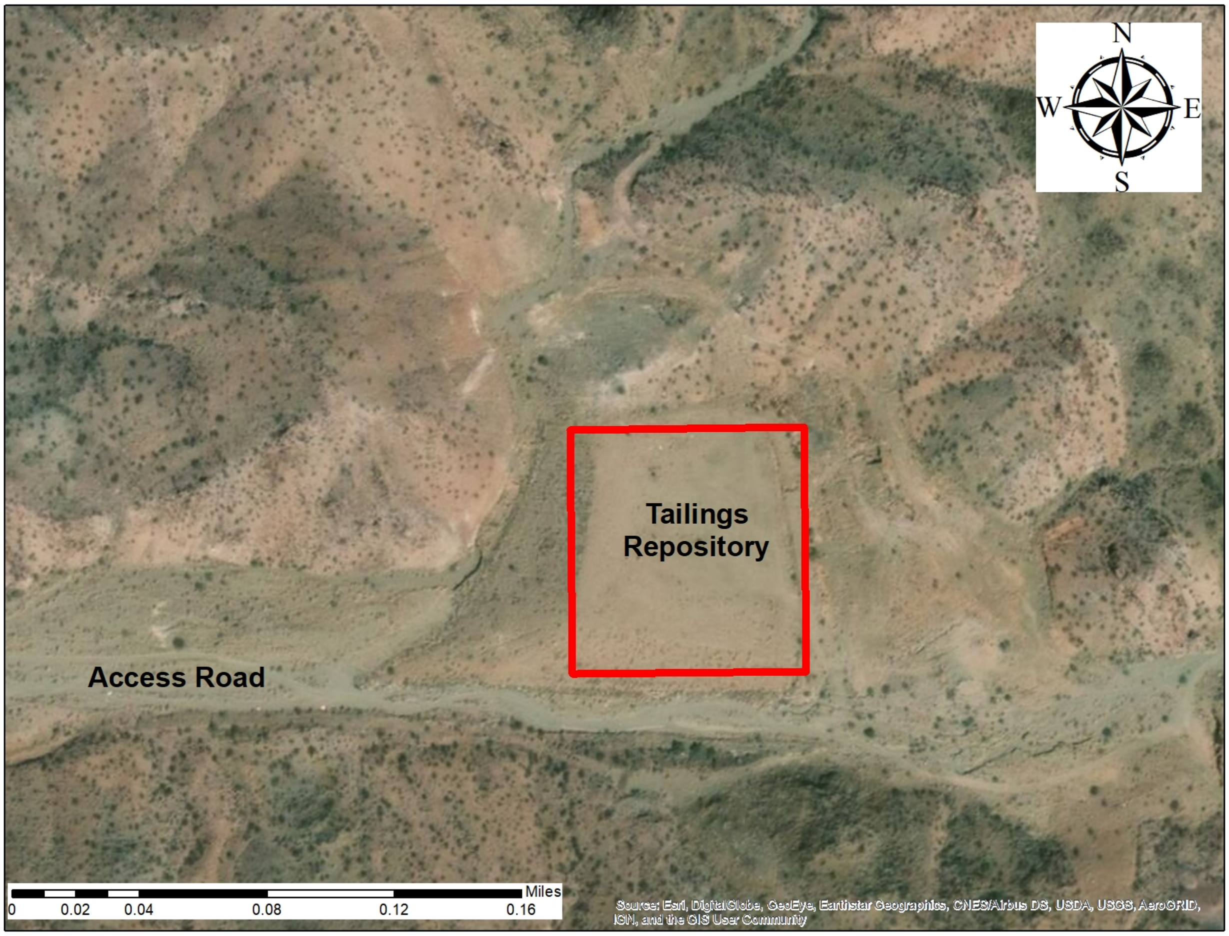

Figure 1-4. Tyro Mill Site Hap Highlighting Site Access Road and Mine Tailing Repository.

The repository is also being affected by erosion. These conditions have allowed the contaminants of concern found in the mine tailings to migrate around the site and be carried off site along the nearby access road. Sampling was done on site in April of 2018 by BLM where elevated levels of uranium, arsenic, copper, nickel, manganese, and antimony were discovered near the access road to the west of the repository [2].

The sampling results from the April 2018 sampling event performed by BLM can be seen in Table 1-1. The red sections in Table 1-1 indicate a non-residential exceedance of the AZ Remediation Standards and yellow indicates a concentration between the Residential and Non-Residential Soil Remediation Standards [3]. The location of the nine soil samples collected during the sampling event can be seen in Figure 1-4 (note that no scale was provided for the figure).

Table 1-1. XRF Samples with Exceedances from April 2018 Sampling Event [3].

Reading No	Time	Site	Latitude	Longitude	U	U Error	As	As Error	Cu	Cu Error	Ni	Ni Error	Mn	Mn Error	Sb	Sb Error
381	4/13/18 1	Tyro Mill	35.22511	-114.4596	<LOD	151.46	<LOD	87.66	13440.75	817.98	24717.64	1133.52	2341.07	689.09	126.82	41.43
382	4/13/18 1	Tyro Mill	35.22519	-114.4601	301.95	71.58	180.07	45.57	23249.77	621.16	39557.13	836.88	2849.13	456.19	4179.94	637.77
383	4/13/18 1	Tyro Mill	35.22518	-114.4603	453.42	91.76	129.36	53.8	28977.64	782.98	52754.04	1078.74	3789.62	578.02	39772.89	6309.97
385	4/13/18 1	Tyro Mill			<LOD	300000	160.71	25.44	8100.91	225.79	13017.14	302.58	1606.86	160.92	416.78	50.02
386	4/13/18 1	Tyro Mill					0.011	0.002	0.616	0.019	1.026	0.026	0.132	0.016	<LOD	0.008
387	4/13/18 1	Tyro Mill	35.22407	-114.4610	275.37	74.48	67.03	40.99	24115.28	642.76	42397.95	875.26	2822.97	466.89	1660.16	248.03
388	4/13/18 1	Tyro Mill	35.22393	-114.4613	378.4	100.69	194.88	58.71	32453.7	865.64	58117.01	1186	2747.87	571.95	1925.38	356.72
389	4/13/18 1	Tyro Mill					0.004	0.002			1.366	0.039	0.113	0.018	<LOD	0.009
390	4/13/18 1	Tyro Mill	35.22426	-114.4619	149.09	54.57	118.73	33.41	16420.65	445.82	29259.8	610.95	2332.11	354.22	196	59.57
394	4/13/18 1	Tyro Mill	35.22405	-114.4623	215.85	61.05	122.16	37.63	18973.83	508.56	34260.5	699.2	2479.15	383.23	259.35	69.36
395	4/13/18 1	Tyro Mill	35.22400	-114.4632	234.94	60.66	169.22	40.03	18586.7	505.67	32635.55	688.81	3410.19	429.33	501.21	94.74
396	4/13/18 1	Tyro Mill	35.22394	-114.4634	191.82	48.13	103.43	29.5	14496.71	392.13	26250.74	540.1	2219.68	319.44	181.63	55

Figure 1-5. Nine Sampling Locations Conducted by the BLM in 2018 [3].

2.0 Work Plan

Prior to the start of sampling or analysis, a Work Plan was prepared. The Work Plan is comprised of a Sampling and Analysis Plan (SAP) and a Health and Safety Plan (HASP) which details the work and methods that were used throughout the completion of the Tyro Mill PA/SI project. The Work Plan can be viewed in Appendix A.

3.0 Field Work

Over a 2 day period, January 25th and 26th of 2019, the Tyro Mill team and three interns from ACGM Engineering went to the site to collect soil samples. The weather on site for both days was clear skies with some cloud cover with temperatures in the mid 60 degrees Fahrenheit with slight to no wind. Upon arrival at the site, the ACGM Engineering team discovered that the outer liner of the repository has been exposed due to erosion. The liner on the southern edge of the repository near the road on the base was visible, pictures of the exposed liner can be viewed below in Figure 3-1 and in Appendix B.

Figure 3-1. Exposed Line Visible near Southern Edge of Repository.

Also, a small shooting range has been set up on the northwest corner of the repository. The shooting range presents a potential for lead contamination at the site which would not be due to the tailings. The area is frequently used for recreation activities such as camping which was indicated by a fresh fire pit found at the site and a regular traffic of off-roading vehicles and ATVs.

Per the Work Plan, 80 grid samples were to be taken along with three background samples and hotspot samples as needed. All grid samples were approximately 100 feet apart as displayed in figure 3-1. Once on site, the team broke up into three different groups, having two groups grid out the different points using flag markers and the other team following behind collecting the one gallon soil samples. The two teams flagging the points used a 300 feet tape measure to measure out the proper distance (100 ft) between each of the flags in the North, East, South and West directions as detailed on the sampling map. Each sample point was marked using a handheld GPS unit when the sample was taken.

Figure 3-2 shows the sampling map including any adjustments made while in the field. Samples that were not collected due to location restrictions have been marked with a red "X". The samples that were not collected are as follows:

- TM_G1
- TM_G2
- TM_G16
- TM_G24
- TM_G25
- TM_G26
- TM_G33
- TM_G34
- TM_G35
- TM_G36

The deviation from the Work Plan was due to the locations of the above sampling points. Once on site it was determined that the listed sample points were not within site boundaries due to their location on the mountain slopes east of the repository and were located in unimpacted native area. The steep slopes of the mountain sides also proved the points to be difficult to reach, and thus the Technical Advisor for ACGM Engineering decided to remove the points from sampling.

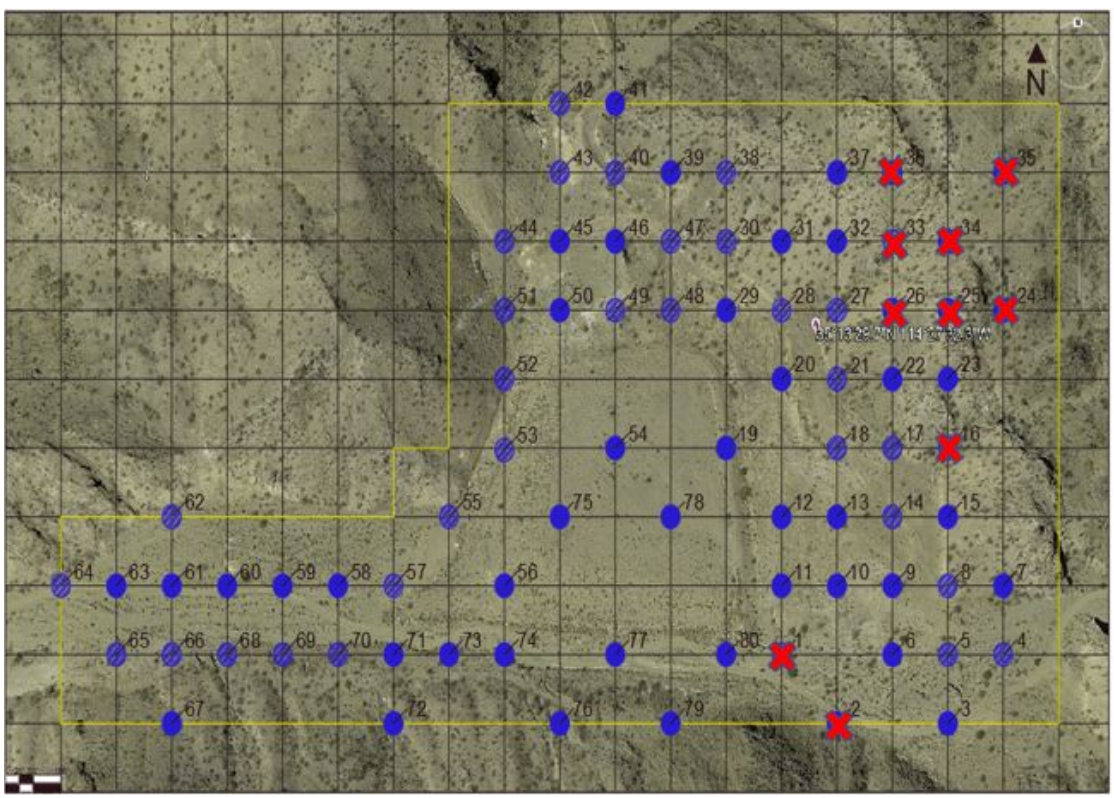

Figure 3-2. Sampling Map with Exclusions.

Each member of ACGM Engineering wore the proper personal protection equipment (PPE) as stated in the HASP within the Work Plan. Each member wore latex gloves, and proper clothing (long pants, hiking shoes, sunglasses, and hats); latex gloves were changed when taking each sample to lower the risk of cross contamination. Handheld GPS units were used to mark the location of each point. On the site the safety officer determined that the use of hazmat suits or dust masks would not be necessary. Once all points had been flagged, two teams were formed for the completion of the sampling and one member remained at the van to work sample control. Each sampling team noted the following information for each sample take:

- Sample Number
- Time
- GPS Coordinates
- Soil Type, Appearance, and Color
- Sampler

While in the field, a total of 5 hotspot samples and 3 background samples were collected, resulting in a total of 78 soil samples with aid from the TA. Hotspot samples were taken at locations where large amounts of tailings could be visibly seen and background samples were taken at locations that were in areas of similar soils, but undisturbed and sufficiently far from the site to not be impacted. The locations of the hotspots and background samples can be viewed on Figure 3-3.

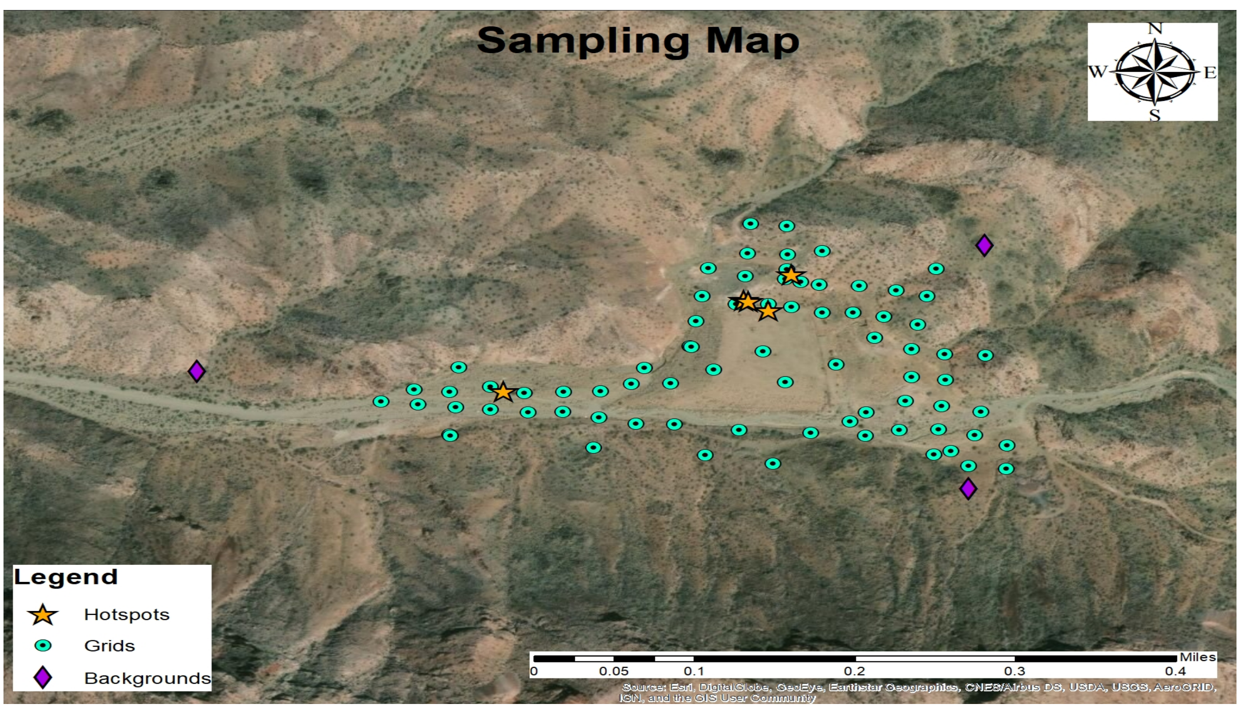

Figure 3-3. Final Sampling Map.

All images taken during the sampling event of the Tyro Mill site can be viewed in Appendix B.

Field and Laboratory notes taken by ACGM Engineering during sampling and analysis can be viewed in Appendix C. Each sample was collected in a one gallon Ziploc bag and labeled using the following layout: [Tyro Mill_Type-Number]. The type of sample was determined as Grid, Hot-Spot or Background sample. Surveying flags were placed in each individual soil sample bag for further identification of specific locations. The sample location will be noted in the field notes.

Example label for a grid sample: TM_G#

Example label for a hotspot sample: TM_H#

Example label for a background sample: TM_B#

Soil samples were stored in four plastic tubs that contained an official ACGM Engineering chain-of-custody. For the two day sampling event two members of ACGM Engineering were assigned as QA/QC officers. The officers were in charge of documentation, packing, and storing the collected soil samples. Each soil sample was documented on a chain-of-custody form and stored in one of the four plastic tubs. Samples were transported to the Northern Arizona University Environmental Engineering facilities.

4.0 Testing and Analysis

4.1 Drying

Drying of the soil samples was completed using ASTM 2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. The drying of the samples was completed in the Materials Lab within the Engineering Building at Northern Arizona University (NAU).

PPE was worn by the team while working in the lab and with the soils and all containers were clearly marked to identify the samples.While the samples were drying in the oven a sign was also posted to warn others of the potential toxicity of the samples. Pictures of the drying process can be viewed in Appendix C.

Figure 4-1. Samples Drying in the Materials Oven.

4.2 Sieving

Sieving of the samples was completed using ASTM C136 Standard Test Methods for Sieve Analysis of Fine and Coarse Aggregates, modified to use a #40 sieve instead of a #60 sieve to have enough present in the sieved sample to analyze. This deviation from the Work Plan was determined by the technical advisor and agreed upon by the client. The sieving of the samples was completed in the Materials Lab within the Engineering Building at NAU.

PPE was worn by the team while working in the lab and with the soils and all containers were clearly marked to warn others of the potential toxicity of the samples. Refer to the SAP in Appendix A of the Work Plan for details on how the lab space and materials were decontaminated. Pictures of the sieving process can be viewed in Appendix C.

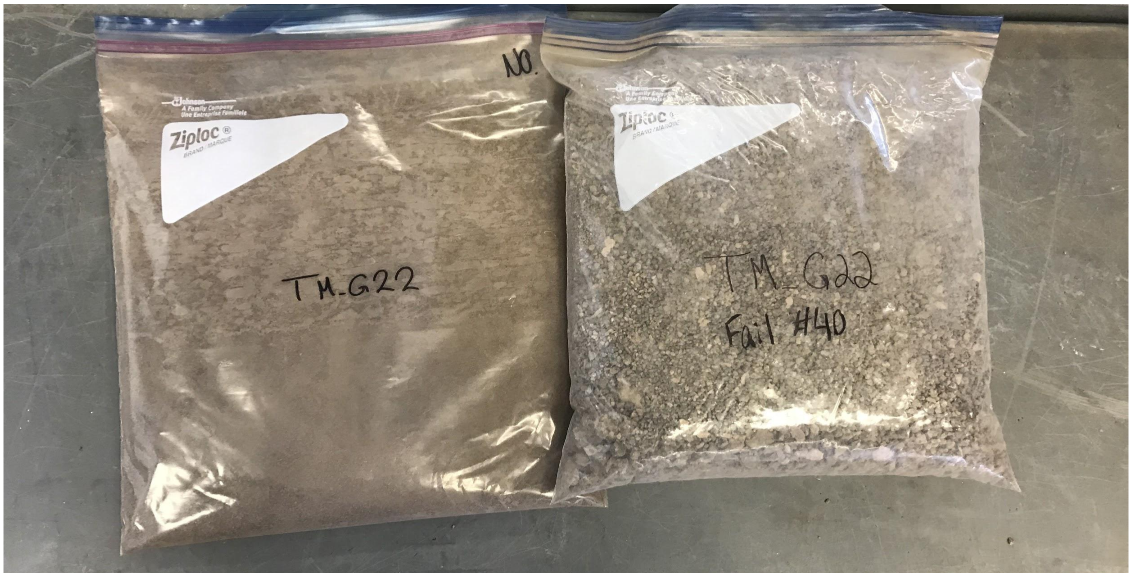

Figure 4-2. Soil Sample with Pass #40 (Left) and Fail #40 (Right).

4.3 X-Ray Fluorescence Analysis

X-Ray Fluorescence (XRF) analysis was completed following EPA Method 6200: Field Portable X-Ray Fluorescence Spectrometry for the Determination of Elemental Concentrations for Soil and Sediment. This method was developed to provide a preliminary identification of elements present in a soil sample to be used in conjunction with additional confirmatory testing. Based on the method, each sample that has passed through the No.40 sieve was be placed into a one gallon Ziploc bag and nine, approximately 1 gram, subsamples were taken using sample cups as seen in Figure 4-3. The XRF analysis of the samples was completed in the Materials Lab within the Engineering Building at NAU.

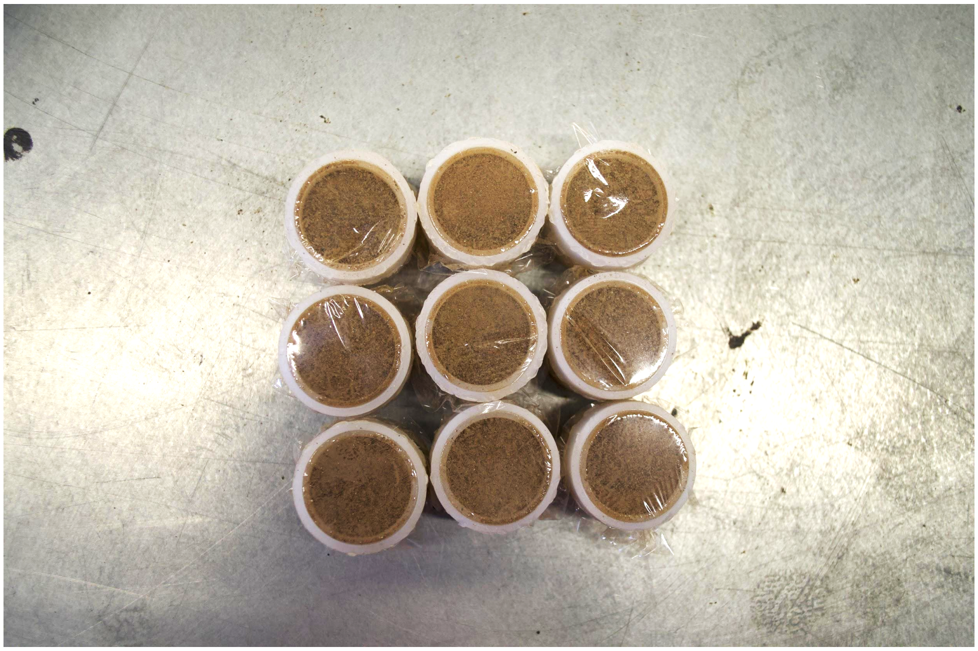

Figure 4-3. Soil Samples Prepared for XRF Analysis Divided into subsamples.

The subsamples were then placed one at a time into the XRF mobile test stand and analyzed with the handheld Thermo Scientific Nikon XL3t GOLDD+ XRF device provided by the BLM. Each sample was shot for a minimum of 90 seconds and the XRF device was calibrated at the beginning and end of each lab session using a provided soil sample from the manufacture with known contaminant levels. If the error in the calibration readings was lower than 20 percent, the XRF was determined to be calibrated and to provide accurate readings.

Once the data from the analysis was downloaded using the Thermo Scientific software, it was converted to an Excel file (the downloaded data will be provided electronically to BLM on a thumb drive). The maximum and minimum readings for each sample set were discarded and the remaining values were averaged for each contaminant. In the event of readings that were below the level of detection (LOD), values were assigned at 50% of the LOD value and were placed in the appropriate cells to average. The LOD levels from the standard reading method (SRM) provided by the manufacture of the XRF were used.

ACGM Engineering selected 20 soil samples to send to Western Technologies Inc. for FAAs analysis. Samples were prepared for shipping in glass containers and stored in an controlled environment until transport. Each glass container was labeled using the same format as described above.

The results of the XRF analysis can be viewed in Appendix D.

5.0 Results and Selection of Contaminants of Concern

5.1 PA/SI Screening Criteria to Determine COCs

The following sections (background threshold values, human health and ecological criteria) were used as the criteria in determining the contaminants of concern (COCs) that were selected.

5.1.1 Background Threshold Values Criteria

Three background samples were taken in the field in areas that were uphill or upstream from the tailings repository. The background samples represent the naturally occurring metals and elements that are present in the area. Using the background concentrations for the area it allowed ACGM Engineering to compare the soil samples that are expected to be contaminated from the tailings pile to the naturally occurring concentrations. If a sample contains a concentration greater than the average background concentration it is determined to be a potential contaminant of concern that will be further evaluated against the Arizona Residential and Non-Residential Soil Remediation Standards as well as the EPA Soil Screening Levels.

5.1.2 Human Health Criteria

Due to the location of Tyro Mill being a rural area with no possibility of development the Arizona non-residential soil remediation standards were primarily used to select the contaminants of concern. The Arizona residential remediation standards were taken into account but due to the nearest residential area being located miles away and fact that the Tyro Mill land will not be developed in the future were not be used in determination of the COCs. If a contaminant exceeds the standards for non-residential it will be determined to be a COC. Table 5-1 below displays a section of the Arizona Soil Remediation Standards.

Table 5-1. Arizona Soil Remediation Standards.

Arizona Soil Remediation Standards		
Contaminant	**Residential (ppm)**	**Non-Residential (ppm)**
Uranium	16	200
Lead	400	800
Arsenic	10	10
Zinc	2300	310000
Copper	3100	41000
Nickel	1600	2000
Manganese	3300	32000
Vanadium	78	1000
Cadmium	39	510
Antimony	31	410
Mercury	6.1	62

5.1.3 Ecological Criteria

In determining the ecological criteria the EPA ecological soil screening levels as displayed in Table 5-2 were used. Using the corrected XRF values is a contaminant exceeded the regulations multiple times it was determined to be an ecological COC.

Table 5-2. EPA Ecological Soil Screening Levels [5].

Ecological Soil Screening Levels in PPM			
Contaminant	**Plants**	**Avian Wildlife**	**Mammals**
Lead	120	11	56
Arsenic	18	43	46
Zinc	160	46	79
Copper	70	28	49
Nickel	38	210	130
Manganese	220	4300	4000
Vanadium	-	7.8	280
Cadmium	32	0.77	0.36
Silver	560	4.2	14
Barium	-	-	2000

5.2 X-Ray Fluorescence

After the analysis of the XRF data, the averaged values for each sample were then corrected using a correlation created with 20 samples that were further analyzed in a third party lab as explained in section 4.3 and compared to the Arizona Residential and Nonresidential Remediation Standards [4] as well as the EPA Ecological Standards [5] to determine the contaminants of concern (COC). Table 5-2 shows the EPA Ecological Soil Screening Levels followed. The COCs for human health were determined using the Non-Residential Arizona Soil Remediation Standards as guidance. The focus was the Non-Residential Standards because the Tyro Mill site will never be developed into a residential area because of its location and the fact that it is owned by the BLM as public land and. As seen in the XRF data, arsenic exceeded the 10 parts per million Non-Residential Standards seen in Table 5-1 a total of 57 times. None of the other contaminants exceeded the Non-Residential Standard, which allowed us to come to the conclusion that arsenic was the only contaminant of concern for the human health risk assessment.

For ecological risk, the COCs were determined by comparing the XRF data to the EPA ecological standards:

- Lead
- Zinc
- Manganese
- Vanadium
- Cadmium

These COCs were chosen based on the tabulated results shown in Table 5-3 which shows how many times the standard for each contaminant was exceeded according to the XRF data. The contaminants not listed in Table 5-3 did not exceed the EPA Ecological Standards.

Table 5-3. Ecological Risk Assessment COC Exceedances.

Number of Samples with Exceedances of Ecological Risk Standards					
Eco. Type	**Pb**	**Zn**	**Mn**	**V**	**Cd**
Birds	43	37	0	65	33
Mammals	1	19	0	0	1
Plants	2	0	61	0	1

5.3 Correlation

While determining the COCs for the human health and ecological risk assessments, the collected XRF data needed to be corrected due to error in the machine. XRF machines are typically used in the field to get a preliminary idea of what contaminants are present at a site, however they are not the most reliable test for determining the actual contaminant concentrations. To better determine the arsenic concentrations on site the following samples were sent to Western Technologies for FAA analysis:

- TM_B1
- TM_B3
- TM_HS1
- TM_HS2
- TM_HS4
- TM_G5
- TM_G8
- TM_G10
- TM_G22
- TM_G37

- TM_G39
- TM_G42
- TM_G43
- TM_G47
- TM_G52
- TM_G63
- TM_G20
- TM_G32
- TM_G77
- TM_G97

The 20 samples chosen represent a range of the XFR results obtained, from high to low concentrations. The data is then plotted as shown in Figure 5-1 in order to find the correction factor to correct the XRF Arsenic results obtained. Figure 5-1 below displays the graphical correlation between the FAA results and the XRF results. The correlation provided an R^2 value of 0.328 and an R value of 0.57.

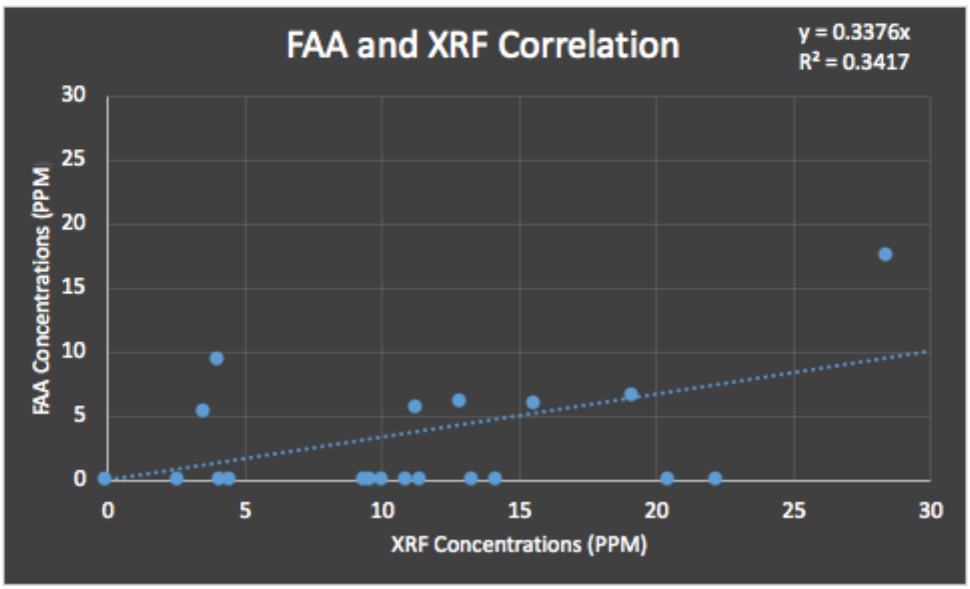

Figure 5-1. XRF and FAA Correlation [6].

The XRF data were then corrected using Equation 5-1 below.

Equation 5-1. XRF Corrected Value Equation Derived from Correlation Data.

$$Corrected\ Value = 0.3376 * XRF\ value$$

The corrected XRF values showed TM_G43 and TM_G78 have exceedances over the Non-Residential AZ Remediation standards for arsenic. Cadmium and Silver concentrations showed one exceedance for each over the Non-Residential AZ Remediation Standard for TM_G57. The location of TM_G57 was near a fire pit with indications of locals camping in the specific area. Pictures of the all sampling locations can be seen in Appendix B.

Figure 5-2. Fire Pit on Site Near TM_G57 Sample.

Arsenic was previously determined to be a COC for human health risk due to several exceedances of the allowable 10 PPM standard set by the Arizona Residential and Non-Residential Soil Remediation Standards found in the corrected XRF data. Figure 5-3 shows the Contaminant Map for Arsenic developed with the Corrected XRF data. As seen in the figure, there were only two samples after correction that exceeded the 10 PPM standard, compared to 57 exceedances before the correction.

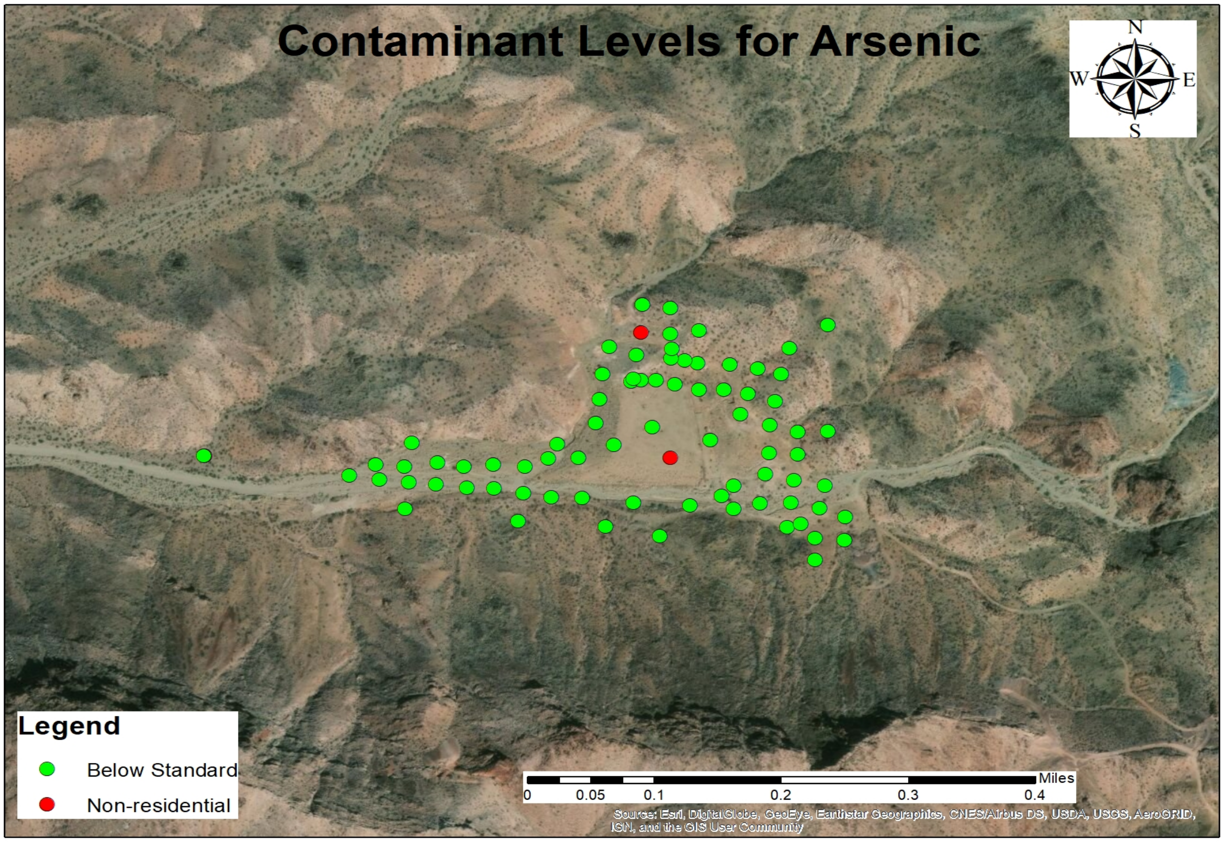

Figure 5-3. Arsenic Contaminant Map with Results of Corrected XRF Data

The sample located on top of the repository is TM_G43 and has a 10.4 ppm arsenic concentration which is slightly above the AZ Residential and Non-Residential standard of 10 ppm. Soil sample TM_G78 is located on the northern edge of the repository with an arsenic concentration of 10.1 ppm, which slightly exceeds the standards.

Refer to Appendix C and Appendix D for field notes and XRF data.

5.4 Determination of EPCs.

The background samples using the corrected XRF values for arsenic are as follows in Table 5-4.

Table 5-4. Background Sample Concentration Arsenic Example.

Sample	Arsenic Concentration (ppm)
TM_B1	3.2
TM_G3*	3.8
TM_B3	4.2
Average	3.7

The values indicate the three samples are representative of the sites naturally occurring elements. If the grid soil samples collected exceed these concentrations it can be determined that the soil at the specific location is contaminated.

The background for each contaminant can be viewed in the raw data in Appendix C.

Sample TM_G3 was designated as a background sample by the guidance of the TA in the field. For determination of the EPCs the background and hotspot values were omitted as they are biased samples. Using the corrected XRF values for arsenic the average concentration of Arsenic was determined to be 4.7 ppm and the standard deviation was 2.35. The relation between corrected XRF data and distribution of concentrations showed a normal distribution. Figure 5-4 below displays the distribution graph of the arsenic concentrations in ppm.

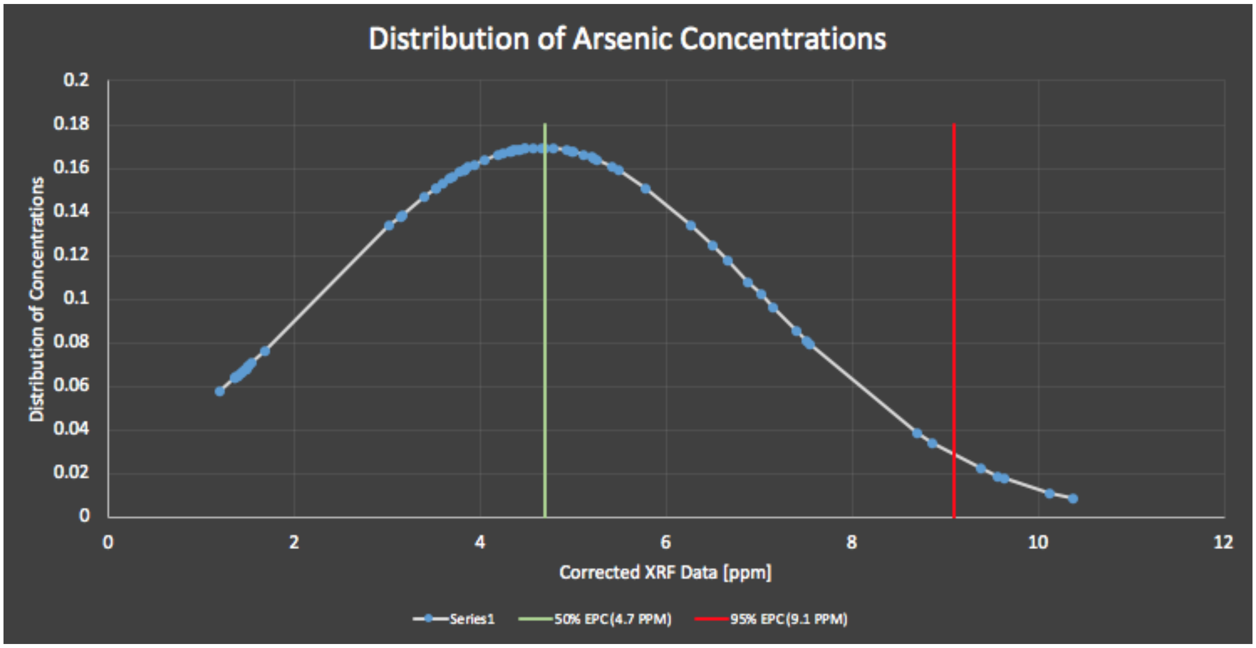

Figure 5-4. Distribution of Arsenic Concentrations [6].

Using the normal distribution ACGM Engineering was able to determine the estimated permissible concentrations at a 50% and 95% confidence interval. The 50% EPC is the mean arsenic concentration and the 95% EPC is two standard deviations above the mean arsenic concentration. The EPC values can be viewed in Table 5-5 below.

Table 5-5. Estimated Permissible Concentrations for 50% and 95% Confidence Level.

Estimated Permissible Concentrations	
50% EPC	4.7 ppm
95% EPC	9.1 ppm

6.0 Risk Assessment

Once the XRF data had been corrected using the correlation equation developed from the outside lab analysis, all COCs were confirmed and the 50% and 95% EPCs were determined, a human health risk assessment was developed. This human health risk assessment consisted of four major parts that will be detailed below in Section 6.1 Human Health Risk Assessment. The corrected XRF data was also used in an Ecological Risk Assessment for several species- both endemic to the area and threatened or endangered- where the contamination found on site was compared to the Ecological Soil Screening Levels as developed by the EPA. The analysis used to determine which local species would be at risk from the contamination at the Tyro Mill site is detailed below in Section 6.2 Ecological Risk Assessment.

6.1 Human Health Risk Assessment

6.1.1 Hazard Identification

The first step of conducting a human health risk assessment includes the identification of the hazards present at the site [8]. The hazard identification for the Tyro Mill site was conducted through the sampling event and analysis of the contaminants present at the site. One human health risk COC was identified (arsenic) at the Tyro Mill site as discussed above through the analysis of the XRF data corrected using the correlation equation explained in Equation 5-1.

When humans are overexposed to arsenic in small amounts it can act as an irritant to the lungs, cause a sore throat, cause nausea or vomiting, decrease production of white blood cells, cause abnormal heart rhythms, damage blood vessels, and cause tingling in the hands or feet. Ingesting low levels of arsenic can also cause darkening of the skin, warts, or sores on the palms or torso. Dermal contact with arsenic can cause redness or swelling of the affected area. The International Agency for Research on Cancer had determined that exposure to inorganic arsenic can have carcinogenic effects, specifically cancer of the lungs, bladder, and liver. In extreme, rare cases, over-exposure to arsenic may be fatal as it is a known human carcinogen (Class A) by the EPA [7].

6.1.2 Dose-Response Assessment

The purpose of the dose-response assessment step of the human health risk assessment is to develop a known relationship between the dose of contaminant being analyzed in the human health risk assessment at which the adverse health effects explained above will occur [8]. For contaminants that have not undergone extensive research relating to dose-response relationships, an outside study would be necessary, however, because arsenic is a commonly-studied contaminant its dose-response assessment has already been conducted by the EPA. The dose-response assessment relationships are recognized by the EPA through the application of Cancer

Slope Factors (CSF) and Reference Doses (RfDs). Using the EPA IRIS tool, the dose-response assessment for arsenic was conducted and the CSF and RfD values necessary to use in Tyro Mill site human health risk assessment were determined. The CSF of arsenic is 1.5 (kg-day/mg) [6]. The units are in relation to body weight (kg) time duration (day) and concentration (mg). The RfD is 3E-4 mg/kg-day [6].

6.1.3 Exposure Assessment

The types of exposure that are analyzed for the human health risk assessment are as follows:

- Oral Ingestion of Soil
- Dermal Contact

One exposure scenario has been identified for this site: a recreational camper scenario using a time duration of 14 days. The 14 day time limit was determined by the state regulation that allows for a person to camp in one spot for a total duration of 14 days at a time.

Residential and worker scenarios will not be considered because the site will never be developed for residential use and there is no need for a worker scenario since the site has already been remediated. Table 6-1 shows the variables accounted for in calculating the chronic daily intake.

Table 6-1. Components of Chronic Daily Intake Equation for Dermal Exposure Scenario [8].

Dermal Contact Exposure		
Variable	**Description**	**Unit**
CDI	Chronic Daily Intake	mg/kg-day
CS	Chemical Concentration in Soil	mg Arsenic/kg soil
CF	Conversion Factor	mg soil/ kg soil
SA	Skin Surface Area available	cm2 skin/event
E	Number of Events	event/exposure
AF	Soil-to-Skin Adherence Factor	mg soil/cm2 skin

ABS	Absorption Factor	Unitless
EF	Exposure Frequency	days/year
ED	Exposure Duration	years
BW	Body weight	kg
AT	Averaging Time	days

Equation 6-1. Chronic Daily Intake Equation for Dermal Contact Exposure Pathway [8].

$$CDI = \frac{CS \times CF \times SA \times E \times AF \times ABS \times ED \times EF \times ED}{BW \times AT}$$

Table 6-2. Pertinent Variables with Corresponding Units for Ingestion Exposure Pathway[8].

Ingestion Exposure		
Variable	**Description**	**Unit**
CDI	Chronic Daily Intake	mg/kg-day
CS	Chemical Concentration in Soil	mg Arsenic/kg soil
IR	Ingestion Rate	mg soil/day
CF	Conversion Factor	mg soil/ kg soil
EF	Exposure Frequency	days/year
ED	Exposure Duration	years

BW	Body weight	kg
AT	Averaging Time	days

Equation 6-2. Chronic Daily Intake Calculation for Ingestion Exposure Pathway [8].

$$CDI = \frac{CS \times IR \times CF \times ED \times EF \times ED}{BW \times AT}$$

Table 6-3. Values Used in Chronic Daily Intake Calculations [7][8][9].

CDI Equation Variables for all Exposure Pathways		
Equation Variable	Value	Units
CS 50 EPC	4.5	mg/kg
CS 95 EPC	9.2	mg/kg
IR (Adult)	100	mg soil/day
IR (child)	200	mg soil/day
CF	0.000001	mg soil/kg soil
EF	14	days/year
ED (adult)	20	years
ED (child)	12	years
BW (adult)	70	kg

BW (child)	33	kg
AT (carcinogen)	25500	days
AT (non-carcinogen)	4380	days
SA	13760	cm2 skin/event
E	4	events
AF	1.45	mg soil/cm2 skin
ABS	0.04	none

Table 6-4 below displays the calculated chronic daily intake values for both children and adult carcinogen and non-carcinogen scenarios using the appropriate CDI equations and the values presented in Table 6-4 for the Ingestion of Soil Exposure Pathway.

Table 6-4. Calculated CDI values for Ingestion Exposure Pathway.

Exposure Type	Dose	CDI
Adult Carcinogen	50 EPC	7.06E-08
	95 EPC	1.44E-07
Adult Non-Carcinogen	50 EPC	2.47E-07
	95 EPC	5.04E-07
Child Carcinogen	50 EPC	1.80E-07
	95 EPC	3.67E-07
Child Non-Carcinogen	50 EPC	1.05E-06

	95 EPC	2.14E-06

Table 6-5 below displays the calculated chronic daily intake values for both children and adult carcinogen and non-carcinogen scenarios using the appropriate CDI equations and the values presented in Table 6-5 for the Dermal Contact Exposure Pathway.

Table 6-5. Calculated CDI Values for Dermal Contact Exposure Pathway.

Exposure Type	Dose	CDI
Adult Carcinogen	50 EPC	2.25E-06
	95 EPC	4.61E-06
Adult Non-Carcinogen	50 EPC	7.87E-06
	95 EPC	1.61E-05
Child Carcinogen	50 EPC	2.87E-06
	95 EPC	5.86E-06
Child Non-Carcinogen	50 EPC	1.67E-05
	95 EPC	3.41E-05

6.1.4 Risk Characterization

To characterize the risk at the Tyro Mill site, the information gathered in the hazard identification, dose-response assessment, and exposure assessment steps is combined to perform a calculation that will predict the risk. Cancer risk (carcinogenic) was determined by multiplying the chronic daily intake value for each exposure scenario by the provided EPA cancer slope factor and the Hazard Index (non-carcinogenic) was determined by dividing the chronic daily intake for each exposure scenario by the EPA reference dose.

Table 6-6 below displays the calculated risk of arsenic by oral ingestion for both adult and child carcinogen and non-carcinogen assessments.

Table 6-6. Results of Human Health Risk Assessment for Ingestion Exposure Pathway.

Oral Ingestion				
Exposure Point Concentrations	Adult Carcinogen	Adult Non-Carcinogen	Child Carcinogen	Child Non-Carcinogen
50 EPC	1.06E-07	8.22E-05	2.70E-07	3.49E-04
95 EPC	2.16E-07	1.68E-04	5.51E-07	7.13E-04

The exposure point concentrations evaluated for oral ingestion exposure route are below the set EPA standards for human health risk. The adult and child carcinogen scenario results are less than one in million. The non-carcinogen for adult and child scenarios show that exposure point concentrations have a hazard index less than 1.0. This indicates that the exposure route for oral ingestion does not pose as a significant threat for human health risk for the Tyro Mill site.

Table 6-7 below displays the calculated risk of arsenic by dermal contact for both adult and child carcinogen and non-carcinogen assessments. The scenario is evaluated over a 14 day recreational exposure.

Table 6-7. Results of Human Health Risk Assessment for Dermal Exposure Pathway.

Dermal Contact				
Exposure Point Concentrations	Adult Carcinogen	Adult Non-Carcinogen	Child Carcinogen	Child Non-Carcinogen
50 EPC	3.38E-06	2.62E-03	4.30E-06	5.57E-03
95 EPC	6.91E-06	5.36E-03	8.80E-06	1.14E-02

The exposure point concentrations for arsenic at 50 and 95 percent do not pose as a significant human health risk for dermal contact exposure. EPA standards indicate carcinogenic risk is present when exposure point concentrations is higher than one in a million and the non-carcinogenic risk is greater than 1.0. The Tyro Mill site is currently safe for locals to occupy the area for recreational activities.

6.2 Ecological Risk Assessment

While on site, ACGM also conducted an ecological survey of the area to determine which plants, insects and animals are at risk to contamination. The following were found or are known to be on site:

- Plants
  - Desert Marigolds
  - Ferocactus gracilis or 'Fire Barrel Cactus'
  - Fickeisen plains cactus
- Insects
  - Mayfly
  - Stonefly
- Animals
  - Wild Burros
  - Bighorn Sheep
  - Hualapai Mexican Vole
  - Mojave Desert Tortoise (Endangered)
- Birds
  - California Condor (Endangered)
  - California Least Tern

It is noted that ACGM Engineering only visibly seen desert marigolds, fire barrel cactus, Fickeisen plains cactus, and fecal matter that could indicate wild burros. The remaining species listed are based on research of known species that are present within the region of the Tyro Mill site [9].

Table 6-8 below displays the COCs and the frequency with which an exceedance of one of the three categories occurred for each identified COC. Each of the five COCs determined for the ecological risk assessment exceeded one of the three categories (birds, mammals, or plants) a significant number of times, meaning a risk to that ecological category is present at the site. Figures 6-1 and 6-2below show some of the plants that were viewed on site.

Figure 6-1. Desert Marigold Located on Site.

Figure 6-2. Fire Barrel Cactus Located On Site.

Table 6-8. Explanation of COCs Selected for Ecological Risk Assessment.

Number of Samples with Exceedances of Ecological Risk Standards					
Eco. Type	**Pb**	**Zn**	**Mn**	**V**	**Cd**
Birds	**43**	**37**	**0**	**65**	**33**
Mammals	**1**	**19**	**0**	**0**	**1**
Plants	**2**	**0**	**61**	**0**	**1**

The ecological risk that is present for the birds, mammals and plants discussed above can be qualitatively determined using the information presented in Table #. The average lead concentration for the soil samples was 19 ppm, with the highest lead concentration recorded at 252 ppm for TM_G50 located on the northern edge of the repository. Lead contamination at the Tyro Mill site presents a risk to birds like the California Condor and the California Least Tern. Zinc had an average concentration of 60 ppm with the highest concentration reported at 151 ppm for TM_G78 located on top of the repository. Zinc at the site poses a threat to both birds and mammals found at the site. Manganese has an average concentration of 292 ppm with the highest concentration reporting at 459 ppm for TM_G9 located southeast of the repository. Manganese is a danger to plants like Desert Marigolds and several species of cacti at the site. Cadmium reported an average concentration of 33 ppm with the highest concentration of 57.6 ppm for TM_G55 located west of the repository. Field notes indicate grid sample 55 was near a fire pit. Vanadium reported an average concentrations of 10.8 ppm with the highest concentration at 622 ppm for TM_G57 located at the west end of the site. It is noted that the high concentration is not representative of the other soil samples collected on site. Vanadium and cadmium are a danger to birds found at the site. The ecological risk assessment above presents qualitative data analysis of which identified species may be at risk due to the contamination present at the Tyro Mill site. Reference XRF corrected data for ecological risk assessment to view all soil sample exceedances based on EPA ecological soil screening levels.

7.0 Project Impacts

The following sections address the environmental, social, and economic impacts that are associated with the Tyro Mill site.

7.1 Environmental Impacts

ACGM Engineering identified that erosion is present at the southern edge of the repository cap during the two-day sampling trip. Continuation of the erosion may increase the risk of contamination spreading towards the main access road. The native flora and fauna survey indicate that the identified species may be at risk due to the following COCs: lead, zinc, manganese, vanadium, and cadmium. ACGM engineering recommends that BLM post signs around the repository to restrict target shooting in the area as a preventative measure for additional contamination.

7.2 Social Impacts

The human health risk assessment for ingestion and dermal contact exposure pathways indicate that the Tyro Mill site does not pose a significant risk to recreational users. The current tailings repository is sufficiently containing the contamination on the site with respect to the AZ Non-Residential standards. If the shooting range found on the site continues additional health risk assessments may need to be conducted to ensure contaminant concentrations are below soil standards.

7.3 Economic Impacts

BLM may need to conduct further remediation if the repository liner around the perimeter of the repository were to fail. Five Year reviews may need to be performed in order to monitor health and ecological risk at the site.

8.0 Summary of Engineering Work

The Tyro Mill PA/SI project was originally planned to start at October 31st 2018 and set to finish on May 10th 2019 with a duration of 25 weeks. Along that time frame the tasks required to complete the project were set in order to meet the deadline of the project. Figure 8-1 shows the estimated schedule with each task and the time required to complete. Highlighted in orange is the critical path set for the project.

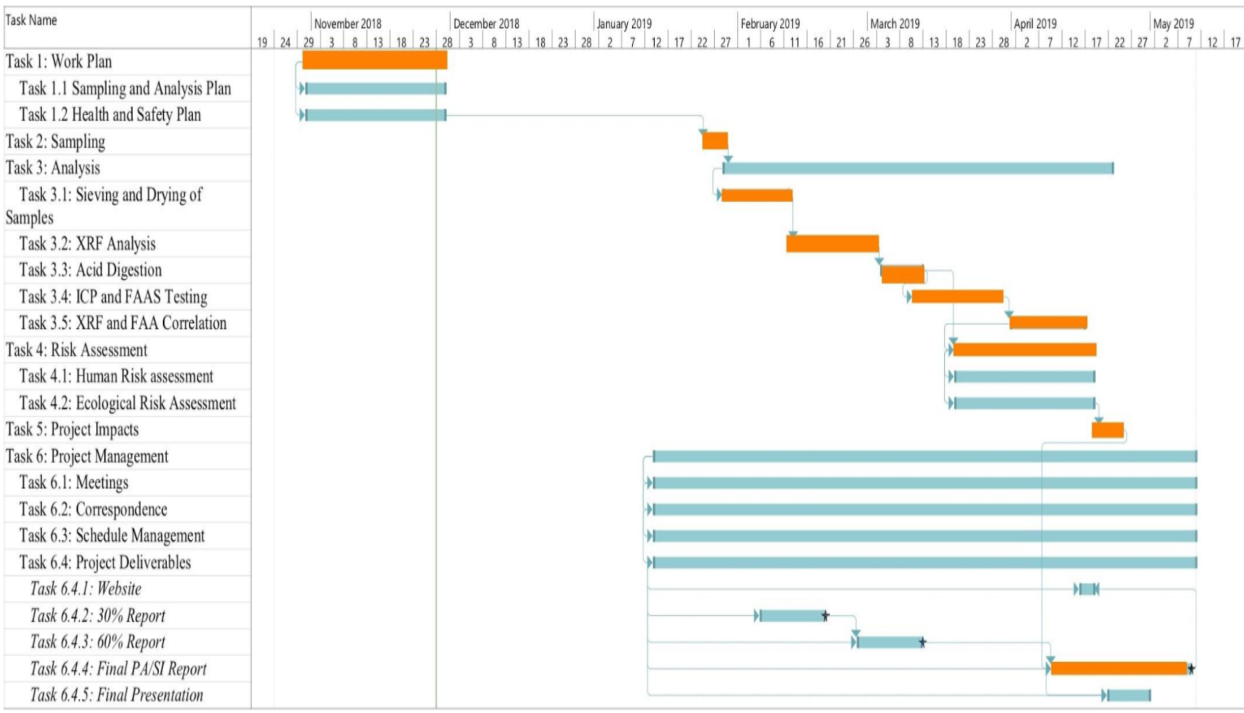

Figure 8-1. Original Gantt Chart for Tyro Mill Project.

Due to changes in NAU's lab usage policy, ACGM team members could not access the NAU Materials Lab at the planned time which caused a delay of about a week to the project. The changes to the policy were made in order to insure the safety of the members accessing the lab. Tasks 3.1 and 3.2 were rescheduled to end at an earlier time, from Feb 6th 2019 for drying and sieving, and Feb 27th 2019 for XRF analysis to Feb 11th 2019 and Mar 1st 2019 on the modified Gantt chart. ACGM team members completed Tasks 3.1 and 3.2 in the new scheduled times. After the completion of Task 3.2, ACGM members determined that Task 3.3 Acid Digestion was no longer required per the guidance of the TA for the completion of the project. With the exclusion of Task 3.3 Acid Digestion ACGM members were able to make up the time that was lost in order to access the Materials Lab and continue progressing with the original times for the rest of the required tasks. Figure 8-2 shows the modified Gantt chart with the updated start and end time for each task, and the removal of Task 3.3 Acid Digestion. Highlighted in orange is the critical path set for the project.

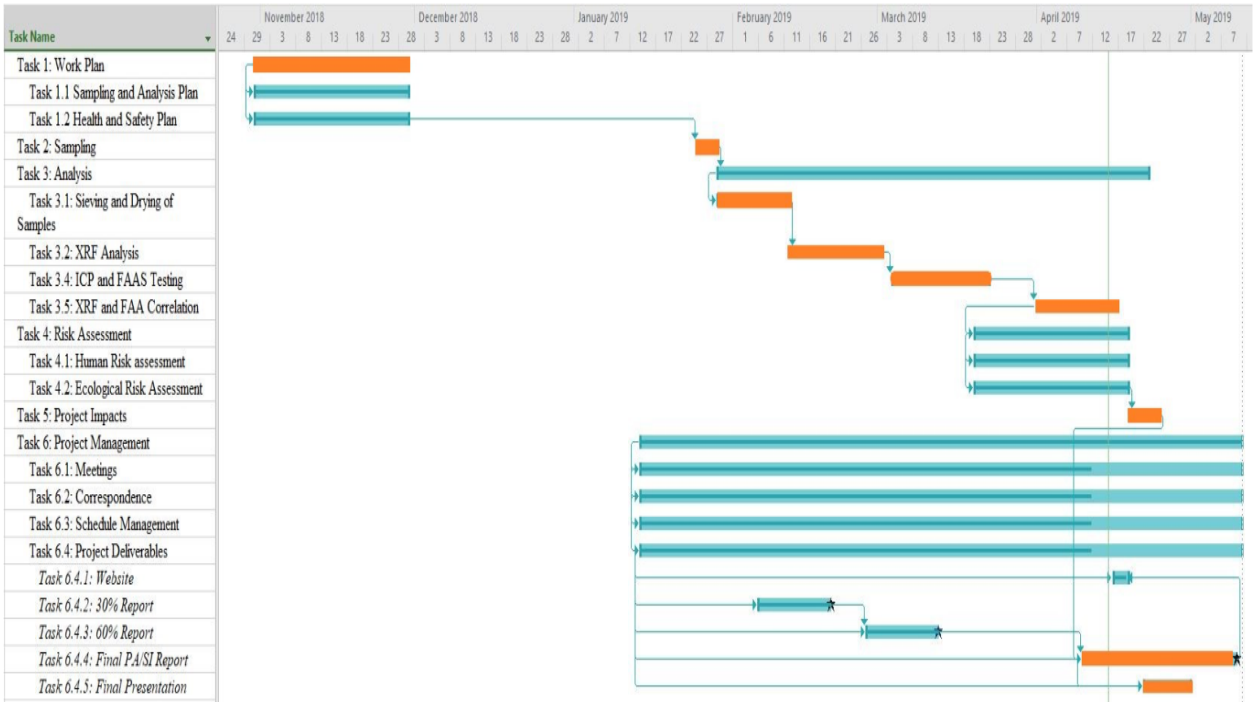

Figure 8-2. Modified Final Gantt Chart for Tyro Mill Project.

8.1 Summary of Engineering Costs

Table 8-1 below displays the employees of ACGM Engineering and the code that will be used to reference them throughout.

Table 8-1. ACGM Employee Codes.

Classification	**Code**
Senior Engineer	SENG
Engineer	ENG
Lab Technician	LAB

Engineering Intern	INT

The qualifications of each employee are as follows:

- SENG: PE Licenses, master's degree, 15 years experience
- ENG: PE or has their EIT and are working towards a PE, bachelor's degree, 4 years experience
- LAB: OSHA Certification, ASTM Certifications, 1 year experience
- INT: Working towards a B.S. in Engineering

The roles and qualifications determined in order to complete the project have not been changed. Table 8-2 shows the estimated hours required to complete the project from each employee.

Table 8-2. Projected Hours for Tyro Mill Project.

Projected Hours				
Task	SENG Hour	ENG Hour	LAB Hour	INT Hour
Task 1 Work Plan	40			
Task 1.1 Sampling and Analysis Plan	3	8	3	6
Task 1.2 Health and Safety Plan	3	8	3	6
Task 2 Sampling	32			
Task 3 Analysis	326			
Task 3.1 Sieving and Drying of Samples	0	10	45	40
Task 3.2 XRF Analysis	0	10	45	40
Task 3.3 Acid Digestion	0	10	45	40
Task 3.4 ICP and FAA Testing	0	10	3	0
Task 3.5 XRF and FAA Correlation	0	14	0	14
Task 4 Risk Assessment	66			
Task 4.1 Human Health Risk Assessment	3	20	0	10
Task 4.2 Ecological Risk Assessment	3	20	0	10
Task 5 Project Impacts	48			
Task 6 Project Management	108			
Total (Hours)	**620**			

Based on the estimated hours to complete each task by each employee, Table 8-3 below shows the actual hours required to complete the Tyro Mill Project.

Table 8-3. Actual Hours for Tyro Mill Project.

Actual (Logged) Hours				
Task	SENG Hour	ENG Hour	LAB Hour	INT Hour
Task 1 Work Plan	89			
Task 1.1 Sampling and Analysis Plan	2	26	0	20
Task 1.2 Health and Safety Plan	2	21	0	18
Task 2 Sampling	119			
Task 3 Analysis	170			
Task 3.1 Sieving and Drying of Samples	0	0	49	10
Task 3.2 XRF Analysis	4	13	78	6
Task 3.5 XRF and FAA Correlation	2	8	0	0
Task 4 Risk Assessment	33			
Task 4.1 Human Health Risk Assessment	4	11	0	2
Task 4.2 Ecological Risk Assessment	4	10	0	2
Task 5 Project Impacts	5			
Task 6 Project Management	156			
Total (Hours)	**572**			

Based on the hours spent by each employee in ACGM Engineering, the following Table 8-4 shows the estimated cost of engineering services in order to complete the project.

Table 8-4. Projected Cost of Engineering Services.

1.0 Personnel			
Classification	**Hours**	**Rate $/Hr**	**Cost**
SENG	36	$194	$6,984
ENG	432	$134	$57,888
LAB	156	$48	$7,488
INT	212	$22	$4,664
Total Personnel	**836**	**N/A**	**$77,024**

2.0 Travel								
Item	**Quantity**	**Days**	**$/Day**			**$/mile**	**Mileage**	**cost**
vehicle	1	2	$43			0.445	400	$264
hotel	3	1	$98					$294
			Breakfast	**Lunch**	**Dinner**			
perdium	6	2	$9	$11	$21	N/A		$312
Total Travel	**N/A**							**$870**

3.0 Supplies				
Supply	**cost/supply**	**unit**	**quanitity**	**cost**
Gloves	$10	2	100	$19
Ziploc Bags	$8	5	28	$40
Measuring Tape	$25	2	1	$50
Surveying Flags	$11	2	100	$22
Hazmat Suites	$11	12	1	$136
Walkie Talkie	$30	1	4	$30
5 Gallon Buckets	$55	1	20	$55
Trowels	$4	4	1	$14
Trash Bags	$15	1	50	$15
Total Supplies	**N/A**			**$382**

4.0 Subcontract		
Sample Quantity	**Cost/Sample**	**Cost**
20	**$150**	**$3,000**
Total		**$81,276**

Due to some differences in cost and the total amount of hours contributed to the project, the actual cost of engineering services was lower than expected. The actual project cost can be seen below in Table 8-5.

Table 8-5. Actual Cost of Engineering Services.

1.0 Personnel			
Classification	**Hours**	**Rate $/Hr**	**Cost**
SENG	69	$194	$13,386
ENG	251	$134	$33,634
LAB	128	$48	$6,144
INT	124	$22	$2,728
Total Personnel	**572**	**N/A**	**$55,892**

2.0 Travel								
Item	**Quantity**	**Days**	**$/Day**			**$/mile**	**Mileage**	**cost**
vehicle	1	2	$43			0.445	400	$264
hotel	3	1	$98					$294
			Breakfast	**Lunch**	**Dinner**			
perdium	6	2	$9	$11	$21	N/A		$312
Total Travel	**N/A**							**$870**

3.0 Supplies				
Supply	**cost/supply**	**unit**	**quanitity**	**cost**
Gloves	$10	2	$100	$19
Ziploc Bags	$8	5	$28	$40
Measuring Tape	$25	2	$1	$50
Surveying Flags	$11	2	$100	$22
Hazmat Suites	$11	12	$1	$136
Walkie Talkie	$30	1	$4	$30
5 Gallon Buckets	$55	1	$20	$55
Trowels	$4	4	$1	$14
Trash Bags	$15	1	$50	$15
Total Supplies	**N/A**			**$382**

4.0 Subcontract		
Sample Quantity	**Cost/Sample**	**Cost**
20	**$14**	**$280**
Total		**$57,424**

The project ended up being approximately $24,000 under the original estimated budget.

8.2 Conclusion

The human health risk assessment indicated that arsenic was the only COC, however with the 95% EPC at 9.1 ppm it was determined that the risk was low and of little concern to the public health. The ingestion of soil and dermal contact exposure pathways for arsenic were determined to have a cancer risk less than one in a million and a hazard index less than one for non-carcinogenic assessments. The low risk levels indicate that the remediation efforts completed by Red J Environmental and the BLM have been effective in containing the contamination due to the mine tailings on site. A full ecological risk assessment was not completed, however, using the EPA SSLs, the listed COCs do present a risk to the flora and fauna of the surrounding area. Based on the results of the PA/SI, it is recommended that the client look more into the ecological hazards present on site, however, the clean-up activities previously conducted on site have been effectively maintained and there is little to no risk to human health at the site.

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Appendix A: Work Plan

See attached Electronic Appendix

Appendix B: Photos

See attached Electronic Appendix

Appendix C: Lab and Field Notes

See attached Electronic Appendix

Appendix D: XRF Data

See attached Electronic Appendix