Southwest Sites Consulting
Engineering and Environmental Services

Red Cloud Mine
Final Proposal

Prepared for
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ACRONYMS AND ABBREVIATIONS

AA - Atomic adsorption
ALM- Adult Lead Methodology
BLM - Bureau of Land Management
COC - Contaminants of Concern
EPA - Environmental Protection Agency
HAZWOPER - Hazardous Waste Operations and Emergency Response
ICPAES - Inductively Coupled Plasma Atomic Emission Spectroscopy
IEUBK - Integrated Exposure Uptake Biokinetic model
IRIS - Integrated Risk Information System
PA- Preliminary Assessment
SHEDS - Stochastic Human Exposure and Dose Simulation
SI- Site inspection
XRF - X-Ray Fluorescence

1.0 Project Understanding

1.1 Project Purpose

The Red Cloud Mine, located near Yuma Arizona, currently consists of 20.66 acres of land including the mine and several hundred tons of mine tailings. These tailings and their respective contaminants and hazardous materials, have been washed down Black Rock Wash, which is on land managed by the Bureau of Land Management (BLM). BLM land is used by the public and tailings continue to disperse and migrate in the area. These tailings and possible contaminants pose a threat to the safety and health of humans, the environment, and other flora and fauna. In order to characterize the extent of the risk associated with the contaminants at Red Cloud Mine, it is necessary to perform a preliminary assessment (PA) and site inspection (SI). Based on the sampling results, the team will evaluate potential contaminant exposure to recreational users (hikers, campers, off-highway vehicles). If the risk is deemed unacceptable, the team will evaluate options to reduce the risk, such as consolidating and capping the tailings in an on-site repository.

1.2 Project Background

1.2.1 Red Cloud Mine Location

The Red Cloud Mine is located in La Paz County in the southwest corner of Arizona (see Figure 1.1). The site is approximately 50 miles south of Quartzite and 23 miles north of Yuma. The site can be accessed by Red Cloud Road, a rough but maintained dirt road, off of Highway 95 in Yuma. The Colorado River is 5 miles south of the site and the Yuma Proving Ground military reserve is 2 miles west. Images showing the location of the mine in relation to nearby cities can be seen in Figure 1.1 and Figure 1.2 [1]

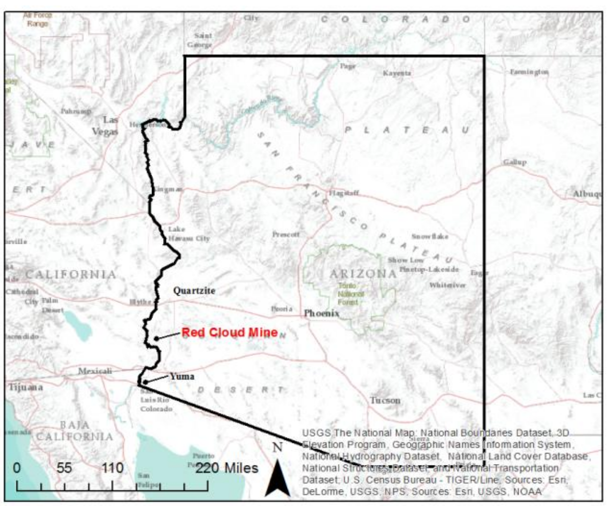

Figure 1.1: Location of Red Cloud Mine in La Paz County, AZ. (Google Earth.)

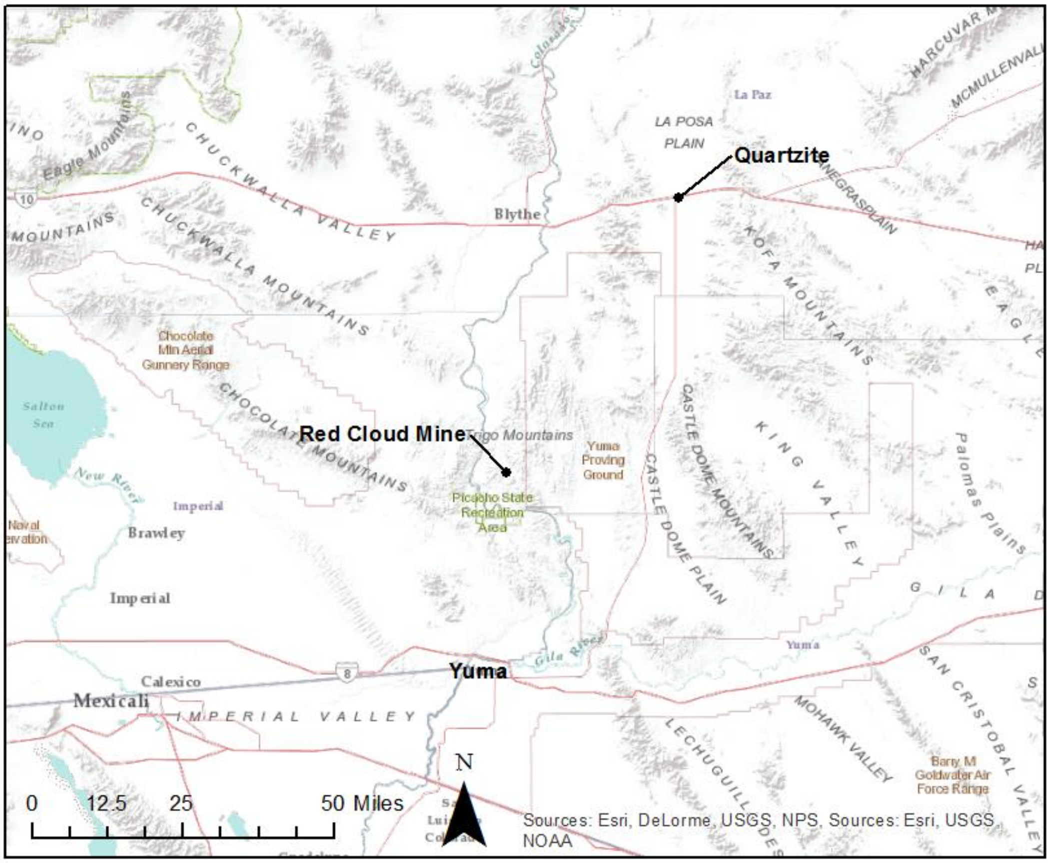

Figure 1.2: Red Cloud Mine in association to Yuma and Quartzite, Arizona. (USGS).

The Red Cloud mine itself is located on private property, and is therefore unable to be surveyed or evaluated [1]. The tailings pile, 1.3 acres in size, which is located just south of the mine, is located on land administered by the BLM. The tailings pile has been eroded allowing the tailings to migrate into the nearby wash, Black Rock Wash, which empties into the Colorado River 5 miles to the south (see Figure 1.3). Figure 1.4 details the tailings pile.

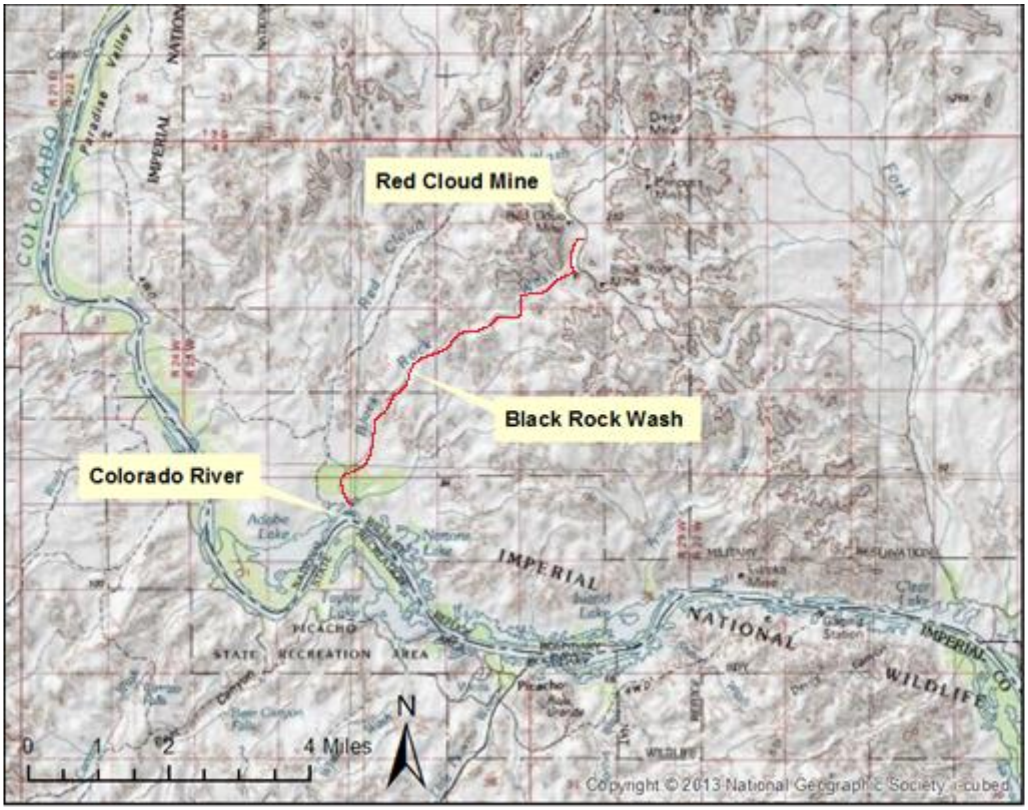

Figure 1.3: Map of Black Rock Wash feeding into Colorado River, Red Cloud Mine and Red Cloud Mine Road. (BLM).

Figure 1.4: Areal view of the size of the tailings pile, 1.3 acres. (Google Earth.)

1.2.2 Red Cloud Mine History

The Red Cloud mine originally opened in 1878, and was mainly used to mine silver ore until its closing in the 1890s. After the 1890s the mine's ownership became complex, seeing many different owners until the start of World War I when a high demand for lead arose. This need ultimately prompted the United States government to purchase the mine due to the mine's high lead content [1]. Since the 1950's, the site has been closed and reopened as a specimen mine for wulfenite crystals, a lead molybdate. During this time, the tailings have also been reworked for lead, zinc and silver. Wayne Thompson owned the mine in 1995 but today it is owned by a dentist from Kansas who is keeping it open for mineral collectors. During the many years of mining, ore tailings were consolidated in a tailings pond located south of the mine site [2]. The main contaminants of concern (COC) located in the tailings pond are lead, zinc, molybdenum, and iron.

1.2.3 Site Hydrology

The tailings in the wash are situated on top of Holocene alluvium deposits of unknown thickness. Although the alluvium deposits are composed primarily of fine sand and gravel, at deeper layers caliche has formed, which is a naturally cemented sedimentary rock [3]. The caliche is semi-permeable, meaning that water is not easily infiltrated downward. Due to this, the wash floods during heavy rainstorms, which are typical in the region. During these heavy rainstorms rock, sediment, and tailings are transported down the wash, where the water eventually empties into the Colorado River. The annual precipitation of the area is 3.57 inches, most of which occurs in heavy rain events in the summer months [3]. During most of the year however, the wash is dry. The water table is approximately 500 feet below the surface, which was documented during floods in the historic mine workings. The only surface water sources in the area are the washes, during storm events, and the Colorado River to the south.

1.2.4 Site Usage

There are no communities within 20 miles of the site; therefore, the local groundwater has no direct use. Quartzite is 50 miles north of the mine. In 2003, Quartzite had a population of 3,643 [4]. Quartzite draws their water from 2 wells that are all 1,000 ft deep [5]. The closest city to the mine is Yuma which is 23 miles south of the mine. Yuma's population is 91,923 in 2013 [6]. Yuma's main source of water is from the Colorado River; some groundwater is also used [7].

The mine site, as well as the land surrounding the mine, is used extensively for public recreation, especially during the winter months. The site is accessed by the Red Cloud Road, which runs adjacent to the Black Rock Wash. The area is popular amongst tourists, ATV riders, and mineral collectors.

The main exposure routes of these contaminants are through inhalation and ingestion, as the wash and the nearby dirt access road are moderately trafficked by tourists and personal motorized vehicles.

1.2.5 Previous Investigations of Site

Several investigations by the BLM have been conducted at Red Cloud Mine and have provided background information on the tailings, with respect to location, size, characteristics, and the compaction of the mine tailings. Additionally, investigative information was provided by the BLM for the minerals and estimates of heavy metal concentrations on site in 2003. This information indicated that the tailings piles contain high concentrations of heavy metals including lead, iron, and zinc. These concentrations as well as remediation standards set forth by the state of Arizona can be seen below in Table 1.1. Lead concentrations in the wash are more than five times the remediation standards. Therefore remediation of the site appears to be necessary.

Table 1.1: Concentration levels of contaminants from samples taken in 2003 and Arizona Soil Remediation Standards. [1] [8]

Contaminant	Concentration in tailings pile (mg/kg)	Concentration in Black Rock Wash (mg/kg)	Background Concentrations (mg/kg)	AZ Soil Remediation Standard Non-residential Risk Non-carcinogen (mg/kg)
Lead	8,090 - 12,397	4,428	99	800
Zinc	37,197 - 62,259	24,794	215	310,000

The tailings themselves are highly compacted and are a fine to medium grained bright red material. The tailings pond has been documented to be a rough trapezoidal shape spanning a 1.3-acre area (see Figure 1.3 and 1.4). The tailings piles get deeper as they get closer to the wash, where they appeared, at the time of the investigation, to be 10-12 feet deep. The Black Rock Wash follows the tailing pile on the north-northeastern side of the wash for 376 feet. The previous investigation also showed there was significant water migration from the tailings pile into the wash [1].

Figure 1.5: Ground view of the size of the tailings pile. (BLM).

A reconnaissance geochemical survey was also completed at the Red Cloud Mine in 2009 by the BLM in order to determine the mineral potential of the area. Soil collected downstream in the washes around the mine were tested for heavy metal concentrations, which were determined to be the following: silver (up to 70ppm), lead (up to 5%), zinc (up to 7,000 ppm), and molybdenum (up to 200ppm) [9]. The Arizona soil remediation standards for silver and molybdenum are 5100 mg/kg or 5100ppm.

1.3 Technical Considerations

In order to properly perform an inspection of Red Cloud Mine, a wide range of technical work will have to be performed. This technical work will include proper sampling and characterization of waste, utilization of X-ray fluorescence technology, atomic adsorption (AA), inductively coupled plasma-atomic emission spectroscopy (ICPAES), and risk assessment.

1.3.1 Field Sampling and Characterization

For proper field sampling, the contaminants of concern (COC's) must first be identified as well as the background contaminant concentrations and site present and future use. The use and future use of the site must also be known to determine the area sampled and soil depth sampled. The field sampling technique will need to adequately cover the area showing the extent of contamination present at the site. This will include determining the percentage of the area that can be considered uncontaminated, determining if hotspots are larger than a critical size, and determining the arithmetic average concentration of the contaminants at Red Cloud. The Arizona BLM's Field Sampling Plan and Quality Assurance Project Plan for Red Cloud Mine will be referenced for field sampling [9]. The EPA's Contaminated Sites and Sampling Design Guidelines [10] provides a list of sampling techniques used at waste sites, and equations and tables to determine the number of samples, critical size of hotspots, and other necessary parameters. All data must meet a 95% upper-confidence limit to be deemed reliable by EPA standards [10]. After samples are properly collected, labeled, and stored, then testing can take place.

1.3.2 X-ray Fluorescence

X-ray Fluorescence (XRF) is an integral component in fast and effective sampling of metal contaminated sites in-situ and ex-situ. Utilizing X-rays, XRF machines are able to accurately measure the concentration of contaminants, specifically metals in a soil sample in a few minutes [11]. This saves time and money on chemical analysis. A field portable XRF can be utilized either in-situ or ex-situ. AA and ICPAES performed on a subset of the samples is also required to ensure accuracy of XRF readings [12].

1.3.3 Wet Chemical Analysis

The main analytical tests performed for this project may include atomic adsorption (AA) and ICPAES. Flame atomic adsorption tests quantify the amount of element present in a sample by atomizing the sample with fire and passing an element-unique wavelength through the sample cloud [11]. EPA method 7000B outlines flame AA for many metals including lead, zinc, mercury, and silver. It details methods for reagent choice, preparation of stock metal solutions, and quality control [13]. ICPAES utilizes the measurement of photon emissions to determine the types of elements present as well as the concentration of elements present. EPA method 6010B outlines the procedure for accurately performing ICPAES [14]. Instrumental detection limits for AA is between 1 and 35 μg/L depending on the specific metal as seen in Table 1 of the EPA 7000B document [13]. ICPAES has greater speed than AA and is more sensitive, able to detect metals at concentrations as low as one part in 10^{15} [14].

1.3.4 Risk

Contaminant concentrations will ultimately be compared to the Arizona Department of Environmental Quality soil remediation levels [15] to determine whether risk to users exist. This evaluation will center on the health risk to people and the ecosystem from exposure to the site per EPA superfund guidance. This includes evaluating the possible exposure scenarios for each COC and evaluating the risk of adverse health effects and cancer from the known contaminant concentrations. Carcinogens and non-carcinogens encompass all risk scenarios regarding contaminants. The EPA's Integrated Risk Information System (IRIS) is a comprehensive source of reference concentrations, slope factors, and possible damage related to individual chemicals. Due to the lack of data and laboratory testing on humans, risk data is highly uncertain and the EPA builds many safety factors into their calculations [16]. Many effective models have been designed to estimate the blood and tissue concentrations of a number of contaminants. Integrated Exposure Uptake Biokinetic model (IEUBK) is an effective model to estimate blood-lead levels in children and the Adult Lead Methodology (ALM) does the same for adults. The EPA also has the Stochastic Human Exposure and Dose Simulation Model (SHEDS) system which is a compilation of models for different contaminants in various mediums [17].

1.4 Potential Challenges

There is potential for this project to present challenges to Southwest Sites Consulting and in turn, the client. The possibility of unfavorable weather conditions on the day of the site visit could cause problems. The team will come prepared for any type of weather condition. This issue will be avoided by labeling containers in a way that is all weather proof and will not fade or become illegible. Proper training in the lab prior to testing will take place in order to not waste sample or create unusable data. Access to Black Rock Wash may be a problem due to the wash being roughly 4.5 miles long and in between moderate sized mountains. Google maps and ArcGIS will be used in order to determine terrain conditions so that access points to the wash will be mapped out prior to the site visit.

1.5 Stakeholders

The primary stakeholder for this project is the Bureau of Land Management (BLM). Secondary stakeholders include the community that could be affected through recreational usage of the area surrounding the mine. The tailings have migrated off of the private land and into Black Rock Wash. These tailings and contamination put local traffic, which access this area by Red Cloud Road, at risk. These groups include mainly campers and personal motorized vehicle users – at risk. Local traffic, as well as future land users of the Red Cloud Mine, will benefit from the information that results from this project and any further action that occurs as a result of the PA/SI, especially in terms of risk mitigation or remediation.

2.0 Scope of Services

The scope of services details the work that is expected to be performed to meet the needs the client.

2.1 Task 1.0 Work Plan

A Work Plan will be completed prior to the site visit and will detail the activities that will be carried out on site. Appended to the Work Plan will be the Sampling and Analysis Plan as well as the Health and Safety Plan.

2.1.1 Subtask 1.1 Sampling and Analysis Plan

Little is known about how far the tailings in the wash have migrated, therefore a systematic sampling plan will be determined prior to the site visit. In order to determine how many sampling points are needed, the spread of the tailings will be determined on site, and the EPA's Contaminated Sites and Sampling Design guidelines will be followed [9]. The sampling and analysis plan (SAP) will include these sampling locations, how many samples will be collected, and the correct procedures to be followed when collecting and transporting samples, including a sample labeling system.

Sampling analysis, including sample preparation and experimental procedures following standard methods, will also be included in this document along with QC/QA protocol for the project.

2.1.2 Subtask 1.2 Health and Safety Plan

The Health and Safety Plan will assess the risk management measures that will be followed during the site visit. The plan will address human health effects as well as safety precautions that will be taken on site and during laboratory testing.

2.2 Task 2.0 Sampling

As part of the PA/SI, on-site sampling will be required. The field work and sampling will be done in accordance to the Work Plan.

2.3 Task 3.0 Analysis

The analysis section details the chemical tests and procedures which will be utilized to determine contaminant concentrations to be used in risk analysis. The analysis task will be done in accordance to the Work Plan.

2.3.1 Subtask 3.1 X-Ray Fluorescence

X-Ray Fluorescence (XRF) will be performed on each sample in accordance to section 3.1.2 of the SAP.

2.3.2 Subtask 3.2 Sample Preparation for Atomic Absorption

Preparation of samples will be performed by the team before Atomic Absorption (AA) is done. This will include drying, sieving, and acid digestion of samples. Preparation will follow sections 3.1.1 and 3.1.2 in the SAP.

2.3.3 Subtask 3.3 Atomic Absorption

Atomic Absorption spectroscopy (AA) will be sub-contracted to the NAU chemistry lab. The lab will be given a subset of the total samples to perform analysis on in order to obtain correlation curves for the XRF data.

2.4 Task 4.0 Risk Assessment

The following details the procedures and methodologies which will be employed to perform a risk assessment as required by the PA/SI.

2.4.1 Subtask 4.1 Human Health

In orderly to properly assess and investigate Red Cloud Mine a risk assessment centered on human health will need to be performed. A risk assessment includes the following: The hazard quotient and slope factors for each COC will be found through the EPA's IRIS database to assess toxicity [16]. An exposure assessment of COC's to humans will be created based upon likely uses at the site (workers, recreational activity). Next, soil and dust exposure rates will be estimated. Carcinogenic and non-carcinogenic risk computations for each COC other than Pb will be computed according to standard risk calculations [16]. For Pb, which has no reference dose value, the Integrated Exposure Biokinetic and Uptake (IEUBK) for children and the Adult Lead Methodology (ALM) for adults will be utilized for risk assessment [17].

2.4.2 Subtask 4.2 Ecological Health

In addition to the human-health risk assessment, an ecological risk assessment will be performed at Red Cloud Mine. This process will include identification of the COC's and the identification of potentially sensitive flora and fauna, especially endangered species. Extremely detailed field notes will be taken while on site to identify vegetation and animals. With the above information, a qualitative risk assessment can be performed in accordance to animal study data from the IRIS database [9].

2.5 Task 5.0 PA/SI

All work performed will be documented in the PA/SI report and will be delivered to the BLM and serve as an assessment of the Red Cloud Mine site, indicating the possible need for further remediation at the site.

2.6 Task 6.0 Project Management

Project Management of the Red Cloud Mine evaluation will include careful planning and internal tracking hours spent on the project, organizing information and tasks through project meetings, and accounting of resources to achieve the goal of delivering a thorough and informative PA/SI to the BLM upon completion. Two aspects of project management will be to communicate project progress to the BLM as well as to provide the BLM with final document results. Specifically, the deliverables will include: the Work Plan, a 50% report, the PA/SI, final presentation and website.

2.7 Exclusions

Any and all actions not explicitly stated in the scope of services will not be performed by the team including implementation of remediation or follow up assessments.

3.0 Schedule

The schedule outlines and illustrates the due dates and time allowances for each section of the scope of services. The tasks and deadlines are best represented by the GANTT chart presented on the following page (Figure 3.1). The project will commence on 10/20/15 and be completed by 05/09/16. The 50% PA/SI will be due 3/18/16, the team presentation will be due 4/29/16, and the PA/SI and website will be due 5/6/16. The critical path begins with the Work Plan and follows with the Fieldwork and Sampling, Sample Analysis, Risk Assessment, Project Management, and the final deliverables.

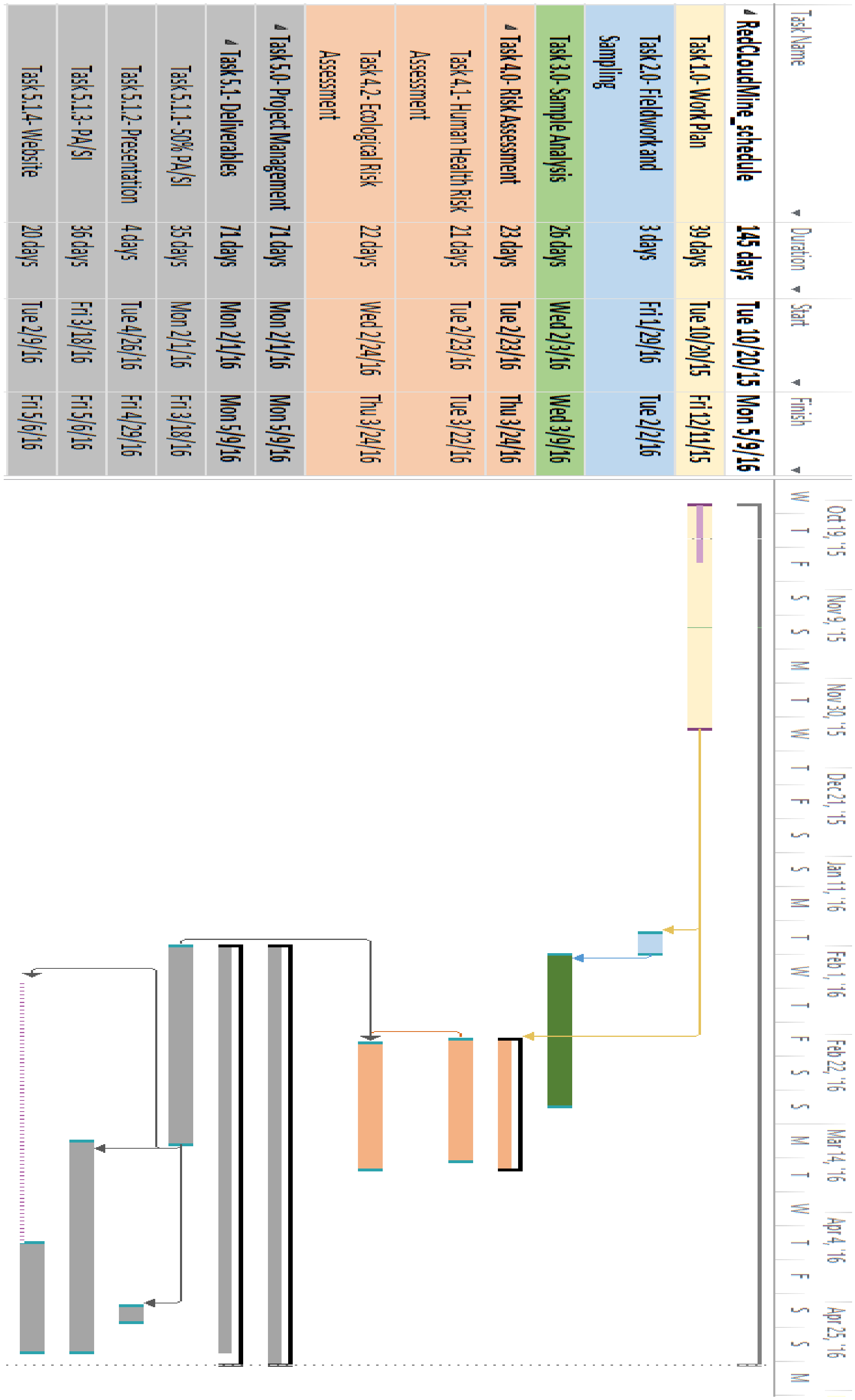

Figure 3.1: GANTT chart outlining tasks and deadlines of the project.

4.0 Staffing and Cost of Engineering Services

This section details the personnel required for this project as well as a breakdown of duties, timeframes, and estimated cost of engineering services. This includes travel, training, and subcontractor costs.

4.1 Staffing Breakdown

A senior engineer (SENG) with past experience with preliminary investigations and site assessments will be required to guide the team and offer their expertise and recommendations throughout the project. The senior engineer will also be expected to facilitate communication between the team and the client. An additional engineer (ENG) will be required to supplement the senior engineer's knowledge and provide assistance to the senior engineer. A lab technician (LAB) will perform sieving, drying, and handling of soil samples after sampling has taken place. An intern (INT) will also be hired to provide experience to an aspiring engineer. The intern will be given small tasks throughout the project to facilitate productivity. Both the lab technician and the intern will conduct XRF soil analysis. Table 4.1 details the tasks and sub-tasks required to complete the project, as well as a breakdown of the time each personnel will work on each task.

Table 4.1 Tasks Hourly Breakdown

Task	Total Hours	SENG	ENG	LAB	INT
TASK 1.0 WORK PLAN	100	15	70	0	15
Subtask 1.1 Sampling and Analysis Plan	70	10	50	0	10
Subtask 1.2 Health and Safety Plan	30	5	20	0	5
TASK 2.0 SAMPLING	130	0	100	0	30
TASK 3.0 ANALYSIS	48	0	13	30	7
Subtask 3.1 Sample Preparation for XRF	8	0	4	0	4
Subtask 3.2 XRF	36	0	6	30	
Subtask 3.3 Sample Preparation for AA	6	0	3	0	3
TASK 4.0 RISK ASSESSMENT	20	0	15	0	5
Subtask 4.1 Human Health	10	0	8	0	2
Subtask 4.2 Ecological Helath	10	0	7	0	3
TASK 5.0 PA/SI	70	50	20	0	0
TASK 6.0 PROJECT MANAGEMENT	10	10	0	0	0

4.2 Costs of Engineering Services

Table 4.2 shows the total cost calculation for this project factoring salaries, travel expenses, and chemical analysis. The total project cost is estimated to be $53,493.

Table 4.2. Total Cost Calculation

1.0 Personnel	Classification	Hours	Rate, $/hr	Cost $
Senior Engineer	SENG	80	195	15600
Engineer	ENG	271	67	18157
Intern	INT	119	22	2618
Lab Technician	LAB	280	48	13440
	Total Personnel	750		49815
2.0 Travel Expenses				1764
2.1 Hotel	3 days			800
2.2 Per Diem	3 days			500
2.3 Rental Vehicle	3 days			200
2.4 Travel	Travel for sampling	660 miles	$0.40/mi	264
3.0 Subcontract	Analytical Chemistry	30 samples	5$/sample	150
4.0 Total Cost				53493

5.0 References

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