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Environmental impact of the Three Kids Mine tailings, Henderson, NV

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ENVIRONMENTAL IMPACT OF THE THREE KIDS MINE TAILINGS,

HENDERSON, NV

by

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ABSTRACT

Environmental Impact of the Three Kids Mine Tailings, Henderson, NV

by

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This research focused on the distribution of the Three Kids Mine tailings in surface soils in and around the mine in Henderson, Nevada. It is situated next to the communities of Calico Ridge and Lake Las Vegas Resort, and, just the west of the Lake Mead Recreation area. Even though the mine has been inactive for almost 50 years (1917-1961), tailings piles and other sources of contamination on the mine are currently exposed to the atmosphere. In this study, surface soil samples were collected along eight transects emanating from the center of Three Kids Mine tailing piles up to five miles in one mile increments. The soil samples were analyzed for lead, manganese, arsenic, and 12 other elements using x-ray florescence spectroscopy (XRF). The results of this study show that there is transport of mine tailings to surface soils at locations adjacent to the mine. The majority of the elements (Mn, Cu, Zn, As, Sr, Mo, and Pb) at these sites have concentrations above the limit of detection; chromium, cobalt, mercury, nickel, and selenium are below the limit of detection in the soil samples; and, iron, rubidium, and zirconium stay fairly constant within a factor of three or four fold.

Examination of the transect maps shows that the mining wastes are transported the farthest from the center of the waste piles along Transects 1 and 2, which go up to three miles the north east and east from the site, respectively. The concentrations of manganese, arsenic, and lead in Transects 1 and 2, at one mile from the mine, are also found to be significantly higher than the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL). The topography (altitude) of these transects is initially increasing from the west to the mine, with mountains in the path of Transect 2, and subsequently decreasing toward the Las Vegas Wash and Lake Mead. Relatively low transport of the wastes occurs on Transects 3-8, in the direction of the River Mountains, the City of Henderson, the communities of Calico Ridge, and the western edge of the Lake Las Vegas Resort, going out to between a half mile and one mile from the mine. Overall, there is contamination of surface soils adjacent to the mine site, with manganese, arsenic, and lead contamination reaching up to between one and three miles. Further study is needed to show conclusively that the mine waste has reached the communities of Calico Ridge and Lake Las Vegas Resort.

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I would also like to thank the kindness of Mindy Unger-Watkins, a principal of the Lakemoor Canyon project at Three Kids Mine for the permission to provide a tour in the mine and to investigate inside the mine site. In addition, a special thanks to all my friends for their consideration and motivation.

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CHAPTER 1

INTRODUCTION

Once the largest manganese mine in America and currently the site of a proposed 1,260-acre housing development, the Three Kids Mine (TKM) in the City of Henderson, shut down almost 50 years ago (Rafferty, 1992, p. 16) (Figure 1). Little is known about the impact of its wastes on the surrounding environment. Previous studies showed that the wastes have high concentrations of manganese (Mn), arsenic (As), and lead (Pb) (Naugle, 1997; Sims, 1997, 2008), suggesting that studies were needed to investigate the possible transport offsite of these, and other elements. In this thesis research, performed during the summers of 2010 and 2011, top soil samples (0 - 0.5 cm), which were judged to have been undisturbed by human activities for at least 50 years, were collected around the TKM, including the communities of Calico Ridge and Lake Las Vegas Resort, as well as a part of the Lake Mead Recreation area. The samples were analyzed by X-ray fluorescence spectroscopy to determine the concentrations of potentially hazardous elements such as arsenic, lead, and 12 other elements. The results from the analysis of the samples suggest that there is movement of tailings particles toward the Las Vegas Wash, toward the communities of Calico Ridge Lake Las Vegas Resort, and in the direction of Lake Mead.

The first chapter provides a formal statement of the purpose, research questions/hypotheses, and significance of the study. Chapter 2 contains a historical perspective and reviews the chemical properties of the target elements, transport mechanisms, and a sampling map description. Chapter 3 contains a description of sampling trips, sample collection, sample preparation, and analytical methods used in this

study. Chapter 4 contains the results and discussion. Finally, the conclusions and recommendations for future study are presented in Chapter 5.

Statement of the Purpose

The Three Kids Mine (TKM) is located approximately six miles north of Henderson, 15 miles east of Las Vegas, two miles south of the Las Vegas Wash, and five miles southwest of Lake Mead (Figures 2 and 3). The mine was the largest supplier of manganese in America, contributing one-third of the national production (Rafferty, 1992). It exploited extensive amounts of ore from the surface in an open-pit operation. When World War I started, the mining activity began in late 1917 and operated at irregular intervals until July 1961. Mining activities at Three Kids Mine produced toxic elements of arsenic, mercury, and lead as by-products during the manganese extraction (Naugle, 1997). When the mine was closed and abandoned in 1961, all machinery, equipment, and buildings were removed, leaving behind unprotected tailings piles, wastes, and three open pits. Currently, the tailing piles are exposed to the atmosphere and are not lined (Sims, 1997). Even though the mine has been inactive for almost 50 years, the potential environmental dangers from the hazards present must not be ignored, especially since there is a proposal to build houses on the site. Tentatively called Lakemoor Canyon, this 1,260-acre residential development project is planned by Unger Development (Twitchell, 2009).

The goal of this research is to document the environmental contamination, if any, from the Three Kids Mine tailings on the surrounding land. Abandoned mines can be the source of elevated concentrations of toxic substances in soil and sediments (Astrom &

Nylund, 2000; Hu, Chen, X., Shi, Chen, Y., & Lin, 2008; and Kim, et al, 2007). Earlier studies by Naugle (1997), Sims (1997), and Sims and Bottenberg (2008), focused on Three Kids Mine and established that chromium, manganese, cobalt, nickel, arsenic, cadmium, and lead are found in and around the mine. Sims and Bottenberg (2008) analyzed surface soils in the eastern and western dry washes of the Three Kids Mine and found arsenic at concentrations ranging from 200 mg/kg (ppm) to 1130 mg/kg and lead at concentrations ranging from 20 mg/kg to 8400 mg/kg (0.84%). An ancillary focus of my research is the potential contaminant transport to the community of Calico Ridge, as well as in the Las Vegas Wash, causing a concern for human and ecosystem health (Figure 2).

Figure 1 The sign at the entrance of the Three Kids Mine

Figure 2 Location of Three Kids Mine in Nevada. Mapquest.

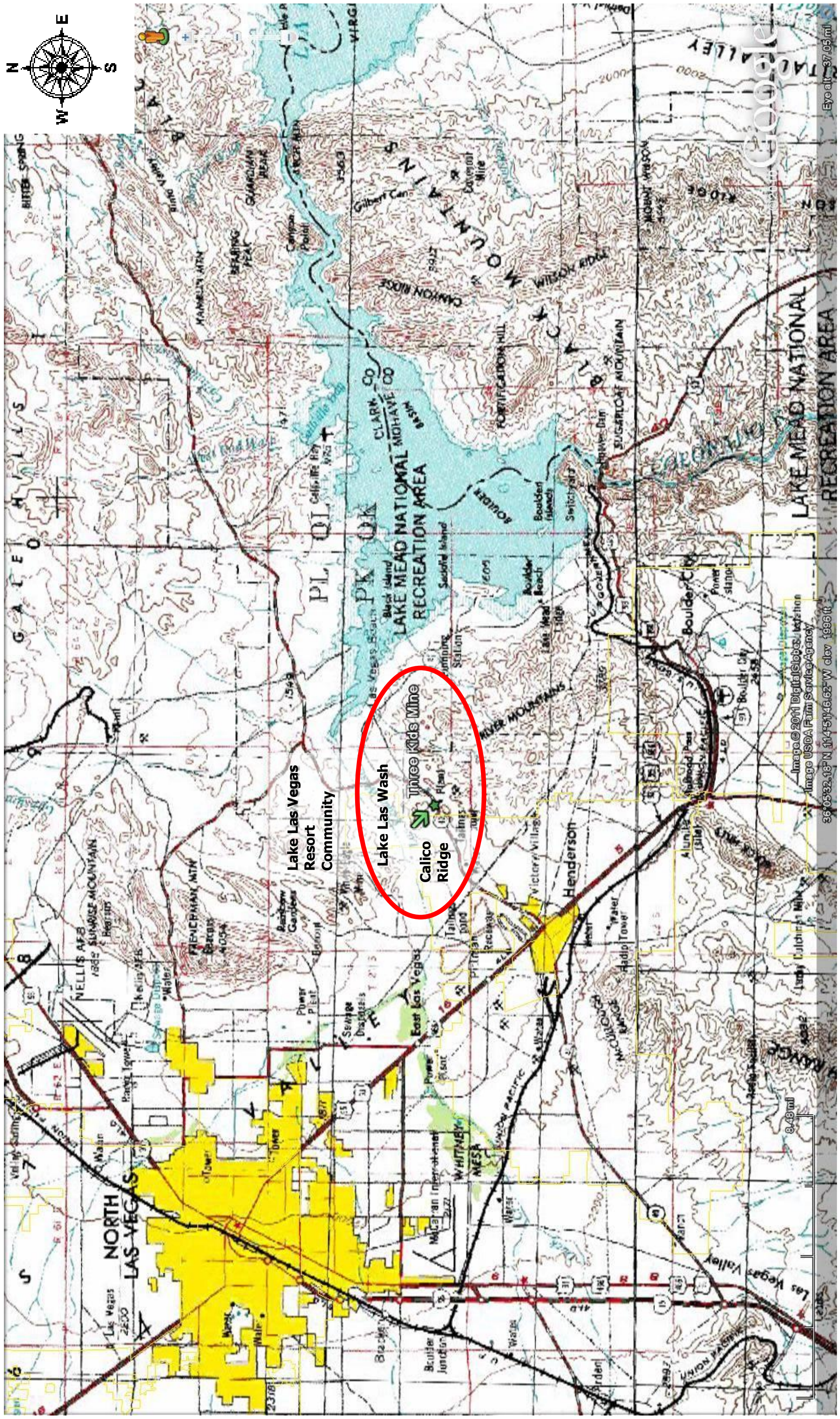

Figure 3 Topographical Map of Three Kids Mine. Google Earth

Research Questions

This research addresses the following questionS:

1) Are the tailing particles from Three Kids Mine contaminating the surrounding environment?

If so,

2) How far are the contaminants from the mine site traveling from the site, and in which direction?

3) Is there potential harm to residential areas surrounding the mine site from dispersal of the tailing particles?

To answer these questions, a sampling map was created to show the transport patterns of the tailing particles along offsite transects at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) radii from the mine's tailing piles (Figure 4).

It was decided that several transects were necessary because of the significant variability of wind and surface water runoff directions, since the potential transport of tailings and highly contaminated soils from the mine are likely due to wind and rain. In this study, eight radial transects were chosen for evaluation based on data reports from the Clark County Department of Air Quality and Enviornmental Management and the Las Vegas Wash Comprehensive Adaptive Management Plan. The Clark County Department of Air Quality and Enviornmental Management has two operating EPA air monitoring sites in Henderson, recording wind direction and speed. Wind direction at these locations, neither of which are located very close to the mine, can vary going southwest and southeast in annual periods of time, but the wind direction is most likely influenced by

the surrounding mountains around the mine site (EPA 32-003-0007 and EPA 32-003-02980). The Las Vegas Wash Comprehensive Adaptive Management Plan contains information about surface water runoff from Three Kids Mine to the Las Vegas Wash examined by the Clark County Regional Flood Control District.

In approaching and answering the above research questions, I proposed three hypotheses:

1) Contaminants from the Three Kids Mine tailings will be found in surface soil beyond the boundaries of the mine site.
2) A map of the concentration of lead, arsenic, manganese and other elements will show high concentrations in the tailing pile material at Three Kids Mine and decreasing concentrations in surface soil, as a function of direction and distance (to five miles) due to wind and rain transport of particles from the waste piles.
3) The elemental concentrations in surface soil along the eight radial transects will be above the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL).

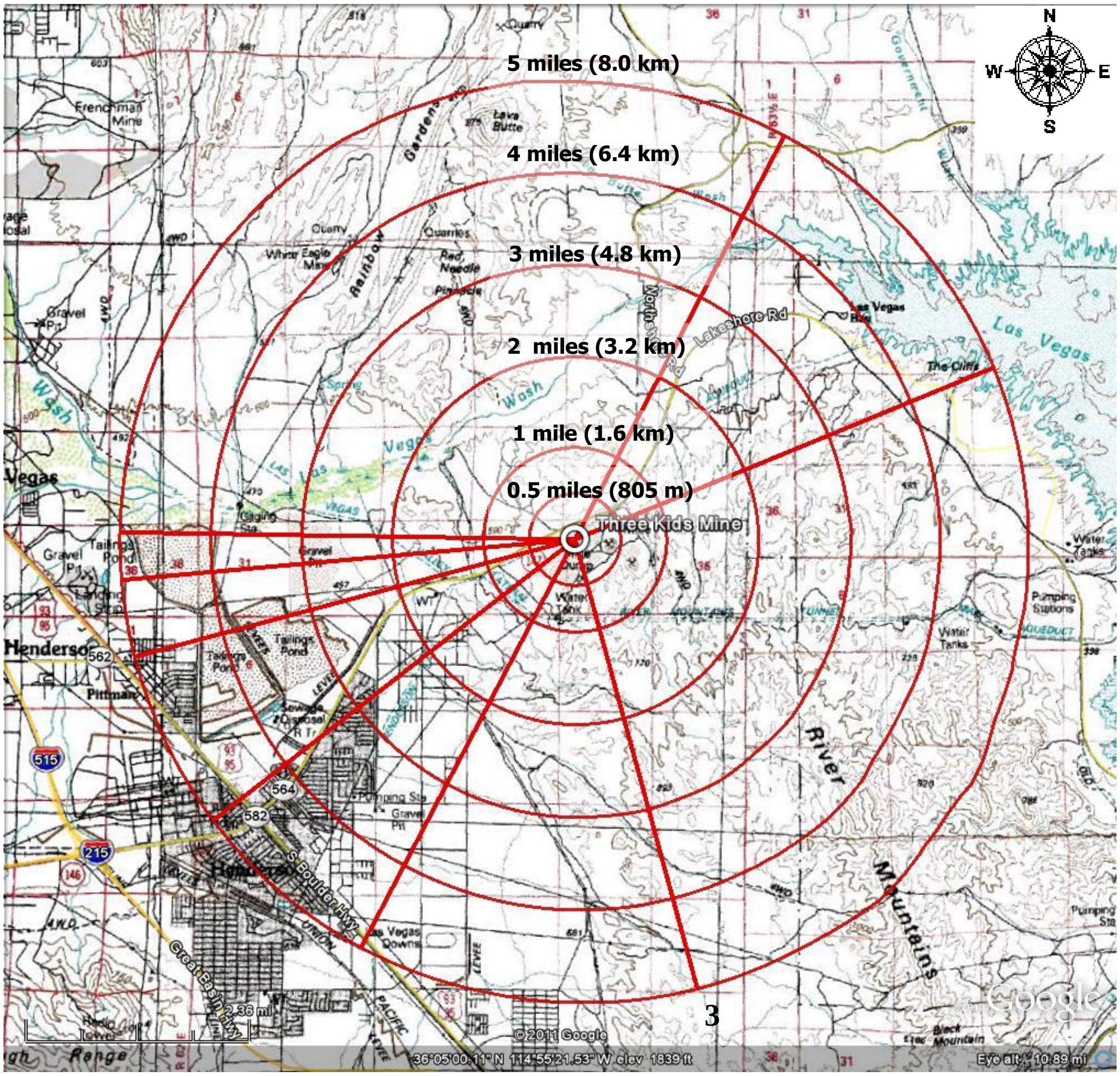

Figure 4 Eight transects at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the center of the Three Kids Mine tailings. Google Earth.

Significance of the Study

The tailing particles from Three Kids Mine contains toxic elements such lead, manganese, mercury, and arsenic. Although small amounts of these elements are common in the environment and diet necessities, toxic levels of any of them can be serious health concerns for occupational or residential exposure. They can cause acute or chronic poisoning and further it can result in psychological and neurological damage to the central nervous function, blood composition, and vital internal organs (Järup, 2003).

Therefore, this study is important to inform the public about the transport of the Three Kids Mine tailings to the surrounding environment. The map of tailings distribution, transport, and these can be used to assist decision makers and residential project developers in determining what protective actions need to be taken to ensure protection of the environment as well as current or future residents near the mine site.

CHAPTER 2

LITERATURE REVIEW

Historical Perspective

In 1917, Three Kids Mine was discovered by three gentlemen, B.R. Jefferson, B. Edwards, and J. Marrs (Hunt, McKelvey, & Wiese, 1942, p. 300). High concentration of manganese was found at the mine site, between 20% and 40%, and led to name the region as the Manganese District. Later, the mine site was renamed the Las Vegas District, after the Frenchman Mountains were added the district. Manganese, atomic number 25, is used as a hardening substance in the production of steels. During the war periods, manganese was in critical need. At the beginning of World War I, the mining activity started and operated irregularly until 1961. The discovery of the mine stimulated an intense excavation of manganese at the site. Soon after, the Three Kids Mine became the largest manganese mine in America (Rafferty, 1992; Tingley, Horton, & Lincoln, 1993). The total production of ore from the site is estimated between 2.2 and 2.8 million tons (Plaster, 1978).

It was found that the manganese was deposited in the interface between the River Mountain volcanogenic layers and the sedimentary Muddy Creek formation (Hunt et al, 1942, p. 305) (Figure 5). The sedimentary rock of the Muddy Creek formation covers the layers of the volcanic rock around the River Mountains. The physical difference between the two layers can be detected from the fact that the sedimentary layers have the ridges and valleys which volcanic rocks lack (Longwell, Pampeyan, & Roberts, 1965, p. 87). In addition, the Muddy Creek formation is rich with pale yellowish-beige colored beds in a

"fine-grained or gritty matrix" while the volcanic rocks are dark red to black colored beds (Hunt et al, 1942, 303).

In the mid-Tertiary, the River Mountains were formed as thick stratigraphic sequences of volcanic lava flows (Hewett & Fleischer, 1960; Hunt et al, 1942; Longwell, 1928; Longwell et al, 1965; McKelvey, Wiese, & Johnson, 1949). Subsequently, a series of folding and faulting occurred because of compression and extension, resulting in anticlines and synclines on the site. The extensional processes also caused the synclines to drop down and form a basin or graben. Later in a late Miocene and early Pliocene era, the sedimentary rocks of the Muddy Creek formation superimposed over the Tertiary volcanic rocks. Units at the site contain conglomerates and sandstones which are distributed into siltstone, clay, tuff, limestone and massive beds of gypsum (Longwell et al, 1965). Also during this time, faulting of the land continued to generate many grabens and synclines (Figure 6). The site is now "an open basin surrounded on the south, east, and north by volcanic units of the River Mountains and opening to the west. Prior to mining activities, the properties sat on a gently northwest sloping, thin, alluvial plain deposit [that are positioned in the sedimentary rocks of the Muddy Creek formation] within the basin with gullies" (Stinchfield, 2007).

The origin of manganese deposition at the site is predicted in three hypotheses: (1) from the decomposition process of volcanic rocks and minerals with oceanic deposits; (2) from the reducing procedure on sulfate organics in the shore; or (3) from the alteration and hydrothermal replacement of oxides at the surface of the sea (Johnson & Trengove, 1956; Wolf, 1976). The manganese was generally observed in the form of a soft dark brown to black material. It was often found in tuffaceous sandstone and siltstone textures.

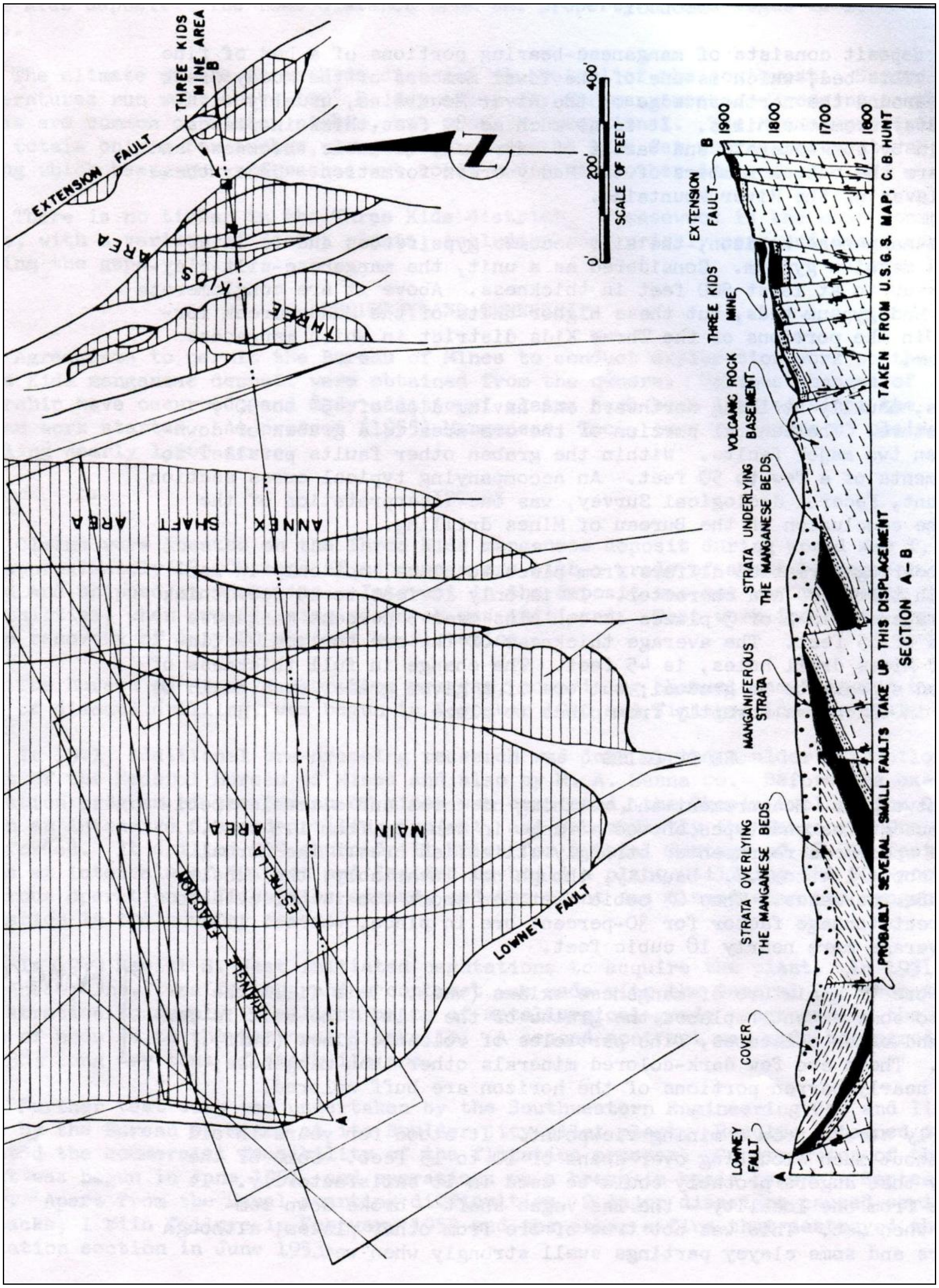

Figure 5 The Geology of Three Kids Mine. Cross section of ore bed (Johnson & Trengove, 1956)

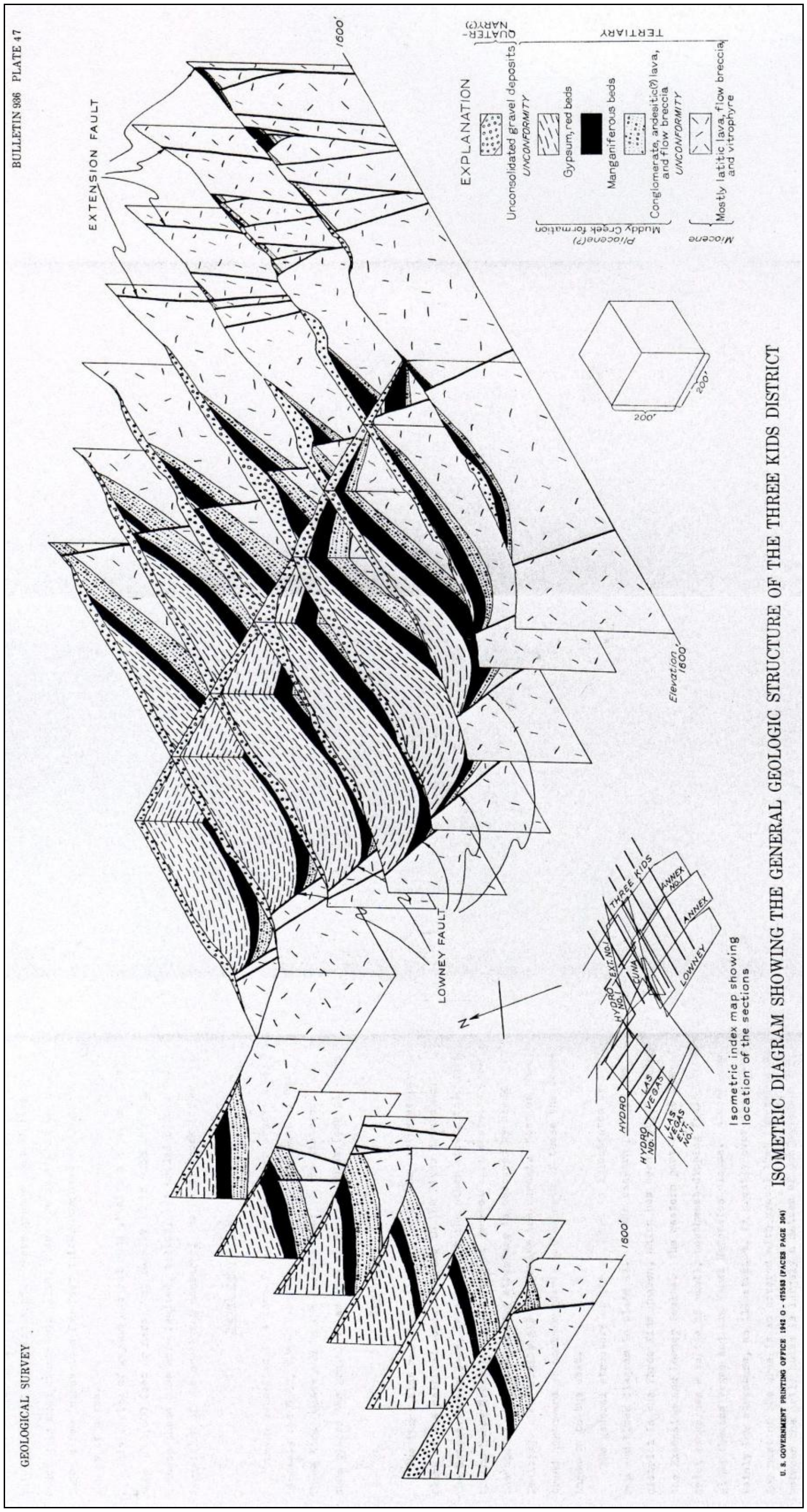

Figure 6 The Geology of Three Kids Mine. Grabens and synclines visible. From plate 47 of Hunt et al, 1942.

The most common manganese minerals in the area consist of psilomelane [$BaMn_8O_{16}(OH)_4$], pyrolusite (MnO_2), manganite [MnO(OH)], and neotocite (hydrous Mn, Fe silicates) (Hewett and Webber, 1931). The other possible manganese minerals are cryptomelane [KR_8O_8,R·$Mn^{II}Mn^{IV}$] and hollandite [BaR_8O_{16},R = Mn_{IV},Fe_{III}] (Hewett & Fleischer, 1960).

After the discovery of the mine, extensive amounts of ore were stripped from the surface in an open-pit operation. In January of 1918, the first loads of ore were milled. The ore at the site had been exploited, approximately 2.5 million tons in 20 % manganese on average (McKelvey et al, 1945). However, the demand for manganese decreased by the end of World War I. Eventually, the mine became dormant. As the Boulder Dam Manganese Co. (BDMC) was founded in 1936, the company requested the Metallurgical Research Laboratory (MRL) to experimentally process ore from Three Kids Mine. Initially, the loads of unprocessed ore were shipped by rail to New Jersey for processing. As World War II broke out, the demand for manganese from the U.S. government was recognized and the first mill was constructed in 1942 so that the ore would be processed at the site. Later in 1952, Manganese, Inc. constructed the second mill. Table 1 shows the chronology of Three Kids Mine operations.

Compared to the first mill (1943-44), the second mill (1952-1961) improved machine installment and chemical processes although it suffered a series of accidents when the nodulizing kiln fell onto the ground, and when the mill building was replaced from destroyed by fire. Figures 7 and 8 present the ore crushing plant and the remodeled fireproof conveyor belt. Both mills operated by a pyrometallurgical process involving milling, thickening, drying, calcining, and nodulizing. When the ore was milled, it was

Table 1

Three Kids Mine Time Line (from Johnson &Trengove, 1956; Stinchfield, 2007)

Date	Event
1917	B.R. Jefferson, R.N. Edwards, and J.F. Marrs discovered manganese at Three Kids Mine
1918	First loads of ore had been mined
WWI	Manganese was mine and shipped
1920 to 1936	The mine was dormant
1936	The Boulder Dam Manganese Co. (BDMC) was founded
WWII	Mining activities revived
1943	The first mill was constructed
1951	Manganese, Inc. built an improved mill
1952	The remodeled mill opened
1953	The nodulizing kiln was crashed to the ground and repaired
1953	The mill building was destroyed from fire accident
1955	Processing Plant remodeled
1961	The mine and mill were closed

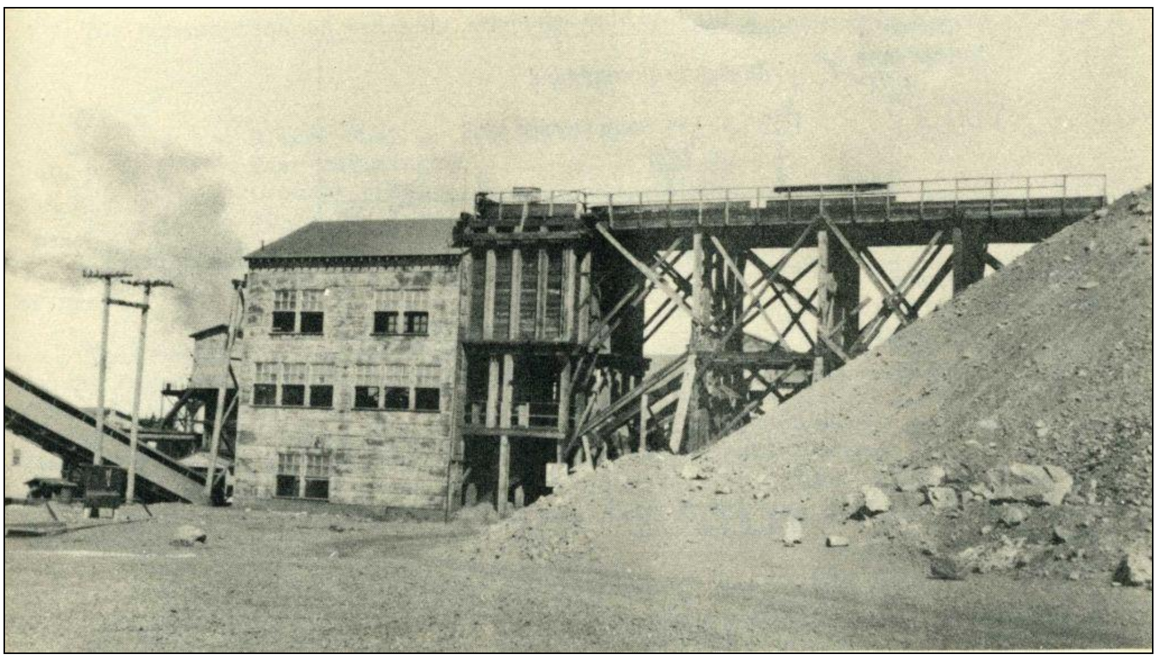

Figure 7 Ore crushing plant at Three Kids Mine (Johnson & Trengove, 1959).

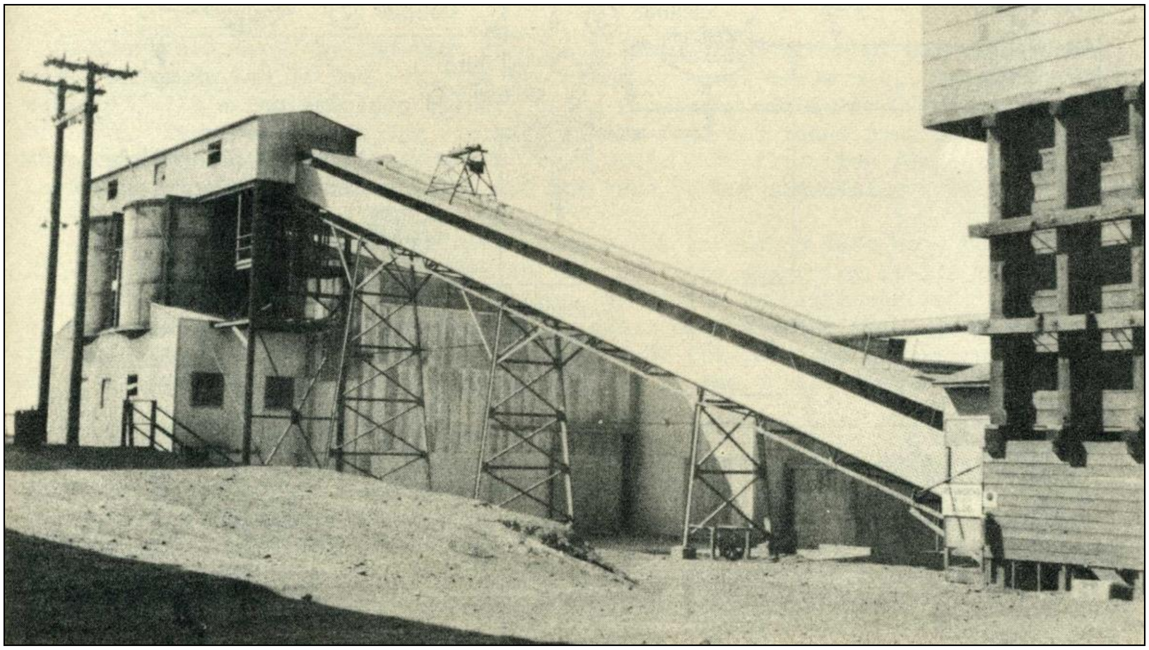

Figure 8 Remodeled fireproof conveyor belt at Three Kids Mine (Johnson & Trengove, 1959).

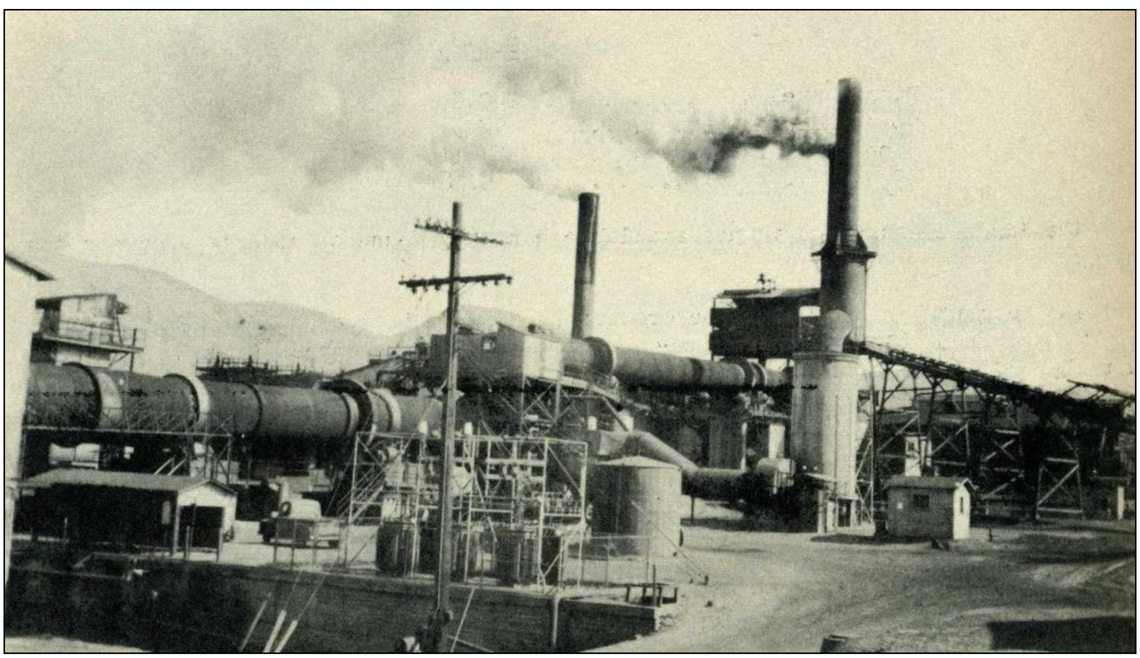

Figure 9 Calcining and nodulizing kilns (Johnson &Trengove, 1959).

leached with a sulfurous acid (SO_2 gas and water) to extract out the manganese and other target metals into solution. Previously, in the first mill, the metals were then precipitated out, thickened, and dried in a kiln to nodulize them (Figure 9). In contrast, the second mill utilized an emulsion of flotation reagents after milling, and sulfurous acid extraction.

To produce an emulsion, the ore was placed in flotation tanks and mixed with a solution of sulfurous acid (water and sulfur dioxide are combined to maintain a low pH and to enhance flotation), diesel fuel, tall oil soap (a detergent), oronite S (sodium sulfonyl sulfate, a detergent), and sodium carbonate (Na_2CO_3) . As a result, foam containing manganese oxide and manganese sulfate was produced and eventually thickened. The thickened foam was then placed in a kiln for nodulizing. In the meantime, tailings from the thickeners were then pumped to the tailings ponds where the mill process wastewaters joined and flowed to the Las Vegas Wash. Tailings contained arsenic, lead, and other flotation residues. This process reveals that the impacts of hazardous chemicals from the mill operation may involve the potential contamination of the environment.

Moreover, carbon dioxide, sulfur, zinc, lead, and other impurities were vaporized at high temperature up to 2400 ºF and released to the air during the calcining process. Sometimes strontium sulfate was added to the calcine to enhance lead salt production. In 1961, the mine and mill were closed when the government contracts were terminated. Currently, the mine is left with serious issues of unsecured open mine pits, unprotected tailing piles, and fine dusts of mill processing wastes and residues (Figures 10 and 11). Tailings are dry and dusty on the ground surface. Large quantities of tailing piles reach up to 1800 feet above mean sea level (MSL) in elevation (Stinchfield, 2007). Since the

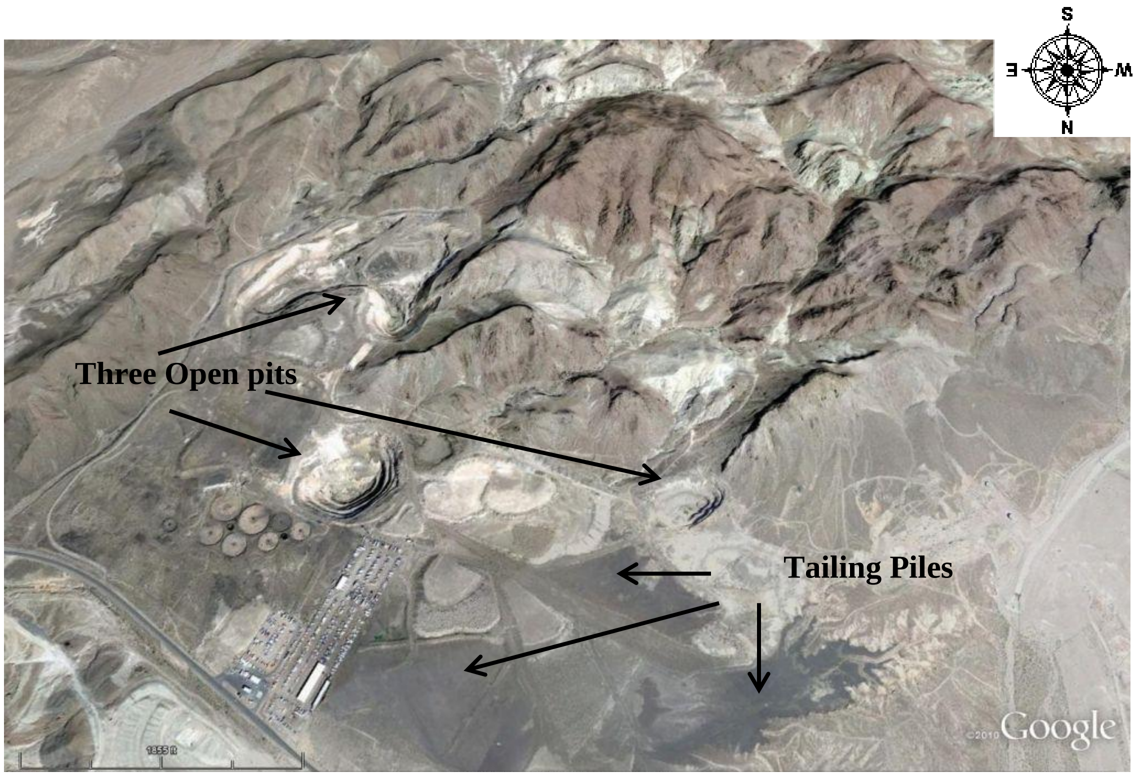

Figure 10 Aerial view looking south showing tailing piles in the Three Kids mine. Google Earth.

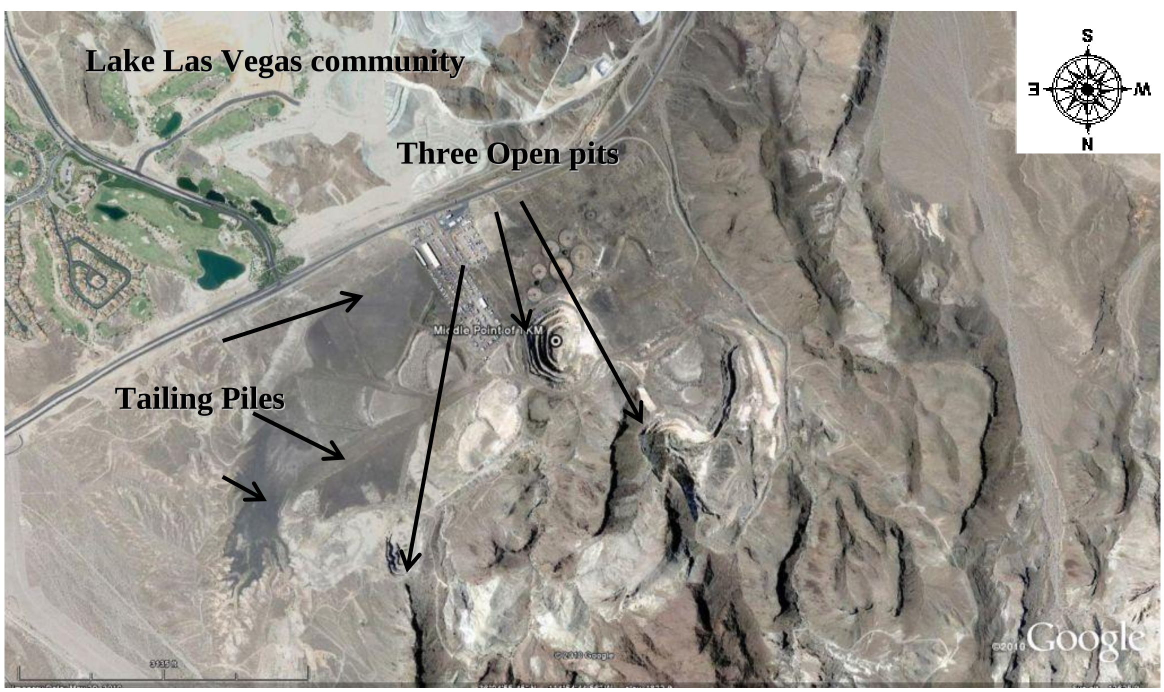

Figure 11 Aerial view looking down on the mine site. Google Earth.

area involves high velocity of wind and surface runoff during raining season, the potential contamination around the mine site should be assessed.

Chemical properties of the Target Elements

This section discusses a brief overview of the chemical properties of the elements that are dictated by the X-ray Fluorescence Spectroscopy. Target elements are chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, rubidium, strontium, zirconium, molybdenum, mercury, and lead.

Arsenic

Arsenic, a metalloid element, ranks twentieth among elements in the earth's crust (Hawley's Condensed Chemical Dictionary, 1993). Its most common oxidation states are +3 (arsenates (III) or arsenites) and +5 (arsenates (V), AsO_4^{3-}). Arsenic is often considered as a potent poison on living organisms. Long term oral exposure to low level of arsenic may cause organ damage, and it increases the risk of skin cancer, bladder cancer, and lung cancer (Agency for Toxic Substances and Disease Registry [ATSDR], 2007). Arsenic contaminated soil can affect the drinking water sources as the contaminated soils enter the stream. According to the National Academy of Science [NAS] (1977), the mobility of arsenites and arsenate (V) may be prevented in the presence of ferric hydroxide, which causes low solubility within a stable Eh-pH range.

Lead

Lead, although it is not a particularly abundant element in the continental crust of the earth, is easily found in ore deposits, including Three Kids Mine. It is often considered as "a cumulative poison and used to a common occupational hazard" (Emsley, 2007).

Lead pollution occurred as a result of anthropogenic activities, involving power plants, smelters, mines, and motor vehicle exhaust (Hutchinson & Meema, 1987). Over the past few decades, motor vehicle emission and lead exposure from industrial operations increased lead distribution in the environment (Farmer, 1987; Ludwig, Diggs, Hesselberg, & Maga, 1965). In general, naturally occurring lead has a low mobility in soils because of its low solubility (Erel, Veron, & Halicz, 1997). Therefore, once soil is contaminated with lead, it is difficult to separate lead from the soil matrix (Wixson & Davies, 1993).

Manganese

Manganese is a naturally occurring element, ranking the twelfth most abundant element in the earth's crust (Hawley's Condensed Chemical Dictionary, 1993). Even though it is an essential nutrient that enhances enzyme system and energy metabolism in humans, it can cause health problems such as behavioral change and severe nervous system effects when large quantities are ingested (ATSDR, 2007). The most common oxidation states of manganese are 2+, 3+, and 4+. Table 2 shows the manganese minerals incorporated with its oxidation state.

Table 2
Manganese Minerals and Oxidation States

Mineral	Formula	Oxidation State
pyrolusite	MnO_{2+}	4+
manganite	$MnO(OH)$	3+
psilomelane	$BaMn_8O_{16}(OH)_4$	2+, 4+
rhodocrosite	$MnCO_3$	2+
cryptomelane	$KR_8O_8,R\cdot Mn^{III}Mn^{IV}$	3+, 4+
Hollandite	$BaR_8O_{16},R = Mn_{IV},Fe_{III}$	4+

Manganese is a strongly persistent element. Rather than breaking down in the environment, either it changes its form, attaches to other particles in water, or settles into the sediment. For this reason, manganese may contribute a serious contamination by transporting hazardous materials away from the mine site as can be seen in Table 3. For copper, iron, and molybdenum, strontium, and zirconium, it is dangerous when large quantities are ingested. In contrast, for chromium, cobalt, nickel, selenium, mercury, and lead, even small quantities that are ingested can be toxic.

Table 3
Metal Absorption in the Presence of Manganese

Metal	Process
Chromium	Transport of Cr(VI) occurs due to oxidation of chromium on manganese oxide surface (Eary & Ral, 1987).
Iron	Form in hydrous Mn and Fe oxides. Even though lead, zinc, and chromium are strongly incorporated into Fe-Mn compounds, iron is the strongest one to be associated in the sediment (Samanidou & Fytianos, 1987).
Cobalt	Strong uptake to manganese oxide coated sediments. Slow desorption studied (Kay et al, 2001)
Nickel	Reversible absorption to manganese oxide coated sediments (Kay et al, 2001).
Copper	High absorption affinity to MnO_2 but natural organic matter levels can block MnO_2 surface absorption (Godtfredsen & Stone, 1994).
Zinc	High absorption affinity bound to manganese and iron oxides in soil. Slow desorption observed (Bogaz, 1993).
Selenium	Iron oxyhydroxide (FeO(OH)) has a greater affinity for selenate and selenite than manganese dioxide. Selenate does not absorb on manganese dioxide. pH and particle concentration inversely affect on selenium adsorption (Balistrieri & Chao, 1990).
Strontium	Strongly absorbed to manganese or iron as a function of pH. Slow desorption observed (Trivedi & Axe, 1999).
Zirconium	Absorption to Mn exists in experiment with a catalyst (Inan & Alta, 2011).
Molybdenum	During adsorption to Mn, Mo isotopes are fractionated but its behavior is more significant in seawater than in ferromanganese nodules (Baring & Anbar, 2004).
Mercury	Presence of sulfate or chloride reduces mercury uptake but equilibrium shows strong retention to uptake Hg(II) by hydrous manganese (IV) oxide (Thanabalasingam & Pickering, 1985).

Transport Mechanisms

Atmospheric Transport

Contaminant transport can occur through the air pathway when the Three Kids Mine tailing particles are mobilized and carried by wind. Due to the occasional high wind events and the exposed tailing piles, an air transport pathway is the main concern for public exposure to the tailings and contaminated soils (Figure 12). When the tailings and contaminated soils are picked up by wind, they can be deposited on the soil surface near the mine forming a reservoir of harzardous substances, which may later be resuspended back into the air and transported farther way and possibly to nearby houses. These materials can be deposited directly onto the backyard soil surfaces or possibly permeate into houses primarily through attic vents, doors, and open windows. Considering that humans spend 65-90% of the time in their houses, the contaminant transport toward the residential area is a vital problem (Robinson, 1977).

The Clark County Department of Air Quality and Environmental Management has operated two EPA air monitoring sites in Henderson, recording wind direction and speed. One station, EPA 32-003-0007, at GPS coordinates N36°2.04, W114°59.88, was managed from January 1, 2003 to January 1, 2008. Second station, EPA 32-003-0298, at GPS coordinates N36°2.94, W115°3.18, has been active since February 13, 2007 until the present time. The one located closer to the mine site is the EPA 32-003-0007. Records show wind directions predominately toward the southeast in a wind rose diagram as shown in Figure 13. On the other hand, the currently active site EPA 32-003-0298, around eight miles (13 km) southwest of the mine, presents the prevailing wind direction going toward the southwest in its wind rose diagram as shown in Figure 14. Based on

personal field experience, winds frequently blow from the east downhill toward the occupied houses in Calico Ridge; however, the wind direction often changes blowing from the west to Lake Mead. Wind direction is most likely influenced by the nearby mountains around the mine site and the EPA monitoring stations most likely do not provide information that can be extrapolated to the Three Kids Mine site.

Water Transport

Tailings and contaminated soils can also be transported off the mine site through surface runoff. Annual rainfall average is 11.4 centimeters per year (Stinchfield, 2007). In the late 1960s and early 1970s, the Clark County Regional Flood Control District distinguished a tributary, where storm water flows from Three Kids Mine to the Las Vegas Wash (The Las Vegas Wash Comprehensive Adaptive Management Plan, 1999). There is a possibility that the surface runoff enters the tributary and thereby contaminates the wash. Water can pick up tailings and impacted soil from the mine site and move them into the Las Vegas Wash. As shown in Figure 15, culverts protrude from the mine underneath Lake Mead Drive. The culverts may allow a route for toxic substances to leave mine site via surface water flow during rain events. From field experience, tailings and contaminated soil were found at the culverts on both sides of Lake Mead Drive. In addition, water can dissolve and transport soluble contaminants across the surface, where they can permeate the subsurfaces in the vicinity of the mine (Dean, Moore, & Nealson, 1981). If contaminated water flows to the Las Vegas Wash, it may possibly contaminate Lake Mead because "the Las Vegas Wash is a tributary to [the lake] and … the only channel through which the valley's excess water flows to the lake" (ENSR International,

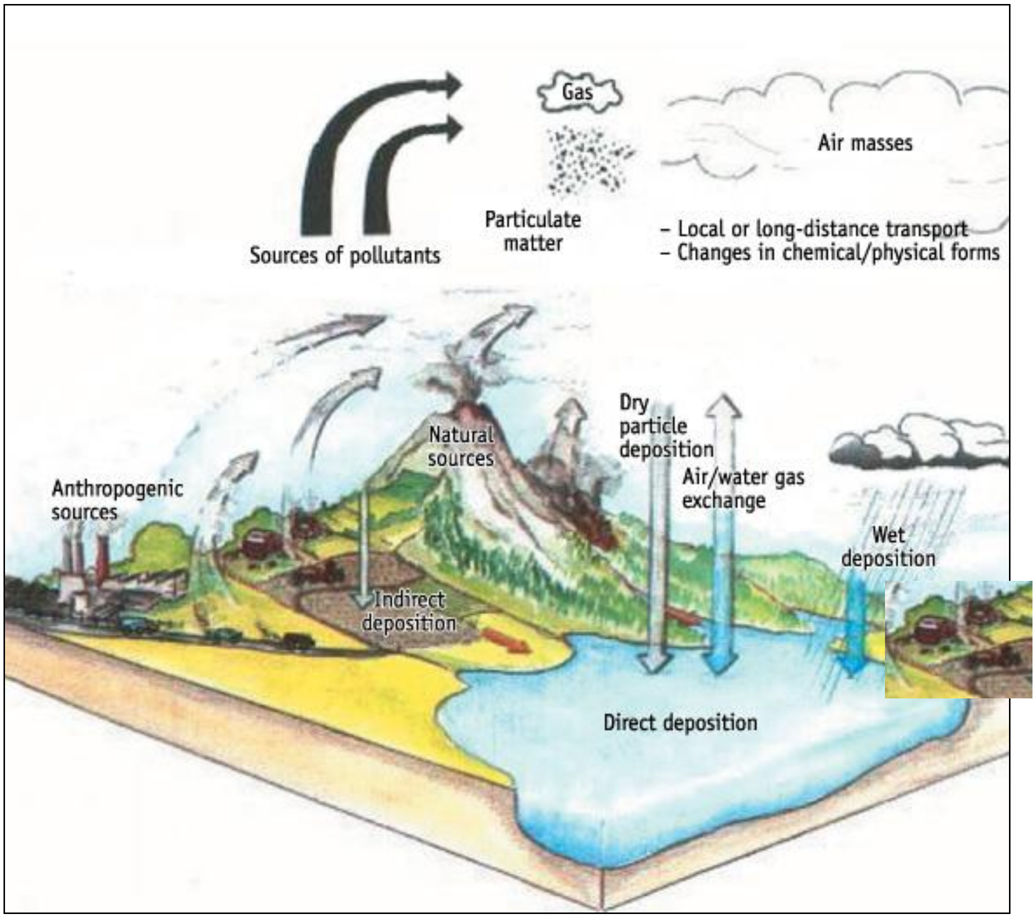

Figure 12 Atmospheric deposition processes (revised from ioe.ucla.edu/reportcard/).

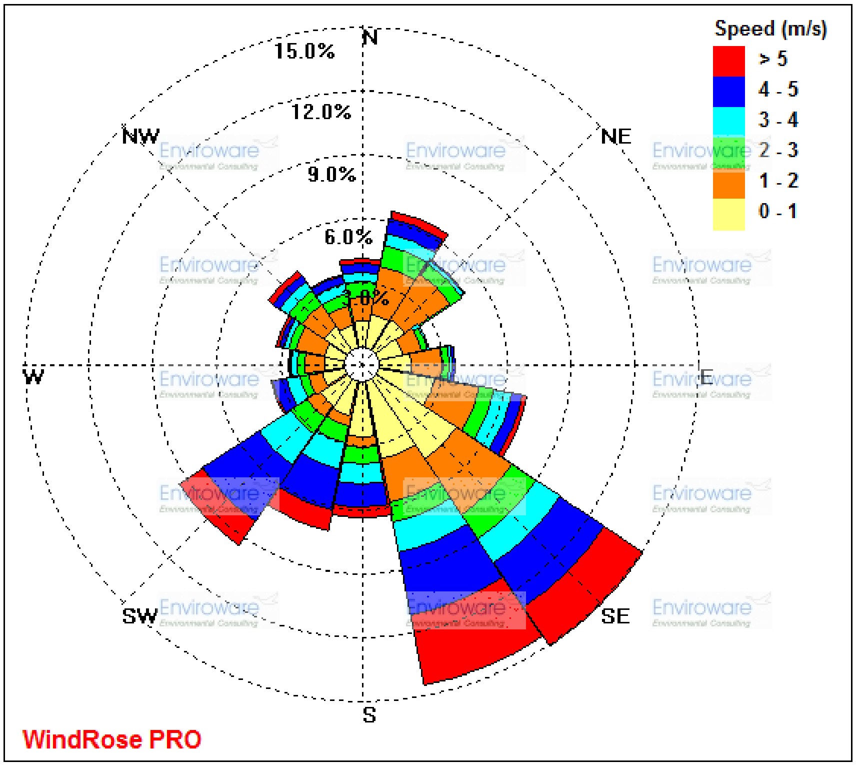

Figure 13 Wind Rose Diagram at the EPA site 32-003-0007.

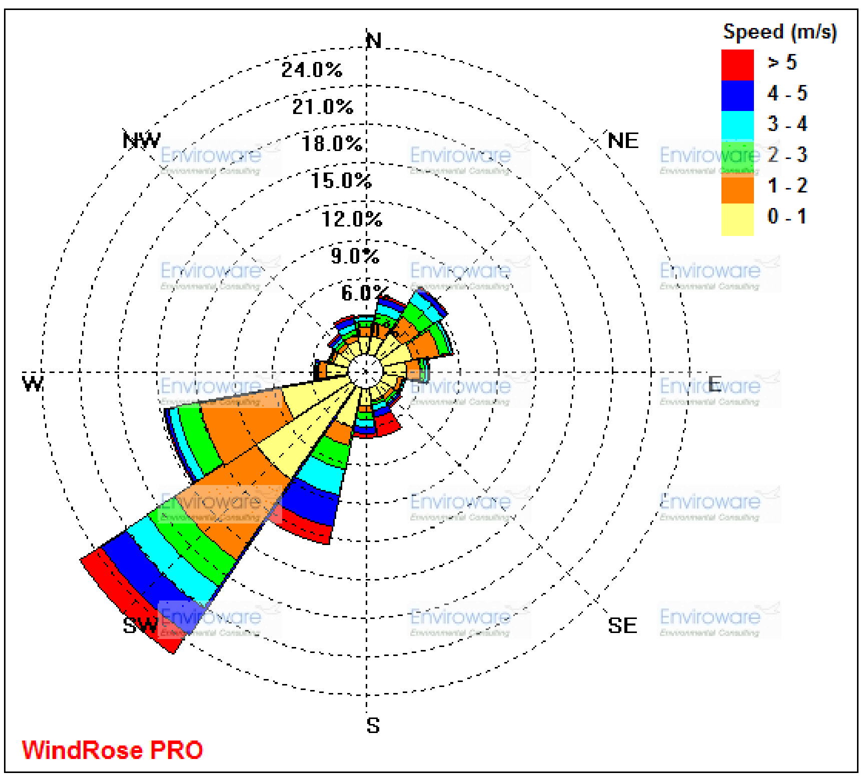

Figure 14 Wind Rose Diagram at the EPA site 32-003-0298.

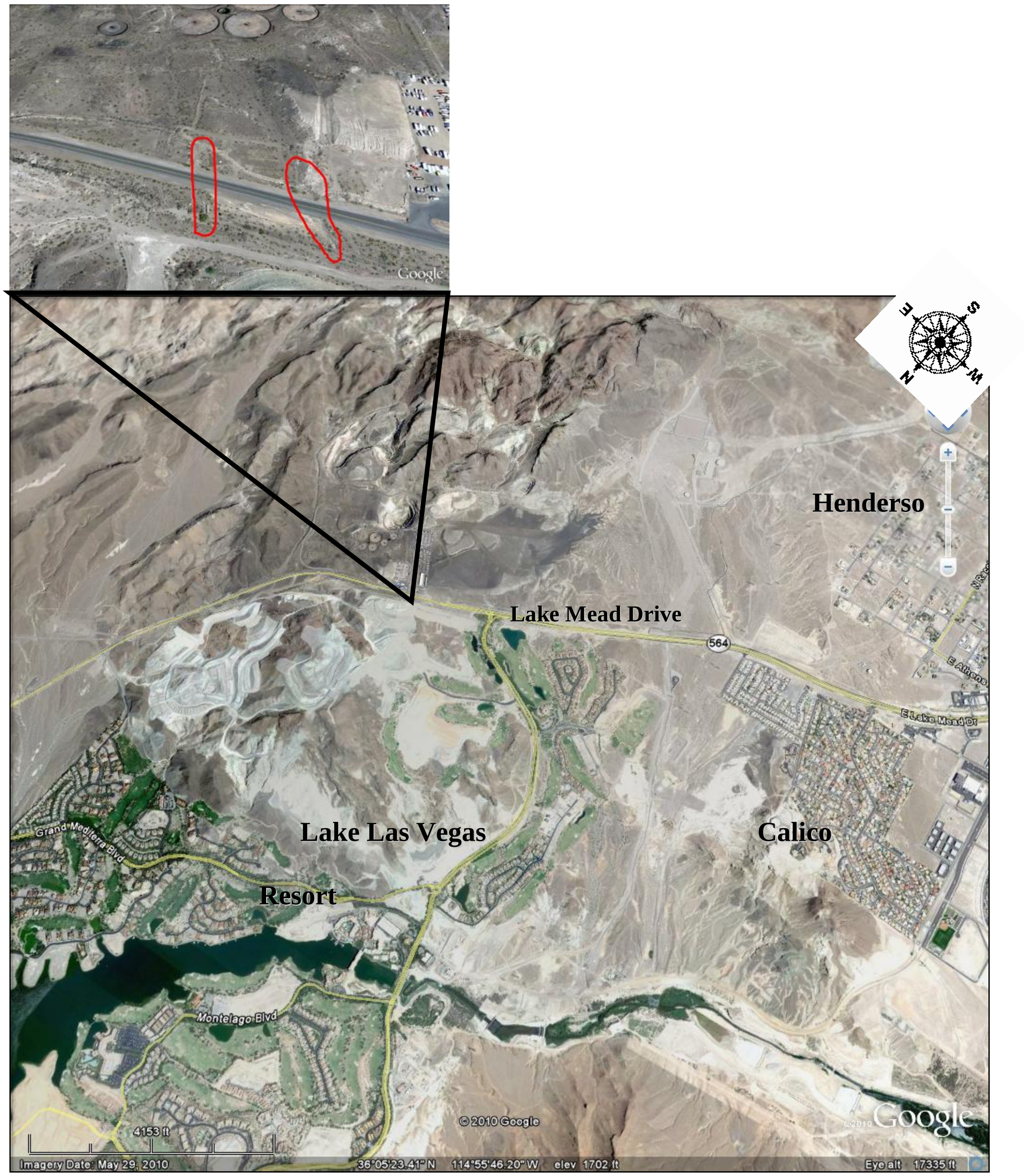

Figure 15 Culverts underneath the Lake Mead Pkwy circled in red. Google Earth.

2005). Although the U.S. Geological Survey (USGS) and the Clark County Regional Flood Control District cannot determine exact measurements of storm water, urban runoff, and intercepted shallow ground water in the Las Vegas Wash, a particular concern in this research is that surface runoff is transporting tailings and contaminated soil from the mine to offsite.

Sampling Map Description

This study considers the directions of wind and surface water movement during rain events (Figure 16). From this information, eight sampling transects were identified around the middle point of the Three Kids Mine tailings. A particular focus of the research is the potential contamination of the nearby communities, for instance, Lake Las Vegas Resort, Calico Ridge, and the Las Vegas Wash. To determine possible exposure to the residents, four transects are selected going from the mine site. In addition, four other transects are selected going from the site north to the Las Vegas Wash, east to Lake Mead, and south to the River Mountains. Sampling will be performed at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) from the middle point of Three Kids Mine at N36°4.993', W114°55.196', in increasing radii (Figure 17).

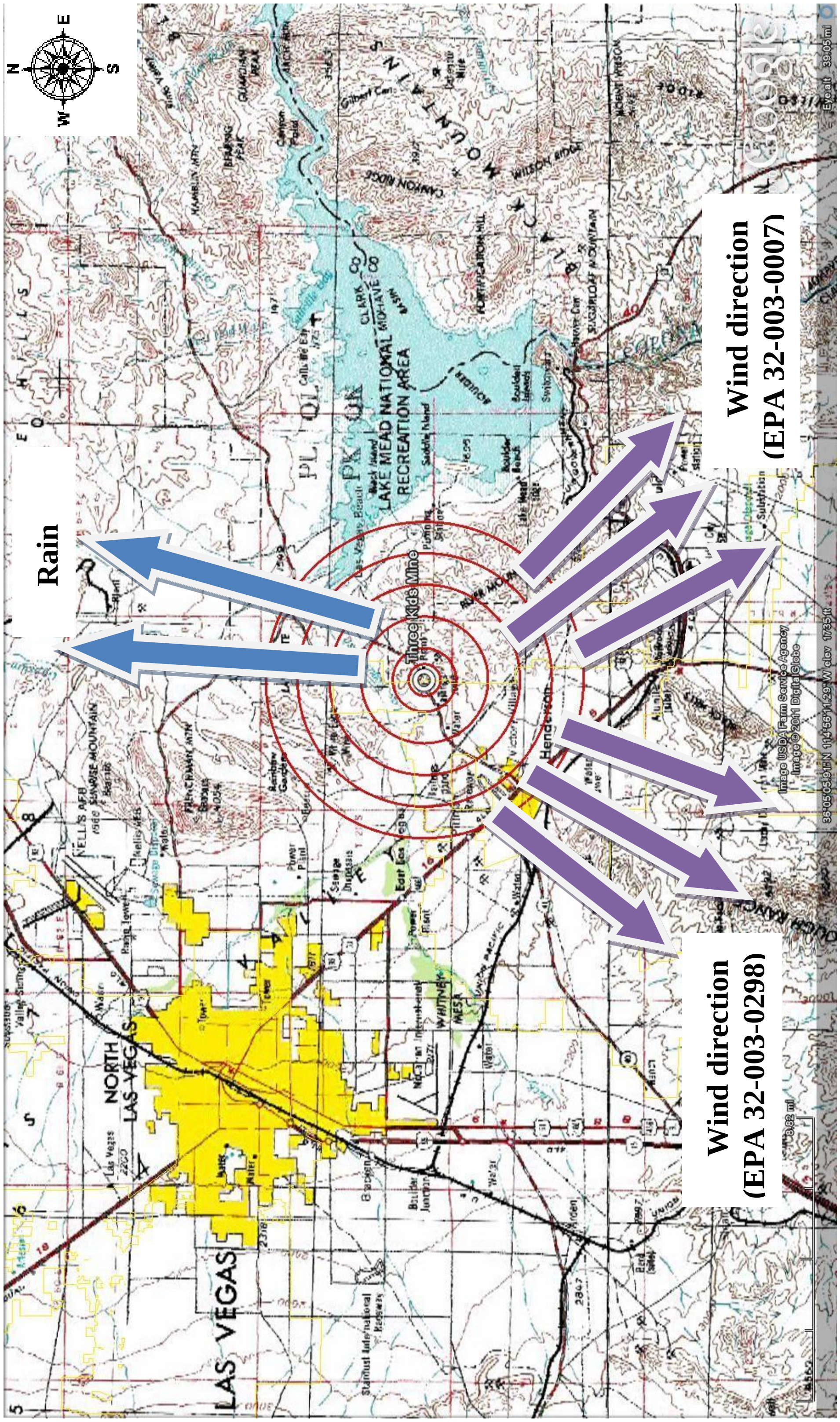

Figure 16 Potential tailing deposition within a distance of 5 miles (8 km) from Three Kids Mine. Google Earth.

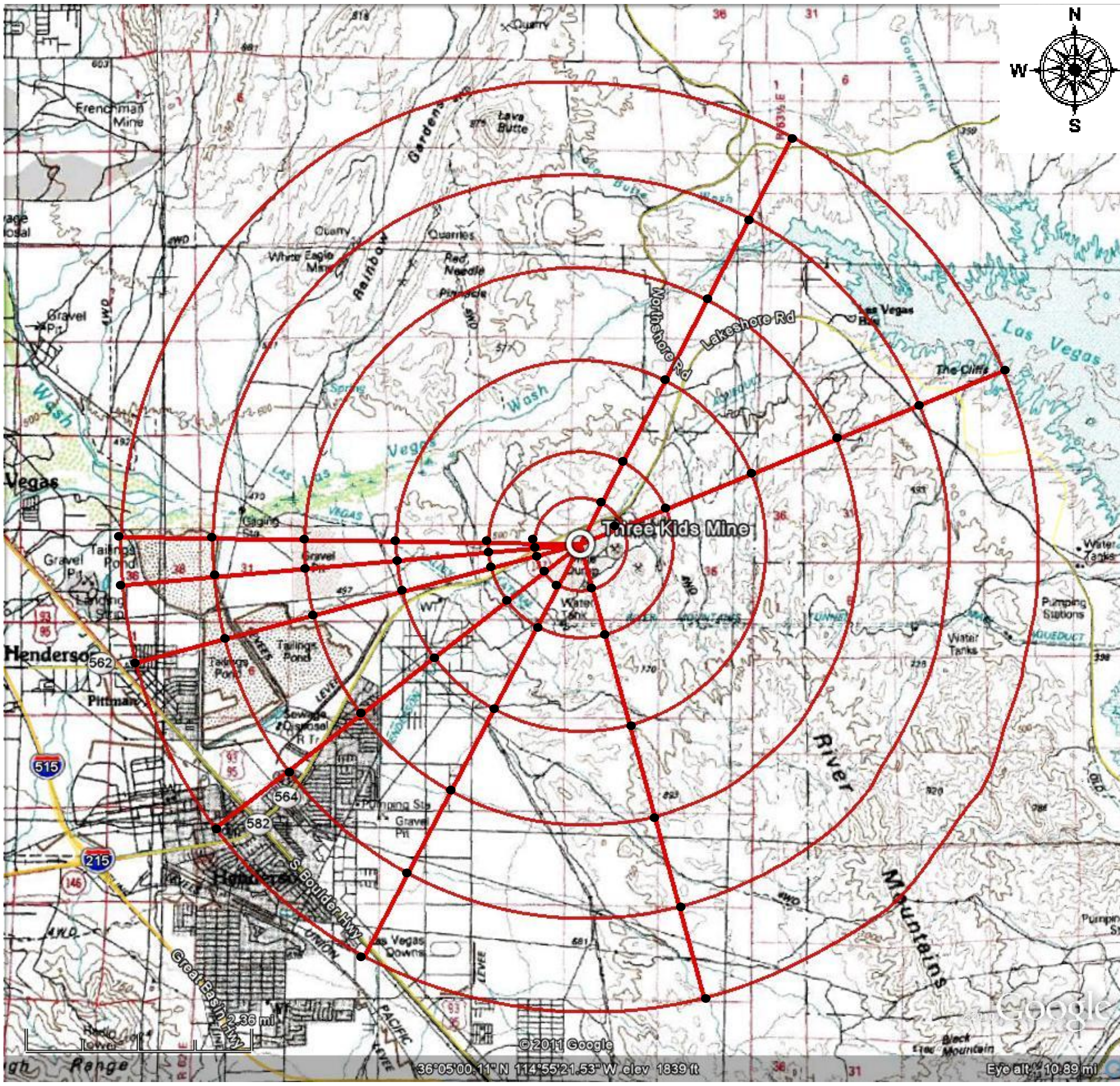

Figure 17 Sampling Locations on eight transects at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings. Google Earth.

CHAPTER 3

METHODOLOGY

To test my hypotheses (see page 6, Chapter 1), soil samples were collected at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) radii on eight transects from the center of the Three Kids Mine tailings (see page 27, Chapter 2) during the summer of 2010 and the summer of 2011. All sites sampled in this study are numbered as shown in Figure 18. This chapter covers intrusive analysis of multi-elemental concentrations of arsenic, manganese, lead, and 12 other elements in soil samples, using x-ray florescence spectroscopy (XRF). A map was then generated based on the locations and chemical compositions of soil samples and is formed in Chapter 4 to show potentially hazardous zones in the proximity of Three Kids Mine.

Sampling Trips

The first sampling trip utilized earlier studies by Naugle (1997) and Sims (1997) on the Three Kids Mine, where hazardous chemicals were found in and around the mine, involving arsenic, chromium, cobalt, lead, manganese, and nickel. With extensive knowledge about the contamination from the site, it was integral to do the preliminary research since it has been approximately 13 years since their studies. Soils near the mine site were collected along Lake Mead Drive and analyzed to determine if these were contaminants to be found beyond the boundary of the Three Kids Mine.

Based on the sampling map as shown in Figure 17 in Chapter 2, the second sampling trip was accomplished by locating the sampling points with a local street map and a

Global Positioning System (GPS) device (Eterx, Garmin International, Inc., Olathe, Kansas, USA). For the local area, offsite transects from the mine site were drawn on a copy of a city of Henderson map (California state automobile association, San Francisco, California, USA), so that some of the transects went through populated area, such as Calico Hills. For the mountains and the mine site, sampling points' coordinates were entered into Google Earth, which obtained geographic displays so that the sampling points would be found by the observation of local features, such as power poles or roads, and then the final location verified by the GPS.

A sampling trip to the mine site was also arranged with Mindy Unger-Watkins who is a principal in the planning of the Lakemoor Canyon project at Three Kids Mine site. She took me to three open pits, flotation tanks, and tailing piles inside the mine site. The tailing piles, seen in the Figures 10 and 11 as dark colored areas, are most likely a significant source for contamination in and around the mine. Soil samples were collected from the tailing piles throughout the site to characterize the tailings.

Sample Collection

Samples were collected to a depth of 0.5 centimeters with each sample weighing approximately 0.5 kg. Most of the time, if necessary, the rocks were removed prior to sampling . A square point stainless steel shovel (Ames True Temper, Pennsylvania, USA) was used for surface soil sampling. The shovel was placed on the ground and tilted slightly to set the top 0.5 centimeters (Figure 19). Samples in wastes were avoided. Five soil samples were collected at the center and each corner around a 3m x 3m sample area and combined to produce a composite sample for each location. If the sample site

was disturbed from anthropogenic activities, nature plants had to be present and in most site, varnished rocks with only top-side varnish were present so that an undisturbed area near the site was sampled. Some samples but not all were collected near or under plant bushes. Sometimes the samples were taken near bushes where there was a sufficient quantity of top soil. Dust samples were also collected by gently sweeping dust off the surface into a dust pan with a fine brush near the soil sampled by the shovel. In addition, one attic dust sample was collected near one mile away from the mine in Transect 7.

All samples collected in this study were stored in Ziploc® Freezer Bags (Indianapolis, IN) or Hefty® One Zip® Jumbo Storage Bags (Lake Forest, IL) depending on the sample size, assigned an I.D, and sealed. Sample identification consisted of the date of site and sample number, for examples, 5-30-2010-1 was the first sample collected on May 30th in 2010. The pertinent information was recorded. Pictures of each sampling location with its sample bag were taken for the purposes of visual record (Figure 20). The geographical coordinates and the altitude of each sampling site were established with the Global Positioning System device (GPS). The wind directions and speed were recorded using the professional military compass (Jinhua Xinxiang Optical Instrument Factory, Zhejian, China) and the mini Thermo Anemometer Airflow Meter (Extech Instrument Corporation, Massachusetts, USA). Appendix 1 contains a list of all of the samples collected in this study. The samples are listed in Table 4. All of the surface soil samples were then distributed according to locations of the tailing piles and eight transects at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) from the center of the Three Kids Mine tailing piles in Tables 5.

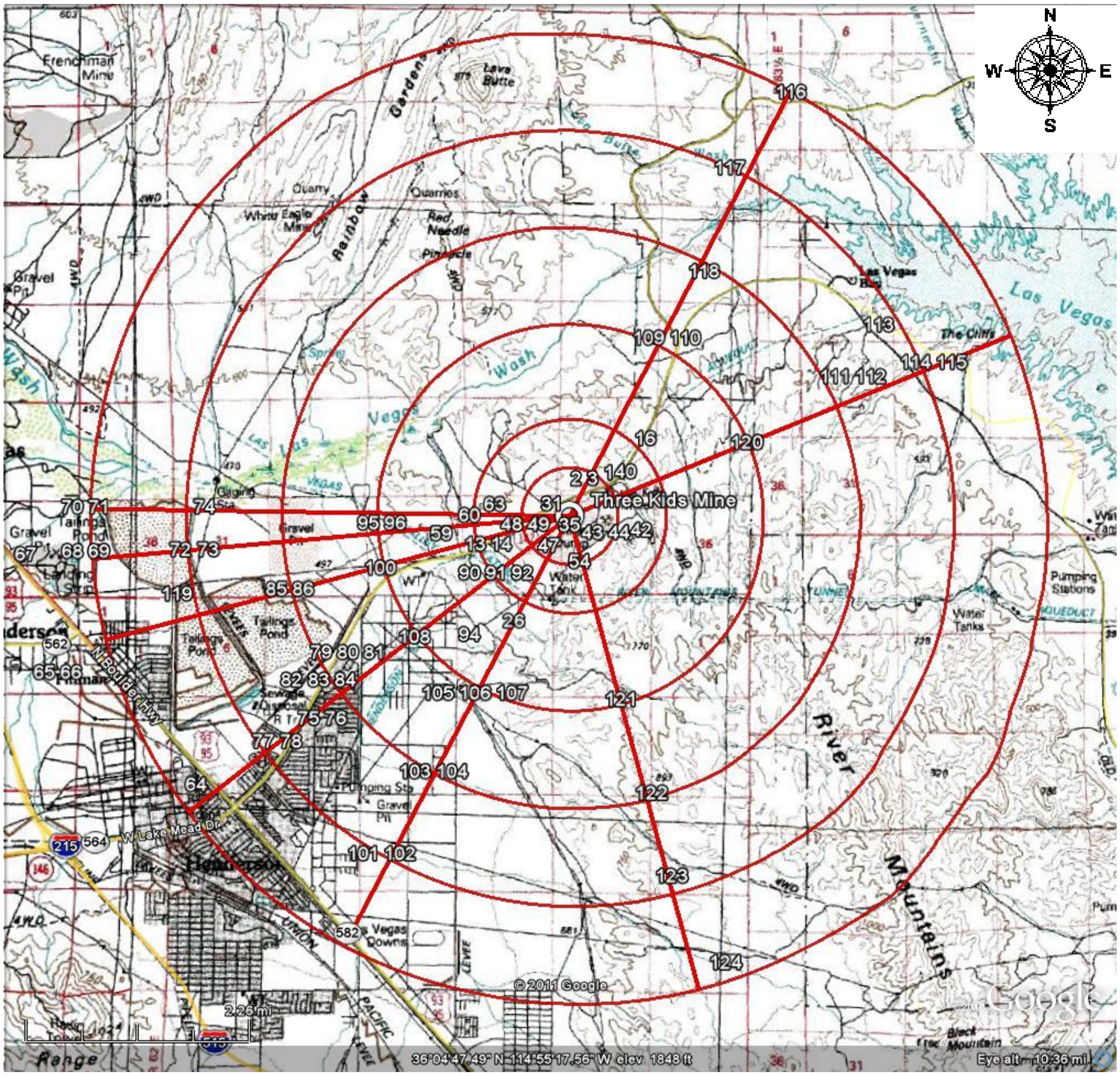

Figure 18 Topographical Sample Location Map of Three Kids Mine. Google Earth.

Figure 19 Scooping the top 0.5 centimeters of soil surface.

Figure 20 Soil sample with three sampling sites in the picture. Total five samples were collected at the corner and each corner around a 3m x 3m sample area. Two sampling sites are beyond the picture.

Table 4
Sample Information

#	Sample Name	Longitude	Latitude	Elevation (ft)	Notes
1	5-30-2010-1	N 36º05.269’	W 114º54.758’	1806	Near the gate at mine
2	5-30-2010-2	N 36º 05.329'	W 114º54.879’	1806	1st drain by the gate
3	5-30-2010-3	N 36º 05.329'	W 114º 54.879'	1806	Crust layer by drain
4	5-30-2010-4	N 36º 05.210'	W 114º 54.949'	1793	2nd drain near boats
5	5-30-2010-5	N 36º 05.224'	W 114º 54.968'	1784	across street, on 2nd drain
6	5-30-2010-6	N 36º 05.235'	W 114º 54.904'	1804	Across street, 1st drain
7	5-30-2010-7	N 36º 05.093'	W 114º 55.253'	1753	W of boat sale, by mine
8	5-30-2010-8	N 36º05.051'	W 114º 55.382'	1735	Crust layers; boat storage
9	5-30-2010-9	N 36º 04.975'	W 114º 55.563'	1707	dried water flow from site
10	7-23-2010-1	N 36º 04.577'	W 114º 56.350'	1758	Golda and Lake Mead
11	7-23-2010-2	N 36º 04.570'	W 114º 56.322'	1780	
12	7-23-2010-3	N 36º 04.831'	W 114º 55.862'	1752	
13	7-23-2010-4	N 36º 04.852'	W 114º 55.841'	1754	
14	7-23-2010-5	N 36º 04.831'	W 114º 55.862'	1752	
15	7-23-2010-7	N 36º 05.661'	W 114º 54.354'	1807	
16	7-23-2010-9	N 36º 05.689'	W 114º 54.352'	1751	
17	8-19-2010-1	N 36° 05.242'	W 114° 54.798'	1812	Near entry of the mine
18	8-19-2010-3	N 36° 05.273'	W 114° 54.743'	1731	Inside pipe next to entry
19	8-19-2010-4	N 36° 05.277'	W 114° 54.775'	1730	Outside pipe next to entry
20	8-19-2010-5	N 36° 05.251'	W 114° 54.862'	1804	
21	8-19-2010-6	N 36° 05.251'	W 114° 54.862'	1804	Near the edge of culvert
22	8-19-2010-7	N 36° 05.243'	W 114° 54.931'	1788	Near the edge of culvert
23	8-19-2010-8	N 36° 05.211'	W 114° 54.947'	1782	
24	8-19-2010-10	N 36° 05.211'	W 114° 54.947'	1784	
25	8-19-2010-11	N 36° 05.277'	W 114° 54.775'	1745	Tin can collected
26	5-26-2011-1	N 36º 04.023'	W 114º 55.833'	1920	Next to power poll
27	5-26-2011-2	N 36º 04.901'	W 114º 55.508'	1727	
28	5-26-2011-3	N 36º 04.751'	W 114º 55.510'	1830	Culvert near the site
29	5-26-2011-4	N 36º 04.917'	W 114º 55.329'	1864	26º 300-334 FPM
30	6-10-2011-2	N 36º 04.965'	W 114º 55.300'	1780	38.2º 472-600 FPM
31	6-10-2011-3	N 36º 04.989'	W 114º 55.277'	1763	0.5 cm surface soil
32	6-10-2011-4	N 36º 04.958'	W 114º 55.258'	1762	0.5 cm surface soil
33	6-10-2011-5	N 36º 04.929'	W 114º 53.269'	1798	30 cm soil profile
34	6-10-2011-6	N 36º 04.799'	W 114º 55.442'	1803	Overflow from tailing
35	6-10-2011-7	N 36º 04.799'	W 114º 55.316'	1842	50º 472-511 FPM
36	6-20-2011-1	N 36º 05.176'	W 114º 55.755'	1850	Saw a truck, collect a tin
37	6-20-2011-2	N 36º 05.205'	W 114º 54.732'	1796	Near flotation tanks
38	6-20-2011-3	N 36º 05.148'	W 114º 54.780'	1845	Inside #2 tank wall
39	6-20-2011-6	N 36º 05.132'	W 114º 54.855'	1832	Hilltop near the gate wall
40	6-20-2011-9	N 36º 05.278'	W 114º 54.693'	1807	Windblown in bottle
41	6-20-2011-10	N 36º 05.081'	W 114º 54.555'	1855	Roads inside the mine
42	6-20-2011-11	N 36º 04.979'	W 114º 54.516'	1859	Wind to SE, inside tailing
43	6-20-2011-12	N 36º 04.843'	W 114º 54.794'	1843	
44	6-20-2011-13	N 36º 04.843'	W 114º 54.794'	1843	
45	6-20-2011-14	N 36º 04.799'	W 114º 54.928'	1882	Mine hole near ridge pile

FPM stands for feet per minute

Table 4 (cont'd)
Sample Information

#	Sample Name	Longitude	Latitude	Elevation (ft)	Notes
46	6-20-2011-15	N 36º 04.799'	W 114º 54.928'	1882	Mine hole near ridge pile
47	6-20-2011-16	N 36º 04.727'	W 114º 55.302'	1796	Overflow toward open pit
48	6-20-2011-17	N 36º 04.806'	W 114º 55.422'	1803	Blank basin; wind to E
49	6-20-2011-18	N 36º 04.806'	W 114º 55.422'	1803	Windblown sample; sand
50	6-21-2011-1	N 36º 05.132'	W 114º 54.855'	1832	Can and rocks
51	6-21-2011-2	N 36º 05.278'	W 114º 54.693'	1807	Broken bottle with rocks
52	6-21-2011-3	N 36º 04.810'	W 114º 54.825'	1869	
53	6-21-2011-4	N 36º 04.982'	W 114º 54.901'	1845	Drain bet. tank and boat
54	6-21-2011-5	N 36º 04.584'	W 114º 55.085'	1872	
55	6-21-2011-6	N 36º 04.956'	W 114º 55.250'	1779	
56	6-21-2011-7	N 36º 04.972'	W 114º 55.168'	1777	Wind 2º 255-334 FPM
57	6-21-2011-8	N 36º 04.972'	W 114º 55.168'	1777	
58	6-21-2011-9	N 36º 04.972'	W 114º 55.168'	1777	
59	6-26-2011-1	N 36º 04.972'	W 114º 55.168'	1777	Attic dust
60	6-26-2011-2	N 36º 04.887'	W 114º 56.434'	1659	Near the attic dust
61	6-26-2011-3	N 36º 04.800'	W 114º 56.318'	1686	
62	6-26-2011-4	N 36º 04.927'	W 114º 55.890'	1733	Near Lake LV resort
63	6-26-2011-5	N 36º 04.985'	W 114º 55.912'	1678	May be disturbed land
64	6-30-2011-1	N 36º 02.577'	W 114º 59.353'	1819	Near BMI complex
65	6-30-2011-2	N 36º 03.581'	W 115º 0.910'	1688	Homeless people living
66	6-30-2011-3	N 36º 03.581'	W 115º 0.910'	1689	Swiping with dust pan
67	6-30-2011-4	N 36º 04.645'	W 115º 1.273'	1647	Undisturbed in houses
68	6-30-2011-5	N 36º 04.673'	W 115º 0.608'	1598	Windblown from N
69	6-30-2011-6	N 36º 04.673'	W 115º 0.608'	1599	Organic swiping
70	6-30-2011-7	N 36º 05.073'	W 115º 0.613'	1589	Dust pan used (2mm)
71	6-30-2011-8	N 36º 05.073'	W 115º 0.613'	1589	Top soil surface
72	6-30-2011-9	N 36º 04.688'	W 114º 59.394'	1585	Dust pan used (2mm)
73	6-30-2011-10	N 36º 04.688'	W 114º 59.394'	1585	Top soil surface
74	6-30-2011-11	N 36º 05.075'	W 114º 59.280'	1563	No strong wind
75	6-30-2011-12	N 36º 03.173'	W 114º 58.229	1771	Dust pan, wind from NE
76	6-30-2011-13	N 36º 03.173'	W 114º 58.229	1772	Shovel used (0.5 cm)
77	6-30-2011-14	N 36º 02.965'	W 114º 58.456'	1789	Wind blowing from mine
78	6-30-2011-15	N 36º 02.965'	W 114º 58.456'	1789	Dust pan (2mm)
79	7-6-2011-1	N 36º 03.865'	W 114º 57.674'	1701	Wind from E
80	7-6-2011-2	N 36º 03.865'	W 114º 57.674'	1701	Dust pan under rocks
81	7-6-2011-3	N 36º 03.865'	W 114º 57.674'	1701	Wind from E
82	7-6-2011-4	N 36º 03.517'	W 114º 57.995'	1756	Bet Pawnee & Navajo
83	7-6-2011-5	N 36º 03.517'	W 114º 57.995'	1756	Dust Pan (2 mm)
84	7-6-2011-6	N 36º 03.517'	W 114º 57.995'	1756	Dust under rocks (10 cm)
85	7-6-2011-7	N 36º 04.333'	W 114º 58.322'	1657	Shovel used (0.5cm)
86	7-6-2011-8	N 36º 04.333'	W 114º 58.322'	1657	Dust Pan (2 mm)
87	7-6-2011-9	N 36º 04.770'	W 114º 56.223'	1697	Power lines
88	7-6-2011-10	N 36º 04.770'	W 114º 56.223'	1697	Dust Pan (2 mm)
89	7-6-2011-11	N 36º 04.910'	W 114º 56.271'	1654	Wind from LV lake
90	7-6-2011-12	N 36º 04.479'	W 114º 56.012'	1756	Wind from mine and E

FPM stands for feet per minute

Table 4 (cont'd)
Sample Information

#	Sample Name	Longitude	Latitude	Elevation (ft)	Notes
91	7-6-2011-13	N36º04.479'	W 114º56.012'	1756	Dust pan (2 mm)
92	7-6-2011-14	N36º04.479'	W 114º56.012'	1756	Wind from LV wash
93	7-6-2011-15	N36º04.679'	W 114º56.174'	1705	Wind from LV wash
94	7-6-2011-16	N36º04.987'	W 114º56.311'	1647	Wind from LV wash
95	7-16-2011-1	N36º04.929'	W 114º57.290'	1676	Shovel (0.5cm)
96	7-16-2011-2	N36º04.929'	W 114º57.290'	1676	38º 137-334 FPM
97	7-16-2011-3	N36º04.870'	W 114º57.317'	1628	Huge hole, no wind
98	7-16-2011-4	N36º04.864'	W 114º57.301'	1629	Shovel (0.5cm)
99	7-16-2011-5	N36º04.864'	W 114º57.301'	1629	Dried water wash
100	7-16-2011-6	N36º04.525'	W 114º57.309'	1654	Construction on complex
101	7-16-2011-7	N36º01.963'	W 114º57.279'	1954	Shovel (0.5cm)
102	7-16-2011-8	N36º01.963'	W 114º57.279'	1954	SE 21.5º 846-944 FPM
103	7-16-2011-9	N36º02.701'	W 114º56.706'	1958	Dark colored top soil
104	7-16-2011-10	N36º02.701'	W 114º56.706'	1958	SW 18-22º 590-649 FPM
105	7-16-2011-11	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
106	7-16-2011-12	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
107	7-16-2011-13	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
108	7-16-2011-14	N36º03.907'	W 114º56.922'	1805	SE 26º 590-944 FPM
109	7-21-2011-1	N36º06.601'	W 114º54.106'	1513	65º 590 FPM
110	7-21-2011-2	N36º06.601'	W 114º54.106'	1513	Same area as 7-21-2011-1
111	7-23-2011-1	N36º06.250'	W 114º52.024'	1648	26-28º 393-688 FPM
112	7-23-2011-2	N36º06.250'	W 114º52.024'	1648	Same area as 7-23-2011-2
113	7-23-2011-3	N36º06.725'	W 114º51.725'	1286	Dried water flow
114	7-23-2011-4	N36º06.386'	W 114º51.105'	1453	Wind 17º 314-728 FPM
115	7-23-2011-5	N36º06.386'	W 114º51.105'	1453	Wind 17º 314-728 FPM
116	7-27-2011-1	N36º08.839'	W 114º52.705'	1380	Wind 27º 255 FPM
117	7-27-2011-2	N36º08.152'	W 114º53.391'	1385	Wind 15º 373 FPM
118	7-27-2011-3	N36º07.213'	W 114º53.683'	1384	Wind 16º 373 FPM
119	7-27-2011-4	N36º04.289'	W 114º59.585'	1596	Water washed down to the other side of BMI complex
120	7-31-2011-1	N36º05.651'	W 114º53.224'	1859	Wind 37.5º 570-610 FPM
121	8-20-2011-1	N36º03.357'	W 114º54.629'	2384	Wind 17º 472-511 FPM
122	8-20-2011-2	N36º02.539'	W 114º54.296'	2684	Wind 22º 511-531 FPM
123	8-20-2011-3	N36º01.795'	W 114º54.075'	2618	Wind 35º 742-512 FPM
124	8-20-2011-4	N36º01.038'	W 114º53.488'	2610	Wind 19º 590-610 FPM

FPM stands for feet per minute

Table 5

Breakdown of samples in transects at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) from the center of the Three Kids Mine tailing piles

Samples collected in tailing piles				
6-10-2011-4	6-20-2011-2	6-20-2011-13	6-20-2011-17	6-21-2011-6
6-10-2011-5	6-20-2011-3	6-20-2011-14	6-20-2011-18	6-21-2011-7
6-10-2011-6	6-20-2011-6	6-20-2011-15	6-21-2011-3	6-21-2011-8
6-10-2011-7	6-20-2011-10	6-20-2011-16	6-21-2011-4	6-21-2011-9

Distance (mile)	Transect 1
0.5 (805 m)	8-19-2010-1, 8-19-2010-3, 8-19-2010-4, 8-19-2010-11, 5-30-2011-1, 5-30-2011-2, 5-30-2011-3, 5-30-2011-4, 5-30-2011-5, 5-30-2011-6, 6-21-2011-2, 6-21-2011-6
1 (1.6 km)	7-23-2011-7, 7-23-2011-9
2 (3.2 km)	7-21-2011-1, 7-21-2011-2
3 (4.8 km)	7-27-2011-3
4 (6.4 km)	7-27-2011-2
5 (8.0 km)	7-27-2011-1
Distance (mile)	**Transect 2**
0.5 (805 m)	6-20-2011-9, 6-20-2011-11, 6-20-2011-12, 6-21-2011-1, 6-21-2011-2
1 (1.6 km)	7-23-2010-9
2 (3.2 km)	7-31-2011-1
3 (4.8 km)	7-23-2011-1, 7-23-2011-2
4 (6.4 km)	7-23-2011-4, 7-23-2011-5
5 (8.0 km)	NA; disturbed land near Lake Mead
Distance (mile)	**Transect 3**
0.5 (805 m)	6-21-2011-5
1 (1.6 km)	NA
2 (3.2 km)	8-20-2011-1
3 (4.8 km)	8-20-2011-2
4 (6.4 km)	8-20-2011-3
5 (8.0 km)	8-20-2011-4
Distance (mile)	**Transect 4**
0.5 (805 m)	6-20-2011-16
1 (1.6 km)	5-26-2011-1, 7-6-2011-16
2 (3.2 km)	7-16-2011-11, 7-16-2011-12
3 (4.8 km)	7-16-2011-9, 7-16-2011-10
4 (6.4 km)	7-16-2011-7, 7-16-2011-8
5 (8.0 km)	NA; public building construction
Distance (mile)	**Transect 5**
0.5 (805 m)	6-10-2011-6, 6-20-2011-16, 6-20-2011-17, 6-20-2011-18
1 (1.6 km)	7-6-2011-12, 7-6-2011-13
2 (3.2 km)	7-6-2011-16, 7-16-2011-14
3 (4.8 km)	7-6-2011-1, 7-6-2011-2, 7-6-2011-4, 7-6-2011-5, 7-6-2011-6
4 (6.4 km)	6-30-2011-12, 6-30-2011-13, 6-30-2011-14, 6-30-2011-15
5 (8.0 km)	6-30-2011-1

NA = Not Available

Table 5 (cont'd)

Breakdown of samples in transects at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km from the center of the Three Kids Mine tailing piles

Distance (mile)	Transect 6
0.5 (805 m)	7-23-2010-3, 7-23-2010-4, 7-23-2010-5, 5-26-2011-2
1 (1.6 km)	7-23-2010-1, 7-23-2010-2, 6-26-2011-3, 7-6-2011-9, 7-6-2011-10
2 (3.2 km)	7-16-2011-6
3 (4.8 km)	7-6-2011-7, 7-6-2011-8
4 (6.4 km)	7-27-2011-4, 7-27-2011-5, 7-27-2011-6
5 (8.0 km)	6-30-2011-2, 6-30-2011-3
Distance (mile)	Transect 7
0.5 (805 m)	6-26-2011-4
1 (1.6 km)	6-26-2011-2, 6-26-2011-3
2 (3.2 km)	7-16-2011-3, 7-16-2011-4, 7-16-2011-5
3 (4.8 km)	NA; disturbed area (houses)
4 (6.4 km)	6-30-2011-9, 6-30-2011-10
5 (8.0 km)	6-30-2011-4, 6-30-2011-5, 6-30-2011-6
Distance (mile)	Transect 3
0.5 (805 m)	5-30-2010-9, 8-19-2010-1, 8-19-2010-3, 8-19-2010-4, 8-19-2010-11, 6-26-2011-5
1 (1.6 km)	7-6-2011-11
2 (3.2 km)	7-16-2011-1, 7-16-2011-2
3 (4.8 km)	NA; disturbed area (houses)
4 (6.4 km)	6-30-2011-11
5 (8.0 km)	6-30-2011-7, 6-30-2011-8

NA = Not Available

Sample Preparation

Once back at the laboratory, all samples were stored in Sterilite® tote boxes (Townsend, Ma) to avoid interference from UV light, moisture, and other factors. The composite sample of five soil samples from each site was thoroughly mixed and dried in an oven at 110°C. The drying process should be done promptly to decrease interference from the sample quality damage (Carter, 1993). The composite sample was sieved (18 x 16 mesh; 2.29 mm) to remove debris like big rocks and organic materials. Subsequently, it was placed in a polyethylene, open-ended XRF samples cup (Chemplex® Industries, Inc., Palm City, Florida, USA). Each sample cup was capped on one end, filled, and capped on the other end with Diamond® plastic wrap (Reynolds consumer products, Richmond, Virginia, USA) (Figure 21-24). A permanent marker was used to label each sample cup with the sample name. Prepared samples were analyzed in order.

Figure 21 XRF sample cups, capped on one end

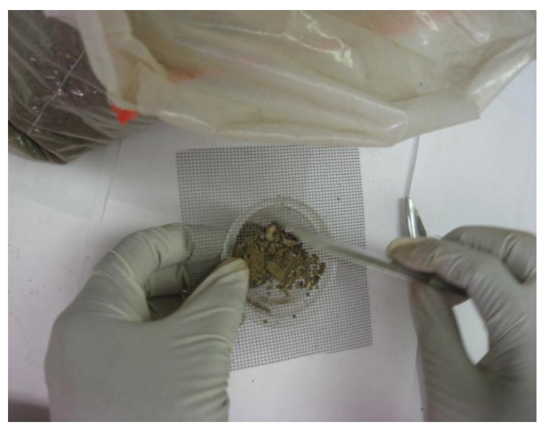

Figure 22 Sieving a composite sample

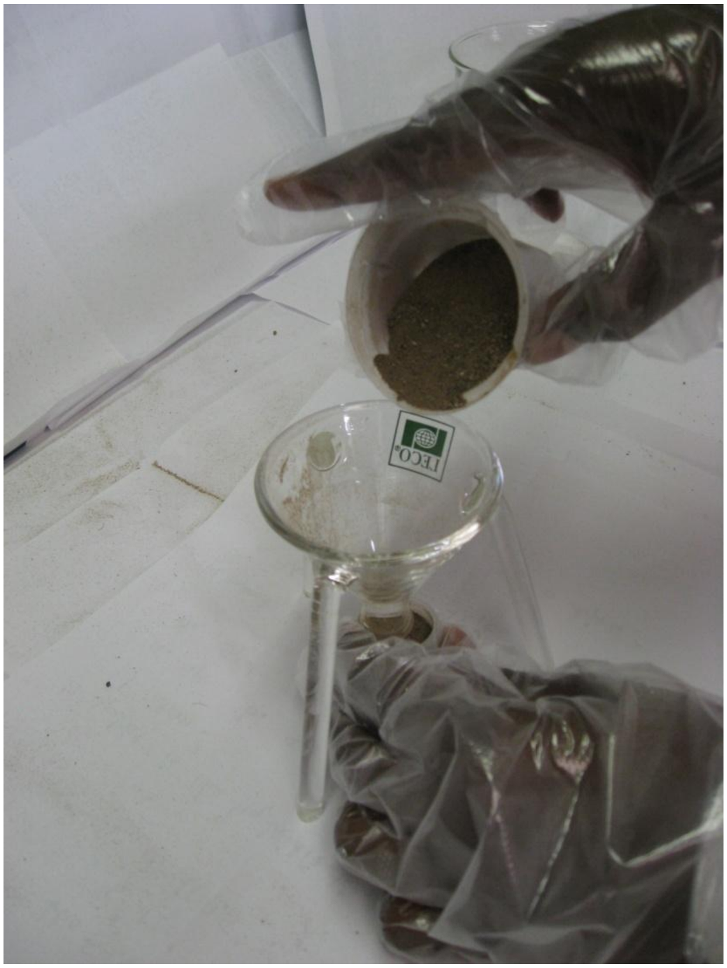

Figure 23 Filling a cup with sample

Figure 24 Sample filled XRF sample cups capped on both ends

Analytical Methods

The analytical technique used in this study was X-ray fluorescence to examine the chemical composition of soil samples. XRF analysis is rapid and non-destructive. It is widely used for the multi-elemental analysis of archaeological samples, lead paint inspection, metal samples, rocks, soil, toys, and consumer goods. The analytical work was performed at the Environmental Health Laboratory at UNLV and the Department of Chemistry at UNLV.

All the soil samples were analyzed in triplicate with a NITON XLp 703A portable X-ray spectrometer equipped with a 40 mCi ^{109}Cd radioisotope source, a silicon PiN, and Peltier cooled detector (Thermo Fisher Scientific, Billerica, Massachusetts, USA). Samples were measured for a duration of 60 seconds in bulk sample mode (up to 9.52 mm depth). The Thermo Scientific Niton Data Transfer (NDT™) software was used to deliver a full set of XRF data to a computer with an additional Excel converted file. The Thermo Scientific Niton XRF analyzer quantifies elements ranging from chromium (element 24) through lead (element 82), measuring x-ray energies from 5.41 keV up to 84.92 keV in the case of Pb k-shell fluorescent x-rays excited with a ^{109}Cd isotope (Niton Europe GmbH, Munchen, Germany). A total of 15 elements analyzed in this study include chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, rubidium, strontium, zirconium, molybdenum, mercury, and lead. The applicable range of this study goes up to percent levels of lead and manganese.

Figure 25 Instrument setup with samples awaiting analysis.

Figure 26 Instrument setup with a sample in the XRF stand

Before the sample analysis was started, the computer was directly connected to the analyzer (Figure 25). Initiation of the XRF required cooling down of the detector and shutter calibration, which takes 15 to 30 minutes before analyzing samples. Each triplicate sample was analyzed in total six runs, three runs from the top of the sample cup and three runs from the bottom. The sample cup was positioned in front of the probe window inside a XRF stand for analysis (Figure 26). When a sample was irradiated with primary x-rays, inner shell electrons were excited and electrons from higher energy levels moved to fill the vacancy. Then, the intensities of emitted secondary (fluorescent) x-radiation from the samples were measured. The elemental concentrations were determined by the number of counts at a given energy per unit of time for XRF analysis.

XRF spectrometer was internally calibrated according to Environmental Protection Agency (EPA) Method 6200 modified to use of fundamental parameters (FP) method. The FP analysis is based on built-in mathematical algorithms that calculate the quantitative effect of the detector's response to pure element samples. This calibration is verified with standard reference materials (SRM) obtained from the U.S. National Institute of Standard and Technology (NIST). Two NIST SRMs were used: SRM 2709 San Joaquin Soil (low-level) and SRM 2711 Montana Soil (high-level). SRMs were used as continuous calibration verification (CCV) standards by calculating a percent difference (%D), as seen in the following equation:

$$\%D = \frac{(C_s - C_k)}{C_k} \times 100$$

%D = Percent difference
C_k = Certified concentration of standard sample
C_s = Measured concentration of standard sample

The %D within ± 20% of the certified values is required (EPA 6200 Method: Field portable x-ray fluorescence spectrometry for the determination of elemental concentrations in soil and sediment, 2007). The percent recoveries were also calculated, as seen in the following equation:

$$\%\,\mathrm{Re}\,c = \frac{Mean\_Value}{Certified\ /\ Information\_Value} \times 100$$

Certified and information values are provided by the National Institute of Standards and Technology for SRM 2709 San Joaquin Soil and SRM 2711 Montana Soil.

In addition, limits of detections (LODs) were provided by the instrument manufacture as reference in Figure 27. Accuracy and precision of the XRF measurements were verified by analysis of NIST SRM 2709 San Joaquin Soil and SRM 2711 Montana Soil. They were verified by calculating a relative standard deviation (RSD) between duplicate measurements of SRMs, as seen in the following equation:

$$RSD = \frac{s}{x} \times 100$$

RSD = relative standard deviation for the precision measurement
s = standard deviation of the concentration
x = mean concentration of the concentration

An RSD below 20% of the certified values is required (Taylor, 1987).

NITON® XLi/XLt 700 Series Instruments

Elemental Limits of Detection in Soils, mg/kg (ppm)

NITON's XLi/XLt 700 Series environmental analyzers offer analytical performance that is unsurpassed in the industry. Various excitation options, including the high performance 40mCi ^{109}Cd and the x-ray tube, are available depending on your particular analytical requirements. The following chart details the sensitivity (LOD) of our XLi 732 analyzer equipped with the 40mCi ^{109}Cd, along with the ^{241}*Am* isotope and ^{55}*Fe* isotope, versus that of our XLt 792 equipped with the miniaturized x-ray tube.

These LOD's are specified for both a SiO (sand) matrix and a typical soil matrix represented by NIST Standard Reference Materials (SRM). The SRM matrix represents the closest matrix to what would be considered a "real world" soil sample. NITON specifies detection limits following the EPA protocol of 99.7% confidence level. Individual LOD's improve as a function of the square root of the testing time.

XLi/XLt 700 Series Analyzers — 60 Second Measurement Time

	^{109}Cd Isotope (40mCi)		*Miniaturized X-ray Tube*	
	Sand Matrix	*SRM Matrix*	*Sand Matrix*	*SRM Matrix*
Cr	115	160	250	350
Mn	60	230	150	250
Fe	100	230	150	250
Co	50	230	30	200
Ni	75	75	60	100
Cu	50	75	100	125
Zn	30	60	40	75
As	10	12	10	15
Se	7	10	10	15
Pb	12	15	12	20
Hg	15	18	12	20
Rb	5	7	5	15
Sr	10	15	15	25
Zr	5	18	X	X
Mo	5	7	X	X
	^{241}Am Isotope (14mCi)			
Cd	35	50	30	50
Ag	190	130	30	50
Ba	35	80	X	X
Sn	140	180	50	75
Sb	65	35	50	75
	^{55}Fe Isotope (20mCi)			
V	120	100		
Ti	350	520		
Ca	0.15%	0.13%		
K	0.35%	0.35%		

XRF limits of detection (LOD's) are dependent on the following factors:

1) Testing time
2) Soil matrix
3) Level of statistical confidence
4) Excitation Source

Please Note
Ongoing research and advancments in our XLi/XLt Series analyzers will lead to continual improvement in many of the values detailed in this chart. Please contact NITON or your local NITON representative for the latest performance specifications.

❖ **Different instrument configurations offer varying advantages in analytical capability for specific elements, long-term cost-of-ownership and in regulatory requirements. Please contact NITON or your NITON representative to discuss which analyzer configuration will best fit your application and analytical needs.**

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Figure 27 Limits of detection list for XRF instrument used in this study (mg/kg)

CHAPTER 4

RESULTS AND DISCUSSION

The collection and analysis of the soil samples is discussed in Chapter 3. The results are the mean of six analyses of each sample, three runs by analyzing from the top of the sample cup and three runs from the bottom. The reported uncertainty is one standard deviation from the mean value. A total of 15 elements (chromium, manganese, iron, cobalt, nickel, copper, zinc, arsenic, selenium, rubidium, strontium, zirconium, molybdenum, mercury, and lead) are reported for each sample. The results are interpreted in with respect to the hypotheses.

Sample Data

Eight transects are numbered as shown in Figure 28. For each transect, the results for all analysis of the elements in the surface soil samples are found in Table 6. All results are reported in units of mg/kg (ppm) of soil sample. The graphs of the concentrations for each element are shown in Figures 29-30, except chromium, cobalt, nickel, selenium, and mercury, which are found below limit of detection (LOD) throughout the entire sampling area. In Figures 31-32, the y-axis is log of the concentration data to highlight the low concentrations. Maps of the elemental concentrations for each transect are found in Figures 33-43.

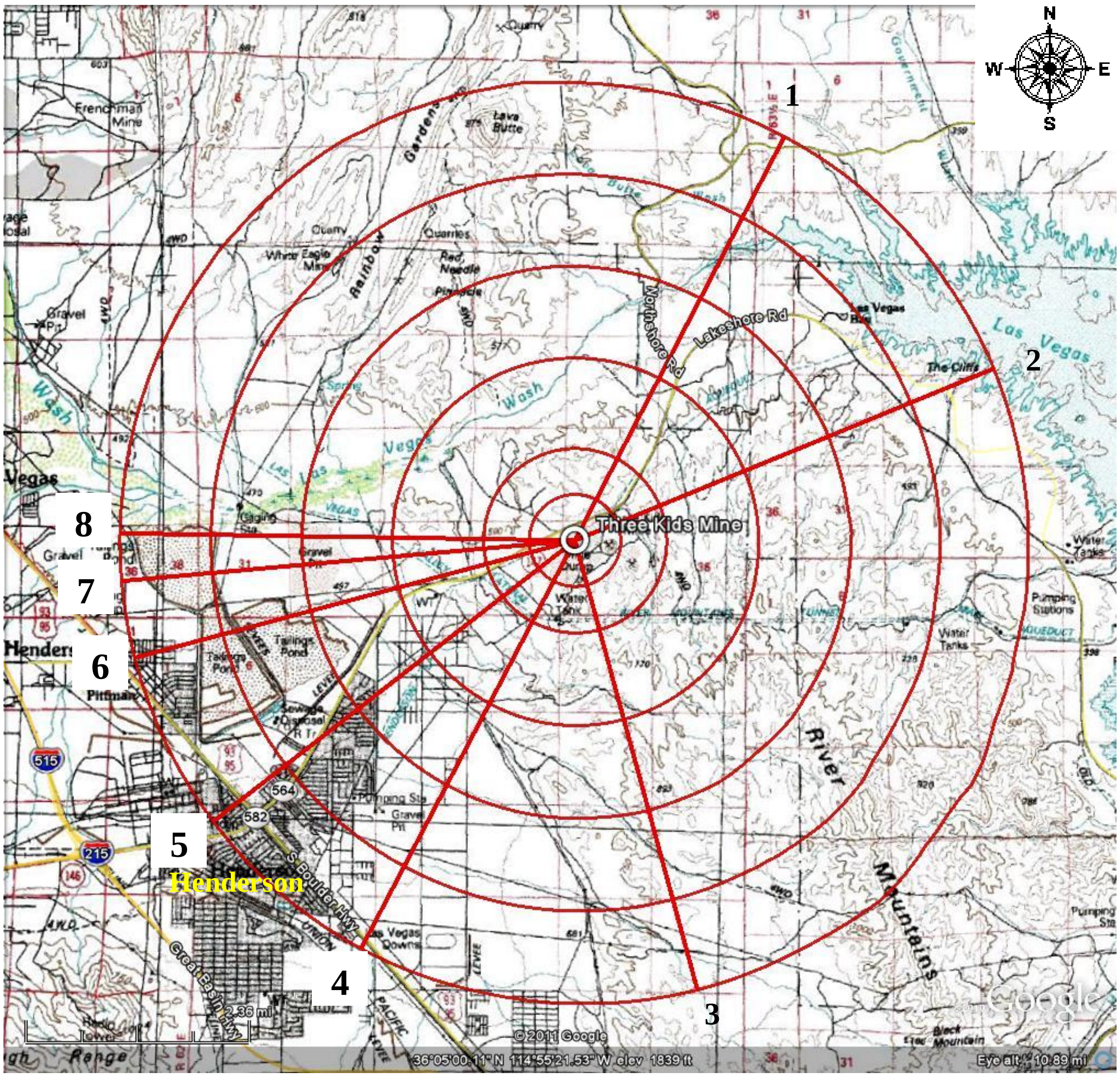


Figure 28 Eight transects at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings. Google Earth.

Table 6

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Chromium (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	< 115	< 115	< 115	< 115
0.5 (805 m)	< 115	< 115	< 115	< 115
1 (1.6 km)	< 115	< 115	NA	< 115
2 (3.2 km)	< 115	< 115	< 115	< 115
3 (4.8 km)	< 115	< 115	< 115	< 115
4 (6.4 km)	< 115	< 115	< 115	< 115
5 (8.0 km)	< 115	NA	< 115	NA
Distance (mile)	Concentration of Manganese (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	15.3% ± 0.1%	15.3% ± 0.1%	15.3% ± 0.1%	15.3% ± 0.1%
0.5 (805 m)	12.6% ± 0.1%	11.6% ± 0.1%	13.4k ± 0.2k	80.9k ± 0.6k
1 (1.6 km)	32.9k ± 0.3k	65.4k ± 0.5k	NA	870 ± 90
2 (3.2 km)	1700 ± 100	1190 ± 90	500 ± 100	660 ± 80
3 (4.8 km)	630 ± 90	710 ± 80	300 ± 100	480 ± 80
4 (6.4 km)	410 ± 80	510 ± 80	380 ± 90	470 ± 80
5 (8.0 km)	290 ± 90	NA	420 ± 80	NA
Distance (mile)	Concentration of Iron (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	40.8k ± 0.4k	40.8k ± 0.4k	40.8k ± 0.4k	40.8k ± 0.4k
0.5 (805 m)	27.1k ± 0.3k	29.0k ± 0.3k	19.5k ± 0.2k	48.3k ± 0.4k
1 (1.6 km)	18.3k ± 0.2k	23.2k ± 0.2k	NA	20.2k ± 0.1k
2 (3.2 km)	24.5k ± 0.2k	23.4k ± 0.2k	20.8k ± 0.1k	21.6k ± 0.1k
3 (4.8 km)	24.1k ± 0.2k	19.0k ± 0.1k	19.2k ± 0.1k	18.7k ± 0.1k
4 (6.4 km)	20.9k ± 0.1k	22.6k ± 0.2k	19.8k ± 0.1k	21.4k ± 0.1k
5 (8.0 km)	20.5k ± 0.1k	NA	23.2k ± 0.2k	NA
Distance (mile)	Concentration of Cobalt (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	< 50	< 50	< 50	< 50
0.5 (805 m)	< 50	< 50	< 50	< 50
1 (1.6 km)	< 50	< 50	NA	< 50
2 (3.2 km)	< 50	< 50	< 50	< 50
3 (4.8 km)	< 50	< 50	< 50	< 50
4 (6.4 km)	< 50	< 50	< 50	< 50
5 (8.0 km)	< 50	NA	< 50	NA
Distance (mile)	Concentration of Nickel (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	< 75	< 75	< 75	< 75
0.5 (805 m)	< 75	< 75	< 75	< 75
1 (1.6 km)	< 75	< 75	NA	< 75
2 (3.2 km)	< 75	< 75	< 75	< 75
3 (4.8 km)	< 75	< 75	< 75	< 75
4 (6.4 km)	< 75	< 75	< 75	< 75
5 (8.0 km)	< 75	NA	< 75	NA

NA = Not available; 1k = 1000ppm; 1% = 10,000ppm

Table 6 (cont'd)

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Chromium (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	< 115	< 115	< 115	< 115
0.5 (805 m)	< 115	< 115	< 115	< 115
1 (1.6 km)	< 115	< 115	< 115	< 115
2 (3.2 km)	< 115	< 115	< 115	< 115
3 (4.8 km)	< 115	< 115	NA	NA
4 (6.4 km)	< 115	< 115	< 115	< 115
5 (8.0 km)	< 115	< 115	< 115	< 115

Distance (mile)	Concentration of Manganese (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	15.3% ± 0.1%	15.3% ± 0.1%	15.3% ± 0.1%	15.3% ± 0.1%
0.5 (805 m)	74.0k ± 0.5k	14.6k ± 0.2k	920 ± 80	44.5k ± 0.4k
1 (1.6 km)	420 ± 70	830 ± 90	520 ± 80	680 ± 90
2 (3.2 km)	630 ± 90	550 ± 80	430 ± 70	410 ± 80
3 (4.8 km)	980 ± 90	490 ± 80	NA	NA
4 (6.4 km)	900 ± 100	600 ± 100	430 ± 90	390 ± 80
5 (8.0 km)	1300 ± 100	< 60	410 ± 80	360 ± 80

Distance (mile)	Concentration of Iron (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	40.8k ± 0.4k	40.8k ± 0.4k	40.8k ± 0.4k	40.8k ± 0.4k
0.5 (805 m)	27.2k ± 0.3k	20.1k ± 0.2k	18.9k ± 0.1k	23.0k ± 0.2k
1 (1.6 km)	16.1k ± 0.1k	20.3k ± 0.1k	17.7k ± 0.1k	22.8k ± 0.2k
2 (3.2 km)	23.1k ± 0.2k	17.7k ± 0.1k	14.5k ± 0.1k	19.4k ± 0.1k
3 (4.8 km)	20.9k ± 0.1k	21.7k ± 0.1k	NA	NA
4 (6.4 km)	26.3k ± 0.2k	27.9k ± 0.2k	24.0k ± 0.2k	21.4k ± 0.1k
5 (8.0 km)	28.2k ± 0.2k	9680 ± 90	20.2k ± 0.1k	19.9k ± 0.1k

Distance (mile)	Concentration of Cobalt (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	< 50	< 50	< 50	< 50
0.5 (805 m)	< 50	< 50	< 50	< 50
1 (1.6 km)	< 50	< 50	< 50	< 50
2 (3.2 km)	< 50	< 50	< 50	< 50
3 (4.8 km)	< 50	< 50	NA	NA
4 (6.4 km)	< 50	< 50	< 50	< 50
5 (8.0 km)	< 50	< 50	< 50	< 50

Distance (mile)	Concentration of Nickel (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	< 75	< 75	< 75	< 75
0.5 (805 m)	< 75	< 75	< 75	< 75
1 (1.6 km)	< 75	< 75	< 75	< 75
2 (3.2 km)	< 75	< 75	< 75	< 75
3 (4.8 km)	< 75	< 75	NA	NA
4 (6.4 km)	< 75	< 75	< 75	< 75
5 (8.0 km)	< 75	< 75	< 75	< 75

NA = Not available; 1k = 1000ppm; 1% = 10,000ppm

Table 6 (cont'd)

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Copper (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	260 ± 40	260 ± 40	260 ± 40	260 ± 40
0.5 (805 m)	220 ± 30	260 ± 50	< 50	180 ± 30
1 (1.6 km)	110 ± 30	110 ± 30	NA	< 50
2 (3.2 km)	< 50	< 50	< 50	< 50
3 (4.8 km)	< 50	< 50	< 50	< 50
4 (6.4 km)	< 50	< 50	< 50	< 50
5 (8.0 km)	< 50	NA	< 50	NA
Distance (mile)	Concentration of Zinc (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	2050 ± 50	2050 ± 50	2050 ± 50	2050 ± 50
0.5 (805 m)	920 ± 30	2710 ± 40	190 ± 10	860 ± 30
1 (1.6 km)	260 ± 20	480 ± 30	NA	78 ± 11
2 (3.2 km)	87 ± 12	160 ± 10	70 ± 10	78 ± 11
3 (4.8 km)	61 ± 12	60 ± 10	45 ± 10	63 ± 11
4 (6.4 km)	91 ± 11	81 ± 12	42 ± 11	59 ± 11
5 (8.0 km)	63 ± 11	NA	53 ± 11	NA
Distance (mile)	Concentration of Arsenic (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	3690 ± 80	3690 ± 80	3690 ± 80	3690 ± 80
0.5 (805 m)	2890 ± 60	820 ± 40	120 ± 10	2260 ± 50
1 (1.6 km)	800 ± 40	800 ± 40	NA	< 10
2 (3.2 km)	< 10	< 10	< 10	< 10
3 (4.8 km)	< 10	< 10	< 10	< 10
4 (6.4 km)	< 10	< 10	< 10	< 10
5 (8.0 km)	< 10	NA	< 10	NA
Distance (mile)	Concentration of Selenium (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	< 7	< 7	< 7	< 7
0.5 (805 m)	< 7	< 7	< 7	< 7
1 (1.6 km)	< 7	< 7	NA	< 7
2 (3.2 km)	< 7	< 7	< 7	< 7
3 (4.8 km)	< 7	< 7	< 7	< 7
4 (6.4 km)	< 7	< 7	< 7	< 7
5 (8.0 km)	< 7	NA	< 7	NA
Distance (mile)	Concentration of Rubidium (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	120 ± 10	120 ± 10	120 ±10	120 ± 10
0.5 (805 m)	64 ± 7	53 ± 5	83 ± 4	150 ± 10
1 (1.6 km)	57 ± 5	44 ± 7	NA	71 ± 3
2 (3.2 km)	74 ± 3	79 ± 3	93 ± 3	70 ± 3
3 (4.8 km)	64 ± 3	85 ± 3	72 ± 3	76 ± 3
4 (6.4 km)	72 ± 3	73 ±3	87 ± 3	79 ± 3
5 (8.0 km)	70 ± 3	NA	86 ± 3	NA

NA = Not available; k value represents three digits (1k=1000ppm)

Table 6 (cont'd)

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Copper (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	260 ± 40	260 ± 40	260 ± 40	260 ± 40
0.5 (805 m)	120 ± 30	< 50	< 50	100 ± 30
1 (1.6 km)	< 50	< 50	< 50	< 50
2 (3.2 km)	< 50	< 50	< 50	< 50
3 (4.8 km)	< 50	< 50	NA	NA
4 (6.4 km)	< 50	< 50	< 50	< 50
5 (8.0 km)	< 50	< 50	< 50	< 50
Distance (mile)	Concentration of Zinc (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	2050 ± 50	2050 ± 50	2050 ± 50	2050 ± 50
0.5 (805 m)	640 ± 30	260 ± 20	76 ± 11	340 ± 20
1 (1.6 km)	63 ± 11	78 ± 12	61 ± 11	84 ± 11
2 (3.2 km)	85 ± 12	68 ± 11	60 ± 10	60 ± 10
3 (4.8 km)	82 ± 11	56 ± 11	NA	NA
4 (6.4 km)	81 ± 12	74 ± 12	91 ± 12	58 ± 11
5 (8.0 km)	86 ± 12	83 ± 11	53 ± 11	44 ± 12
Distance (mile)	Concentration of Arsenic (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	3690 ± 80	3690 ± 80	3690 ± 80	3690 ± 80
0.5 (805 m)	1030 ± 40	420 ± 30	< 10	820 ± 40
1 (1.6 km)	17 ± 5	< 10	< 10	< 10
2 (3.2 km)	< 10	< 10	< 10	< 10
3 (4.8 km)	< 10	< 10	NA	NA
4 (6.4 km)	< 10	< 10	< 10	< 10
5 (8.0 km)	< 10	< 10	< 10	< 10
Distance (mile)	Concentration of Selenium (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	< 7	< 7	< 7	< 7
0.5 (805 m)	< 7	< 7	< 7	< 7
1 (1.6 km)	< 7	< 7	< 7	< 7
2 (3.2 km)	< 7	< 7	< 7	< 7
3 (4.8 km)	< 7	< 7	NA	NA
4 (6.4 km)	< 7	< 7	< 7	< 7
5 (8.0 km)	< 7	< 7	< 7	< 7
Distance (mile)	Concentration of Rubidium (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	120 ± 10	120 ± 10	120 ± 10	120 ± 10
0.5 (805 m)	78 ± 8	45 ± 5	76 ± 3	60 ± 5
1 (1.6 km)	69 ± 3	74 ± 3	66 ± 3	79 ± 3
2 (3.2 km)	72 ± 3	62 ± 3	63 ± 3	55 ± 2
3 (4.8 km)	76 ± 3	75 ± 3	NA	NA
4 (6.4 km)	74 ± 3	70 ± 3	70 ± 3	72 ± 3
5 (8.0 km)	63 ± 3	38 ± 2	63 ± 3	68 ± 3

NA = Not available; k value represents three digits (1k=1000ppm)

Table 6 (cont'd)

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Strontium (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	18.7k ± 0.1k	18.7k ± 0.1k	18.7k ± 0.1k	18.7k ± 0.1k
0.5 (805 m)	13.63k ± 0.05k	14.83k ± 0.05k	3690 ± 20	9320 ± 40
1 (1.6 km)	7540 ± 30	14.14k ± 0.04k	NA	800 ± 10
2 (3.2 km)	990 ± 10	620 ± 10	710 ± 10	600 ± 10
3 (4.8 km)	990 ± 10	460 ± 10	600 ± 10	580 ± 10
4 (6.4 km)	660 ± 10	570 ± 10	500 ± 10	590 ± 10
5 (8.0 km)	660 ± 10	NA	440 ± 10	NA
Distance (mile)	Concentration of Zirconium (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	190 ± 30	190 ± 30	190 ± 30	190 ± 30
0.5 (805 m)	190 ± 20	210 ± 30	380 ± 10	160 ± 20
1 (1.6 km)	230 ± 20	200 ± 30	NA	430 ± 10
2 (3.2 km)	480 ± 10	560 ± 10	460 ± 10	460 ± 10
3 (4.8 km)	500 ± 10	630 ± 10	380 ± 10	390 ± 10
4 (6.4 km)	430 ± 10	600 ± 10	410 ± 10	400 ± 10
5 (8.0 km)	610 ± 10	NA	410 ± 10	NA
Distance (mile)	Concentration of Molybdenum (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	44 ± 3	44 ± 3	44 ± 3	44 ± 3
0.5 (805 m)	47 ± 3	54 ± 3	< 5	29 ± 2
1 (1.6 km)	22 ± 2	22 ± 2	NA	< 5
2 (3.2 km)	< 5	< 5	< 5	< 5
3 (4.8 km)	< 5	< 5	< 5	< 5
4 (6.4 km)	< 5	< 5	< 5	< 5
5 (8.0 km)	< 5	NA	< 5	NA
Distance (mile)	Concentration of Mercury (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	< 15	< 15	< 15	< 15
0.5 (805 m)	< 15	< 15	< 15	< 15
1 (1.6 km)	< 15	< 15	NA	< 15
2 (3.2 km)	< 15	< 15	< 15	< 15
3 (4.8 km)	< 15	< 15	< 15	< 15
4 (6.4 km)	< 15	< 15	< 15	< 15
5 (8.0 km)	< 15	NA	< 15	NA
Distance (mile)	Concentration of Lead (ppm)			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	15.3k ± 0.1k	15.3k ± 0.1k	15.3k ± 0.1k	15.3k ± 0.1k
0.5 (805 m)	12.4k ± 0.1k	4260 ± 50	1060 ± 20	4820 ± 50
1 (1.6 km)	2100 ± 30	4170 ± 50	NA	76 ± 7
2 (3.2 km)	160 ± 10	110 ± 10	44 ± 6	60 ± 10
3 (4.8 km)	55 ± 7	62 ± 6	23 ± 5	39 ± 5
4 (6.4 km)	49 ± 6	53 ± 6	< 12	35 ± 5
5 (8.0 km)	24 ± 6	NA	< 12	NA

NA = Not available; k value represents three digits (1k=1000ppm)

Table 6 (cont'd)

XRF results for Three Kids Mine Soil (1σ; 68% confidence interval)

Distance (mile)	Concentration of Strontium (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	18.7k ± 0.1k	18.7k ± 0.1k	18.7k ± 0.1k	18.7k ± 0.1k
0.5 (805 m)	18.54k ± 0.05k	5180 ± 20	740 ± 10	8520 ± 30
1 (1.6 km)	1890 ± 10	750 ± 10	860 ± 10	620 ± 10
2 (3.2 km)	680 ± 10	860 ± 10	830 ± 10	790 ± 10
3 (4.8 km)	550 ± 10	540 ± 10	NA	NA
4 (6.4 km)	740 ± 10	920 ± 10	870 ± 10	820 ± 10
5 (8.0 km)	830 ± 10	500 ± 10	660 ± 10	740 ± 10

Distance (mile)	Concentration of Zirconium (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	190 ± 30	190 ± 30	190 ± 30	190 ± 30
0.5 (805 m)	230 ± 30	220 ± 10	420 ± 10	270 ± 20
1 (1.6 km)	360 ± 10	400 ± 10	340 ± 10	560 ± 10
2 (3.2 km)	480 ± 10	340 ± 10	330 ± 10	330 ± 10
3 (4.8 km)	490 ± 10	510 ± 10	NA	NA
4 (6.4 km)	460 ± 10	480 ± 10	390 ± 10	410 ± 10
5 (8.0 km)	400 ± 10	190 ± 10	410 ± 10	360 ± 10

Distance (mile)	Concentration of Molybdenum (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	44 ± 3	44 ± 3	44 ± 3	44 ± 3
0.5 (805 m)	29 ± 3	20 ± 3	< 5	23 ± 3
1 (1.6 km)	< 5	< 5	< 5	< 5
2 (3.2 km)	< 5	< 5	< 5	< 5
3 (4.8 km)	< 5	< 5	NA	NA
4 (6.4 km)	< 5	< 5	< 5	< 5
5 (8.0 km)	< 5	< 5	< 5	< 5

Distance (mile)	Concentration of Mercury (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	< 15	< 15	< 15	< 15
0.5 (805 m)	< 15	< 15	< 15	< 15
1 (1.6 km)	< 15	< 15	< 15	< 15
2 (3.2 km)	< 15	< 15	< 15	< 15
3 (4.8 km)	< 15	< 15	NA	NA
4 (6.4 km)	< 15	< 15	< 15	< 15
5 (8.0 km)	< 15	< 15	< 15	< 15

Distance (mile)	Concentration of Lead (ppm)			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	15.3k ± 0.1k	15.3k ± 0.1k	15.3k ± 0.1k	15.3k ± 0.1k
0.5 (805 m)	3880 ± 60	830 ± 20	96 ± 7	2530 ± 40
1 (1.6 km)	30 ± 10	100 ± 10	42 ± 6	72 ± 7
2 (3.2 km)	55 ± 6	32 ± 6	31 ± 5	24 ± 5
3 (4.8 km)	82 ± 7	40 ± 10	NA	NA
4 (6.4 km)	60 ± 10	26 ± 6	31 ± 6	22 ± 6
5 (8.0 km)	29 ± 6	< 12	< 12	21 ± 5

NA = Not available; k value represents three digits (1k=1000ppm)

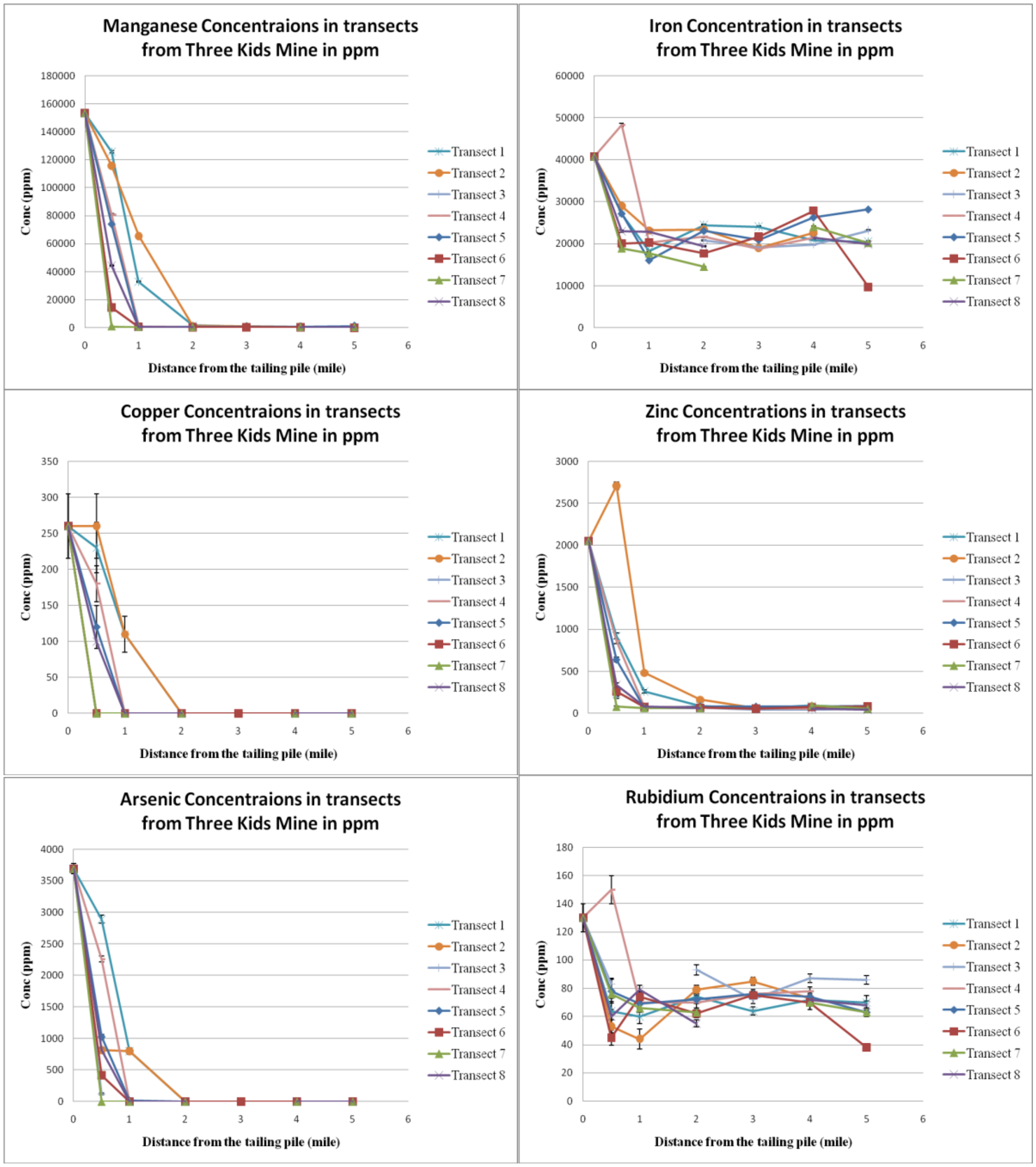


Figure 29 Total Concentrations in top surface soil (mg/kg = ppm) at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for manganese, iron, copper, zinc, arsenic, and rubidium

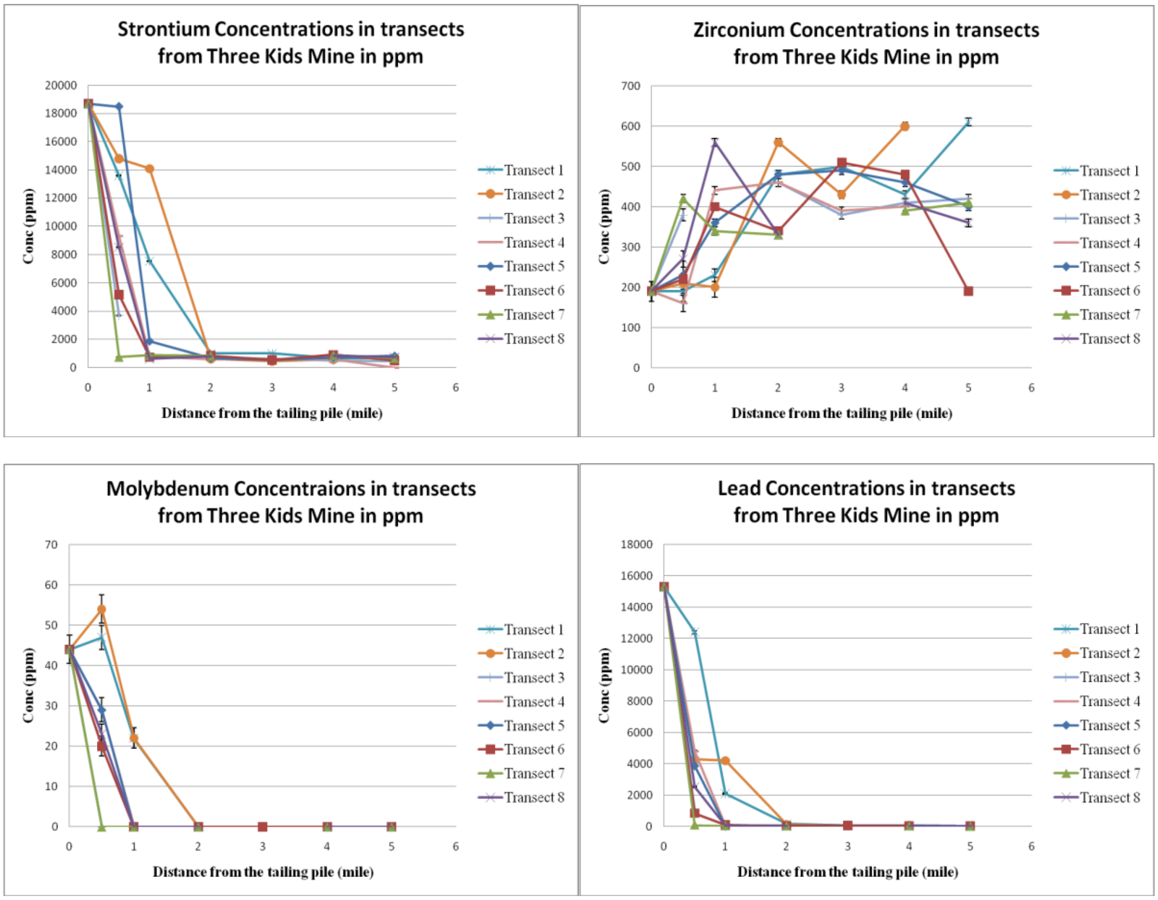


Figure 30 Total Concentrations in top surface soil in log at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for strontium, zirconium, molybdenum, and lead

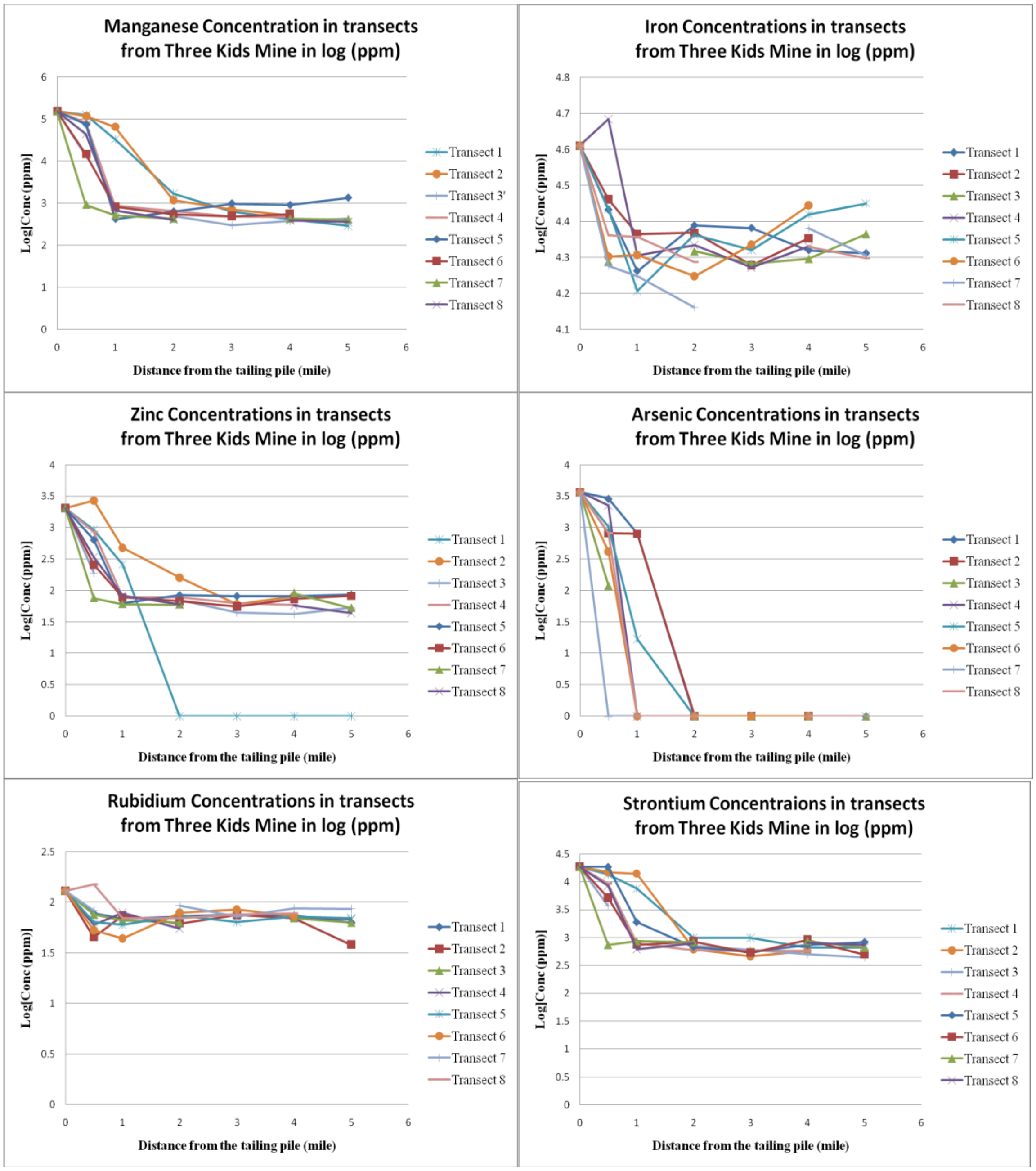
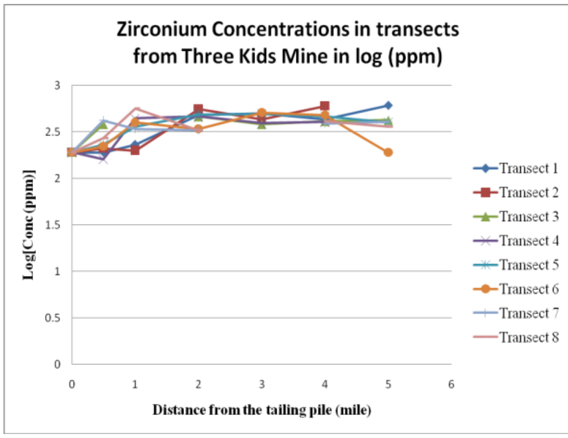


Figure 31 Total concentrations in top surface soil in log at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for manganese, iron, zinc, arsenic, rubidium, and strontium



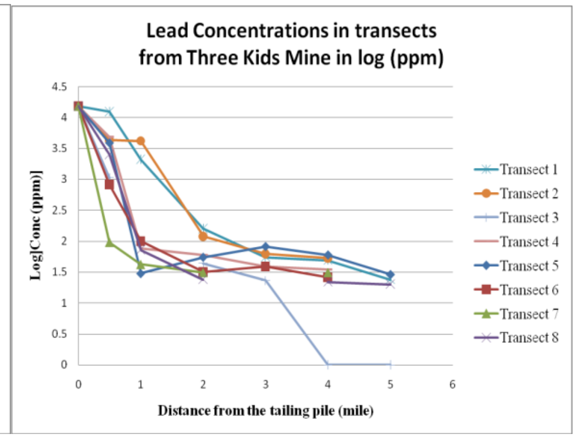


Figure 32 Total concentrations in top surface soil in log at 0.5 miles (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for zirconium and lead

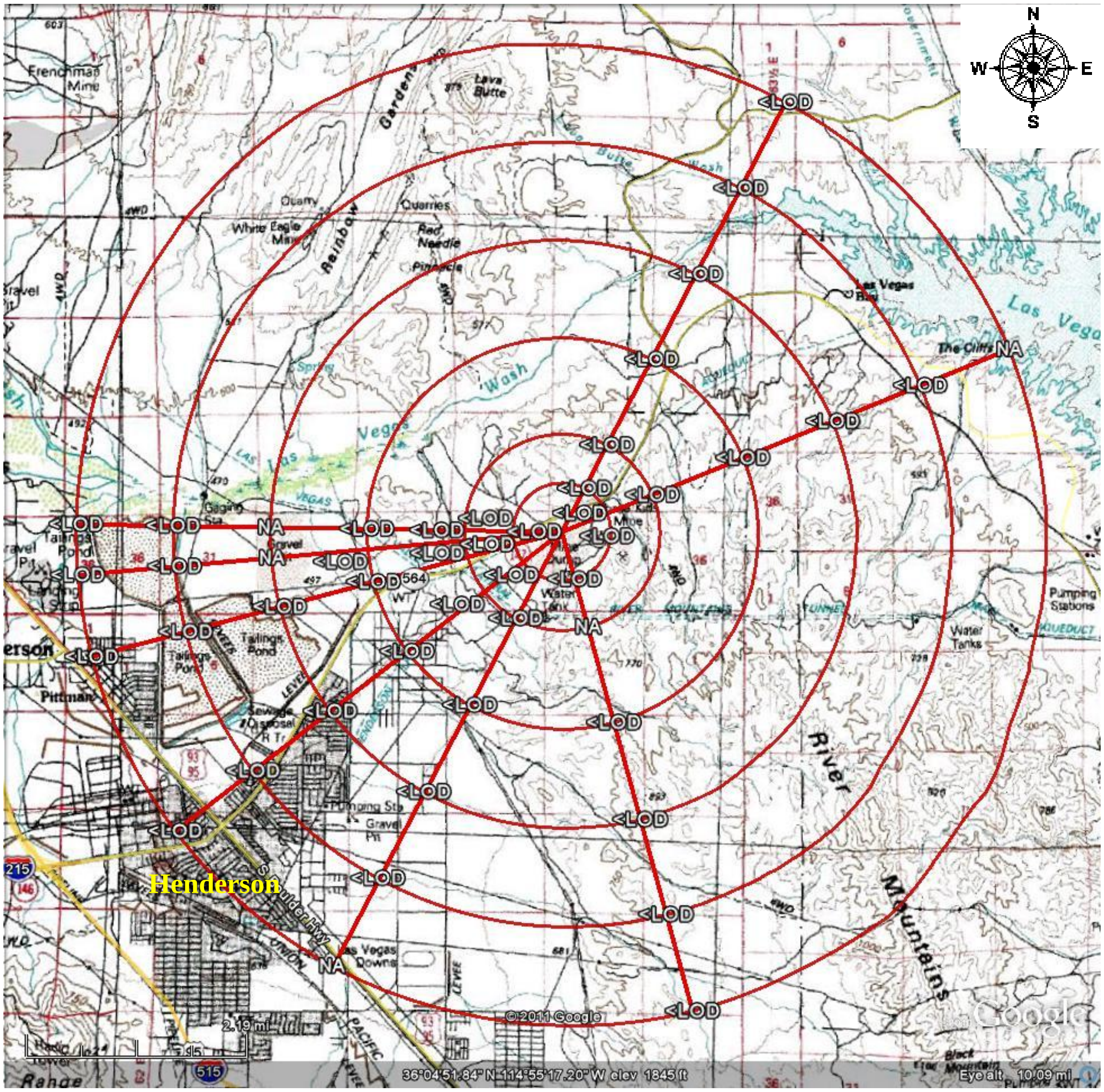


Figure 33 Topographical map for chromium, cobalt, nickel, selenium, and mercury in mg/kg (ppm) Apparently all of soil samples for the elements are at or below the limit of detection (LOD). Not available = NA

Figure 34 Topographical map of manganese concentration in mg/kg (ppm)
Not available = NA

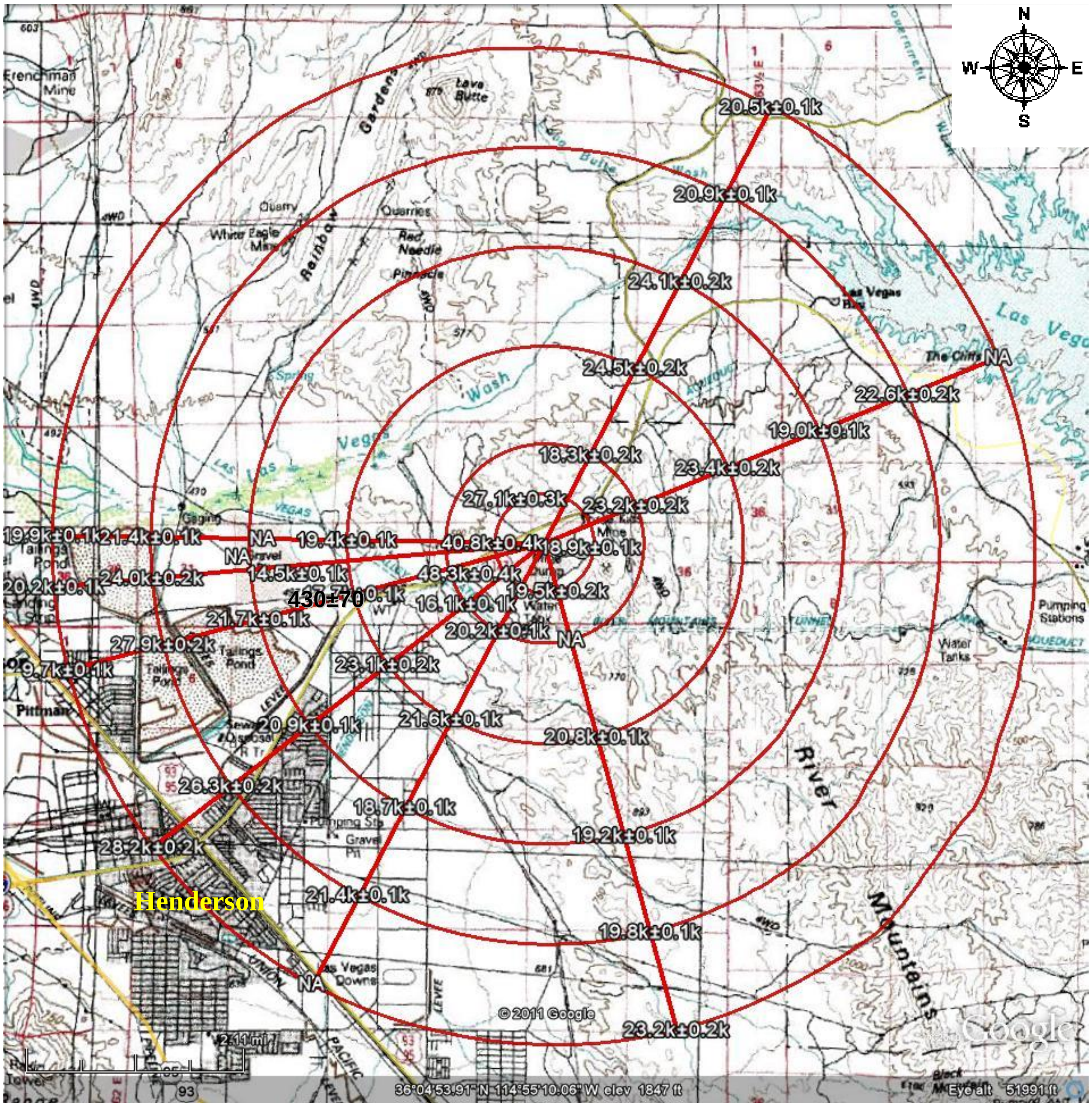


Figure 35 Topographical map of iron concentration in mg/kg (ppm)
Not available = NA

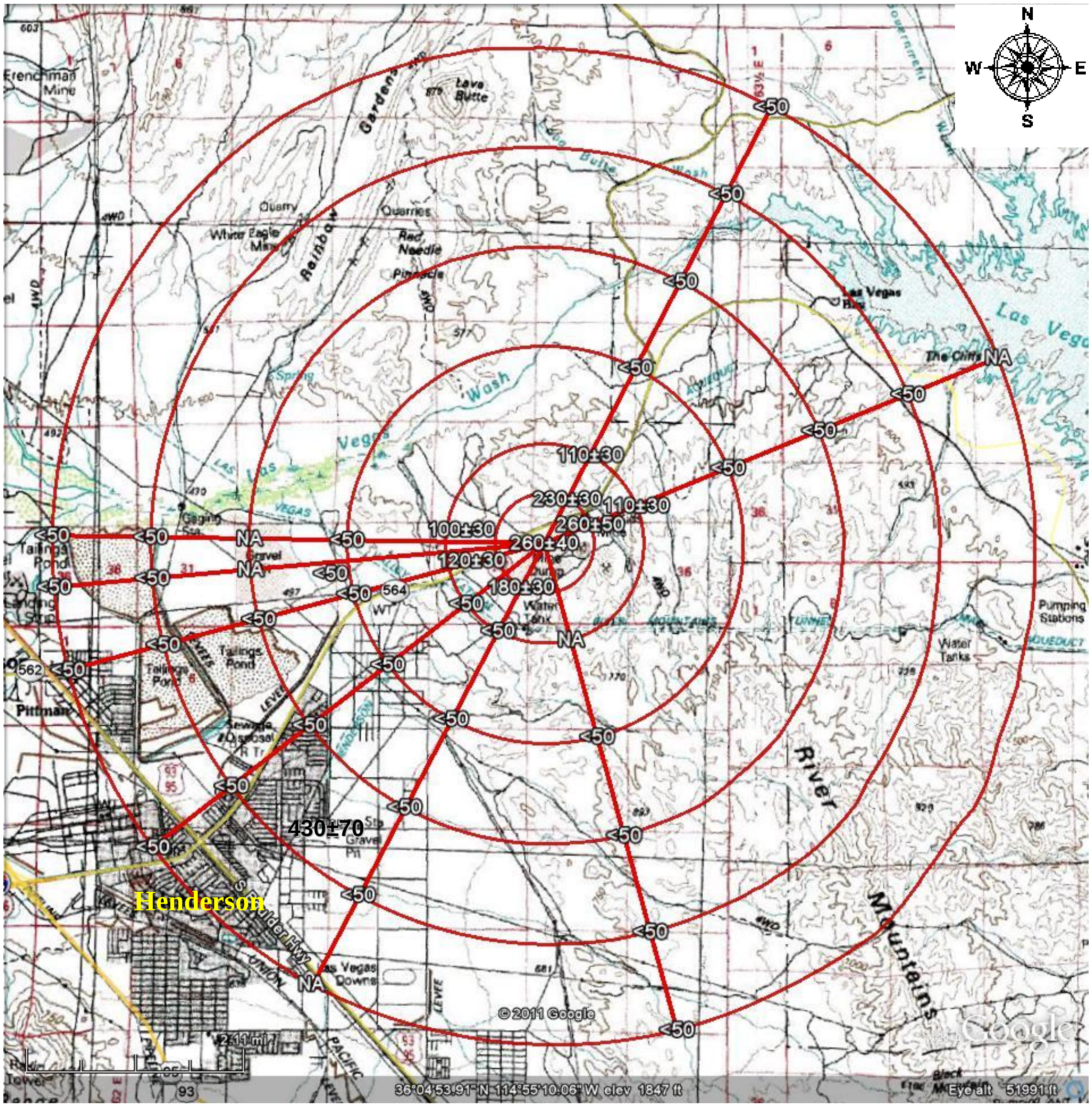


Figure 36 Topographical map of copper concentration in mg/kg (ppm)
Not available = NA

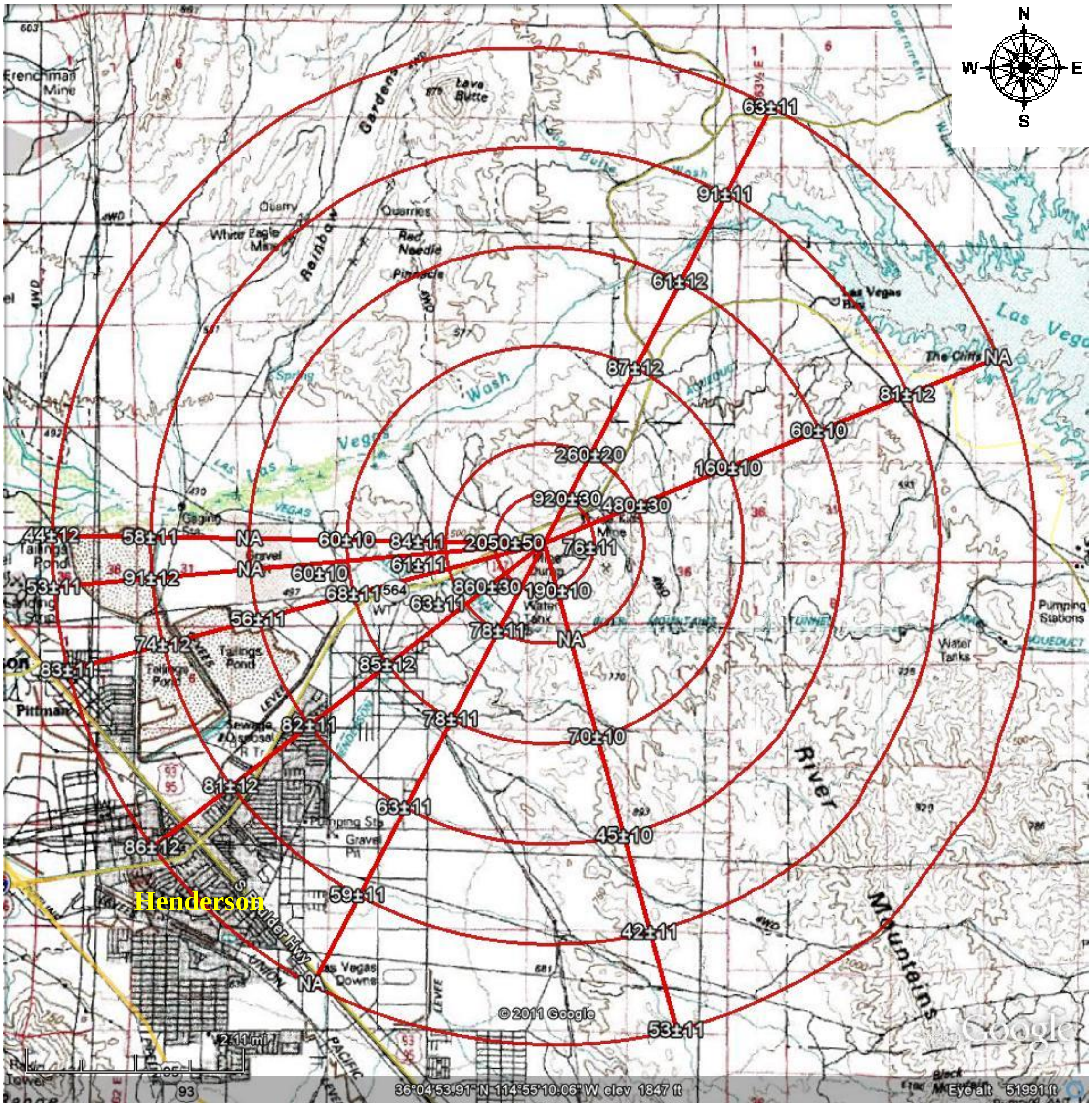


Figure 37 Topographical map of zinc concentration in mg/kg (ppm)
Not available = NA

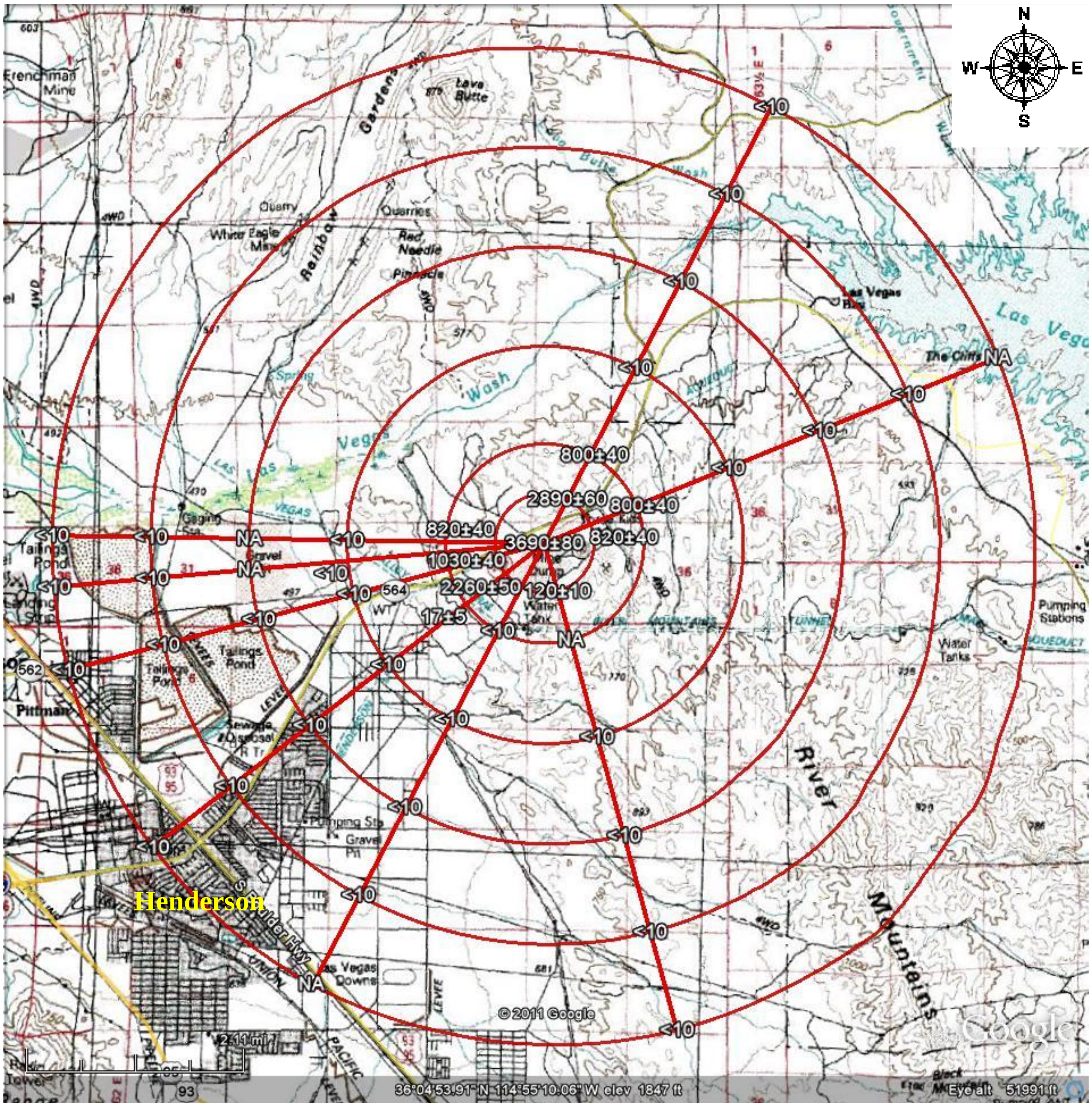


Figure 38 Topographical map of arsenic concentration in mg/kg (ppm)
Not available = NA

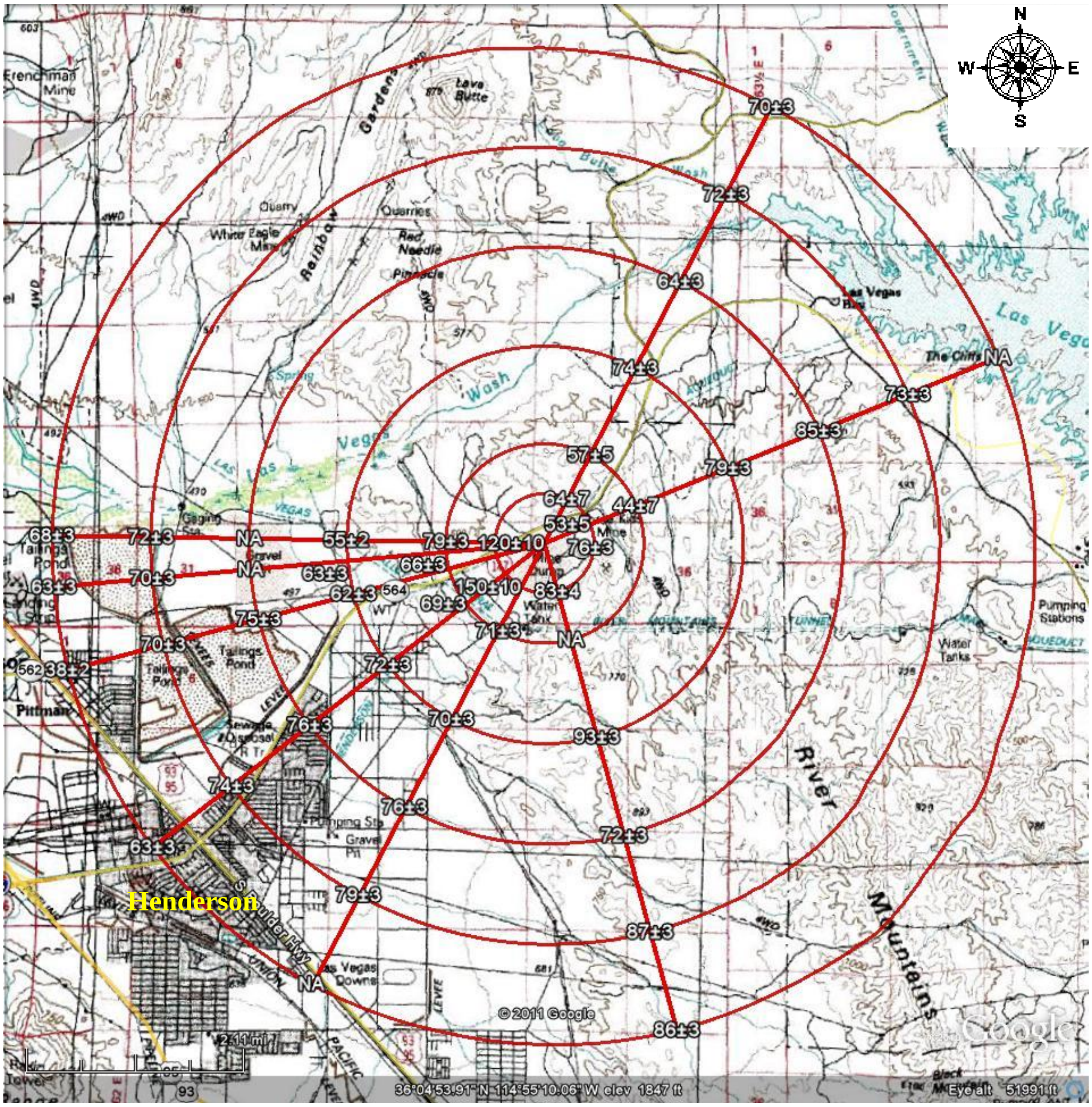


Figure 39 Topographical map of rubidium concentration in mg/kg (ppm)
Not available = NA

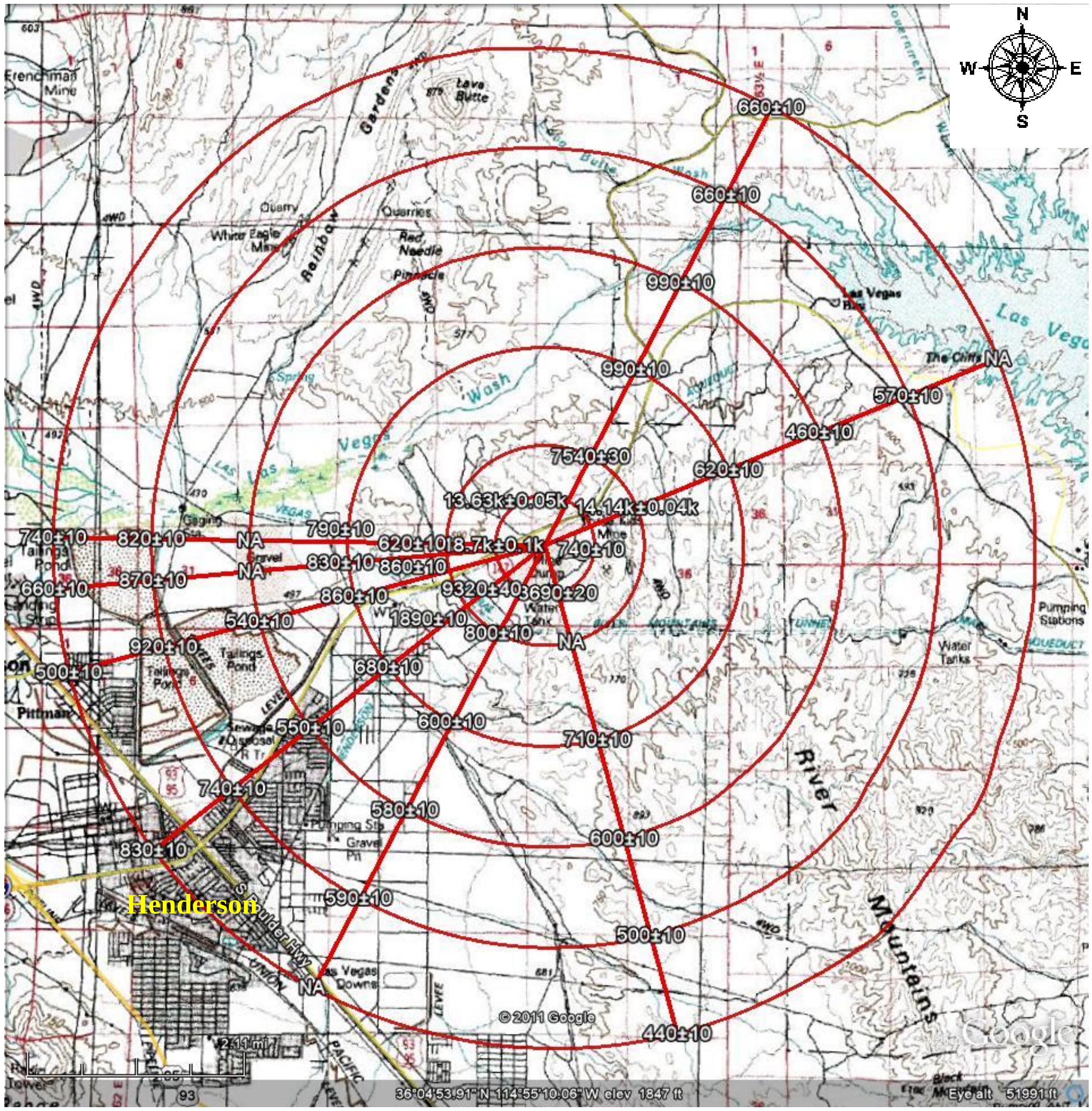


Figure 40 Topographical map of strontium concentration in mg/kg (ppm)
Not available = NA

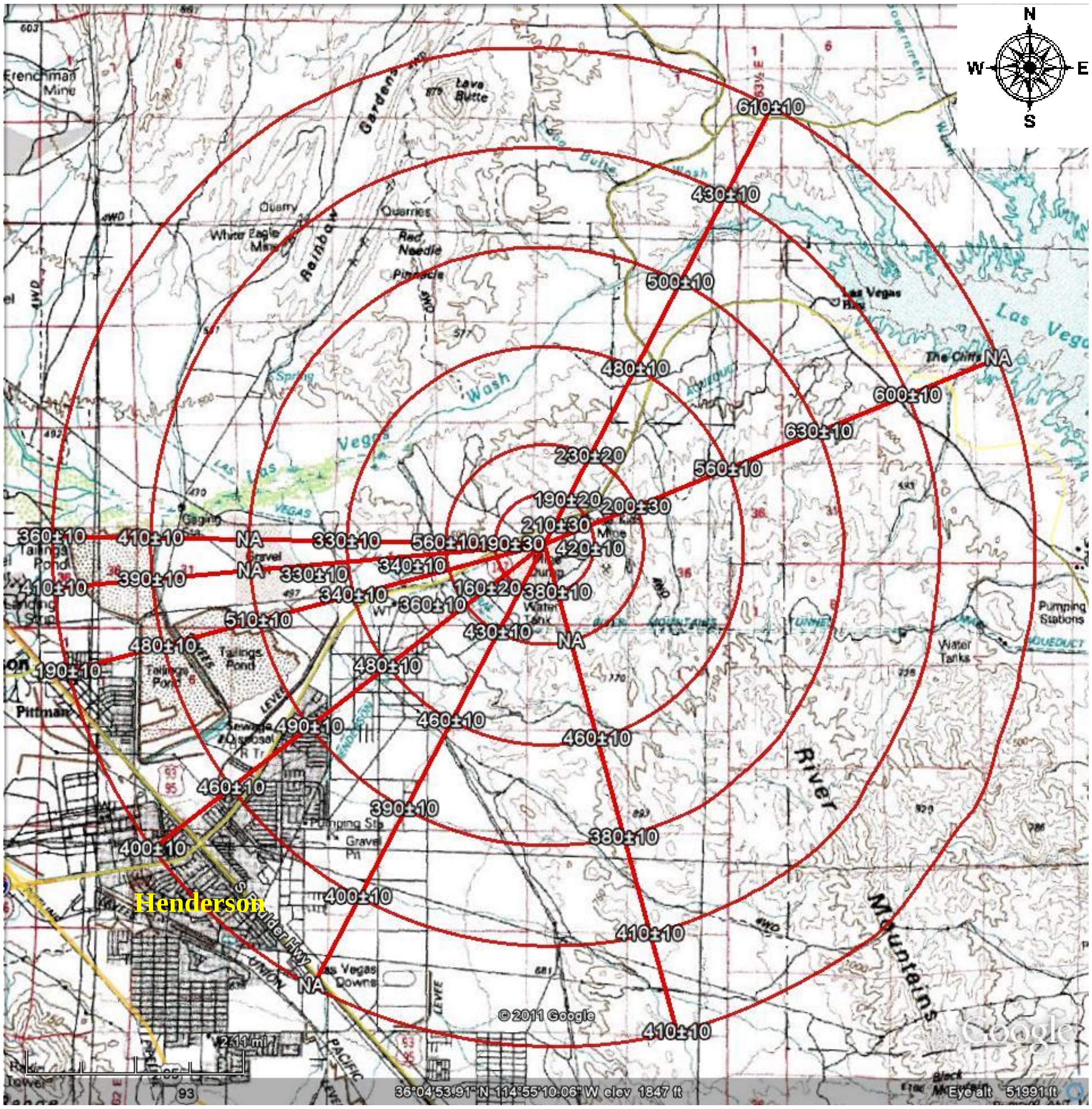


Figure 41 Topographical map of zirconium concentration in mg/kg (ppm)
Not available = NA

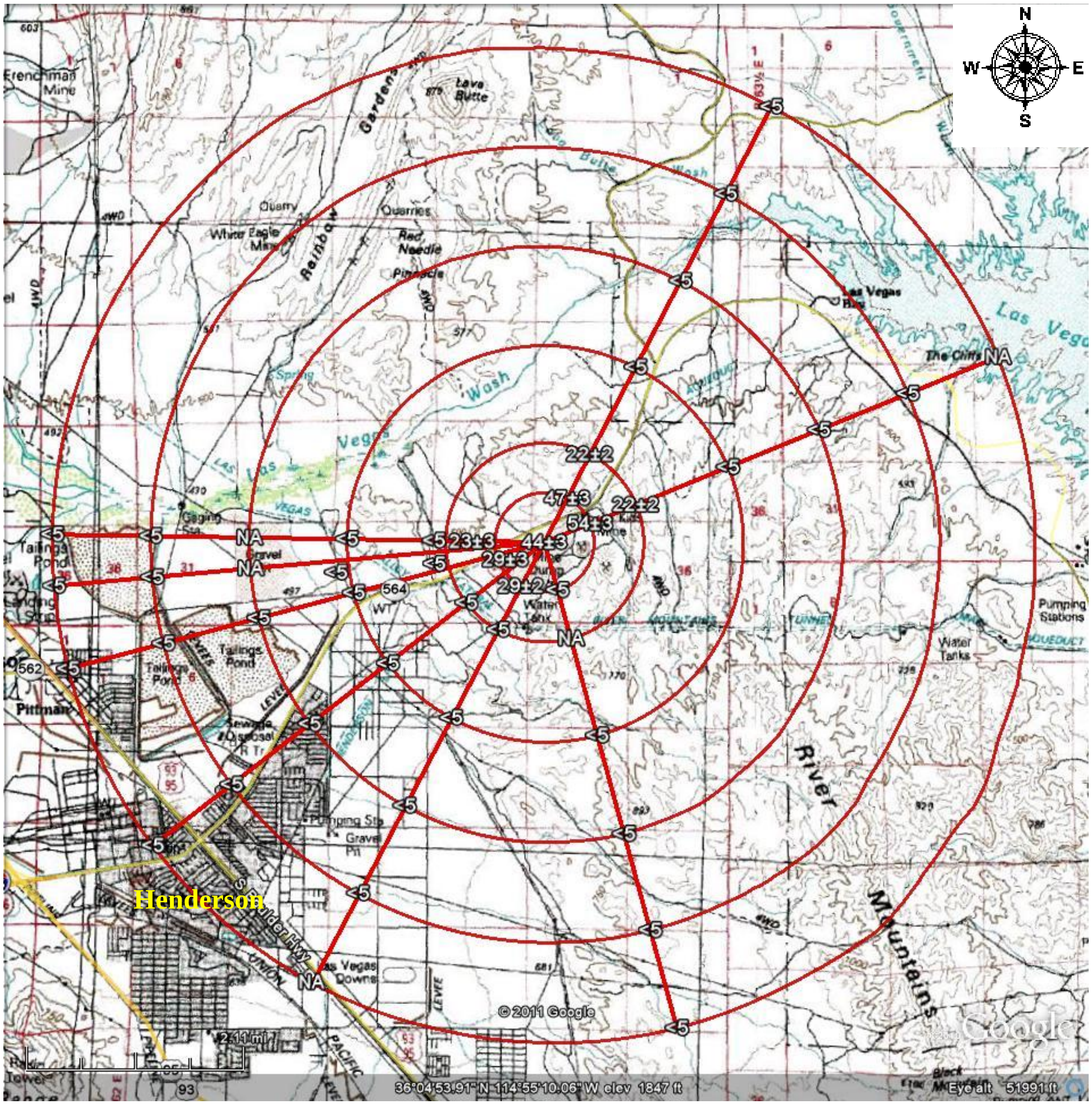


Figure 42 Topographical map of molybdenum concentration in mg/kg (ppm)
Not available = NA

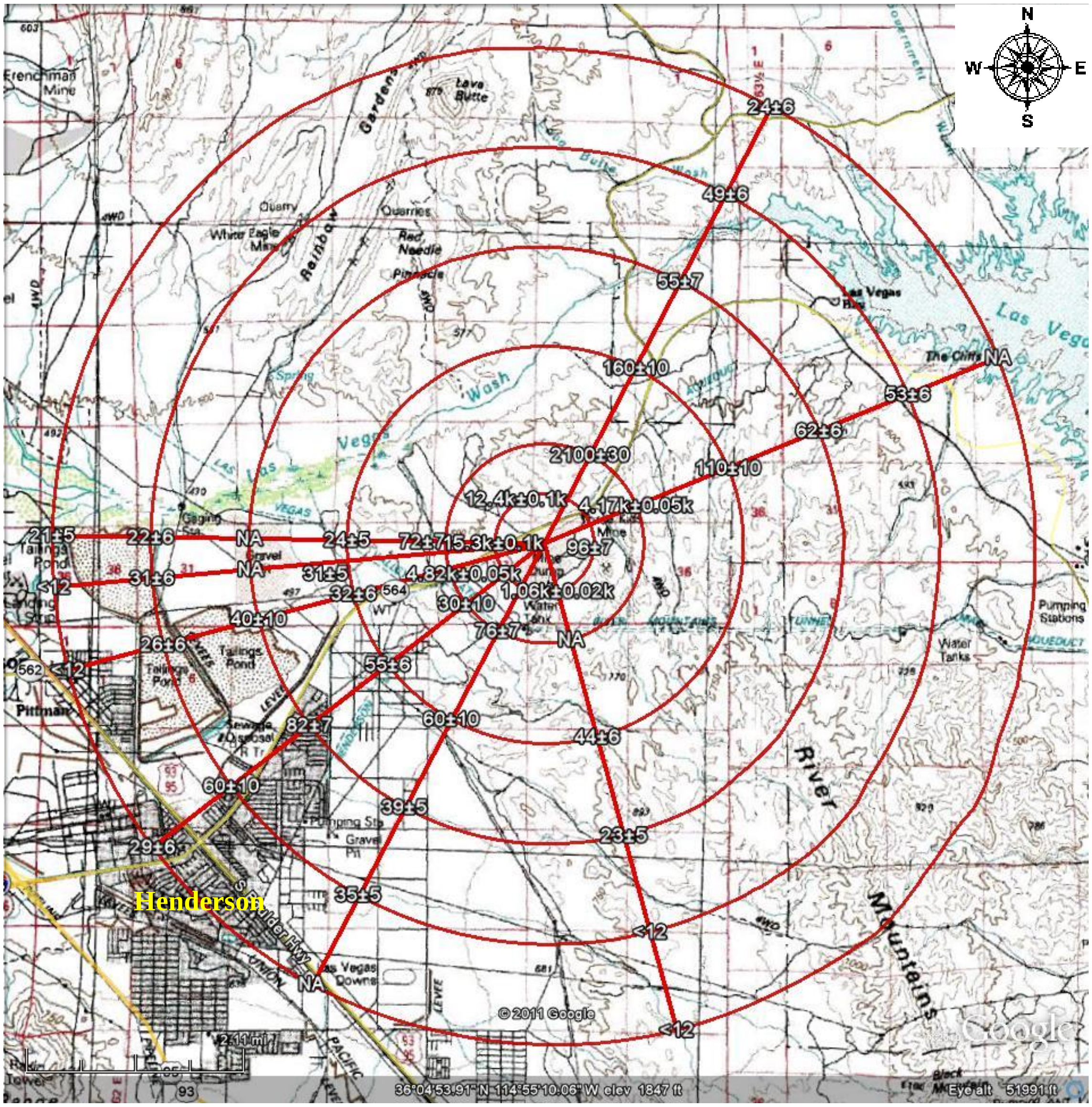


Figure 43 Topographical map of lead concentration in mg/kg (ppm)
Not available = NA

From Table 6 and the graphs (29-43), it is apparent that the highest concentrations are observed in the tailing piles for Mn (153.5 x 10^3 ± 1.0 x 10^3 mg/kg; 15.3 % ± 0.1 %), Fe (40.8 x 10^3 ± 0.4 x 10^3 mg/kg), Cu (260 ± 40 mg/kg), Zn (2050 ± 50 mg/kg), As (3690 ± 80 mg/kg), Rb (120 ± 10 mg/kg), Sr (18.7 x 10^3 ± 0.1 x 10^3 mg/kg), Mo (44 ± 3 mg/kg), and Pb (15.3 x10^3 ± 0.1 x 10^3 mg/kg), except Zr (190 ± 30 mg/kg) and five elements (Cr, Co, Ni, Se, and Hg) that are below the limit of detection. Along the eight transects going from the Three Kids Mine tailing piles, the concentrations of the elements decrease as the distance from the site increases: Mn (153,000 ± 1,000 mg/kg to 290 ± 90 mg/kg), Fe (40800 ± 400 mg/kg to 9680 ± 90 mg/kg), Cu (260 ± 40 mg/kg to LOD), Zn (2710 ± 90 mg/kg to 44 ± 12 mg/kg), As (3690 ± 80 mg/kg to LOD), Rb (120 ± 10 mg/kg to 38 ± 2 mg/kg), Sr (18700 ± 100 mg/kg to 440 ± 10 mg/kg), Mo (44 ± 3 mg/kg to LOD), and Pb (15,300 ± 100 mg/kg to LOD), except unaffected Zr (610 ± 10 mg/kg to 190 ± 30 mg/kg). On the other hand, iron, rubidium, and zirconium stay fairly constant in high concentrations up to 5 miles away from the mine.

Concentrations of the elements are normalized by iron concentrations that are fairly consistent throughout the study area (Table 7 and Figures 44-45). The normalized data show similar to the non-normalized values. For example, ratios of seven elements decrease as the distance from the mine increases: Mn (6.97 x 10^0 to 0.01 x 10^0), Cu (1.20 x 10^{-2} to 0.38 x 10^{-2}), Zn (9.30 x 10^{-2} to 0.21 x 10^{-2}), As (1.67 x 10^{-1} to 0.01 x 10^{-1}), Rb (5.61 x 10^{-3} to 2.24 x 10^{-3}), Sr (8.50 x 10^{-1} to 0.27 x 10^{-1}), Zr (29.9 x 10^{-3} to 3.41 x 10^{-3}), Mo (1.98 x 10^{-3} to 0.61 x 10^{-3}), Pb (6.95 x 10^{-1} to 0.01 x 10^{-1}). Similar to the patterns in concentration, normalized data for iron, rubidium, and zirconium are also constant with no apparent trend.

Table 7

Normalized Fe Ratio for Three Kids Mine Soil

Distance (mile)	Chromium to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Manganese to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	6.97×10^{0}	6.97×10^{0}	6.97×10^{0}	6.97×10^{0}
0.5 (805 m)	4.64×10^{0}	3.99×10^{0}	0.69×10^{0}	1.67×10^{0}
1 (1.6 km)	1.79×10^{0}	2.82×10^{0}	NA	0.04×10^{0}
2 (3.2 km)	0.07×10^{0}	0.05×10^{0}	0.02×10^{0}	0.03×10^{0}
3 (4.8 km)	0.03×10^{0}	0.04×10^{0}	0.02×10^{0}	0.03×10^{0}
4 (6.4 km)	0.02×10^{0}	0.02×10^{0}	0.02×10^{0}	0.02×10^{0}
5 (8.0 km)	0.01×10^{0}	NA	0.02×10^{0}	NA
Distance (mile)	Cobalt to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Nickel to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Copper to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}
0.5 (805 m)	0.83×10^{-2}	0.91×10^{-2}	NA	0.38×10^{-2}
1 (1.6 km)	0.62×10^{-2}	0.49×10^{-2}	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA

NA = Not available

Table 7 (cont'd.)

Normalized Fe Ratio for Three Kids Mine Soil

Distance (mile)	Chromium to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Manganese to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	6.97×10^{0}	6.97×10^{0}	6.97×10^{0}	6.97×10^{0}
0.5 (805 m)	2.72×10^{0}	0.73×10^{0}	0.05×10^{0}	1.93×10^{0}
1 (1.6 km)	0.03×10^{0}	0.04×10^{0}	0.03×10^{0}	0.03×10^{0}
2 (3.2 km)	0.03×10^{0}	0.03×10^{0}	0.03×10^{0}	0.02×10^{0}
3 (4.8 km)	0.05×10^{0}	0.02×10^{0}	NA	NA
4 (6.4 km)	0.03×10^{0}	0.02×10^{0}	0.02×10^{0}	0.02×10^{0}
5 (8.0 km)	0.05×10^{0}	NA	0.02×10^{0}	0.02×10^{0}
Distance (mile)	Cobalt to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Nickel to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Copper to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}
0.5 (805 m)	0.45×10^{-2}	NA	NA	0.45×10^{-2}
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA

NA = Not available

Table 7 (cont'd)
Normalized Fe Ratio for Three Kids Mine Soil.

Distance (mile)	Zinc to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	9.30×10^{-2}	9.30×10^{-2}	9.30×10^{-2}	9.30×10^{-2}
0.5 (805 m)	3.39×10^{-2}	9.36×10^{-2}	0.10×10^{-2}	1.78×10^{-2}
1 (1.6 km)	1.43×10^{-2}	2.08×10^{-2}	NA	0.39×10^{-2}
2 (3.2 km)	0.36×10^{-2}	0.67×10^{-2}	0.33×10^{-2}	0.36×10^{-2}
3 (4.8 km)	0.25×10^{-2}	0.31×10^{-2}	0.23×10^{-2}	0.34×10^{-2}
4 (6.4 km)	0.44×10^{-2}	0.36×10^{-2}	0.21×10^{-2}	0.27×10^{-2}
5 (8.0 km)	0.31×10^{-2}	NA	0.23×10^{-2}	NA
Distance (mile)	Arsenic to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	1.67×10^{-1}	1.67×10^{-1}	1.67×10^{-1}	1.67×10^{-1}
0.5 (805 m)	1.07×10^{-1}	0.28×10^{-1}	0.06×10^{-1}	0.47×10^{-1}
1 (1.6 km)	0.44×10^{-1}	0.35×10^{-1}	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Selenium to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Rubidium to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	5.61×10^{-3}	5.61×10^{-3}	5.61×10^{-3}	5.61×10^{-3}
0.5 (805 m)	2.36×10^{-3}	1.84×10^{-3}	4.26×10^{-3}	3.11×10^{-3}
1 (1.6 km)	3.13×10^{-3}	1.92×10^{-3}	NA	3.50×10^{-3}
2 (3.2 km)	3.02×10^{-3}	3.38×10^{-3}	4.46×10^{-3}	3.25×10^{-3}
3 (4.8 km)	2.65×10^{-3}	4.47×10^{-3}	3.76×10^{-3}	4.05×10^{-3}
4 (6.4 km)	3.43×10^{-3}	3.24×10^{-3}	4.39×10^{-3}	3.67×10^{-3}
5 (8.0 km)	3.41×10^{-3}	NA	3.69×10^{-3}	NA
Distance (mile)	Strontium to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	8.50×10^{-1}	8.50×10^{-1}	8.50×10^{-1}	8.50×10^{-1}
0.5 (805 m)	5.03×10^{-1}	5.12×10^{-1}	1.89×10^{-1}	1.93×10^{-1}
1 (1.6 km)	4.11×10^{-1}	6.11×10^{-1}	NA	0.40×10^{-1}
2 (3.2 km)	0.41×10^{-1}	0.26×10^{-1}	0.34×10^{-1}	0.28×10^{-1}
3 (4.8 km)	0.41×10^{-1}	0.24×10^{-1}	0.31×10^{-1}	0.31×10^{-1}
4 (6.4 km)	0.32×10^{-1}	0.25×10^{-1}	0.25×10^{-1}	0.27×10^{-1}
5 (8.0 km)	0.32×10^{-1}	NA	0.19×10^{-1}	NA

NA = Not available

Table 7 (cont'd)

Normalized Fe Ratio for Three Kids Mine Soil

Distance (mile)	Zinc to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	9.30×10^{-2}	9.30×10^{-2}	9.30×10^{-2}	9.30×10^{-2}
0.5 (805 m)	2.34×10^{-2}	1.30×10^{-2}	0.40×10^{-2}	1.47×10^{-2}
1 (1.6 km)	0.39×10^{-2}	0.39×10^{-2}	0.35×10^{-2}	0.37×10^{-2}
2 (3.2 km)	0.37×10^{-2}	0.38×10^{-2}	0.41×10^{-2}	0.31×10^{-2}
3 (4.8 km)	0.39×10^{-2}	0.26×10^{-2}	NA	NA
4 (6.4 km)	0.31×10^{-2}	0.27×10^{-2}	0.38×10^{-2}	0.27×10^{-2}
5 (8.0 km)	0.31×10^{-2}	0.86×10^{-2}	0.26×10^{-2}	0.27×10^{-2}
Distance (mile)	Arsenic to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	1.67×10^{-1}	1.67×10^{-1}	1.67×10^{-1}	1.67×10^{-1}
0.5 (805 m)	0.37×10^{-1}	0.21×10^{-1}	NA	0.36×10^{-1}
1 (1.6 km)	0.01×10^{-1}	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Selenium to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Rubidium to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	5.61×10^{-3}	5.61×10^{-3}	5.61×10^{-3}	5.61×10^{-3}
0.5 (805 m)	2.88×10^{-3}	2.24×10^{-3}	3.99×10^{-3}	2.61×10^{-3}
1 (1.6 km)	4.28×10^{-3}	3.62×10^{-3}	3.70×10^{-3}	3.46×10^{-3}
2 (3.2 km)	3.13×10^{-3}	3.50×10^{-3}	4.31×10^{-3}	2.86×10^{-3}
3 (4.8 km)	3.62×10^{-3}	3.47×10^{-3}	NA	NA
4 (6.4 km)	2.81×10^{-3}	2.50×10^{-3}	2.93×10^{-3}	3.35×10^{-3}
5 (8.0 km)	2.24×10^{-3}	3.94×10^{-3}	3.10×10^{-3}	3.43×10^{-3}
Distance (mile)	Strontium to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	8.50×10^{-1}	8.50×10^{-1}	8.50×10^{-1}	8.50×10^{-1}
0.5 (805 m)	6.81×10^{-1}	2.58×10^{-1}	0.39×10^{-1}	3.70×10^{-1}
1 (1.6 km)	1.17×10^{-1}	0.37×10^{-1}	0.49×10^{-1}	0.27×10^{-1}
2 (3.2 km)	0.29×10^{-1}	0.49×10^{-1}	0.57×10^{-1}	0.41×10^{-1}
3 (4.8 km)	0.26×10^{-1}	0.25×10^{-1}	NA	NA
4 (6.4 km)	0.28×10^{-1}	0.33×10^{-1}	0.36×10^{-1}	0.39×10^{-1}
5 (8.0 km)	0.29×10^{-1}	0.51×10^{-1}	0.33×10^{-1}	0.37×10^{-1}

NA = Not available

Table 7 (cont'd)

Normalized Fe Ratio for Three Kids Mine Soil

Distance (mile)	Zirconium to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	8.53×10^{-3}	8.53×10^{-3}	8.53×10^{-3}	8.53×10^{-3}
0.5 (805 m)	7.04×10^{-3}	7.38×10^{-3}	19.4×10^{-3}	3.41×10^{-3}
1 (1.6 km)	12.6×10^{-3}	8.75×10^{-3}	NA	21.5×10^{-3}
2 (3.2 km)	19.6×10^{-3}	23.9×10^{-3}	22.1×10^{-3}	21.4×10^{-3}
3 (4.8 km)	20.7×10^{-3}	22.8×10^{-3}	19.7×10^{-3}	20.9×10^{-3}
4 (6.4 km)	20.4×10^{-3}	26.7×10^{-3}	20.7×10^{-3}	18.9×10^{-3}
5 (8.0 km)	29.9×10^{-3}	NA	17.9×10^{-3}	NA
Distance (mile)	Molybdenum to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	1.98×10^{-3}	1.98×10^{-3}	1.98×10^{-3}	1.98×10^{-3}
0.5 (805 m)	1.75×10^{-3}	1.88×10^{-3}	NA	0.61×10^{-3}
1 (1.6 km)	1.22×10^{-3}	0.97×10^{-3}	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Mercury to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Lead to Iron Ratio			
	Transect 1	Transect 2	Transect 3	Transect 4
Tailings	6.95×10^{-1}	6.95×10^{-1}	6.95×10^{-1}	6.95×10^{-1}
0.5 (805 m)	4.58×10^{-1}	1.47×10^{-1}	0.54×10^{-1}	1.00×10^{-1}
1 (1.6 km)	1.15×10^{-1}	1.80×10^{-1}	NA	0.04×10^{-1}
2 (3.2 km)	0.06×10^{-1}	0.05×10^{-1}	0.002×10^{-1}	0.03×10^{-1}
3 (4.8 km)	0.02×10^{-1}	0.03×10^{-1}	0.001×10^{-1}	0.02×10^{-1}
4 (6.4 km)	0.02×10^{-1}	0.02×10^{-1}	NA	0.02×10^{-1}
5 (8.0 km)	0.01×10^{-1}	NA	NA	NA

NA = Not available

Table 7 (cont'd)

Normalized Fe Ratio for Three Kids Mine Soil

Distance (mile)	Zirconium to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	8.53×10^{-3}	8.53×10^{-3}	8.53×10^{-3}	8.53×10^{-3}
0.5 (805 m)	8.48×10^{-3}	11.2×10^{-3}	22.2×10^{-3}	11.6×10^{-3}
1 (1.6 km)	22.4×10^{-3}	19.8×10^{-3}	19.3×10^{-3}	24.5×10^{-3}
2 (3.2 km)	20.8×10^{-3}	19.1×10^{-3}	22.6×10^{-3}	17.1×10^{-3}
3 (4.8 km)	23.4×10^{-3}	23.3×10^{-3}	NA	NA
4 (6.4 km)	17.6×10^{-3}	17.0×10^{-3}	16.4×10^{-3}	19.4×10^{-3}
5 (8.0 km)	14.3×10^{-3}	19.2×10^{-3}	20.6×10^{-3}	18.3×10^{-3}
Distance (mile)	Molybdenum to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	1.98×10^{-3}	1.98×10^{-3}	1.98×10^{-3}	1.98×10^{-3}
0.5 (805 m)	1.08×10^{-3}	1.00×10^{-3}	NA	0.98×10^{-3}
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Mercury to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	NA	NA	NA	NA
0.5 (805 m)	NA	NA	NA	NA
1 (1.6 km)	NA	NA	NA	NA
2 (3.2 km)	NA	NA	NA	NA
3 (4.8 km)	NA	NA	NA	NA
4 (6.4 km)	NA	NA	NA	NA
5 (8.0 km)	NA	NA	NA	NA
Distance (mile)	Lead to Iron Ratio			
	Transect 5	Transect 6	Transect 7	Transect 8
Tailings	6.95×10^{-1}	6.95×10^{-1}	6.95×10^{-1}	6.95×10^{-1}
0.5 (805 m)	1.43×10^{-1}	0.41×10^{-1}	0.05×10^{-1}	1.10×10^{-1}
1 (1.6 km)	0.002×10^{-1}	0.05×10^{-1}	0.02×10^{-1}	0.03×10^{-1}
2 (3.2 km)	0.002×10^{-1}	0.02×10^{-1}	0.02×10^{-1}	0.01×10^{-1}
3 (4.8 km)	0.004×10^{-1}	0.02×10^{-1}	NA	NA
4 (6.4 km)	0.002×10^{-1}	0.01×10^{-1}	0.01×10^{-1}	0.01×10^{-1}
5 (8.0 km)	0.001×10^{-1}	NA	NA	NA

NA = Not available

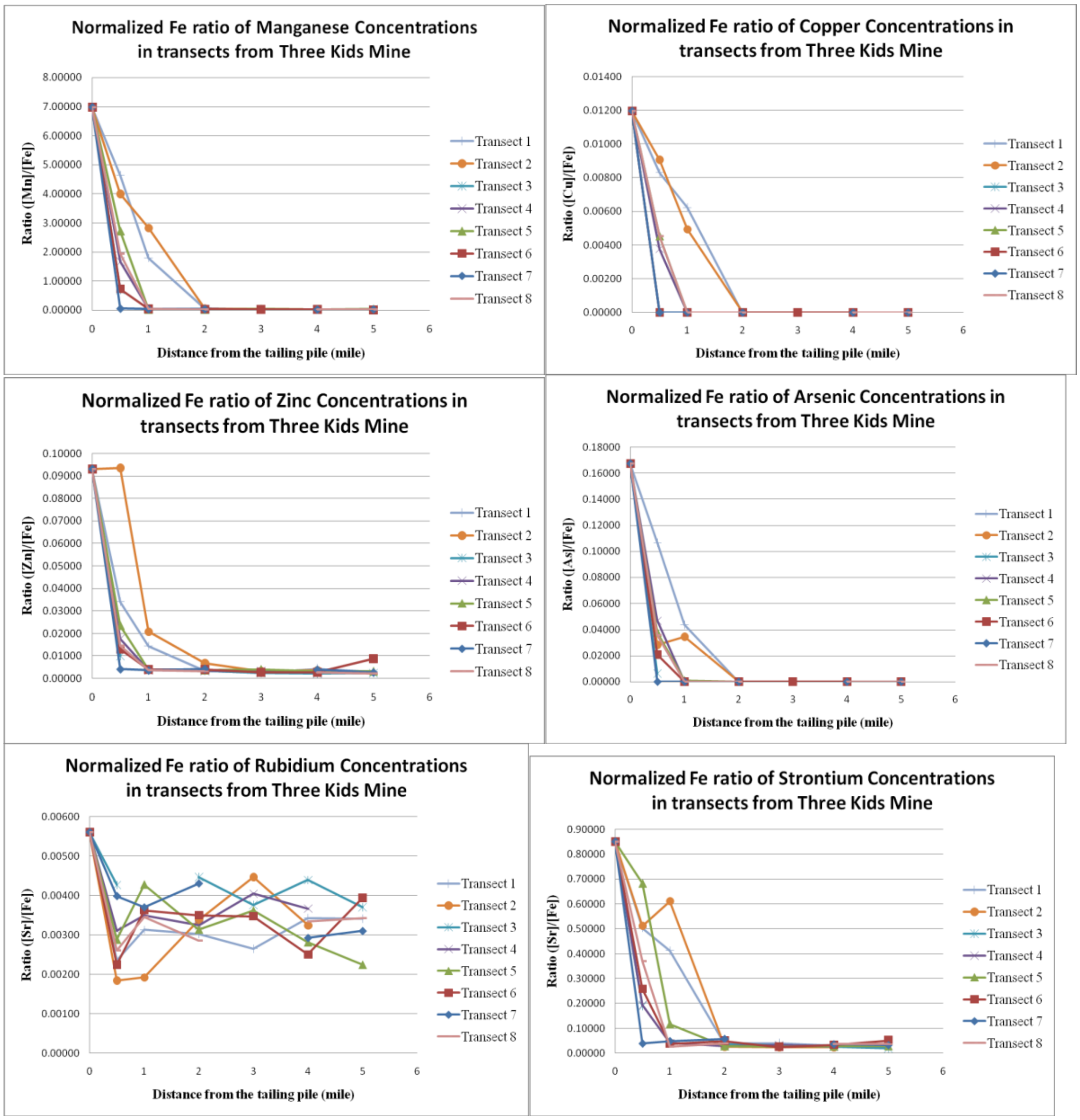


Figure 44 Normalized ratios in top surface soil at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for manganese, copper, zinc, arsenic, rubidium, and strontium

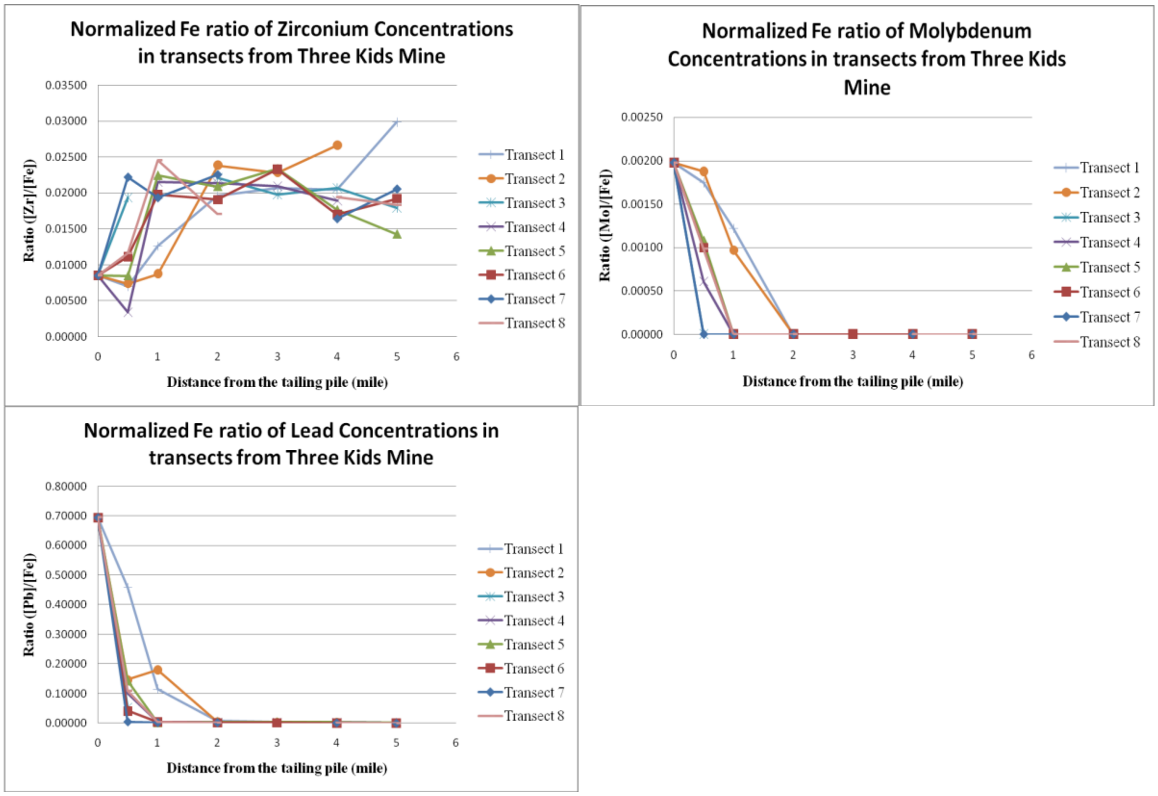


Figure 45 Normalized ratios in top surface soil at 0.5 mile (805 m), 1 mile (1.6 km), 2 miles (3.2 km), 3 miles (4.8 km), 4 miles (6.4 km), and 5 miles (8.0 km) around the middle point of the Three Kids Mine tailings for zirconium, molybdenum, and lead

Statistical Analysis of Research Questions

The results of the research answered the research questions and supported three hypotheses: (1) contaminants from the Three Kids Mine tailings are found in surface soil beyond the boundaries of the mine site; (2) a map of the concentrations of lead, arsenic, manganese, and other elements shows high concentrations in the tailing pile material at Three Kids Mine and decreasing concentrations in surface soil, as a function of direction and distance (to three miles) due to wind transport of particles from the waste piles; and (3) the elemental concentrations in surface soil along the eight radial transects will be above the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL).

Looking at Tables (6-7) and the transect maps of the elemental concentrations (Figure 33 – 43), transport of contaminated soil from the mine is apparent, decreasing concentrations of the elements as a function of distance along the eight transects (see Figure 28, page 48 for transect locations). The concentration ratios of the elements by distance are calculated in Table 8. This table estimates the distance where the elemental concentration significantly drops to the background value in transects. For example, the concentration ratio of manganese between tailing piles and 0.5 mile (805 m) from the mine site is obtained by dividing the averaged manganese concentration at the tailing pile by the averaged manganese concentration at 0.5 mile from the site. A large number of the concentration ratio between near and farther distances to the mine indicates that the elemental concentrations are dramatically decreased between two distances from the center of the tailing piles. The concentration ratios of iron, rubidium, and zirconium stay fairly constant as a function of distance in the study area.

Transects 3, only one transect in the direction to the west of River Mountains, has the short distance transport of the elements, possibly because of the physical barriers from the mountains as shown in Figure 48. Table 8 shows that for Transect 3, the elemental concentration ratios between the tailing pile and 0.5 mile from the mine are above five while the following ratios at further distances are below one and two. It implies that the elements' concentrations are plummeted to background values in half mile and one mile from the tailing piles in Transect 3 and stay fairly constant to the end of this transect. Based on Table 8, the background levels are calculated and compared to natural abundance values in the Earth's crust as shown in Table 9 (Emsley, 2001). It is evident that the study area is naturally high in manganese (580 ± 80 mg/kg) and lead (43 ± 6 mg/kg).

The most obvious patterns of the highest concentration and the farthest transport of manganese, copper, zinc, arsenic, strontium, molybdenum, and lead are presented for Transects 1 and 2. Transect 1 passes through the Lake Las Vegas Resort and stretches to the Las Vegas Wash while Transect 2 crosses the River Mountains and reaches Lake Mead (Figures 46 and 47). Transect 1 passes through the Lake Las Vegas Resort and stretches to the Las Vegas Wash while Transect 2 crosses the River Mountains and reaches Lake Mead (Figures 46 and 47). In Transect 1, the elemental concentrations are decreased to background at one mile and two miles from the center of the Three Kids Mine tailing piles for: Mn (1700 ± 100 mg/kg), Cu (110 ± 30 mg/kg), Zn (260 ± 20 mg/kg), As (800 ± 40 mg/kg), Sr (7540 ± 30 mg/kg), Mo (22 ± 2 mg/kg), and Pb (160 ± 10 mg/kg). The concentrations of the elements in Transect 2 are also plummeted to background at one mile and two miles from the mine, including Mn (1190 ± 90 mg/kg),

Table 8

The elemental concentration ratios by distance

Concentration Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
					Transect 1					
Tailing/0.5 mile	1.22	1.51	1.13	2.23	1.28	2.03	1.37	1	0.94	1.23
0.5 mile/1 mile	3.82	1.48	2.09	3.54	3.61	1.07	1.80	0.83	2.14	5.90
1 mile/2 miles	19.5	0.75	NA	2.99	NA	0.81	7.62	0.48	NA	13.1
2 miles/3 miles	2.68	1.02	NA	1.43	NA	1.16	1	0.96	NA	2.91
3 miles/4 miles	1.54	1.15	NA	0.67	NA	0.89	1.5	1.16	NA	1.12
4 miles/5 miles	1.41	1.02	NA	1.44	NA	1.03	1	0.70	NA	2.04
Concentration Ratios					Transect 2					
Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
Tailing/0.5 mile	1.33	1.41	1	0.76	4.5	2.45	1.26	0.90	0.81	3.56
0.5 mile/1 mile	1.77	1.25	2.36	5.65	1.02	1.21	1.05	1.05	2.45	1.02
1 mile/2 miles	54.9	0.99	NA	3	NA	0.56	22.7	0.36	NA	35
2 miles/3 miles	1.68	1.23	NA	2.67	NA	0.93	1.35	1.30	NA	1.94
3 miles/4 miles	1.39	0.84	NA	0.74	NA	1.16	0.81	0.72	NA	1.17
4 miles/5 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concentration Ratios					Transect 3					
Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
Tailing/0.5 mile	11.5	2.09	NA	10.8	30.7	1.57	5.07	0.5	NA	14.4
0.5 mile/1 mile	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1 mile/2 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2 miles/3 miles	1.67	1.08	NA	1.56	NA	1.29	1.18	1.21	NA	1.91
3 miles/4 miles	0.79	0.97	NA	1.07	NA	0.83	1.2	0.93	NA	NA
4 miles/5 miles	0.88	0.85	NA	0.79	NA	1.01	1.14	0.98	NA	NA
Concentration Ratios					Transect 4					
Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
Tailing/0.5 mile	1.9	0.84	1.4	2.38	1.63	0.87	2	1.19	1.52	3.17
0.5 mile/1 mile	91.9	2.4	NA	11.0	NA	2.14	11.6	0.36	NA	63.4
1 mile/2 miles	1.33	0.94	NA	1	NA	1	1.33	0.96	NA	1.27
2 miles/3 miles	1.37	1.2	NA	1.24	NA	0.92	1.03	1.18	NA	1.54
3 miles/4 miles	1.02	0.87	NA	1.07	NA	0.97	0.98	0.98	NA	1.11
4 miles/5 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Concentration Ratios					Transect 5					
Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
Tailing/0.5 mile	2.07	1.5	2.2	3.20	3.58	1.67	1.01	0.83	1.52	3.94
0.5 mile/1 mile	176	1.7	NA	10.2	60.59	1.13	9.79	0.64	NA	129
1 mile/2 miles	0.67	0.7	NA	0.74	NA	0.96	2.78	0.75	NA	0.55
2 miles/3 miles	0.64	1.1	NA	1.04	NA	0.95	1.24	0.98	NA	0.67
3 miles/4 miles	1.09	0.79	NA	1.01	NA	1.03	0.74	1.07	NA	1.37
4 miles/5 miles	0.67	0.93	NA	0.94	NA	1.17	0.89	1.15	NA	2.07

NA = Not Available

Table 8 (cont'd)

The elemental concentration ratios by distance

Concentration Ratios	Mn	Fe	Cu	Zn	As	Rb	Sr	Zr	Mo	Pb
Transect 6										
Tailing/0.5 mile	10.5	2.03	NA	7.88	8.79	2.89	3.61	0.86	2.2	18.4
0.5 mile/1 mile	17.6	0.99	NA	3.33	NA	0.61	6.91	0.55	NA	8.30
1 mile/2 miles	1.51	1.15	NA	1.15	NA	1.19	0.87	1.18	NA	3.13
2 miles/3 miles	1.12	0.82	NA	1.21	NA	0.83	1.59	0.67	NA	0.82
3 miles/4 miles	0.87	0.78	NA	0.76	NA	1.07	0.59	1.06	NA	1.50
4 miles/5 miles	NA	2.88	NA	0.89	NA	1.84	1.84	2.53	NA	NA
Transect 7										
Tailing/0.5 mile	167	2.16	NA	27	NA	1.71	25.3	0.45	NA	159
0.5 mile/1 mile	1.77	1.07	NA	1.25	NA	1.15	0.86	1.23	NA	2.29
1 mile/2 miles	1.21	1.22	NA	1.02	NA	1.05	1.04	1.03	NA	1.35
2 miles/3 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3 miles/4 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4 miles/5 miles	1.05	1.19	NA	1.72	NA	1.11	1.32	0.95	NA	NA
Transect 8										
Tailing/0.5 mile	3.45	1.77	2.6	6.03	4.5	2.17	2.19	0.70	1.91	6.05
0.5 mile/1 mile	65.4	1.01	NA	4.05	NA	0.76	13.7	0.48	NA	35.1
1 mile/2 miles	1.66	1.18	NA	1.4	NA	1.44	0.78	1.7	NA	3
2 miles/3 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3 miles/4 miles	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4 miles/5 miles	1.08	1.07	NA	1.32	NA	1.06	1.11	1.14	NA	1.10

NA = Not Available

Table 9

Natural Abundances for comparison with Three Kids Mine Background (mg/kg = ppm)

Element	Natural Abundance	Background Level
Cr	50	< 115
Mn	440	580 ± 80
Fe	0.5 - 5%	25000 ± 200
Co	8	< 50
Ni	50	< 75
Cu	20	< 50
Zn	64	69 ± 11
As	10	< 10
Se	5	< 7
Rb	30 - 250	79 ± 4
Sr	18 - 3500	730 ± 10
Zr	35 - 550	360 ± 10
Mo	2	< 5
Hg	0.01 - 5 ppb	< 15
Pb	23	43 ± 6

Values in ppm are parts per million while ppb stands for parts per billion (1σ; 68% confidence interval). 1% = 10,000 ppm

Cu (110 ± 30 mg/kg), Zn (160 ± 10 mg/kg), As (800 ± 40 mg/kg), Sr (14140 ± 40 mg/kg), Mo (22 ± 2 mg/kg), and Pb (110 ± 10 mg/kg). The concentrations of the elements in Transect 2 are also plummeted to background at one mile and two miles from the mine, including Mn (1190 ± 90 mg/kg), Cu (110 ± 30 mg/kg), Zn (160 ± 10 mg/kg), As (800 ± 40 mg/kg), Sr (14140 ± 40 mg/kg), Mo (22 ± 2 mg/kg), and Pb (110 ± 10 mg/kg). This suggests that the tailing particles are transported up to two and three miles from the mine.

Based on a map of the mine boundaries, half mile from the center of the tailing piles on Transects 2 is not in the tailings area but still within the boundary of the mine property. The elemental concentrations at 0.5 mile (805m) from the mine are often noted to be higher in transect 2 than in other transects (1, 3, 4, 5, 6, 7, and 8). During sample collection, it was observed that the wind was blowing predominantly from the west, uphill toward the mine site. Tailing particles blow along Transects 1 and 2 from the mine to the east toward the Las Vegas Wash and Lake Mead, respectively in Figure 49. The road is situated between Transects 1 and 2, going the east downhill toward Lake Mead. Strong wind from the west would carry contaminated soil containing manganese, copper, zinc, arsenic, strontium, molybdenum, and lead in eastern direction, resulting in the highest transport of tailing particles along Transects 1 and 2. This does not agree with the wind flow patterns recorded by the currently active site Environmental Protection Agency (EPA) 32-003-0298 that showed the wind directions predominantly going toward the southwest in its wind rose diagram (see Figure 14 on page 25).

Figure 46 Picture taken from the uphill above the tailing piles toward Transect 1

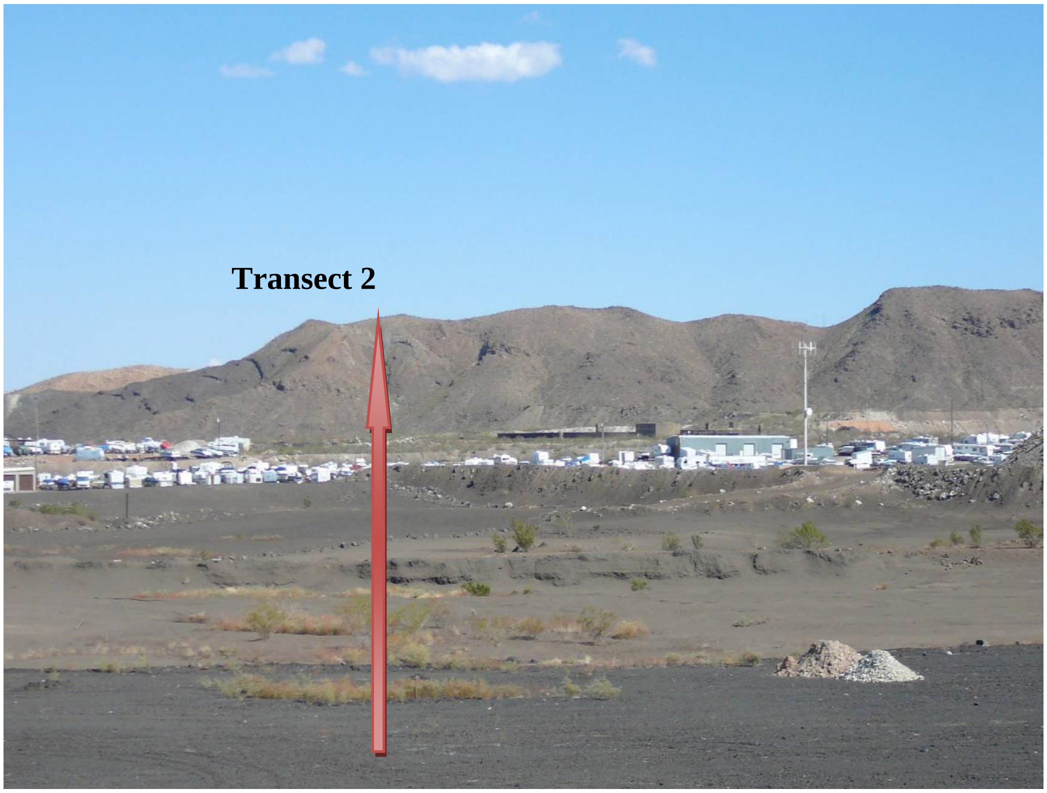


Figure 47 Picture taken from the tailing piles along Transect 2

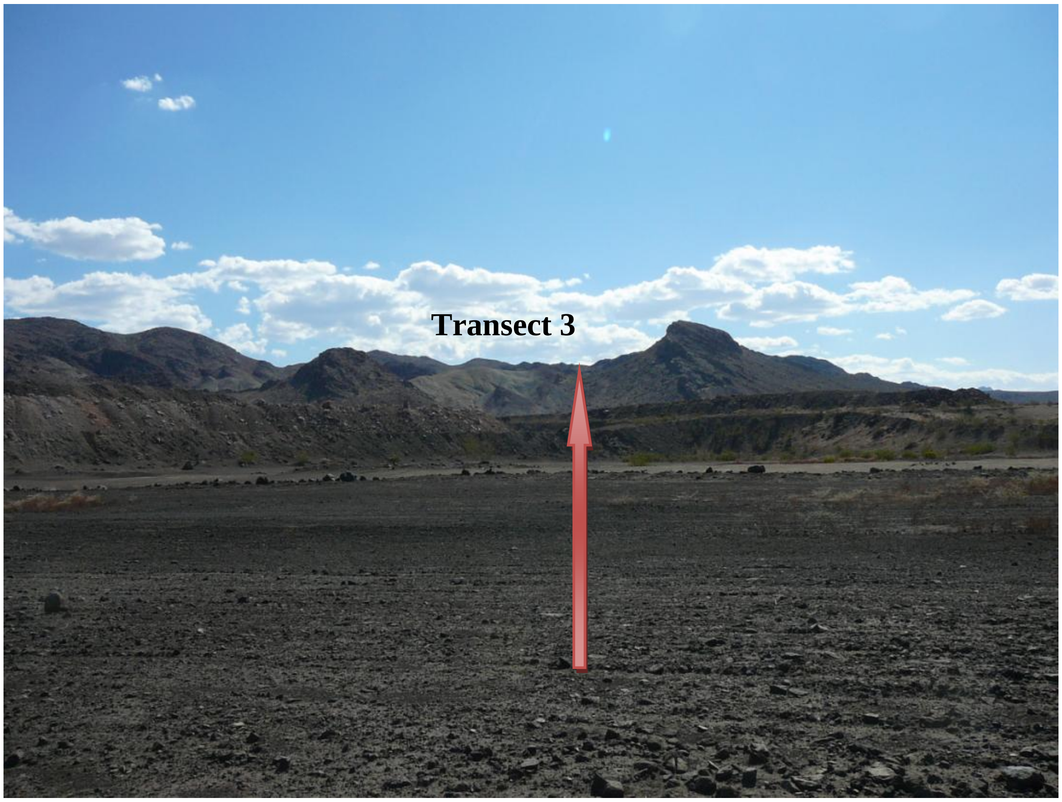


Figure 48 Picture taken from the tailing piles along Transect 3

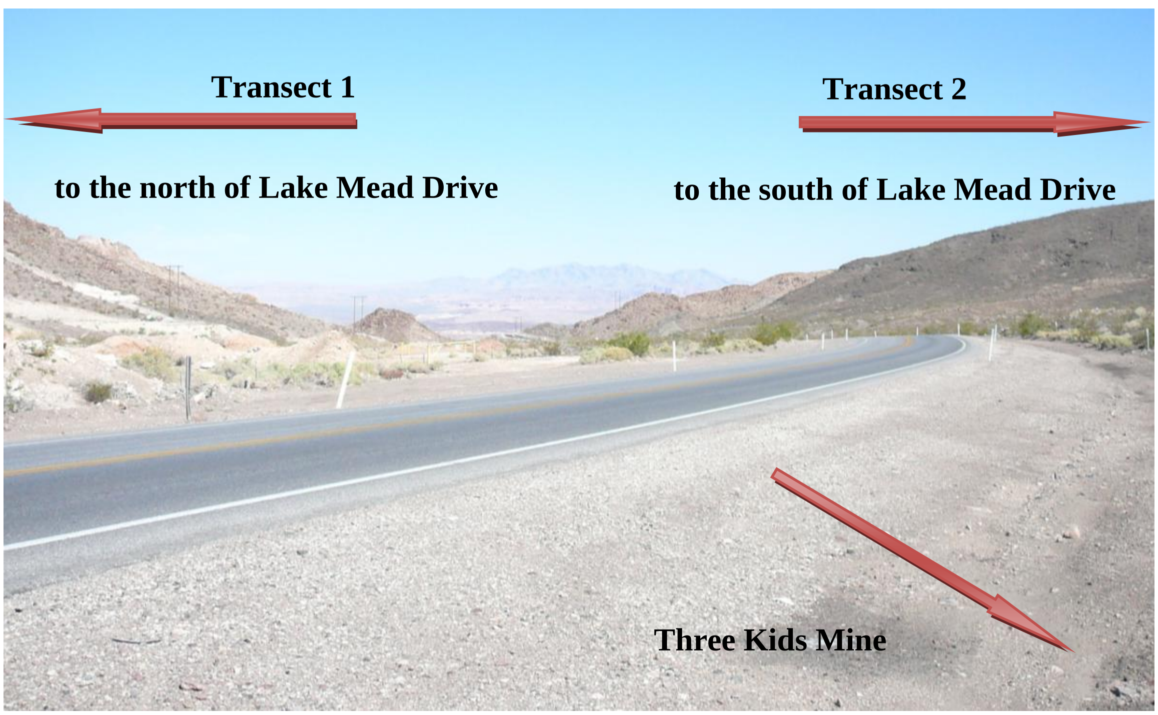


Figure 49 Going downhill from the mine entrance toward Lake Mead between Transect 1 and Transect 2

Rain water from the tailing piles is fairly well isolated and flow to the Las Vegas Wash. On the west of the mine site, two small culverts are found near the gate of the mine site, one protruding from the northern east side of the mine and another culvert under Lake Mead Drive extending to the other side of the road toward the Lake Las Vegas community. One of the culverts is located next to the boat storage area in Figure 50. On the other hand, the western downhill from the main tailing piles is situated next to Lake Mead Drive facing the Lake Las Vegas Resort Community as shown in Figure 51.

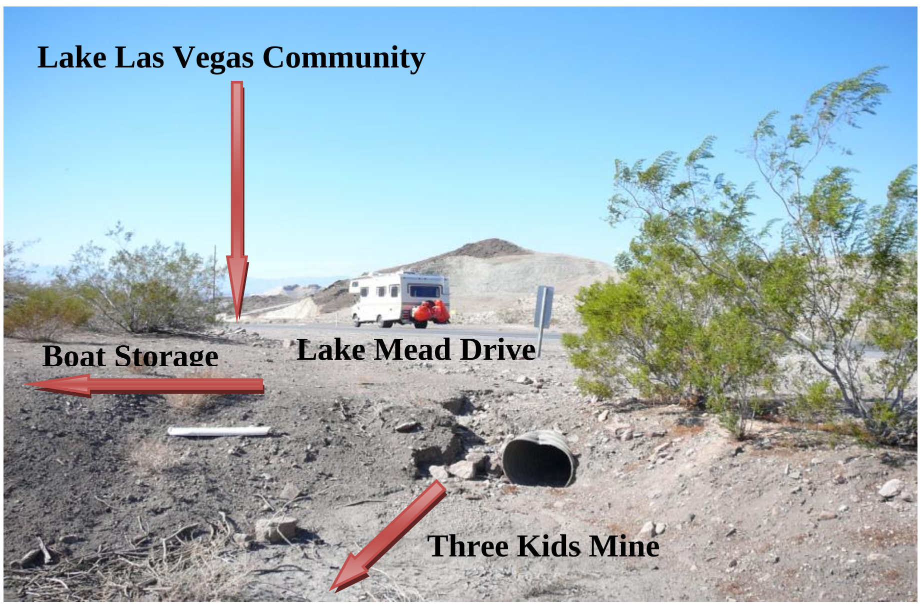


Figure 50 A culvert is found on the front side of the mine site, next to the boat storage area under Lake Mead Drive

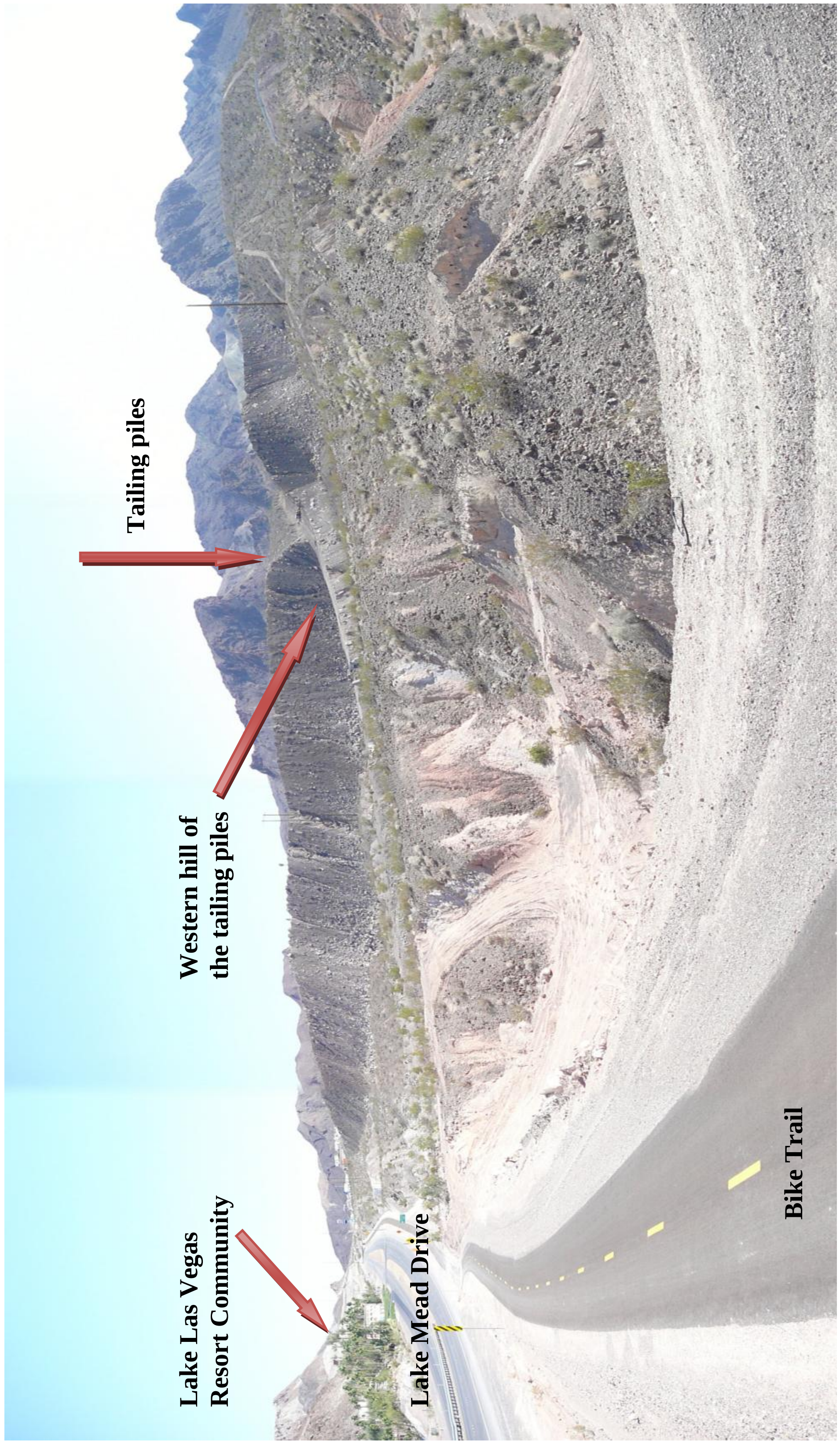


Figure 51 The western downhill from the tailing piles next to the bike trail

Two water washes are observed on the west and east sides of the downhill from the main tailing piles in Figure 52. It is apparent that water transport with contaminated soil from the tailings pile does not drain downhill toward the City of Henderson but is channeled through culverts that go under the bike trail. Bike trail is situated between Lake Mead Drive and near the edge of the mine tailing piles. Near the mine site and the west of boat storage area, the bike trail goes under Lake Mead Drive and extends to the east. Thus, water washes will either drain large quantities of tailings under the road or carry into the lake near golf course in the Lake Las Vegas Resort Community. However, more samples along washes in direction of the Las Vegas Wash and through the Lake Las Vegas Resort should be analyzed to confirm the water transport mechanism. Tailing particles are most likely transported along the transects by wind.

Transects 4-8 have relatively low transport of the elements. From the top of the tailing piles, these transects are going downhill toward the occupied houses in the City of Henderson and traverse the communities of the Lake Las Vegas Resort and of Calico Ridge as shown in Figure 53. The mine property covers approximately 55,321,200 square feet of 18 private and public parcels (Stinchfield, 2007). The surface of the tailing piles is examined as a large, bath-shaped cavity approximately 1800 feet above mean sea level (MSL) in elevation according to Stinchfield. From Table 8, Transects 4, 5, 6, and 8 show tailings transport up to half mile and one mile from the center of the tailing piles above background level. Although Transect 7 shows no offsite transport from the tailing piles, lead is measured above background out to tailing piles and half mile from the site.

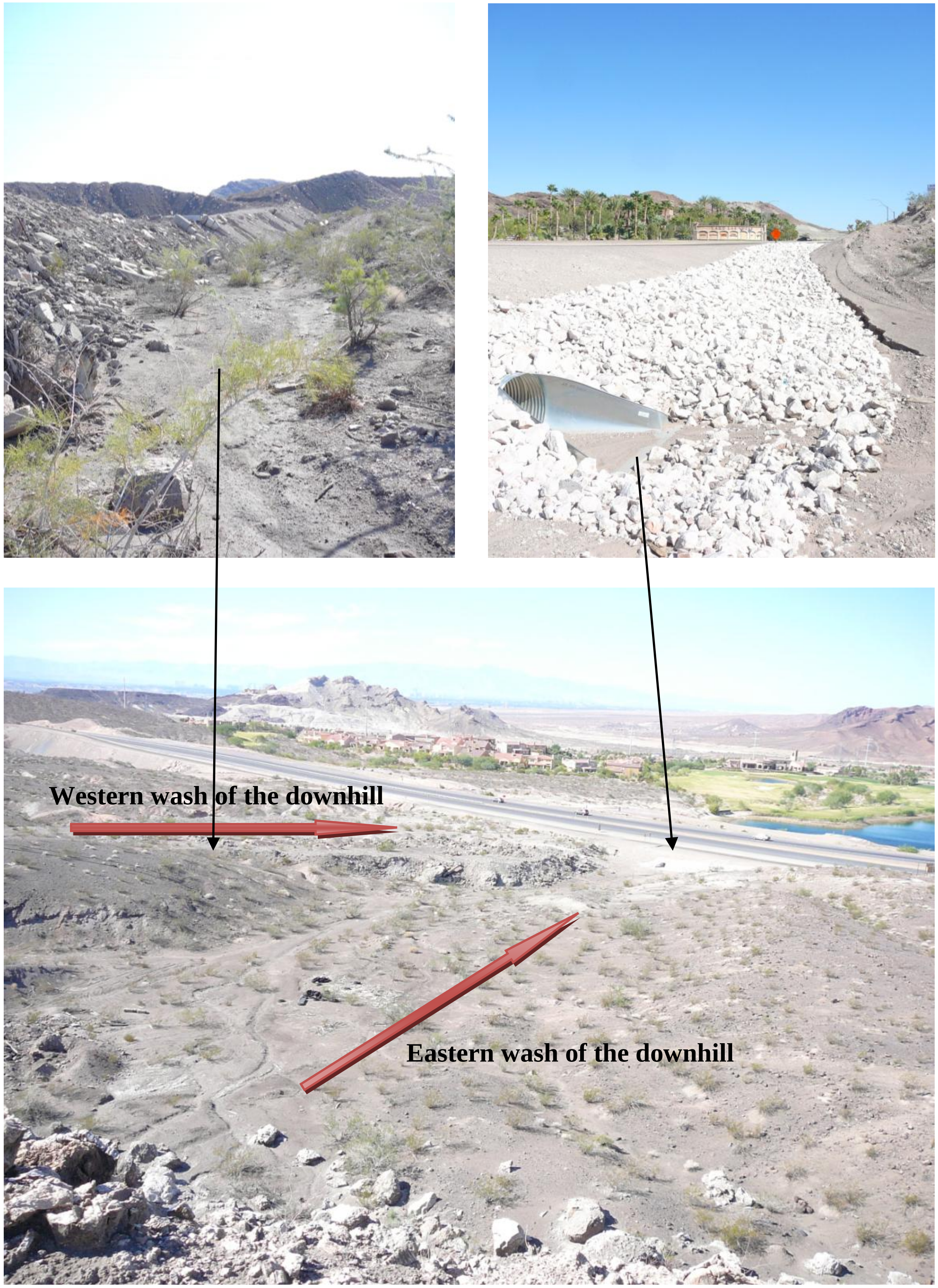


Figure 52 Pictures of the wash passing downhill from the western side of the tailing pile northeast towards Lake Mead Drive showing direction of runoff toward Lake Las Vegas Resort entrance

Figure 53 Panorama from the tailing piles toward Transects 4-8

The elemental concentrations in surface soil along the eight radial transects are compared to the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL) in Table 10. The EPA RSLs are created based on a target cancer risk assessment, the general exposure and risk evaluation, and the Integrated Risk Information System (IRIS). Ratios of Mn, As, and Pb are generated based on the EPA RSL values for the concentrations of the elements at 0.5 mile, 1 mile, and 2 miles from the tailings pile center in Table 11. Compared to the EPA RSL values, the Three Kids Mine tailing pile has the highest ratios: Mn ($8.5x10^1$), As ($9.5x10^3$), and Pb ($3.8x10^1$). At half mile from the tailings pile center, arsenic ratios for all transects are within a factor of a thousand fold while ratios of manganese and lead are a tenfold more than RSL values. However, manganese ratio at one mile from the tailings pile center decreased to a range between one tenth and ten folds for all transects. In contrast, the ratios of arsenic and lead at one mile from the mine site for all transects stay similar as the half mile ratios. At two miles from the tailings pile center, ratios of manganese and lead are reduced to tenth or hundredth folds while arsenic ratios are not established since arsenic concentrations are below the limits of detection.

Table 10
The USEPA Regional Screening Level (RSL) for soil, mg/kg (ppm)

Element	US EPA RSLs (mg/kg, ppm)
Mn	1.8×10^3
Fe	$5.5x 10^4$
Cu	3.1×10^3
Zn	2.3×10^4
As	3.9×10^{-1}
Sr	4.7×10^4
Mo	3.9×10^2
Pb	4.0×10^2

1 k = 1000 mg/kg (ppm)

Although half mile from the Three Kids Mine waste pile on Transect 8 is not within the boundary of the mine property, it is noticeable that the concentrations of manganese, arsenic, and lead are higher than RSL values up at half mile from the mine on Transect 8. Transect 8 stretches five miles from the Three Kids Mine waste pile across the vicinity between the communities of Calico Ridge and the Lake Las Vegas Resort. It is apparent that the concentrations of manganese, arsenic, and lead are higher than RSL values at half mile from the mine site on Transects 1 to 6. However, it is also evident that the concentrations of these elements stay higher than RSL values up to one mile from the tailing pile on Transects 1 and 2: Mn ($1.8x10^{1}$), As ($2.1x10^{3}$), and Pb ($5.2x10^{0}$). As the distance from the mine site increases to 2 miles from the tailings pile center, the ratios of the transects to the EPA RSL values significantly drop to the decimal units.

Table 11

Ratios of Mn, As, and Pb to the US EPA RSL values

Element	Ratios of transects divided by RSL in the tailing pile
Mn	$8.5 x10^{1}$
As	$9.5 x10^{3}$
Pb	$3.8 x10^{1}$

Element	Ratios of transects divided by RSL at 0.5 mile from the tailings pile center							
	T1/RSL	T2/RSL	T3/RSL	T4/RSL	T5/RSL	T6/RSL	T7/RSL	T8/RSL
Mn	$7.0x10^{1}$	$6.4x10^{1}$	$7.4x10^{0}$	$4.5x10^{1}$	$4.1x10^{1}$	$8.1x10^{0}$	$5.1x10^{-1}$	$2.5x10^{1}$
As	$7.4x10^{3}$	$2.1x10^{3}$	$3.1x10^{2}$	$5.8x10^{3}$	$2.6x10^{3}$	$1.1x10^{3}$	NA	$2.1x10^{3}$
Pb	$3.1x10^{1}$	$1.1x10^{1}$	$2.6x10^{0}$	$1.2x10^{1}$	$9.7x10^{0}$	$2.1x10^{0}$	$2.4x10^{-1}$	$6.3x10^{0}$

NA = Not available due to measurements below LOD or not collected at the sampling site

Table 11 (cont'd)

Ratios of Mn, As, and Pb to the US EPA RSL values

Element	Ratios of transects divided by RSL at 1 mile from the tailings pile center							
	T1/RSL	T2/RSL	T3/RSL	T4/RSL	T5/RSL	T6/RSL	T7/RSL	T8/RSL
Mn	$1.8x10^{1}$	$3.6x10^{1}$	NA	$4.8x10^{-1}$	$2.3x10^{-1}$	$4.6x10^{-1}$	$2.9x10^{-1}$	$3.8x10^{-1}$
As	$2.1x10^{3}$	$2.1x10^{3}$	NA	NA	$4.4x10^{1}$	NA	NA	NA
Pb	$5.2x10^{0}$	$1.0x10^{1}$	NA	$1.9x10^{-1}$	$7.5x10^{-2}$	$2.5x10^{-1}$	$1.0x10^{-1}$	$1.8x10^{-1}$

Element	Ratios of transects divided by RSL at 2 mile from the tailings pile center							
	T1/RSL	T2/RSL	T3/RSL	T4/RSL	T5/RSL	T6/RSL	T7/RSL	T8/RSL
Mn	$9.4x10^{-1}$	$6.6x10^{-1}$	$2.8x10^{-1}$	$3.7x10^{-1}$	$3.5x10^{-1}$	$3.1x10^{-1}$	$2.4x10^{-1}$	$2.3x10^{-1}$
As	NA	NA	NA	NA	NA	NA	NA	NA
Pb	$0.4x10^{0}$	$2.7x10^{-1}$	$1.1x10^{-1}$	$1.5x10^{-1}$	$1.4x10^{-1}$	$0.8x10^{-2}$	$7.7x10^{-2}$	$6.0x10^{-2}$

NA = Not available due to measurements below LOD or not collected at the sampling site

Tailing pile shallow core and one attic dust sample

When the samples for this study were scooped from the top 0.5 centimeters of top surface, dark brown colored soil was found. Often, light cream-colored soil was observed below top surface soil. One soil core sample (6-10-2011-5) was collected in one area of the tailing piles to a depth of 30 centimeters (Table 12). This sample was located approximately 160 meters from the center of the tailing piles between Transects 4 and 5. The concentrations of the elements stay fairly constant in depth. For example, lead and manganese in the upper sample (0-3 cm soil depth) are 5240 ± 60 mg/kg (ppm) and 115600 ± 700 mg/kg roughly the same concentrations throughout this core profile, respectively.

One attic dust sample was collected from a vent over the garage of a home in Calico Ridge near the location where top surface soil was taken by the shovel at one mile away from the center of the tailing piles on Transect 7. The sample was collected by gently sweeping dust off the surface from an area in foot into a dust pan with a fine brush. It was then analyzed using XRF and compared with the surface soil collected near the house as shown in Table 13. Comparing the chemical composition in dust and surface soil samples, the majority of the elements in attic dust and surface soil samples has similar value, including three elements (Mn, Zn, and Pb) that are higher in attic dust sample than surface soil.

Table 12

Chemical compositions (ppm) of tailing pile soil core (6-10-2011-5) to a depth of 30 cm in one area of the tailing piles; located approximately 160 m from the center of the tailing piles between Transect 4 and 5

Element	0 - 3 cm	3 - 15 cm	15 - 30 cm
Cr	< 115	< 115	< 115
Mn	115.6k ± 0.7k	102.7k ± 0.6k	100.8k ± 0.6k
Fe	17.8k ± 0.3k	17.1k ± 0.3k	17.6k ± 0.3k
Co	< 50	< 50	< 50
Ni	65 ± 35	44 ± 33	59 ± 34
Cu	210 ± 30	180 ± 30	180 ± 30
Zn	480 ± 30	450 ± 20	440 ± 20
As	640 ± 40	550 ± 40	580 ± 40
Se	< 7	< 7	< 7
Rb	69 ± 6	68 ± 6	66 ± 6
Sr	7190 ± 30	7250 ± 30	7740 ± 30
Zr	140 ± 20	150 ± 20	170 ± 20
Mo	38 ± 3	37 ± 2	36 ± 3
Hg	< 15	< 15	< 15
Pb	5240 ± 60	4560 ± 50	4480 ± 50

1σ; 68% confidence interval

Table 13

Chemical compositions (ppm) of attic dust and soil sample collected at one location, one mile from the center of the tailing piles on Transect 7

Element	Attic dust (6-26-2011-1)	Soil Sample (6-26-2011-2)
Cr	< 115	< 115
Mn	710 ± 80	360 ± 70
Fe	16300 ± 100	15900 ± 100
Co	< 50	< 50
Ni	< 75	< 75
Cu	< 50	< 50
Zn	690 ± 20	50 ± 10
As	< 10	< 10
Se	< 7	< 7
Rb	75 ± 3	64 ± 3
Sr	740 ± 10	910 ± 10
Zr	370 ± 10	310 ± 10
Mo	< 5	< 5
Hg	< 15	< 15
Pb	110 ± 10	29 ± 5

1σ; 68% confidence interval

Method Performance Data

Fundamental Parameters (FP) Calibration Check

The XRF instrument was internally calibrated by a NITON XLp 703a portable X-ray spectrometer according to Environmental Protection Agency (EPA) Method 6200 modified to use of Fundamental Parameters (FP) method. The instrument performed continuous calibration verification (CCV) for analysis of NITON SRM 2709 San Joaquin Soil (low-level) and NITON SRM 2711 Montana Soil (high-level). The percent difference (%D) and percent recoveries (%Rec) are defined in Chapter 3 (see page 44-45). The %D ± 20% of the certified values is considered acceptable for analysis (EPA 6200 Method: Field portable x-ray fluorescence spectrometry for the determination of elemental concentrations in soil and sediment, 2007). As a result, mean values of measured concentrations for SRMs were calculated as well as the certified values, percent differences, and percent recoveries associated with them (Table 14).

Good agreement with certified or consensus values is obtained for low-level SRM 2709 San Joaquin Soil (Table 14). The percent recoveries for five elements (Fe, Zn, Rb, Sr, and Zr) range from 83% for Fe to 108% for Zn. In addition, their percent differences (%D) are within the acceptable limit for: Fe (17%), Zn (8%), Rb (12%), Sr (6%), Zr (1%), and other 5 elements (Cr, Co, Ni, Se, and Hg) are below the limit of detection (LOD) and the percent differences and recoveries cannot be determined. Conversely, seven elements (Fe, Zn, As, Rb, Sr, Zr, and Pb) in high-level SRM 2711 Montana Soil show excellent agreement with certified or consensus values and their percent recoveries range from 80% for Fe to 131% for Zr. Except for Zr (31%), the percent differences for analytes are below the acceptable range of 1 to 20%: Fe (20%), Cu (5%), Zn (7%), As (3%), Rb (5%),

Sr (5%), Pb (1%), and five elements (Cr, Co, Ni, Se, and Hg) are below LOD so their percent differences and recoveries are not available.

XRF Quality Assurance

Following EPA Method 6200, accuracy and precision of the XRF measurements were verified by calculating a relative standard deviation (RSD) of NIST SRM 2709 San Joaquin Soil and NIST SRM 2711 Montana Soil (Table 14). The results were collected by analyzing both sides of XRF sample cup. An RSD below 20% is acceptable value for analysis (Taylor, 1987). Consequently, five elements in SRM 2709 San Joaquin Soil (Fe, Zn, Rb, Sr, and Zr) have RSDs within the acceptable limit of 20%. Five elements (Cr, Co, Ni, Se, and Hg) are below LOD so their RSDs cannot be determined. Conversely, most of the elements in SRM 2711 Montana Soil have RSDs within the acceptable range: Fe (1%), Cu (13%), Zn (5%), As (13%), Rb (3%), Sr (2%), Zr (2%), and Pb (2%). Five elements (Cr, Co, Ni, Se, and Hg) are below LOD and the RSDs are not available.

Table 14

XRF results for NIST SRM 2709 and 2711 soil reference materials. Concentrations are reported in mg/kg (ppm).

Element	NIST SRM 2709 San Joaquin Soil				
	Measured value	Certified or ref value	% D	%Rec.	RSD
Cr	< 115	130 ± 4	NA	NA	NA
Mn	< 60	538 ± 17	NA	NA	NA
Fe	28900 ± 200	35000 ± 1100	17	83	1
Co	< 50	13.4 ± 0.7	NA	NA	NA
Ni	< 75	88 ± 5	NA	NA	NA
Cu	< 50	34.6 ± 0.7	NA	NA	NA
Zn	114 ± 12	106 ± 3	8	108	10
As	< 10	17.7 ± 0.8	NA	NA	NA
Se	< 7	1.57 ± 0.08	NA	NA	NA
Rb	85 ± 6	(96)	12	88	4
Sr	218 ± 5	231 ± 2	6	94	2
Zr	158 ± 5	(160)	1	99	3
Mo	< 5	(2.0)	NA	NA	NA
Hg	< 15	1.40 ± 0.08	NA	NA	NA
Pb	< 12	18.9 ± 0.5	NA	NA	NA

Element	NIST SRM 2711 San Joaquin Soil				
	Measured value	Certified or ref value	% D	%Rec.	RSD
Cr	< 115	(47)	NA	NA	NA
Mn	< 60	638 ± 28	NA	NA	NA
Fe	23100 ± 200	28900 ± 600	20	80	1
Co	< 50	(10)	NA	NA	NA
Ni	< 75	20.6 ± 1.1	NA	NA	NA
Cu	120 ± 20	114 ± 2	5	105	13
Zn	326 ± 16	350.4 ± 4.8	7	93	5
As	102 ± 14	105 ± 8	3	97	13
Se	< 7	1.52 ± 0.14	NA	NA	NA
Rb	104 ± 4	(110)	5	95	3
Sr	232 ± 5	245.3 ± 0.7	5	95	2
Zr	301 ± 7	(230)	31	131	2
Mo	< 5	(1.6)	NA	NA	NA
Hg	< 15	6.25 ± 0.19	NA	NA	NA
Pb	1151 ± 21	1162 ± 31	1	99	2

Values in parentheses are for information only and do not have uncertainties related to them. 1σ; 68% confidence interval. Certified values are ± 95% confidence limit according to National Institute of Standards and Technology. NA = Not available.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The main goal of this study was to document the environmental contamination from the Three Kids Mine tailings on the surrounding land. This study provides important information for the public about the transport of chemical elements of the Three Kids Mine tailings to the surrounding environment. During the summers of 2010 and 2011, the surface soils along the sampling map were collected and analyzed using XRF. Regarding the hypotheses, the results are interpreted and, for each transect, Table 15 summarizes the distances out to which the concentrations of the elements are decisively measured above background and the next distance is where the elemental concentrations have fallen to background.

Table 15
The transport for all transects

Elements	Measured above background to	Measured at background (therefore reaches background before this distance)
	Transect 1	
Mn	2 miles	3 miles
Cu	1 mile	2 miles
Zn	1 mile	2 miles
As	1 mile	2 miles
Sr	1 mile	2 miles
Mo	1 mile	2 miles
Pb	2 miles	3 miles
	Transect 2	
Elements	Measured above background to	Measured at background (therefore reaches background before this distance)
Mn	2 miles	3 miles
Cu	1 mile	2 miles
Zn	2 miles	3 miles
As	1 mile	2 miles
Sr	1 mile	2 miles
Mo	1 mile	2 miles
Pb	2 miles	3 miles

NA = Not available due to measurements below LOD or not collected at the sampling site; 1σ; 68% confidence interval

Table 15 (cont'd)
The transport for all transects

Elements	Measured above background to	Measured at background (therefore reaches background before this distance)
	Transect 3	
Mn	0.5 mile	1 mile
Cu	NA	0.5 mile
Zn	0.5 mile	1 mile
As	0.5 mile	1 mile
Sr	0.5 mile	1 mile
Mo	NA	0.5 mile
Pb	0.5 mile	1 mile
	Transect 4	
Distance (mile)	Measured above background to	Measured at background (therefore reaches background before this distance)
Mn	0.5 mile	1 mile
Cu	0.5 mile	1 mile
Zn	0.5 mile	1 mile
As	0.5 mile	1 mile
Sr	0.5 mile	1 mile
Mo	0.5 mile	1 mile
Pb	0.5 mile	1 mile
	Transect 5	
Elements	Measured above background to	Measured at background (therefore reaches background before this distance)
Mn	0.5 mile	1 mile
Cu	0.5 mile	1 mile
Zn	0.5 mile	1 mile
As	0.5 mile	1 mile
Sr	0.5 mile	1 mile
Mo	0.5 mile	1 mile
Pb	0.5 mile	1 mile
	Transect 6	
Elements	Measured above background to	Measured at background (therefore reaches background before this distance)
Mn	0.5 mile	1 mile
Cu	NA	0.5 mile
Zn	0.5 mile	1 mile
As	0.5 mile	1 mile
Sr	0.5 mile	1 mile
Mo	0.5 mile	1 mile
Pb	1 mile	2 miles

NA = Not available due to measurements below LOD or not collected at the sampling site; 1σ; 68% confidence interval

Table 15 (cont'd)
The transport for all transects

Elements	Measured above background to	Transect 7 Measured at background (therefore reaches background before this distance)
Mn	NA	0.5 mile
Cu	NA	0.5 mile
Zn	NA	0.5 mile
As	NA	0.5 mile
Sr	NA	0.5 mile
Mo	NA	0.5 mile
Pb	0.5 mile	1 mile

Distance (mile)	Measured above background to	Transect 8 Measured at background (therefore reaches background before this distance)
Mn	0.5 mile	1 mile
Cu	0.5 mile	1 mile
Zn	0.5 mile	1 mile
As	0.5 mile	1 mile
Sr	0.5 mile	1 mile
Mo	0.5 mile	1 mile
Pb	0.5 mile	1 mile

NA = Not available due to measurements below LOD or not collected at the sampling site; 1σ; 68% confidence interval

Seven chemical components (Mn, Cu, Zn, As, Sr, Mo, and Pb) are found to be transported away from the Three Kids Mine tailing piles, five elements (Cr, Co, Ni, Se, and Hg) which are measurable by XRF are observed below the limit of detection (LOD), and three elements (Fe, Rb, and Zr) stay fairly constant in the entire sampling area. Most notably, Transects 1 and 2 have the highest concentration and the most distance transport of manganese, copper, zinc, arsenic, strontium, molybdenum, and lead to surface soil. It appears that transect one intersects the Las Vegas Wash at three miles and transect two reaches Lake Mead at five miles. The majority of the elements in these transect is dramatically decreased to background at two and three miles from the mine. The concentrations of manganese, arsenic, and lead in Transects 1 and 2 at one mile from the

center of the tailing piles are found to be significantly higher than the U.S. Environmental Protection Agency (EPA) Regional Screening Level (RSL) for soil as shown in Table 16.

Table 16
Comparison of the USEPA Regional Screening Level (RSL) for soil and the elemental concentrations in transects 1 and 2 at 1 mile from the center of the tailing piles (mg/kg)

Element	RSLs	1 mile Transect 1	T1/ RSL	1 mile Transect 2	T2/ RSL
Mn	1.8k	32.9k ± 0.3k	18	65.4k ± 0.5k	36
As	0.39	800 ± 40	2100	800 ± 40	2100
Pb	400	2100 ± 30	5.2	4260 ± 50	10.6

1 k = 1000 mg/kg (ppm)

On the other hand, Transects 3-8 have relatively low transport of the contaminants up to half and one mile from the mine. Transect 7 shows no offsite transport of tailing particles from the boundaries of the mine property. Transects 3 in the direction to the west of River Mountains, has low transport of the elements, possibly because of the physical barriers of the mountains that stretches five miles from the south edge of the mine site. Transects 5 to 8 go toward the City of Henderson and to the communities of Calico Ridge and the western edge of the Lake Las Vegas Resort. Concentrations of the elements are decreased to the LODs or background levels at half and one mile from the center of the tailing piles.

By visual inspection of the topography, it appears that water runoff is funneled downhill from the tailing piles and through the Lake Las Vegas Resort to the Las Vegas Wash. Although there does not appear to be any way that water transport of the chemical elements targeted would contribute to any sample locations in the eight transects, more studies are needed to confirm water transport. Because the farthest transport of the mine contaminants occurs in the direction of transects 1 and 2, it shows that the wind direction is predominantly from the west uphill to the mine and continues to blow from the mine

site to the east. Wind appears to be the strongest potential mechanism to for contaminant transport from the Three Kids Mine.

Future Study

The current research provided the basis for the mapping of the distribution of chemical components of the environmental contamination from the Three Kids Mine tailings on the surrounding land. To enhance this study, further studies could involve the implementation of a detailed plan to analyze the contaminant movement toward the Las Vegas Wash and toward the communities of Calico Ridge and Lake Las Vegas Resort. For example, inductively coupled plasma atomic emission spectroscopy (ICPAS) and inductively coupled plasma mass spectroscopy (ICPMS) can be used to get a more detailed fingerprint of the mine tailings and might be used to extend the mapping beyond where the XRF reaches the limits of detection. The drawback is that use of these instruments requires sample dissolution. More sensitive XRF instruments might also be used in this research. Another study using Geographic Information Systems (GIS) would make it possible to distinguish a regional distribution of the contaminants, using a topographical map. Finally, the observations and photos during the present study show that there is and has certainly been water transport of the tailing piles toward the Lake Las Vegas Resort and the Las Vegas Wash leading to Lake Mead. If the tailing particles reached Lake Mead with the onset of activities at the Three Kids Mine, a study of sediments from the lake could show an increase in the contaminant elements (Mn, As, Pb, and etc) from the mine site.

APPENDIX I List of All Samples Collected in this Study

Sample Name	Latitude	Longitude	Elevation (ft)	Notes
5-30-2010-1	N 36º05.269’	W 114º54.758’	1806	Near the gate at mine
5-30-2010-2	N 36º 05.329'	W 114º54.879’	1806	1st drain by the gate
5-30-2010-3	N 36º 05.329'	W 114º 54.879'	1806	Crust layer by drain
5-30-2010-4	N 36º 05.210'	W 114º 54.949'	1793	2nd drain near boats
5-30-2010-5	N 36º 05.224'	W 114º 54.968'	1784	across street, on 2nd drain
5-30-2010-6	N 36º 05.235'	W 114º 54.904'	1804	Across street, 1st drain
5-30-2010-7	N 36º 05.093'	W 114º 55.253'	1753	W of boat sale, by mine
5-30-2010-8	N 36º05.051'	W 114º 55.382'	1735	Crust layers; boat storage
5-30-2010-9	N 36º 04.975'	W 114º 55.563'	1707	dried water flow from site
7-23-2010-1	N 36º 04.577'	W 114º 56.350'	1758	Golda and Lake Mead
7-23-2010-2	N 36º 04.570'	W 114º 56.322'	1780	
7-23-2010-3	N 36º 04.831'	W 114º 55.862'	1752	
7-23-2010-4	N 36º 04.852'	W 114º 55.841'	1754	
7-23-2010-5	N 36º 04.852'	W 114º 55.841'	1754	
7-23-2010-6	N 36º 05.717'	W 114º 54.352'	1691	
7-23-2010-7	N 36º 05.661'	W 114º 54.354'	1807	
7-23-2010-8	N 36º 04.831'	W 114º 55.862'	1752	
7-23-2010-9	N 36º 05.689'	W 114º 54.352'	1751	
8-19-2010-1	N 36° 05.242'	W 114° 54.798'	1812	Near entry of the mine
8-19-2010-2	N 36° 05.273'	W 114° 54.743'	1730	Pipe next to entry
8-19-2010-3	N 36° 05.273'	W 114° 54.743'	1731	Inside pipe next to entry
8-19-2010-4	N 36° 05.277'	W 114° 54.775'	1730	Outside pipe next to entry
8-19-2010-5	N 36° 05.251'	W 114° 54.862'	1804	
8-19-2010-6	N 36° 05.251'	W 114° 54.862'	1804	Near the edge of culvert
8-19-2010-7	N 36° 05.243'	W 114° 54.931'	1788	Near the edge of culvert
8-19-2010-8	N 36° 05.211'	W 114° 54.947'	1782	
8-19-2010-9	N 36º 05.211'	W 114º 54.947'	1783	
8-19-2010-10	N 36° 05.211'	W 114° 54.947'	1784	
8-19-2010-11	N 36° 05.277'	W 114° 54.775'	1745	Tin can collected
8-19-2010-12	N 36° 05.251'	W 114° 54.862'	1804	Flat tin can
5-26-2011-1	N 36º 04.023'	W 114º 55.833'	1920	Next to power poll
5-26-2011-2	N 36º 04.901'	W 114º 55.508'	1727	
5-26-2011-3	N 36º 04.751'	W 114º 55.510'	1830	Culvert near the site
5-26-2011-4	N 36º 04.917'	W 114º 55.329'	1864	26º 300-334 FPM
6-10-2011-2	N 36º 04.965'	W 114º 55.300'	1780	38.2º 472-600 FPM
6-10-2011-3	N 36º 04.989'	W 114º 55.277'	1763	0.5 cm surface soil
6-10-2011-4	N 36º 04.958'	W 114º 55.258'	1762	0.5 cm surface soil
6-10-2011-5	N 36º 04.929'	W 114º 53.269'	1798	30 cm soil profile
6-10-2011-6	N 36º 04.799'	W 114º 55.442'	1803	Overflow from tailing
6-10-2011-7	N 36º 04.799'	W 114º 55.316'	1842	50º 472-511 FPM
6-20-2011-1	N 36º 05.176'	W 114º 55.755'	1850	Saw a truck, collect a tin
6-20-2011-2	N 36º 05.205'	W 114º 54.732'	1796	Near flotation tanks
6-20-2011-3	N 36º 05.148'	W 114º 54.780'	1845	Inside #2 tank wall
6-20-2011-4	N 36º 05.148'	W 114º 54.780'	1845	Connect coated near 1 mile
6-20-2011-5	N 36º 05.110'	W 114º 54.836'	1835	
6-20-2011-6	N 36º 05.132'	W 114º 54.855'	1832	Hilltop near the gate wall
6-20-2011-7	N 36º 05.132'	W 114º 54.855'	1832	On the waste pile

Sample Name	Latitude	Longitude	Elevation (ft)	Notes
6-20-2011-8	N 36º 05.278'	W 114º 54.693'	1807	Junk pile near the entrance wall
6-20-2011-9	N 36º 05.278'	W 114º 54.693'	1807	Windblown in bottle
6-20-2011-10	N 36º 05.081'	W 114º 54.555'	1855	Roads inside the mine
6-20-2011-11	N 36º 04.979'	W 114º 54.516'	1859	Wind to SE, inside tailing
6-20-2011-12	N 36º 04.843'	W 114º 54.794'	1843	
6-20-2011-13	N 36º 04.843'	W 114º 54.794'	1843	
6-20-2011-14	N 36º 04.799'	W 114º 54.928'	1882	Mine hole near ridge pile
6-20-2011-15	N 36º 04.799'	W 114º 54.928'	1882	Mine hole near ridge pile
6-20-2011-16	N 36º 04.727'	W 114º 55.302'	1796	Overflow toward open pit
6-20-2011-17	N 36º 04.806'	W 114º 55.422'	1803	Blank basin; wind to E
6-20-2011-18	N 36º 04.806'	W 114º 55.422'	1803	Windblown sample; sand
6-21-2011-1	N 36º 05.132'	W 114º 54.855'	1832	Can and rocks
6-21-2011-2	N 36º 05.278'	W 114º 54.693'	1807	Broken bottle with rocks
6-21-2011-3	N 36º 04.810'	W 114º 54.825'	1869	
6-21-2011-4	N 36º 04.982'	W 114º 54.901'	1845	Drain bet. tank and boat
6-21-2011-5	N 36º 04.584'	W 114º 55.085'	1872	
6-21-2011-6	N 36º 04.956'	W 114º 55.250'	1779	
6-21-2011-7	N 36º 04.972'	W 114º 55.168'	1777	Wind 2º 255-334 FPM
6-21-2011-8	N 36º 04.972'	W 114º 55.168'	1777	
6-21-2011-9	N 36º 04.972'	W 114º 55.168'	1777	
6-26-2011-1	N 36º 04.972'	W 114º 55.168'	1777	Attic dust
6-26-2011-2	N 36º 04.887'	W 114º 56.434'	1659	Near the attic dust
6-26-2011-3	N 36º 04.800'	W 114º 56.318'	1686	
6-26-2011-4	N 36º 04.927'	W 114º 55.890'	1733	Near Lake LV resort
6-26-2011-5	N 36º 04.985'	W 114º 55.912'	1678	May be disturbed land
6-30-2011-1	N 36º 02.577'	W 114º 59.353'	1819	Near BMI complex
6-30-2011-2	N 36º 03.581'	W 115º 0.910'	1688	Homeless people living
6-30-2011-3	N 36º 03.581'	W 115º 0.910'	1689	Swiping with dust pan
6-30-2011-4	N 36º 04.645'	W 115º 1.273'	1647	Undisturbed in houses
6-30-2011-5	N 36º 04.673'	W 115º 0.608'	1598	Windblown from N
6-30-2011-6	N 36º 04.673'	W 115º 0.608'	1599	Organic swiping
6-30-2011-7	N 36º 05.073'	W 115º 0.613'	1589	Dust pan used (2mm)
6-30-2011-8	N 36º 05.073'	W 115º 0.613'	1589	Top soil surface
6-30-2011-9	N 36º 04.688'	W 114º 59.394'	1585	Dust pan used (2mm)
6-30-2011-10	N 36º 04.688'	W 114º 59.394'	1585	Top soil surface
6-30-2011-11	N 36º 05.075'	W 114º 59.280'	1563	No strong wind
6-30-2011-12	N 36º 03.173'	W 114º 58.229	1771	Dust pan, wind from NE
6-30-2011-13	N 36º 03.173'	W 114º 58.229	1772	Shovel used (0.5 cm)
6-30-2011-14	N 36º 02.965'	W 114º 58.456'	1789	Wind blowing from mine
6-30-2011-15	N 36º 02.965'	W 114º 58.456'	1789	Dust pan (2mm)
7-6-2011-1	N 36º 03.865'	W 114º 57.674'	1701	Wind from E
7-6-2011-2	N 36º 03.865'	W 114º 57.674'	1701	Dust pan under rocks
7-6-2011-3	N 36º 03.865'	W 114º 57.674'	1701	Wind from E
7-6-2011-4	N 36º 03.517'	W 114º 57.995'	1756	Bet Pawnee & Navajo
7-6-2011-5	N 36º 03.517'	W 114º 57.995'	1756	Dust Pan (2 mm)
7-6-2011-6	N 36º 03.517'	W 114º 57.995'	1756	Dust under rocks (10 cm)
7-6-2011-7	N 36º 04.333'	W 114º 58.322'	1657	Shovel used (0.5cm)
7-6-2011-8	N 36º 04.333'	W 114º 58.322'	1657	Dust Pan (2 mm)
7-6-2011-9	N 36º 04.770'	W 114º 56.223'	1697	Power lines

Sample Name	Latitude	Longitude	Elevation (ft)	Notes
7-6-2011-10	N 36º 04.770'	W 114º 56.223'	1697	Dust Pan (2 mm)
7-6-2011-11	N 36º 04.910'	W 114º 56.271'	1654	Wind from LV lake
7-6-2011-12	N 36º 04.479'	W 114º 56.012'	1756	Wind from mine and E
7-6-2011-13	N36º04.479'	W 114º56.012'	1756	Dust pan (2 mm)
7-6-2011-14	N36º04.479'	W 114º56.012'	1756	Wind from LV wash
7-6-2011-15	N36º04.679'	W 114º56.174'	1705	Wind from LV wash
7-6-2011-16	N36º04.987'	W 114º56.311'	1647	Wind from LV wash
7-16-2011-1	N36º04.929'	W 114º57.290'	1676	Shovel (0.5cm)
7-16-2011-2	N36º04.929'	W 114º57.290'	1676	38º 137-334 FPM
7-16-2011-3	N36º04.870'	W 114º57.317'	1628	Huge hole, no wind
7-16-2011-4	N36º04.864'	W 114º57.301'	1629	Shovel (0.5cm)
7-16-2011-5	N36º04.864'	W 114º57.301'	1629	Dried water wash
7-16-2011-6	N36º04.525'	W 114º57.309'	1654	Construction on complex
7-16-2011-7	N36º01.963'	W 114º57.279'	1954	Shovel (0.5cm)
7-16-2011-8	N36º01.963'	W 114º57.279'	1954	SE 21.5º 846-944 FPM
7-16-2011-9	N36º02.701'	W 114º56.706'	1958	Dark colored top soil
7-16-2011-10	N36º02.701'	W 114º56.706'	1958	SW 18-22º 590-649 FPM
7-16-2011-11	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
7-16-2011-12	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
7-16-2011-13	N36º03.404'	W 114º56.243'	1940	From SW 510-531FPM
7-16-2011-14	N36º03.907'	W 114º56.922'	1805	SE 26º 590-944 FPM
7-21-2011-1	N36º06.601'	W 114º54.106'	1513	65º 590 FPM
7-21-2011-2	N36º06.601'	W 114º54.106'	1513	Same area as 7-21-2011-1
7-23-2011-1	N36º06.250'	W 114º52.024'	1648	26-28º 393-688 FPM
7-23-2011-2	N36º06.250'	W 114º52.024'	1648	Same area as 7-23-2011-2
7-23-2011-3	N36º06.725'	W 114º51.725'	1286	Dried water flow
7-23-2011-4	N36º06.386'	W 114º51.105'	1453	Wind 17º 314-728 FPM
7-23-2011-5	N36º06.386'	W 114º51.105'	1453	Wind 17º 314-728 FPM
7-27-2011-1	N36º08.839'	W 114º52.705'	1380	Wind 27º 255 FPM
7-27-2011-2	N36º08.152'	W 114º53.391'	1385	Wind 15º 373 FPM
7-27-2011-3	N36º07.213'	W 114º53.683'	1384	Wind 16º 373 FPM
7-27-2011-4	N36º04.289'	W 114º59.585'	1596	Water washed down to the other side of BMI complex
7-31-2011-1	N36º05.651'	W 114º53.224'	1859	Wind 37.5º 570-610 FPM
8-20-2011-1	N36º03.357'	W 114º54.629'	2384	Wind 17º 472-511 FPM
8-20-2011-2	N36º02.539'	W 114º54.296'	2684	Wind 22º 511-531 FPM
8-20-2011-3	N36º01.795'	W 114º54.075'	2618	Wind 35º 742-512 FPM
8-20-2011-4	N36º01.038'	W 114º53.488'	2610	Wind 19º 590-610 FPM

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