Lead risk and remediation strategies in public areas of Broken Hill, NSW

FINAL REPORT

Prepared for the New South Wales Environment Protection Authority Broken Hill Environmental Lead Program by

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Executive Summary

This report presents the findings of an investigation into soil lead concentrations and several associated elements, as well as vegetation cover in urban and semi-urban areas of Broken Hill, NSW, adjacent to the Line of Lode. Four publically accessible sites of interest were assessed, including AJ Keast Park and surrounds, the residential streets adjacent to Block 10, Block 10 Hill and Block 10 Flat. A portable XRF was used to determine the environmental lead concentrations, as well as concentrations of the associated elements arsenic, manganese and zinc. Soil lead concentrations and percentage vegetation cover were measured and input into a risk assessment matrix to attain the category of potential risk of exposure at each site. These analyses showed that the highest risk areas are the surrounds of AJ Keast Park and the residential streets, followed by Block 10 Hill and Block 10 Flat. An assessment of previous remediation efforts revealed that some of these techniques were failing to various degrees. From these results, suggestions for new remediation options were made for each site to decrease the lead risk in Broken Hill.

1. Introduction

In 2015, the New South Wales Environment Protection Authority (NSW EPA) announced that the Broken Hill Environment Lead Program was receiving funding in the value of over AUD 13 million for the purposes of decreasing the blood lead levels of residents in Broken Hill (NSW EPA, 2015). Furthermore, the funding is aimed at decreasing the mental and physical development impacts of lead on children (NSW EPA, 2015). This report contributes to the research gathered under the recent funding program and aims to reduce children's blood lead levels below the current National Health and Medical Research Council (NHMRC) blood lead intervention level (5 µg/dL) (NSW EPA, 2015).

Lead is a highly toxic heavy metal that has been increasingly recognised as a public health risk due to the significant physiological and neurological impacts to human health, even at low concentrations (Lanphear *et al.,* 2005; Cao *et al.*, 2015; Kar-Purkayastha *et al.*, 2011). In children and young adults, blood lead levels less than or equal to 5 µg/dL can delay the onset of puberty, and have adverse reproductive and developmental effects (Taylor *et al.*, 2014).

Blood lead levels below 10 µg/dL are also associated with increased risk of behavioural problems in children and hypertension in adults, particularly in pregnant women (NHMRC, 2014; Boreland & Lyle, 2014). Additionally, a trend has been shown between blood lead levels below 10 µg/dL and adverse cardiovascular effects in adults (Taylor *et al.,* 2014). Blood lead levels of 10 µg/dL are linked to decreased intelligence and impaired neurobehavioral development (CDC, 1991). Studies show that a child's IQ value would be reduced by 1 to 3 scores as their blood lead level increases by 10 µg/dL (Lanphear *et al.*, 2005; Berllinger, 2004; He *et al.*, 2009). Some potentially recognisable effects at this low level include decreased growth and hearing, and a diminished ability to maintain posture (CDC, 1991).

Moderate blood lead levels above 10 µg/dL are associated with anaemia, reduced kidney and nerve function, increased blood pressure and adverse effects on the hematopoietic system (CDC, 1991; NHMRC, 2014; Boreland & Lyle, 2014). Severe lead exposure causing high blood lead levels can lead to convulsions, coma and in some cases death

(CDC, 1991; NHMRC, 2014; Boreland & Lyle, 2014). The largest concern associated with the blood lead levels commonly seen in industrialised countries today are the adverse impacts on brain functioning of young children, which include an increased risk of learning difficulties, which may be irreversible (NHMRC, 2014; Boreland & Lyle, 2014). Lanphear *et al*., (2005) states that children with blood lead levels less than 7.5 μg/dL could have intellectual deficits and that blood lead levels above 10 μg/dL have detrimental effects on brain function, including lowered intelligence, behavioural problems, and weakened performance in school (Lanphear *et al.*, 2005). Lead exposure has also been linked with an increased risk for many conditions and diseases including reading problems, school failure, delinquent behaviour, hearing loss, tooth decay, spontaneous abortions, renal disease, and cardiovascular disease (Lanphear *et al*., 2005). On top of this, the US EPA Integrated Science Assessment for Lead (2013) concluded that there are adverse effects on cognitive function in children with blood lead levels as low as 2 μg/dL, and that these effects may persist into adulthood and be irreversible (Kar-Purkayastha *et al.*, 2011; Taylor *et al*., 2014). It is clear that undue exposure to lead can cause a range of adverse health impacts for everyone, especially children.

2. History of Environmental Lead Pollution in Broken Hill

Broken Hill was discovered by early explorer Captain Charles Napier Sturt during his exploration of Australia when he travelled through the Barrier Ranges (historically known as Stanley's Barrier Ranges) in 1844 (Curtis, 1908) (Appendix 1). It wasn't until 1883 that Charles Rasp, a boundary rider on Mount Gipps Station, discovered the Line of Lode and ultimately its lead bearing ore. Originally Rasp believed the area to be abundant in tin oxide however upon further investigation discovered it was silver, zinc and lead (Bridges, 1920). The discovery of a wealth of resources resulted in an influx of people from the nearby township of Silverton and beyond with people travelling from all over Australia to what would soon become Australia's principal mineral field (Kearns, 1973).

Mining and smelting operations began in Broken Hill in 1885. Since mining of the Line of Lode began, till 1983, total ore production amounted to 145,916,000 tonnes, valued at AUD 3,834 million (Kearns, 1976).

Lead exposure and subsequent poisoning has been a long-term health burden in Broken Hill. Cases of lead poisoning were becoming more prominent throughout the community when Howell (1892) conducted an enquiry into the prevalence of lead in the area, resulting in suggested ways for the community to reduce their exposure to environmental lead. After Howell spoke to Dr Bartley and Dr Blaxland who worked in the Broken Hill hospital it became obvious there were three types of lead poisoning occurring. The first were colic cases which accounted for approximately 85% of lead poisoning, causing liver and kidney problems and interfering with procreative function. The second was when the brain was affected which resulted in epilepsy, dementia and encephalopathy and accounted for 13% of cases. The final 2% was when muscular paralysis occurred (Howell, 1892). Observations confirmed that individuals experienced different symptoms when exposed to various amounts of lead and that absence from the mines resulted in an increase in health. The European Government enacted searching laws in an attempt to shield the public and miners from unnecessary exposure to lead due to public health concerns (Howell, 1892). After further research, it was confirmed that due to the dominant wind direction, homes towards the north were more heavily affected by lead compared to homes to the south. This resulted in the homes and soils accumulating layers of lead and other minerals, with eight out of thirty-one water sources containing up to one quarter of a grain of lead per gallon (Howell, 1892). Mr W.M. Hamlet analysed the smoke being emitted from 28 smelters and showed that the smoke contained 15 tonnes of metallic lead and silver per 24 hours (Howell, 1992). Suggested mitigation techniques by Howell (1892) were to reduce time spent in the underground mines and for miners to rotate and work on the surface more frequently. He went on to suggest miners with serious lead poisoning move to mines that are located away from the Line of Lode (Howell, 1892).

The constant fear of lead poisoning lingered amongst the community with many unsuccessful attempts at mitigation and no attempts at remediation until 1994 when the NSW Lead Management Action Plan was formed. There was a mutual optimism for colic lead poisoning being the most common version of lead poisoning in Broken Hill as it did not permanently incapacitate the individual and merely resulted in short periods of time away from the mines. (The Port Pirie Standard and Barrier Advertiser, 1893). However, despite tolerating the high rate of the lowest fatality type of lead poisoning, there was an understanding in the community that "this matter of lead poisoning is of far-reaching importance, and urgently requires attention in the general public interest" (Newcastle Morning Herald and Miners' Advocate, 1893). Children and women were suffering from lead poisoning with reports of an 8-year-old boy dying after being unconscious for three days following a fit. After the kidney, liver and brain had been analysed in Sydney, results revealed traces of lead in all three organs (Evening News, 1893). The increasing fatalities prompted an attempt to treat the low grade sulphides to reduce the severity of the lead poisoning occurrences (Evening News, 1893). In 1895, the Premier Mr Reid stated that a bill would be drafted that would require smoke consumption be compulsory in all smelting districts of the colony based on the data that was provided by Howell's 1892 enquiry into the prevalence of lead in Broken Hill (Barrier Miner, 1895a). In the same year, the *Lead Poisoning Act 1895* (Vic) (57 No 18) was released and stated that it is illegal to employ a boy younger than 16 years of age to work in a mine, underground or on the surface where lead, lead ore or lead compounds may be present (Barrier Miner, 1895b). Following this, in September of the same year the NSW Government published a new regulation approved by the Lieutenant-Governor mirroring the provisions in the Victorian legislation in relation the employment of boys in mines. The New South Wales regulation also specified that it is illegal to employ boys under the age of 16 to work in a mine, underground or on the surface where lead, lead ore or lead compounds may be present (The Sydney Morning Herald, 1895).

Moving forward in time, sampling of ceiling dust was carried out in 1991 in Broken Hill homes and the results demonstrated that the high levels of lead in the dust was a result of historical and current mining practices with some ceilings having dust containing up to 3.6% lead (Gulson *et al.*, 1994; Van Alphen, 1991). Following this, a blood lead survey of pre-school aged children living in Broken Hill was carried out in 1991 revealing one in five children had blood lead levels greater than 25 µg/dL, which at the time was the NHMRC level of concern (Phillips, 1998). It appeared that the high blood lead levels were occurring due to dust entering the household with levels decreasing with increasing distance from the mines.

Several mitigation strategies have been implemented in an attempt to reduce the community's exposure to lead with the first strategy being the development of the NSW Lead Management Action Plan in 1994. This plan included establishing a Lead Reference Centre that would develop lead management strategies, undertake blood lead sampling, provide education on lead poisoning and establish a Broken Hill Environmental Lead Centre (The Lead Group, 2014). The Broken Hill Environmental Lead Centre was granted AUD 3.4 million for remediation in 1995 and in this process removed more than 100 tonnes of lead-contaminated dust from 130 homes over two years (The Sydney Morning Herald, 1997). They were then granted a further AUD 9 million for remediation over the following 5 years, which would include education campaigns and a revegetation program (The Sydney Morning Herald, 1997).

In a 2006 study by Boreland and Lyle, 10 out of the 88 children tested received immediate home remediation due to their high blood lead levels. The remediation aimed to remove all pathways of lead exposure (Appendix 2) within the home by removing dust from within the house, sealing of cracks with silicone around windows and doors, removal or encapsulation of flaking lead paint and the removal or capping of soil with high lead levels (Boreland & Lyle, 2006). The 2010 State of the Environment Report identified dust containing lead as one of the main air quality problems in the Broken Hill local government area. In an attempt to mitigate this problem Perilya Broken Hill monitors the total lead in the dust as required by the NSW EPA. The aim is to maintain a 90-day average lead in air concentration below the NHMRC goal of 1.5 µg/m³ (Broken Hill City Council, 2010a). The Greater Western Area Health Service (2010) created a Lead Health Operational Plan in 2010 that aimed to increase the number of children having their blood lead levels tested and to ensure blood lead screening was accessible to those who required it the most in order to help target homes that require immediate remediation (Broken Hill City Council, 2010b). In 2012, data from the NSW Health Blood Lead Program revealed that 21% of children between the age of 1 and 4 and 37% of Aboriginal children aged 1 to 4 have blood lead levels greater than 10 µg/dL (Humphries, 2015). These high statistics led to the Broken Hill Environmental Lead Program and the current funding program.

3. Scope

The scope of this report is limited to publically accessible areas on Block 10 including AJ Keast Park and surrounds, the residential streets adjacent to Block 10, Block 10 Hill and Block 10 Flat. The assessment of potential risks to the public of Broken Hill is derived from a matrix using the levels of soil lead and vegetation cover. Furthermore, the report aims to consider evidence of human activity and signs of aeolian and fluvial erosion at the sites to determine the potential for human exposure.

4. Regional Setting

Broken Hill, located in far western New South Wales, is situated on the world's richest silver-lead-zinc mineral deposit (Solomon, 1988). It is home to just over 19,000 people, 6.6% of which are Indigenous and 20% of which are children (ABS, 2016). The area is situated at 315 metres above sea level (Bureau of Meteorology, 2016) in the Barrier Ranges, which is in the Yancowinna County (Woodward, 1952). Broken Hill's average annual rainfall was 259.8 mm in 2015 (Bureau of Meteorology, 2016). Its general climate is quite dry, which makes it particularly vulnerable to dust storms. While dusty conditions are common all year, maximum incidence occurs from August to December, typically with winds from the north-west (Woodward, 1952).

The Broken Hill Line of Lode is a high-grade ore body, with a complex structural and metamorphic history (Pilmer, 1984). The deposit is situated within the Willyama Supergroup, which consists of highly variable lithologies due to a long history of intrusion, sedimentation, metamorphism and deformation (Webster, 2006). The Broken Hill lode takes the form of a bow, which is convex upwards towards the centre and sinks at both ends (Woodward, 1952). It runs for approximately 21 km, with an exposed outcrop in the centre and several undulations to the north and south (Woodward, 1952). The most abundant rocks in the Broken Hill mine sequence are metasediments, which enclose both sulphide and other rocks (Pilmer, 1984). The lead lodes are very diverse, but tend to decrease in rhodonite and increase in sulphide content with depth (Pilmer, 1984).

The ore was formed when ancient sand and shale type sedimentary rocks were replaced through extreme folding and metamorphosed into gneisses and schists (Woodward, 1952). Three tectonic events caused this; the Olarian Orogeny (~1700-1580 Ma), the north-west trending faults that controlled the development of the Adelaide Geosyncline (~50-570 Ma) and finally the Delamerian Orogeny (~500 Ma) (Webster, 2006). These palaeoproterozoic rocks, found in Broken Hill today, formed a relatively stable basin. Due to this stability, much of the originally formed ore was present when mining started in 1883 (Webster, 2006). However, accurate information of the original tonnage of ore is unknown, and estimates have been varied. The Geological Survey of New South Wales has helped to significantly advance the current knowledge of the geology of Broken Hill, but stratigraphic interpretation of the original pre-mining geology is still undetermined (Pilmer, 1984).

While lead contamination in Broken Hill has been caused by the original mining operations, the region continues to be contaminated by the large mining waste dump in the centre of the city (Woodward-Clyde, 1993). It should also be noted that the high soil lead concentrations found in Broken Hill today are highly unlikely to occur naturally, as lead deposits are constrained to the Line of Lode (Stevens, 1994).

The vegetation communities in Broken Hill are dominated by Mulga and Shrublands (Cunningham *et al.,* 1981). These plants are typically very drought resistant, and prefer sandy, loamy or rocky soil types. More details on individual species that are found in these areas can be found in Appendix 3.

5. Methods

5.1 Site Selection

Four sites were selected for sampling. Those selected were a combination of sites that had never been remediated, and those that had been remediated in the past. The sites were also selected based on their potential for contamination and their risk to the public. All sites were on public land and sampling densities were determined specific to each site. The four sites selected were AJ Keast Park and Surrounds, Residential Streets, Block 10 Hill, and Block 10 Flat.

5.1.1 AJ Keast Park and Surrounds

This site is on Gypsum Street between Wills and Sampson Street (Figure 1.). The park is backed by Block 10 and is therefore a prominent source of potential contamination. Previous remediation strategies included a drainage ditch and levee that diverts water away from the lawn area of the park, and a hand washing station to promote good hygiene in lead contaminated areas which will potentially decrease hand to mouth contact of lead contamination in children. Previous remediation efforts have been focused on the park itself and not the area behind it which is easily accessible to the public.

In the park area four transects were measured along the grassed area and samples were taken at 15 m intervals. A transect was measured along the drainage channel (Figure 1.) and measurements were taken at approximately 10 m intervals. At each interval on this transect, three measurements were taken; one in the channel, one on the levee and one on the other side of the levee. This was to determine the quantities of lead (Pb), arsenic (As), manganese (Mn) and zinc (Zn) that were trapped by the levee. Samples on the hill slope directly behind the levee were taken at 1 m intervals wherever soil deposits occurred due to the patchy soil distribution in this section. Four transects were measured on the other side of this hill slope. Sampling on these transects occurred at approximately 20 m intervals.

5.1.2 Residential Streets

This site consists of Gaffney Street, an unnamed lane between Gaffney and Carbon Streets (hereafter referred to as 'Unnamed Lane'), Carbon Street, Carbon Lane, Ryan Street and Sampson Street between their intersection with Gypsum Street and their east end, which adjoins the mining lease. Several of these streets have previously been remediated by laying cracker dust along the pathways, however sections of this have been disturbed (Frances Boreland 2016, pers.comm., 26 Sept.).

Sampling densities for the streets were a sample location in front of every second house on both sides of the street. Extra samples were also taken at the east end of Ryan Street, as the retention dam on the mining lease was observed to be leaking onto the street.

5.1.3 Block 10 Hill

This site is located on the north-west side of South Road (Figure 1.). There are three houses on this site, and part of the site has previously been remediated. (NSW Public Works, n.d.). The front of the site between the road and the houses has previously been topped with 20 mm road base which was laid at a thickness of a minimum of 50 mm. Where the two drainage lines occur coming off the hill (Figure 1.), the road base was compacted and stabilised with 2% cement. Two diversion banks also run along either side of the southernmost drain (NSW Public Works, n.d.). The houses have also undergone remediation works in an attempt to prevent and decrease lead dust from entering the houses (Frances Boreland 2016, pers.comm., 26 Sept.).

The sampling of this site was focused on the section that had not been remediated, as it appears to pose a bigger lead contamination threat to the houses in front of it. Sampling in this site was conducted in a grid of approximately 10 m intervals. Measurements were also taken on the slope of the hill itself and on the ridge separating the two northernmost houses.

5.1.4 Block 10 Flat

This site runs on the north-west side of the mine between South Road and the train line (Figure 1.). It has previously been remediated, and as it is in such close proximity to the mine, there is a high potential for contamination. Previously this site was publically used for recreational purposes, however since remediation, the site has been rarely used, apart from three houses and one commercial building which remain on the site. Remediation for this site involved digging a number of shallow trenches (furrows) which ran perpendicular to the slope of the site. This slowed down rainwater runoff and decreased wind erosion. The site was seeded with chenopod shrubs and later mulch and hay was spread on some areas to further promote establishment of vegetation (Frances Boreland 2016, pers.comm., 26 Sept.).

Sampling for this site was conducted in three transects running parallel along the site with samples taken at approximately 15 m intervals.

5.2 Sampling Methods

5.2.1 Element Concentrations

Elements were sampled using two Olympus Delta Professional 40 kV pXRF analysers. A total of 328 measurements were taken in the Block 10 area of Broken Hill, NSW. Soils were analysed in-situ for Pb, As, Mn and Zn using the factory calibration for soil mode, using all three beams for 20 seconds. It is important to consider the timing used for the three beams of the Portable XRF machine to determine soil lead levels. Whilst three twenty second beams will return Pb, As and Zn concentrations of relatively high accuracy, it is also important to note that when using these settings the accuracy of the Mn concentrations is decreased. Manganese is quantified on the third beam, and therefore a longer beam time would have increased the accuracy of this data. Full data for all elements is located in Appendix 4.

A handheld Garmin GPS 72H device was used to log the coordinates of each sample location.

A silicon dioxide (SiO_2) blank and two Certified Reference Materials (NIST2710a and NIST2711a) were analysed at the beginning and end of each work day and between sites. The mean and % relative standard deviation (RSD) were calculated from these standards to determine the precision in comparison with the certified reference material values (**EPA:** ***NIST2710a*** Pb: Mean - 0.5503, %RSD - 12.9940; As: Mean - 0.1659, %RSD - 13.2959; Zn: Mean - 0.4131, %RSD - 12.1211; Mn: Mean - 0.2027, %RSD - 11.2740; ***NIST2711a*** Pb: Mean - 0.1328, %RSD - 14.8534; As: Mean - 0.0156, %RSD - 9.5756; Zn: Mean - 0.348, %RSD - 12.7568; Mn: Mean - 0.0480, %RSD - 31.7763; **MQU**: ***NIST2710a*** Pb: Mean - 0.5159, %RSD - 0.8501; As: Mean - 0.1431, %RSD - 1.2441; Zn: Mean - 0.4068, %RSD - 1.2981; Mn: Mean - 0.2028, %RSD - 2.3490; ***NIST2711a*** Pb: Mean - 0.1279, %RSD - 3.2883; As: Mean - 0.0086, %RSD - 6.5895; Zn: Mean - 0.0350, %RSD - 15.3990; Mn: Mean - 0.0561, %RSD - 4.5034) and the blank ensured no contamination had occurred within the machine.

5.2.2 Vegetation Cover

Vegetation cover was evaluated as a visual estimation of percentage ground cover. It was acknowledged that some species currently making up ground cover are annual species and are therefore not present year round.

Due to above average rainfall prior to sampling, vegetation cover was likely to be overestimated in comparison with average conditions.

5.2.3 Determining Overall Risk

We used the soil lead concentration reading in combination with vegetation cover to determine the overall risk of the site. A risk matrix (Table 1.) was used to assist with this, and was based on lead concentrations and vegetation cover. Categories were upgraded by one level if the lead level was over 1,000 mg/kg and the site was obviously accessed by humans, or if it had clear evidence of water or wind disturbance that could transport lead to areas which are accessed by the public. This was due to the higher perceived risk to humans if an area had high lead concentrations (>1,000 mg/kg) in combination with regular human activity.

Figure 1. Locations of sample sites in the Block 10 Area

TABLE 1. OVERALL RISK MATRIX						
		Vegetation Cover (%)				
		> 99	95-99	80-94	50-79	< 50
Soil Lead Concentrations (mg/kg)	<300	Very low risk	Very low risk	Very low risk	Low risk	Low risk
	300-900	Low risk	Low risk	Low - Moderate risk	Moderate risk	Moderate risk
	1,000-1,499	Moderate risk	Moderate risk	Moderate - high risk	Moderate - high risk	Moderate - high risk
	1,500-2,499	Moderate - high risk	Moderate - high risk	High risk	High risk	Very high risk
	2,500-4,999	Moderate - high risk	Very high risk	Very high risk	Extremely high risk	Extremely high risk
	>5,000	Moderate - high risk	Extremely high risk	Extremely high risk	Extremely high risk	Extremely high risk

6. Results, Discussion & Recommendations

The sites have been prioritised in the following order based on their frequency of use by members of the public and the overall risk.

6.1 AJ Keast Park and Surrounds

TABLE 2 a. AJ KEAST PARK DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	1,544	86	2,632	1,984	100
Minimum	52.3	0	52	156	0
Mean	341.3	16.6	549.9	620.6	81.5
Median	203	9.3	330	457	100
St. Dev	351.1	23.2	624.5	441.8	37.2
75th Percentile	340	22	581	725	100
NEPM Health Investigation Levels	600	300	9,000	30,000	N/A

TABLE 2 b. AJ KEAST SURROUNDS DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	13,646	368	7,207	10,175	100
Minimum	0.024	0	80	153	0
Mean	11,56.9	42.9	1,836.8	1,802.7	46.8
Median	822	19	1,375	1,428	40
St. Dev	1,633.0	71.1	1,366.1	1,782.3	32.4
75th Percentile	1,375.5	52.5	2,441	2,144.5	80
NEPM Health Investigation Levels	600	300	9,000	30,000	N/A

6.1.1 Lead

Field pXRF analysis of the grassed area at AJ Keast Park revealed lead concentrations nearest the playground of <300 mg/kg, however along the south-east side of the park there were increased concentrations between 301 mg/kg and 2,000 mg/kg (Figure 2.). The mean concentration for lead on the grassed area was 341.3 mg/kg (median – 203 mg/kg, max – 1,544 mg/kg, Table 2a.) and the surrounding area was 1,156.9 mg/kg (median – 822 mg/kg, max – 13,646 mg/kg, Table 2b.). There were signs of flaking lead paint peeling off the park benches which is resulting in further contamination of the soil with lead concentrations as high as 2,974 mg/kg. The drainage line and levee had risk levels ranging from moderate to high with lead concentrations varying between 601 mg/kg to 2,000 mg/kg, suggesting it is effective in reducing the higher lead concentrations from reaching the grassed area (Figure 2.). It appears that lead concentrations increase with increasing distance from the playground and grassed area with the minimum lead concentration being 2,001 mg/kg and the highest concentration exceeding 5,001 mg/kg in the north-east section of the sampling area (Figure 2.). As can be seen in Figure 2., the risk level for exposure to lead at AJ Keast Park and surrounds varies greatly. Figure 2. shows the risk levels are very low on the grassed area and increase to extremely high at the north-east section of the sampling area, following a similar trend to the lead concentrations.

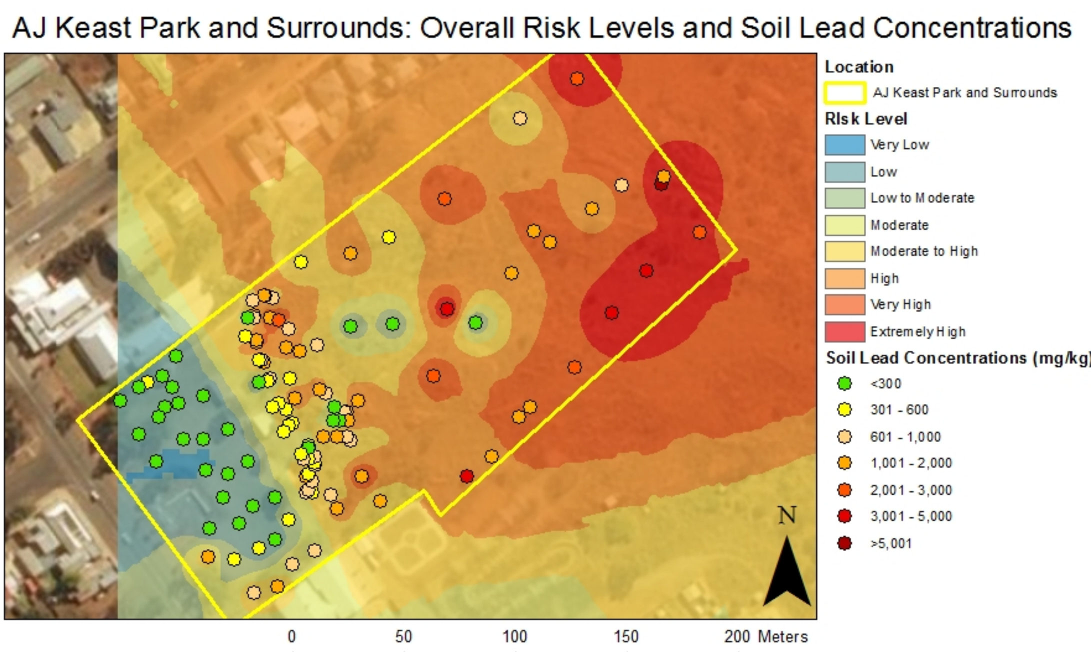

Figure 2. Soil lead concentrations and overall risk at AJ Keast Park and surrounds.

6.1.2 Arsenic

The results revealed the arsenic concentrations at AJ Keast Park follow a similar trend to the lead concentrations and appear to increase with distance from the playground and grassed area (Figure 3.). The mean concentration for arsenic on the grassed area was 341.3 mg/kg (median – 9.3 mg/kg, max – 86 mg/kg, Table 2a.) and the surrounding area was 42.9 mg/kg (median – 19 mg/kg, max – 368 mg/kg, Table 2b.). The very low to low risk areas were distributed on the grassed area and had arsenic concentrations <20 mg/kg to 30 mg/kg, however the area with exposed soil had arsenic concentrations as high as 100 mg/kg (Figure 2. & 3.). The drainage line and levee were relatively low in arsenic with concentrations ranging from <20 mg/kg to 50 mg/kg (Figure 3.). As can be seen in Figure 3., the highest arsenic concentrations were located in the south-east section of the sampling area with concentrations >301 mg/kg.

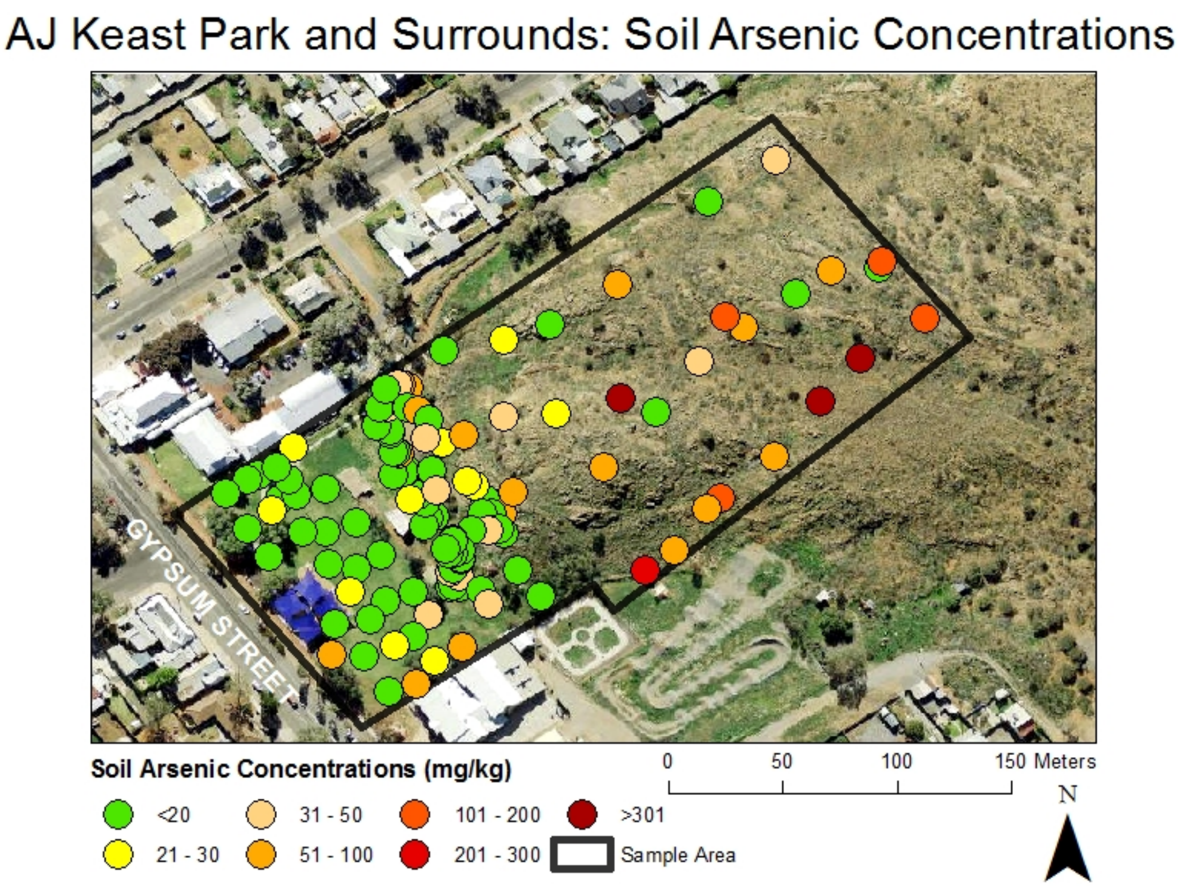

Figure 3. Soil arsenic concentrations at AJ Keast Park and surrounds.

6.1.3 Manganese

Results revealed manganese concentrations to be <1,000 mg/kg on the grassed area with a mean concentration for manganese of 549.9 mg/kg (median – 330 mg/kg, max – 2,632 mg/kg, Table 2a.) and for the surrounding area 1,836.8 mg/kg (median – 1,375 mg/kg, max – 7,207 mg/kg, Table 2b.) (Figure 4.). The area with exposed soil contained higher concentrations, varying between 1,001 mg/kg and 3,000 mg/kg and as a result, produced moderate to high risk levels (Figure 2). The drainage line and levee had manganese concentrations ranging between <1,000 mg/kg and 2,000 mg/kg along with moderate risk levels (Figure 2.). It appears that during high rainfall events, sediment is being washed down the drainage line and is resulting in an accumulation of higher arsenic concentrated sediment on the south side of the drainage line and levee (Figure 4.). This is reflected in the high risk levels seen on the south side of the drainage line in Figure 2. Similar to the lead and arsenic results, it appears the higher concentrations of manganese are located in the north-east and south-east sections of the sampling area with concentrations ranging from 4,001 mg/kg to greater than 10,000 mg/kg (Figure 4.).

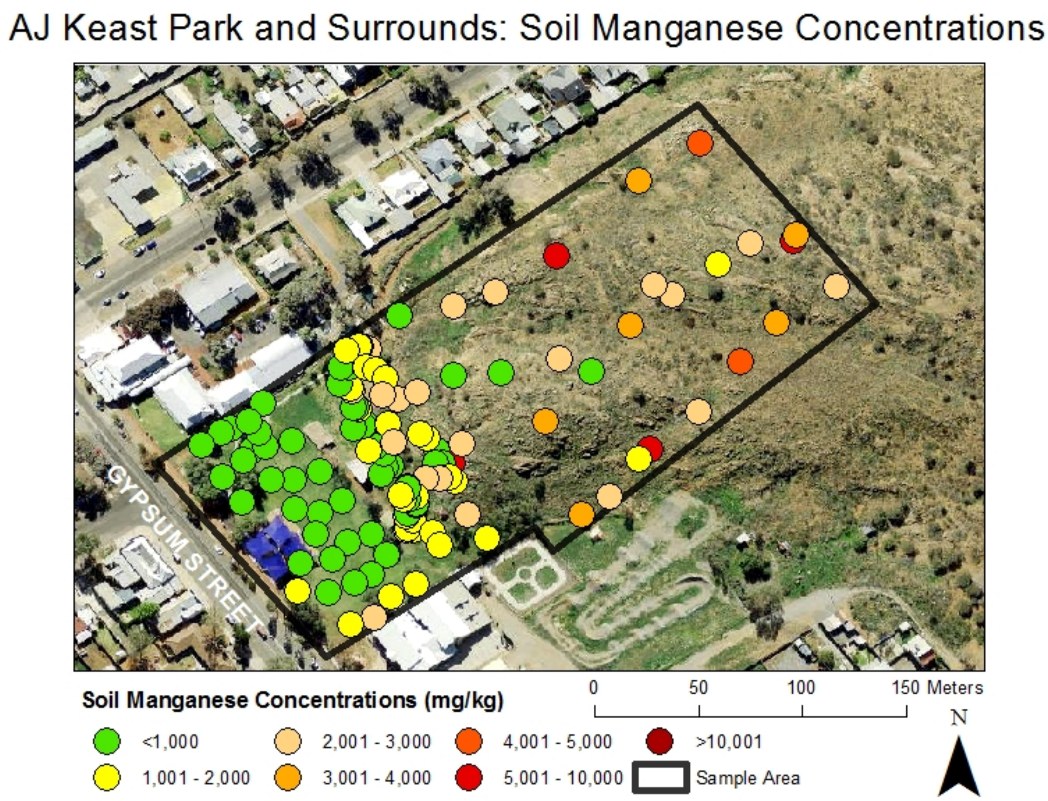

Figure 4. Soil manganese concentrations at AJ Keast Park and surrounds.

6.1.4 Zinc

In comparison to the lead, arsenic and manganese concentrations, the zinc concentrations are relatively low throughout the entire sample area with less than 10 samples having concentrations >6,000 mg/kg (Figure 5.). The mean zinc concentration for the grassed area was 620.6 mg/kg (median – 457 mg/kg, max – 1,984 mg/kg, Table 2a) and for the surrounding area 1,802.7 mg/kg (median – 1,428 mg/kg, max – 10,175 mg/kg, Table 2b.). The majority of samples had zinc concentrations ranging between 201 mg/kg and 2,000 mg/kg. Unlike the results for lead, arsenic and manganese, the playground and grassed area was not dominated by the lowest zinc concentration range despite being a low risk area. The area had only one sample which had zinc concentrations <200 mg/kg and the remainder of the samples were between 201 mg/kg and 2,000 mg/kg (Figure 5.).

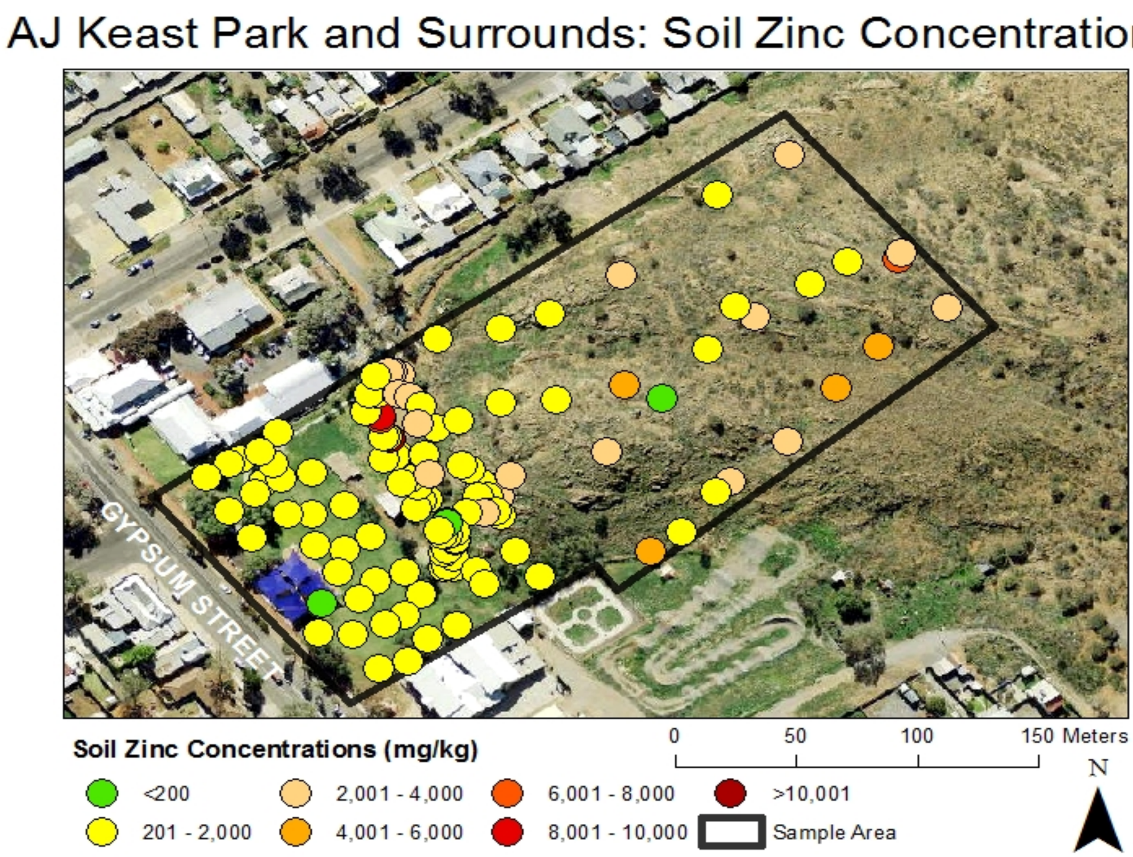

Figure 5. Soil zinc concentrations at AJ Keast Park and surrounds.

Overall, based on the distribution and concentration of lead and arsenic throughout AJ Keast Park and surrounds there are high risk areas containing significant concentrations that exceed the NEPM guidelines of 600 mg/kg and 300 mg/kg (Figure 2., Table 2a. & 2b.). Furthermore, the manganese and zinc concentrations were low and did not exceed the NEPM guidelines of 9,000 mg/kg and 30,000 mg/kg, with maximum concentrations being 7,207 mg/kg and 10,175 mg/kg. These results suggest the manganese and zinc concentrations do not pose a threat to users of AJ Keast Park (Table 2a. & 2b.). The distribution of lead and arsenic concentrations vary across the sampling area with the higher concentrations located in the north-east section and the lower concentrations dominating the grassed area in the south-west section (Figure 2. & 3.).

It is recommended that AJ Keast Park and surrounds receives the highest priority in regards to remediation due to the influx of children and families visiting the area daily. Risk levels vary from very low to extremely high throughout the sampling area (Figure 2.). The playground and grassed area is the centre of activity at AJ Keast Park and had favourable results with the area being identified as a very low risk level (Figure 2.). It is likely that the ground cover decreases lead, arsenic, manganese and zinc concentrations as it stabilises the soil and prevents aeolian and fluvial processes transporting contamination off site. This is supported by lead concentrations as high as 1,062 mg/kg being found in patches of bare soil amongst the grassed area. This is a large difference when compared to the grassed area that revealed lead concentrations <300 mg/kg. Despite these areas being classified as low risk areas based on the Australian guidelines (300 mg/kg in recreational areas), countries such as Canada for example have a soil arsenic guideline of 12 mg/kg in recreational areas (CCME., 2007). Therefore, a soil arsenic concentration of 100 mg/kg in areas where children are exposed regularly is of concern. The application of turf in these bare patches will prevent children having direct contact with soil that otherwise would have accumulated high lead and arsenic concentrations. The Broken Hill Environmental Lead Program have previously installed a hand washing facility that allows children and other users to clean their hands after playing in areas with lead contamination.

The south-east side of the sampling area had exposed soil that revealed high concentrations of lead that exceeded the NEPM guidelines for lead in recreational areas (Figure 2.). These high lead concentrations may be a result from a combination of the lead paint flaking off the park benches and the lack of ground cover which allows contamination to accumulate. It would be beneficial for available funding to be used in re-painting the park benches using lead-free paint following the removal of the lead paint on the park benches, along with other areas in Broken Hill where it occurs. This is a cost effective strategy with the United States Environmental Protection Agency having priced the removal of lead-based paint at US $8 to US $15 per square foot (National Association of Realtors, 2016). The paint can be scraped off using liquid paint remover and a wire brush (Department of the Environment, 2016). This should result in lower lead concentrations and will decrease the exposure to children in AJ Keast Park. The establishment of ground cover along the south-east side will aid in reducing lead concentrations to below the NEPM guideline value of 600 mg/kg. If the application of turf is not suitable due to the aridity of Broken Hill, Nielsen and Kristiansen (2005) suggest an alternative option and advise that woodchips be layered on top of a 50 mm layer of clean topsoil.

The drainage line and levee appear to be effective in reducing the contamination with risk levels decreasing on the south side of the drainage line and levee (Figure 2.). However, lead concentrations exceed the NEPM guidelines as the concentrations increase to between 601 mg/kg and 2,000 mg/kg on the south-east side of the drainage line. As there is already ground cover, Harvey *et al.* (2016) advise applying a 50 mm layer of topsoil to act as a barrier in areas with lead concentrations >1,500 mg/kg. The reformation of the levee where erosion has occurred will aid in reducing the spread of contaminants into the playground and grassed area. Children were seen playing beyond the drainage line and levee and the abundance of rubbish suggests it is a favoured recreational area. Installing a fence between the grassed area and drainage line will prevent children and other users from accessing the high risk level areas. Signage should be placed along the fence at regular intervals informing the public that the area beyond is classified as a high to extremely high risk area that contains high lead and arsenic concentrations.

A study by Henn *et al.* (2011) revealed that lead toxicity was increased among children with high manganese co-exposure. It is for this reason manganese was chosen to be sampled alongside lead in this study. Manganese concentrations were fairly consistent with the majority of samples having manganese concentrations <3000 mg/kg. Several manganese concentrations were almost exceeding the NEPM guidelines but all remained below 9,000 mg/kg. If the suggested remediation techniques are implemented at AJ Keast Park and surrounds, the risk of lead and arsenic exposure to users is expected to be reduced.

6.2 Residential Streets

TABLE 3 a. GAFFNEY STREET DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	4,619	137	10,106	8,607	100
Minimum	295	0	541	852	0
Mean	1,094.9	42.7	3,596.9	2,451.7	9.1
Median	829	38	2,645	1,888	0
St. Dev	1,038.2	32.1	2,736.1	1,799.1	21.5
75th Percentile	1,061	61	4,869	2,640	7.5
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

TABLE 3 b. CARBON LANE DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	1,674	92	3,163	2,406	90
Minimum	244	0	933	419	0
Mean	642.8	27.8	1,807.1	1,203.8	23.7
Median	569	30	1,701	1,112	10
St. Dev	381.8	26.8	742.5	562.1	30.6
75th Percentile	771.5	38.8	2,092.1	1,445.5	27.5
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

TABLE 3 c. UNNAMED LANE DATA SUMMARY					
	Pb (mg/kg)	As (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Vege Cover (%)
Maximum	2,252	135	5,471	4,211	50
Minimum	301	0	921	747	0
Mean	851.3	45.1	2,254.6	1,575.3	10
Median	599	30	1,574	1,033	5
St. Dev	726	41.5	1,564.7	1,141.2	15.8
75th Percentile	627	53	2,304	1,454	10
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

TABLE 3 d. RYAN STREET DATA SUMMARY					
	Pb (mg/kg)	As (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Vege Cover (%)
Maximum	1,384	59	13,154	6,318	65
Minimum	76	0	488	140	0
Mean	569.5	21.2	3,247.3	1,983.1	11
Median	462	17	2,183	1,055	0
St. Dev	376.7	20.4	3207.2	1,733	22.7
75th Percentile	810	35.5	3,131.5	3,184	5
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

TABLE 3 e. CARBON STREET DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	1,023	45	5,094	1,846	30
Minimum	74	0	508	149	0
Mean	304.5	16.07	1,355.4	574.8	3.1
Median	256	11	1,057	391	0
St. Dev	241.1	15.36	1,119.5	487.9	7.9
75th Percentile	297.5	27	1,245	580.5	1
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

TABLE 3 f. SAMPSON STREET DATA SUMMARY					
	Pb (mg/kg)	**As (mg/kg)**	**Mn (mg/kg)**	**Zn (mg/kg)**	**Vege Cover (%)**
Maximum	1,495	108	8,426	4,103	85
Minimum	94	0	592	124	0
Mean	546.2	32.6	1,870.5	1,032	29.1
Median	365	5.7	973	686	20
St. Dev	453.2	45.7	2,296.8	1,118.5	30.1
75th Percentile	779	62	1,897	1,171	50
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

6.2.1 Lead

Figure 6. shows the soil lead concentrations of the residential streets that were tested. It shows that Sampson Street and Carbon Street have soil lead concentrations of between <300 mg/kg to 2,000 mg/kg. Figure 6. shows risk level for lead exposure at the site of residential streets, and the high amount of moderate, low and very low risk levels compared to the other sites that were tested. Figure 6. shows that Sampson Street and Carbon Street have low and moderate risk levels with each having one moderate to high risk level at the ends opposite Gypsum Street. Figure 6. shows that Ryan Street and Unnamed Lane have soil lead concentrations of between <300 mg/kg to 2,000 mg/kg. It also shows that there are more soil lead concentrations from 601-1,000 mg/kg on Unnamed Lane closer to Gypsum Street, and concentrations from <300-600 mg/kg throughout Ryan Street. In addition, Ryan Street has a group of soil lead concentrations from 601-2,000 mg/kg at the end opposite Gypsum Street (Figure 6.). Figure 6. shows that Ryan Street has risk levels ranging from low to extremely high with no very high risk levels, while the Unnamed Lane has risk levels ranging from very low to extremely high with no moderate to high, high, or very high risk levels.

Figure 6. shows that Carbon Lane has a group of soil lead concentrations from 301-600 mg/kg at the end opposite Gypsum Street, and higher concentrations from 601-3,000 mg/kg closer to Gypsum Street. Figure 6. shows that Carbon Lane also has risk levels ranging from moderate to very high and extremely high. Figure 6. show that Gaffney Street was tested in two different sections, with one closer to Gypsum Street and the other towards the intersection with Silver City Highway. Figure 6. shows that Gaffney Street has slightly lower soil lead concentrations closer to Gypsum Street, with many from 301-1,000 mg/kg. It also shows that at the end opposite Gypsum Street, there are more concentrations from 1,001-5,000 mg/kg. Figure 6. shows that Gaffney Street has risk levels ranging from low to extremely high, with more moderate levels near Gypsum Street, and more moderate to high and extremely high levels at the Silver City Highway end. Gaffney Street also has the highest mean and median lead concentrations (mean – 1,094.9 mg/kg and median – 829 mg/kg) (Table 3a.).

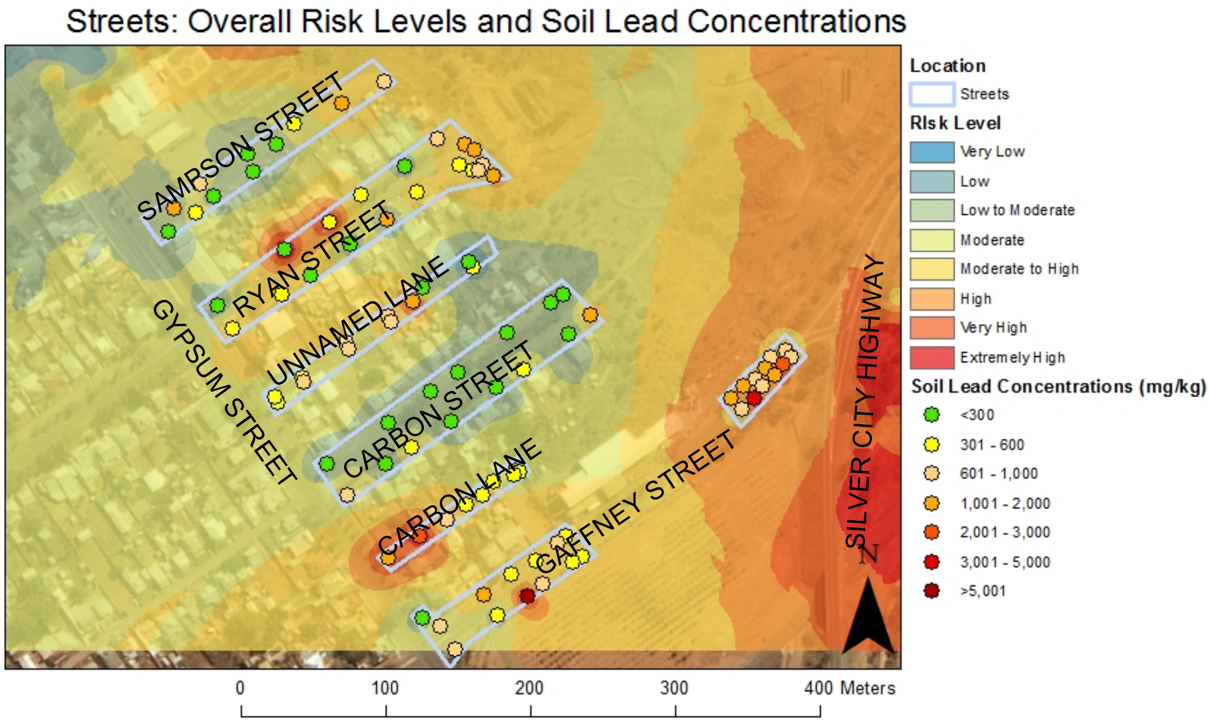

Figure 6. Soil lead concentrations and overall risk on residential streets.

6.2.2 Arsenic

Figure 7. shows that Carbon Street has the lowest arsenic concentrations, up to 50 mg/kg. It also shows that Ryan Street and the Unnamed Lane have arsenic concentrations ranging from <20 mg/kg to 51-100 mg/kg. Ryan Street has more concentrations <20 mg/kg closer to Gypsum Street, and a group of concentrations from 31-100 mg/kg at the opposite end. Table 3c. shows that the Unnamed Lane has the highest mean – 45.1 mg/kg. Figure 7. shows that Carbon Lane has arsenic concentrations ranging from <20 mg/kg to 200 mg/kg. It also has lower concentrations of up to 31-50 mg/kg at the end opposite Gypsum Street, and higher concentrations between 51-200 mg/kg closer to Gypsum Street. Figure 7. also shows that there are slightly lower arsenic concentrations on Gaffney Street closer to Gypsum Street compared to the opposite end, ranging from <20 mg/kg to 51-100 mg/kg, with many from 31-50 mg/kg closer to Gypsum Street. At the opposite end, there is a greater amount of concentrations from 51-100 mg/kg, with one concentration from 101-200 mg/kg and 21-30 mg/kg. Table 3a. also shows that Gaffney Street has the highest median – 38 mg/kg.

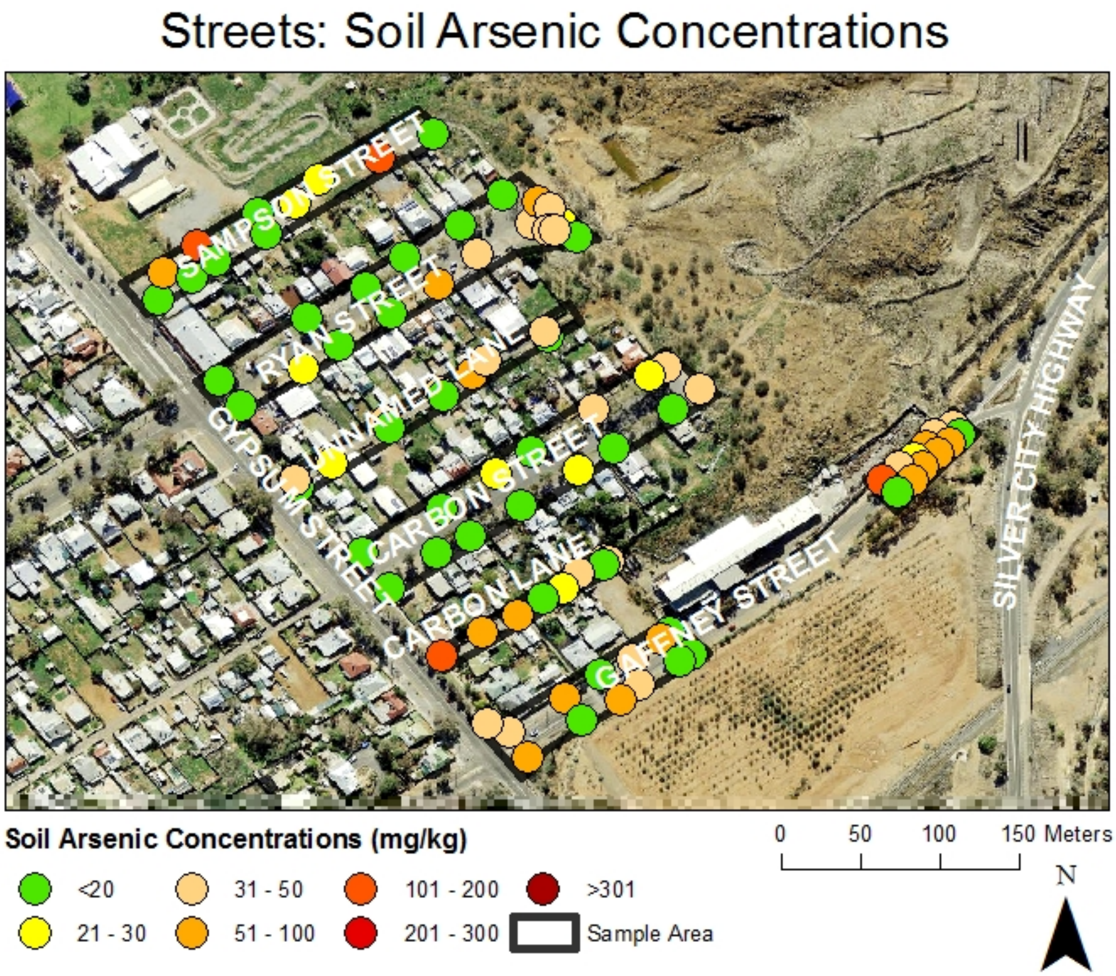

Figure 7. Soil arsenic concentrations on residential streets.

6.2.3 Manganese

Figure 8. shows that Carbon Street and Sampson Street have the greatest concentrations of manganese concentrations less than 1,000 mg/kg. The remaining concentrations for these streets range from 1,001-3,000 mg/kg, each with one concentration from 5,001-10,000 mg/kg. Figure 8. shows that Unnamed Lane had manganese concentrations ranging from <1,000-4,000 mg/kg, with more concentrations from 1,001-2,000 mg/kg closer to Gypsum Street. Carbon Lane has one concentration <1,000 mg/kg with the rest ranging from 1,001-10,000 mg/kg, the latter being closer to Gypsum Street. Figure 8. shows that the majority of the manganese concentrations on Ryan Street range from 1,001-4,000 mg/kg, with one concentration <1,000 mg/kg. There is a group of concentrations from 1,001-2,000 mg/kg and two concentrations >10,001 mg/kg at the end

opposite Gypsum Street. Figure 8. shows that on Gaffney Street, at the end closer to Gypsum Street, there are manganese concentrations ranging from 1,001-10,000 mg/kg, with one concentration <1,000 mg/kg. At the end opposite Gypsum Street there are higher concentrations up to >10,001 mg/kg, with many concentrations from 1,001-10,000 mg/kg. Gaffney Street also has the highest mean – 3,596.88 mg/kg and median – 2,645 mg/kg (Table 3a.).

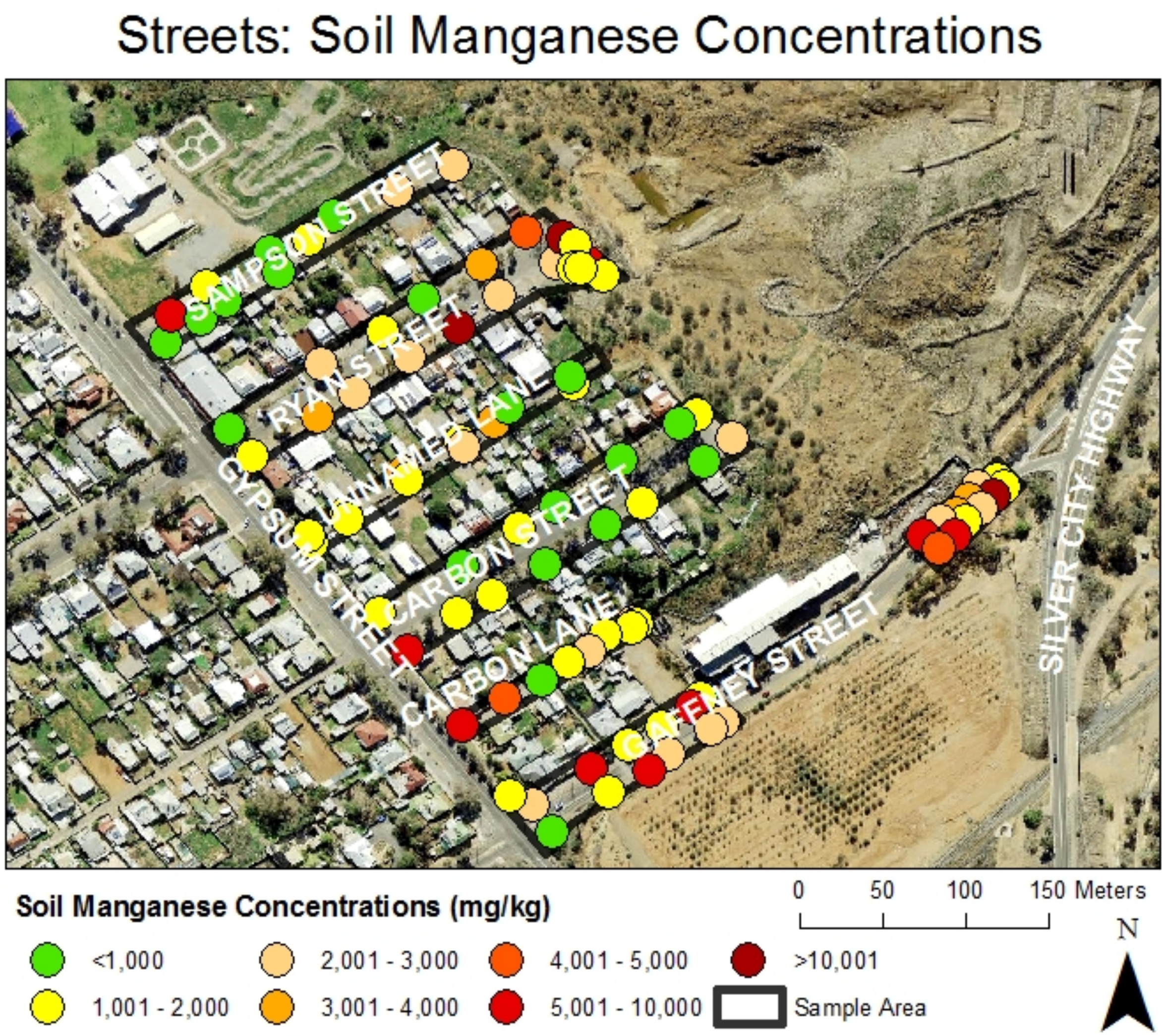

Figure 8. Soil manganese concentrations on residential streets.

6.2.4 Zinc

Figure 9. shows that there are many zinc concentrations from 201-2,000 mg/kg on all of the residential streets. Carbon Street, Ryan Street and Sampson Street each have one concentration of <200 mg/kg, while Gaffney Street is the only street with a concentration from 8,001-10,000 mg/kg. Table 3a. also shows that Gaffney Street has the highest mean (2,451.68 mg/kg) and median (1,888 mg/kg). Figure 9. shows that Carbon Street has the lowest zinc concentrations followed by Unnamed Lane and then Sampson Street which has one concentration from 4,001-6,000 mg/kg. Figure 9. shows that Ryan Street has lower zinc concentrations closer to Gypsum Street, though it has many concentrations from 2,001-8,000 mg/kg. Gaffney Street, closer to Gypsum Street, has concentrations from 201-4,000 mg/kg, while at the opposite end there are higher concentrations of 4,001-6,000 mg/kg, with more concentrations from 2,001-4,000 mg/kg (Figure 9.).

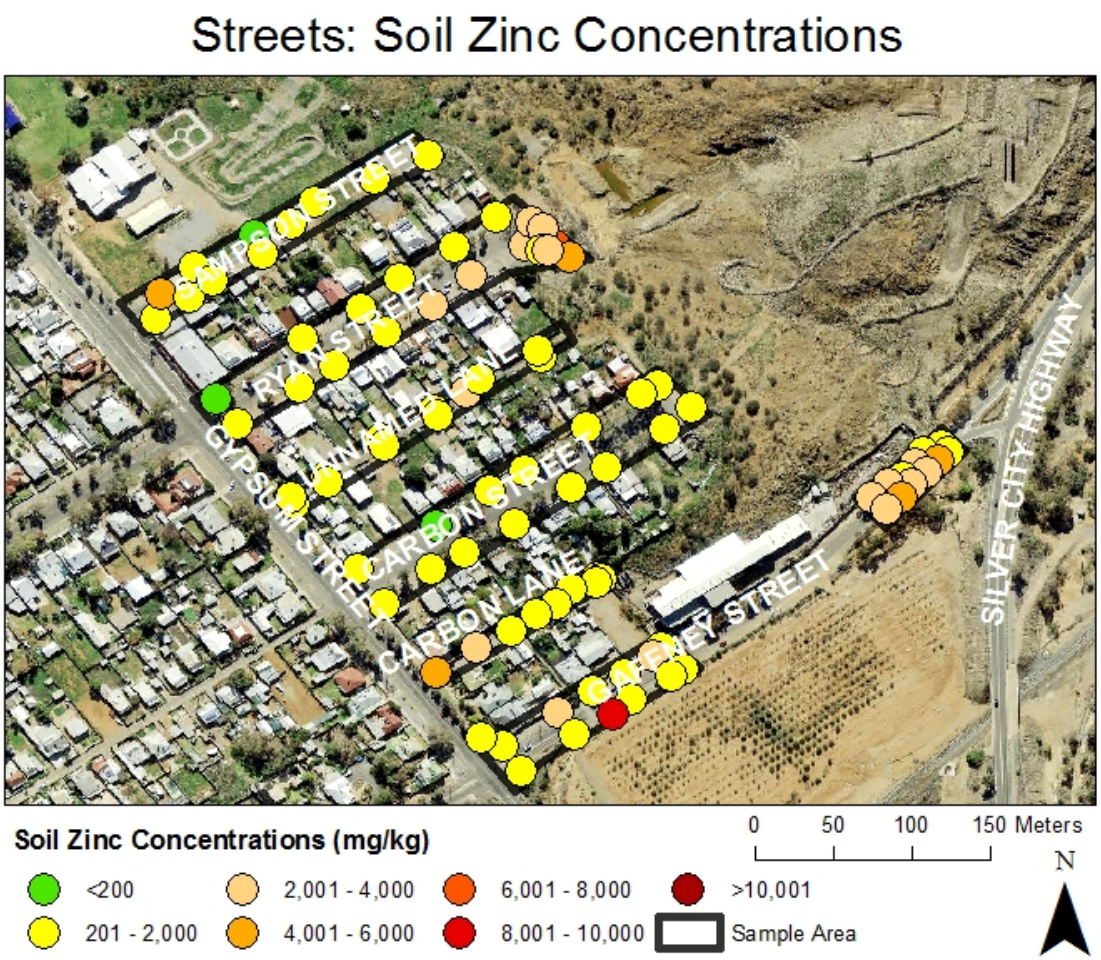

Figure 9. Soil zinc concentrations on residential streets.

The residential streets have been allocated the second highest priority for remediation as they are regularly accessed by the general public and residents. These streets are located on a slight slope and have very little vegetation cover in most areas making them more vulnerable to erosion by wind and water. This means that any remediation which covers areas of the residential streets which received a rating above a low risk level or >300 mg/kg soil lead concentration should be monitored in order to ensure that the remediated areas are well maintained.

These streets have been covered by cracker dust (crushed zeolite) which works to lower the risk of lead contamination where a thick layer is present, though the consistency of cracker dust cover was found to be uneven on some streets. In some cases, the cracker dust had been eroded away, leaving lead contaminated soil exposed. A new layer of cracker dust is recommended on all of the streets, particularly Gaffney Street, Ryan Street, the Unnamed Lane and Carbon Lane, as these all have extremely high risk levels (Figure 6.).

The NEPM guidelines, which provide health investigation levels for soil contaminants, lists the lead investigation level for residential areas as 300 mg/kg. The lead levels for category 'Residential A' applies to the residential streets in Broken Hill as it encompasses residential areas with a garden or area of accessible soil. Every residential street examined is eligible for investigation as all have soil lead concentrations of >300 mg/kg, which exceeds the NEPM guidelines for residential areas.

As discussed in the results section for residential streets, Gaffney Street has two high soil lead concentrations from 3,001-5,000 mg/kg (Figure 6.). Table 1. from Harvey *et al.* (2016, p. 945) describes lead abatement protocol for different ranges of lead concentrations, to >5,000 mg/kg, which have been used in Boolaroo. Based on this table, the areas of high soil lead concentrations on Gaffney Street, which fit into the 2,500-5,000 mg/kg category (Figure 6.), should be excavated up to 50 mm and covered over with 50 mm of new topsoil (Harvey *et al*., 2016). This area can then be covered by new turf, though this would not suit the dry and arid environment of Broken Hill. In shaded areas, mulch cover is suggested in addition to 50 mm of new topsoil, which would be a practical, low cost and low maintenance solution for Broken Hill (Harvey *et al*., 2016). In addition, the areas of soil lead concentrations that fit into the 1,500-2,500 mg/kg category (Figure 6.), found on all residential streets, are eligible for 50 mm of topsoil cover (Harvey *et al.,* 2016). Shaded areas on these streets would also be appropriate for mulch cover over 50 mm of topsoil (Harvey *et al*., 2016).

If remediation using cracker dust, new topsoil or mulch are not satisfactory, or if a more long-term remediation solution is required, geotextile fabric can be used as a physical barrier between contaminated and clean soil. TERRAM provides an orange Hi-Vis geotextile fabric in Australia which is made to prevent the upward movement of contaminated soil and prevent future excavation into contaminated soil. Another option, and alternative to natural turf, is synthetic turf which can start from AUD 30 to AUD 50 per square metre, though this amount will vary depending on the product and supplier. Majority of the cost margins for full installation are between AUD 70 and AUD 100 per square metre, which includes base preparation, and this can be used as a physical barrier at the surface. These solutions are particularly suited for the private properties on these residential streets, especially to remediate yard spaces where children play or where vegetable gardens are placed.

6.3 Block 10 Hill

TABLE 4. BLOCK 10 HILL DATA SUMMARY

	Pb (mg/kg)	As (mg/kg)	Mn (mg/kg)	Zn (mg/kg)	Vege Cover (%)
Maximum	9,906	381	107,388	8,908	100
Minimum	267	0	457	332	0
Mean	2,065.5	86.8	12,672.3	2,775.1	37.6
Median	1,245	51.5	3,323.5	1,831.5	30
St. Dev	2,135.3	92.9	21,179.2	2,220.2	33.2
75th Percentile	3,119.3	130.3	12,385	4,511.5	67.5
NEPM Health Investigation Levels	300	100	3,000	8,000	N/A

6.3.1 Lead

Lead concentrations at this site were very high. Only one reading at this site showed a safe lead concentration of <300 mg/kg. Concentrations between the two houses at this site (Figure 10.) were the most concerning, with all soil lead concentrations being greater than 1,500 mg/kg. In combination with the vegetation cover on this section, the overall risk of the base of the hill is categorised as extremely high. The central section (mid section of slope) of the site is very conflicting with lead concentrations ranging from 601-1,000 mg/kg to greater than 5,001 mg/kg (Table 4.). Considering this, the overall risk for this section is also conflicting, ranging from moderate to extremely high. The overall risk on the steepest section of the hill is moderate to high, as it is better vegetated, and lead concentrations ranged between 601 mg/kg to 2,000 mg/kg (Table 4.).

The ridge along the north-eastern border is generally of low to moderate overall risk. Soil lead concentrations in this area range from <300 mg/kg to 2,000 mg/kg.

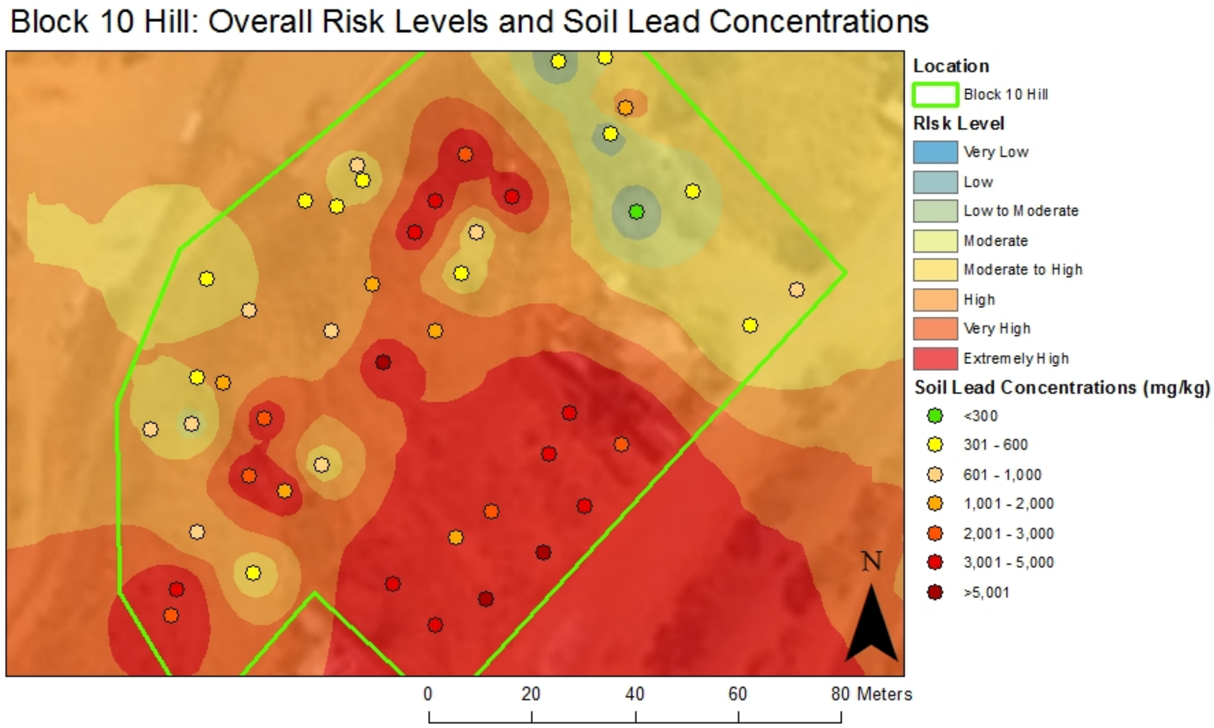

Figure 10. Soil lead concentrations and overall risk at Block 10 Hill

6.3.2 Arsenic

Arsenic concentrations showed great variation across the site, with levels ranging from 0-381 mg/kg (mean – 86.8, median – 51.5) (Figure 11. & Table 4.). There appears to be some trend in the concentrations, with the heavier concentrations on the south-west of the site, while the lower concentrations occur on the north-east side of the site, however this is not a distinct trend, nor is it particularly significant.

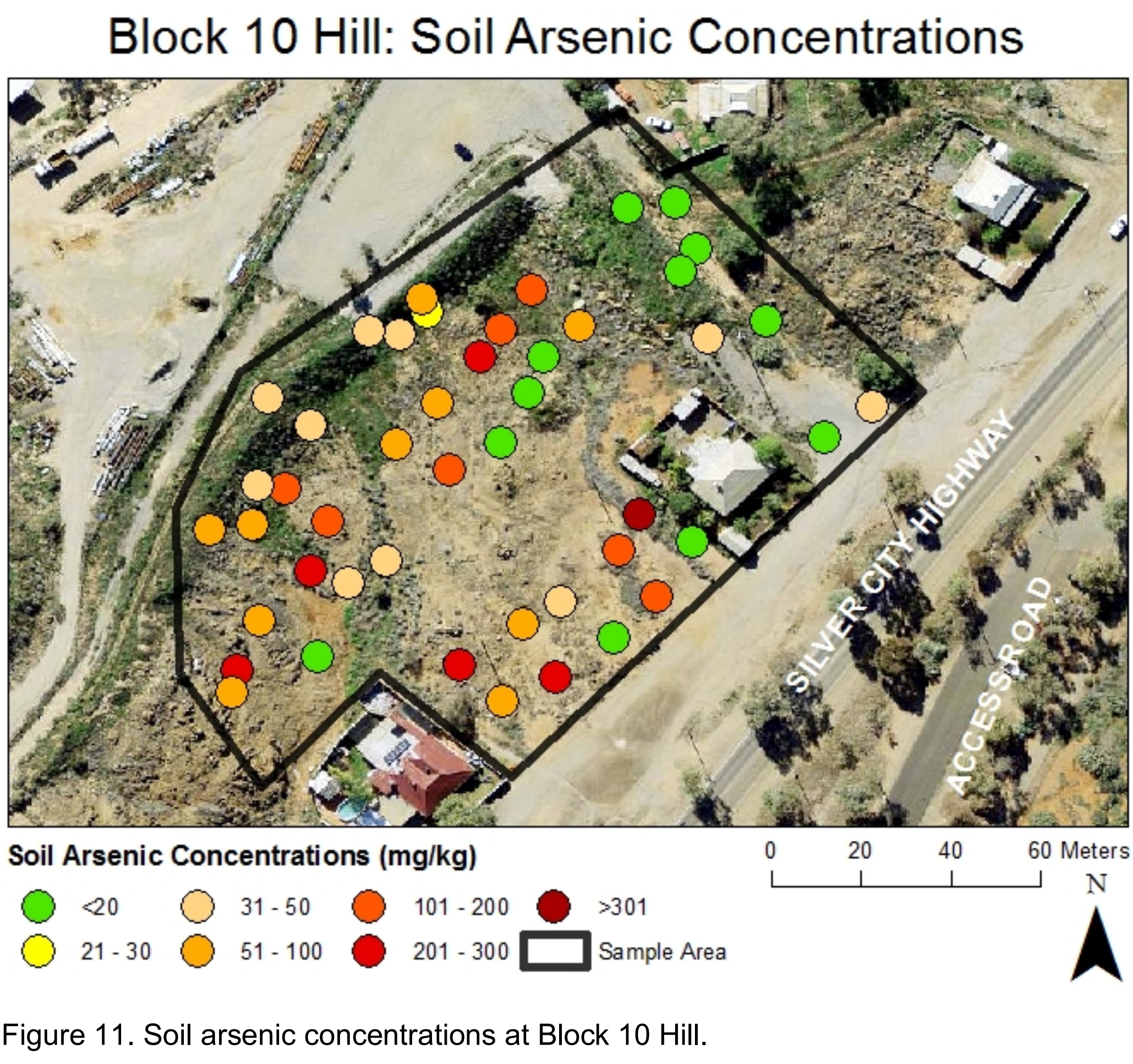

Figure 11. Soil arsenic concentrations at Block 10 Hill.

6.3.3 Manganese

Manganese concentrations were very high across the whole site, except for on the slope itself, and the ridge along the north-east side of the site (Figure 12.). Samples along the slope and the ridge were typically <2,000 mg/kg, whereas samples across the rest of the site were typically 3,000 mg/kg to >10,000 mg/kg (mean – 12,672, median – 3,323.5) (Table 4.)

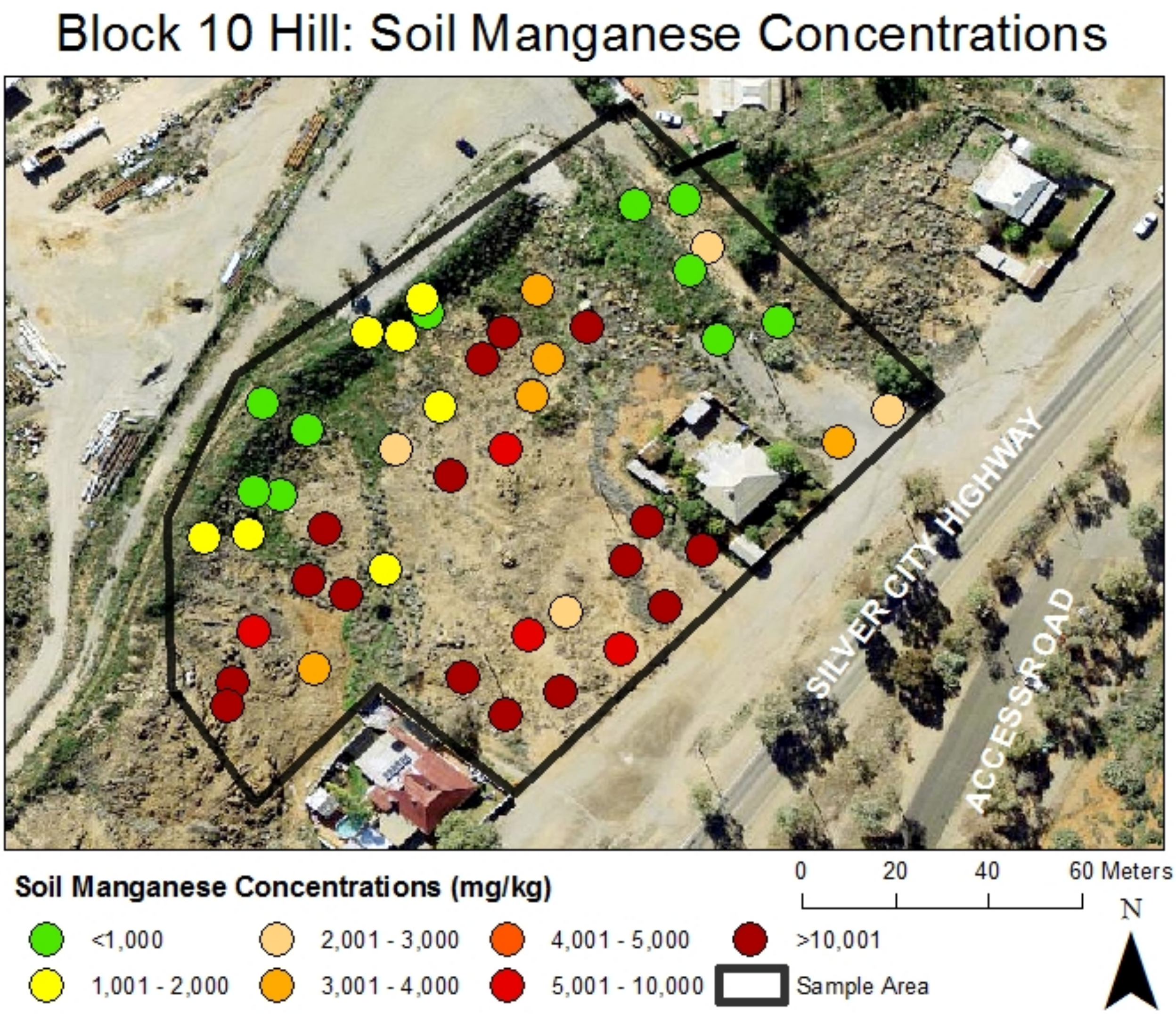

Figure 12. Soil manganese concentrations at Block 10 Hill.

6.3.4 Zinc

Zinc levels were fairly consistent throughout the site (Figure 13.). The mean zinc level was 2,775.1 mg/kg (median – 1831.5) which is well below the NEPM guidelines (Table 4.).

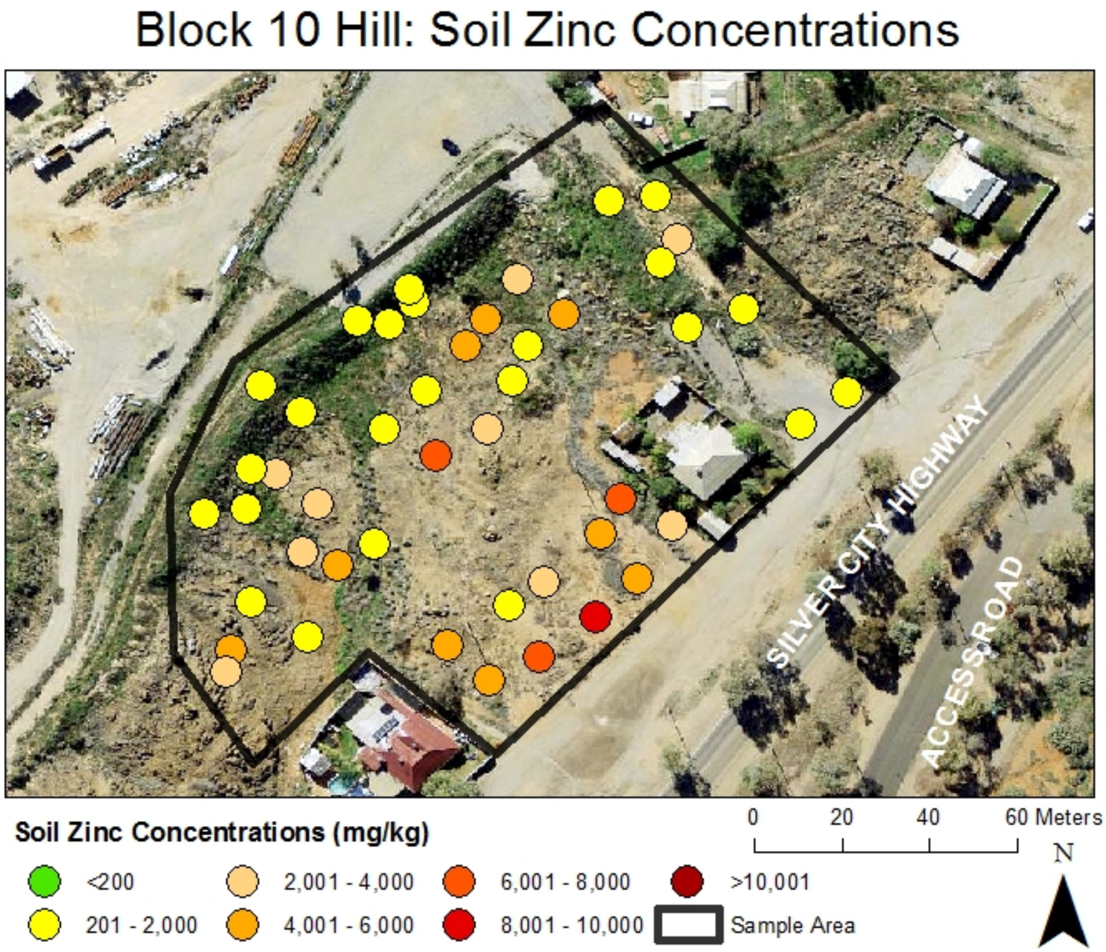

Figure 13. Soil zinc concentrations at Block 10 Hill.

Contamination on Block 10 Hill appears to be mostly entering the site through the two drainage lines running from either side of the hill, towards the centre (Figure 1.). It would appear that previous remediation to stabilise the drainage lines has not been successful in removing the contaminant from the site. This could be due to the contaminant being based off site, and transported onto the site via the drainage lines during periods of heavy rainfall. As there are three houses in the immediate area of the site, as well as evidence of human activity (rubbish and dumped asbestos sheeting) on the site itself, these high concentrations are particularly concerning.

Remediation of the site itself could be conducted in a number of ways. The first would require a clean-up of physical pollution on the site, and vigorous revegetation. Revegetation should be conducted using resilient native species which do not need much long term care. Consideration should also be given to the drainage lines on the site, as some vegetation will not survive when planted along these lines. This technique would be relatively cheap to implement, with the initial work being able to be carried out over a number of days. Whilst plants should be monitored in the short term after planting to ensure their survival, they should require little to no care in the long term. This remediation technique would be useful as it would help to immobilise the contaminants from both fluvial and aeolian forms of transportation, particularly if a dense ground cover is used.

In order to more permanently and thoroughly remediate this site it is essential to locate the source of the contamination. As it appears to be coming from the top of the hill, it would be useful to conduct further studies to identify the major contamination source. If the source can be pinpointed and contained, the most effective way to remediate this site would be to cap it. This would involve applying a layer of geotextile fabric, followed by a thin clay layer, with clean topsoil. This could then be revegetated. By using this method, it would make the site much safer for those using the site directly. Whilst revegetation does minimise transportation of contaminants, this method stops transportation completely, and ensures that the top layer of soil is completely free from harmful levels of contaminants. This remediation technique would be more costly than simply revegetating, however would also be more effective.

It was observed that there are a number of garbage bins on the top of the hill, in the car park for the Block 10 Lookout. Due to the amount and location of physical pollution on the site, it would appear that these bins are being blown or knocked over on a regular basis. Whilst it is highly unlikely that this is contributing in any way to the elemental contamination on site, it would be useful to install stands for the bins to reduce the physical pollution on the site.

6.4 Block 10 Flat

TABLE 5. BLOCK 10 FLAT DATA SUMMARY					
	Pb (mg/kg)	As (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	Vege Cover (%)
Maximum	20,199	2,249	233,844	44,121	50
Minimum	124	0	301	611	0
Mean	3,417.03	152.37	16,356.10	8,660.5	4.6
Median	2,334	80	4450	6,246	0
St. Dev	3,564.05	289.23	35,777.82	7,846.33	10.7
75th Percentile	4,483	204	14,083	12,201	1
NEPM Health Investigation Levels	600	300	30,000	9000	N/A

6.4.1 Lead

Out of the 72 measurements, two had lead concentrations <300 mg/kg, six were within a range of 301-600 mg/kg and fourteen were >5,001 mg/kg (Figure 14.). A greater amount of >5,001 mg/kg concentrations were detected along the access road where vegetation was minimal, whereas scattered distributions of 1,001-5,000 mg/kg concentrations were present throughout the north-west section of land on the Block 10 Flat (Figure 14.). To the north-east, where risk levels were determined to be predominantly moderate, lead concentrations were found to be 301-2,000 mg/kg. To the north-west, lead concentrations were mostly >301 mg/kg. As noted in Table 5., the lead concentrations were the highest – 20,199 mg/kg, the lowest – 124 mg/kg, the median – 2,334 mg/kg, and the mean – 3,417 mg/kg.

Overall, the risk levels on Block 10 Flat varied from low to extremely high, with the majority of the measurements returning extremely high risk levels (Figure 14.). To the north-east of the sample area and within the western extent of the Block 10 Flat, a number of moderate risk levels were determined. However, along the central access road, risk levels were extremely high due to absent or minimal vegetation cover and lead levels above 1,500 mg/kg. To the north-west, the ground surface encapsulated between the South

Road and the access road, demonstrated varying levels of risk from moderate to extremely high (Figure 14.).

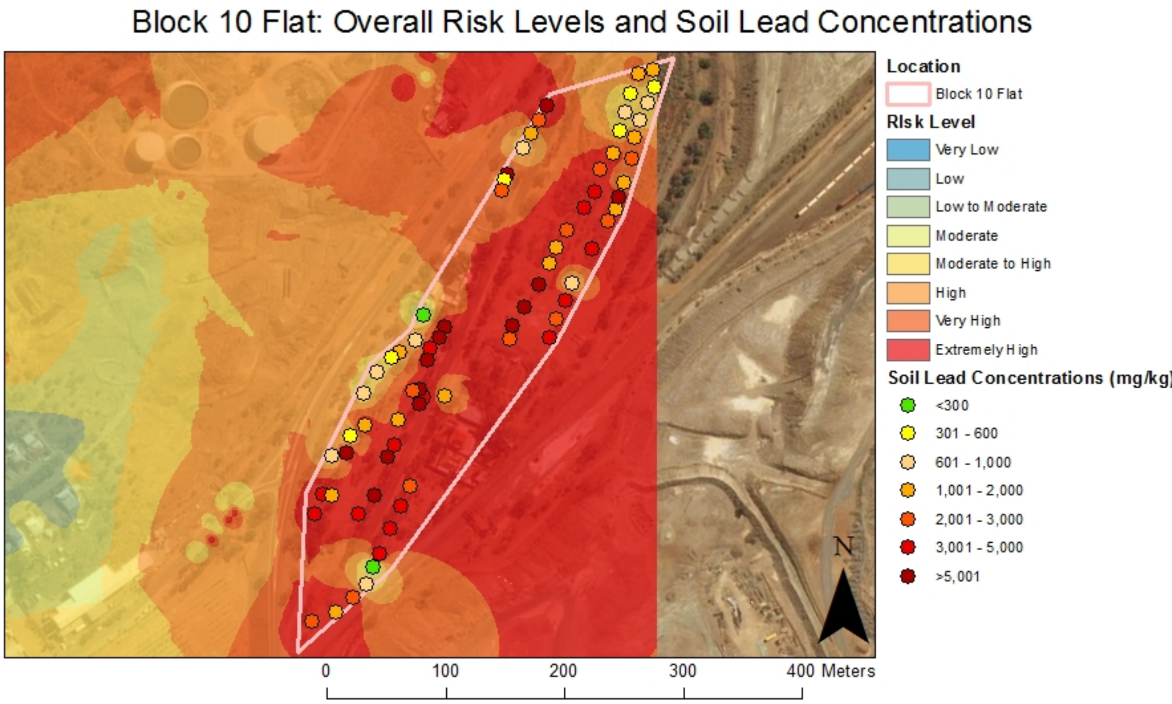

Figure 14. Soil lead concentrations and overall risk at Block 10 Flat.

6.4.2 Arsenic

Arsenic concentrations varied greatly across the Block 10 Flat with concentrations ranging from 0 mg/kg to 2,249 mg/kg (Figure 15., Table 5.). South of the RSPCA and to the east of the South Road, arsenic concentrations were <20 mg/kg with some higher concentrations of 101-200 mg/kg found in the drainage channel. Along the southern section of the access road, concentrations were determined to be significantly higher at >301 mg/kg. Furthermore, in the north-east section of the Block 10 Flat, the majority of concentrations were 51-100 mg/kg of arsenic, with several exceeding 301 mg/kg. Across the north-east section, concentrations varied such that the east-most transect illustrated many concentrations >101 mg/kg compared to the west-most transect that highlighted concentrations to be below 100 mg/kg. As noted in Table 5., the arsenic concentrations had a median – 80 mg/kg and mean – 152.4 mg/kg.

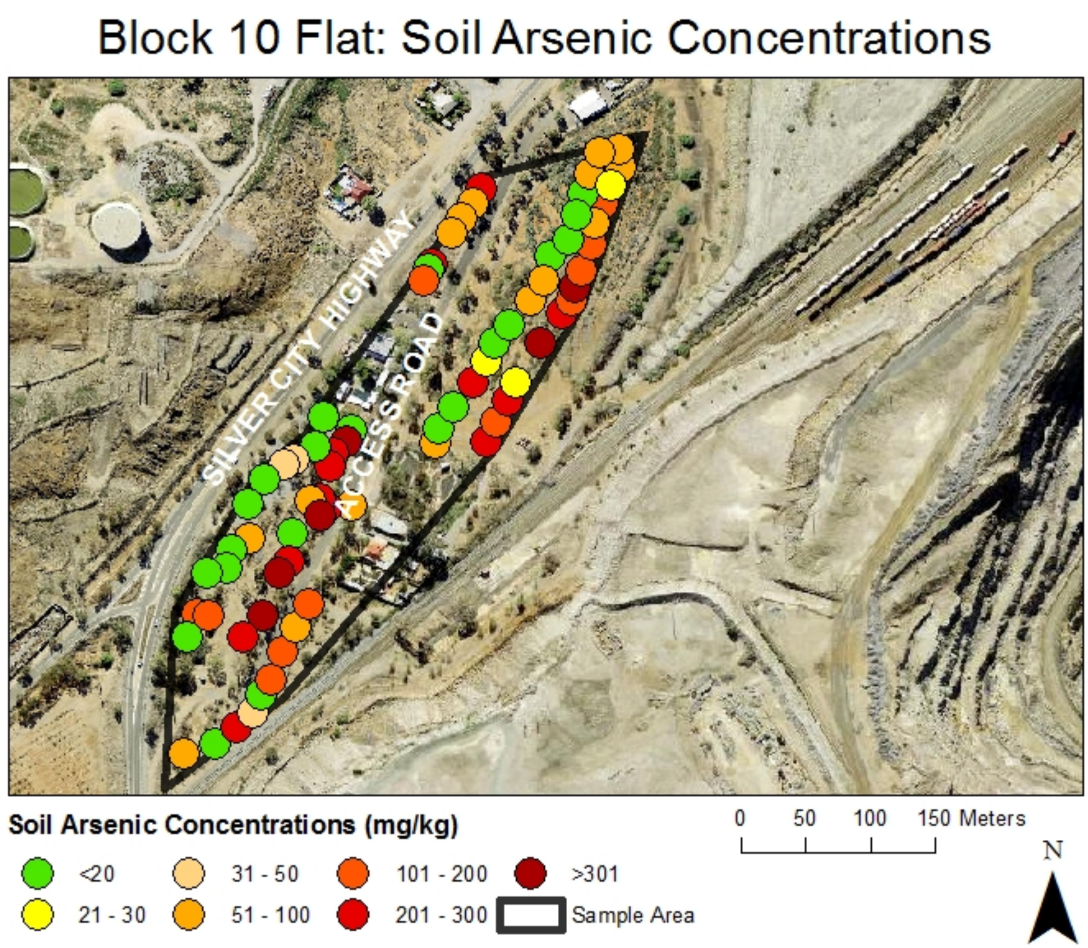

Figure 15. Soil arsenic concentrations at Block 10 Flat.

6.4.3 Manganese

The concentrations of manganese were significantly varied across the Block 10 Flat, ranging between 611 mg/kg to 44,121 mg/kg (Figure 16., Table 5.). Out of the 72 measurements taken, eight had levels below 2,000 mg/kg. In the north-east section, arsenic concentrations exceeded 4,001 mg/kg. Along the access road, manganese concentrations were all greater than 5,001 mg/kg. As noted in Table 5., the manganese concentrations had a median – 6,246 mg/kg and mean – 8,660.5 mg/kg.

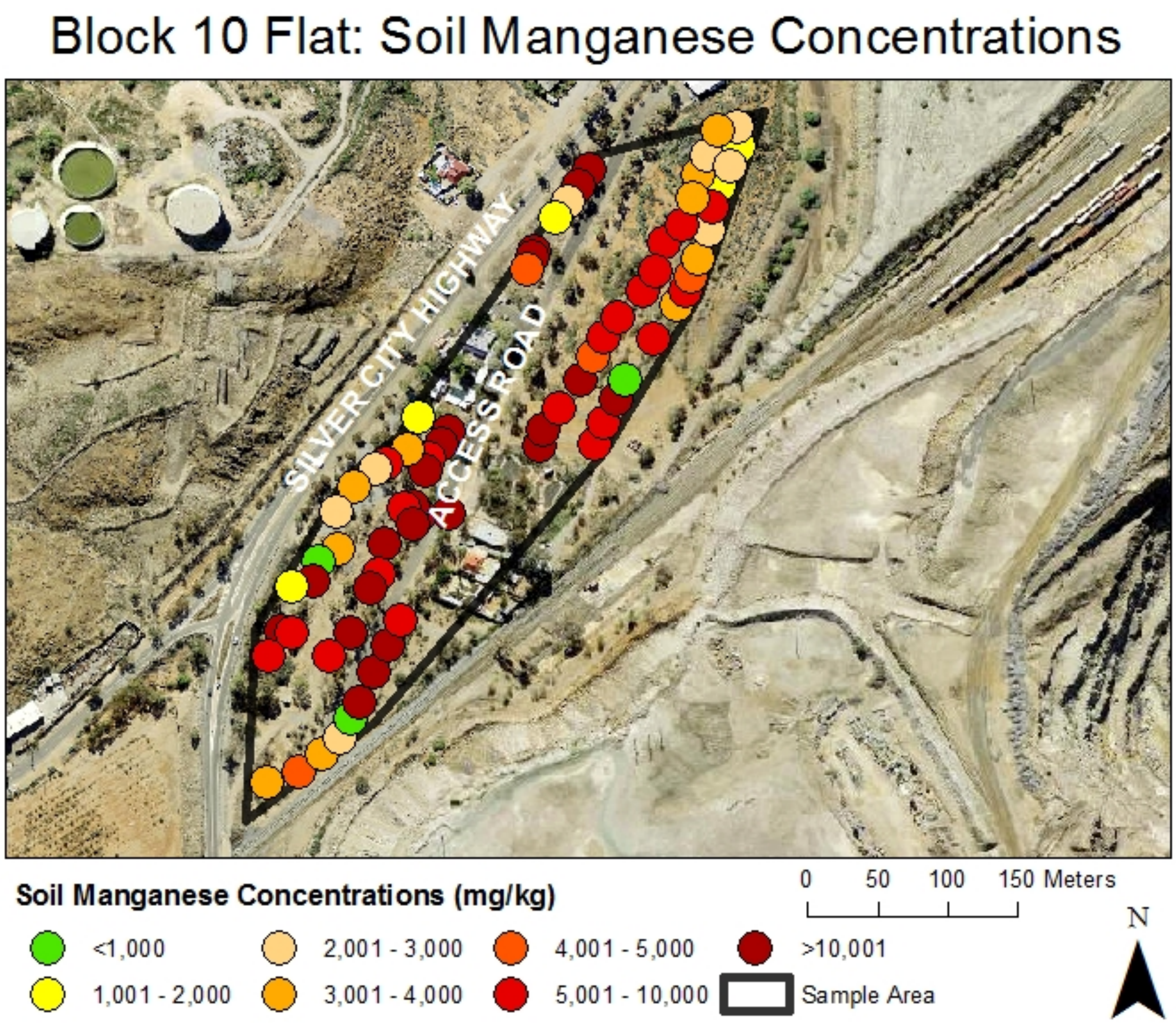

Figure 16. Soil manganese concentrations at Block 10 Flat

6.4.4 Zinc

Zinc concentration patterns on the Block 10 Flat are highly similar to the patterns of lead concentration. Regions of low zinc concentrations are the north-eastern and western extent of Block 10 Flat with concentrations being a minimum of 301 mg/kg (Figure 17.). High zinc concentrations are found along the western margin of the access road and north-western section of exposed ground with a maximum – 233,833 mg/kg. As noted in Table 5., the zinc concentrations had a median – 4,450 mg/kg and mean – 16,356.1 mg/kg.

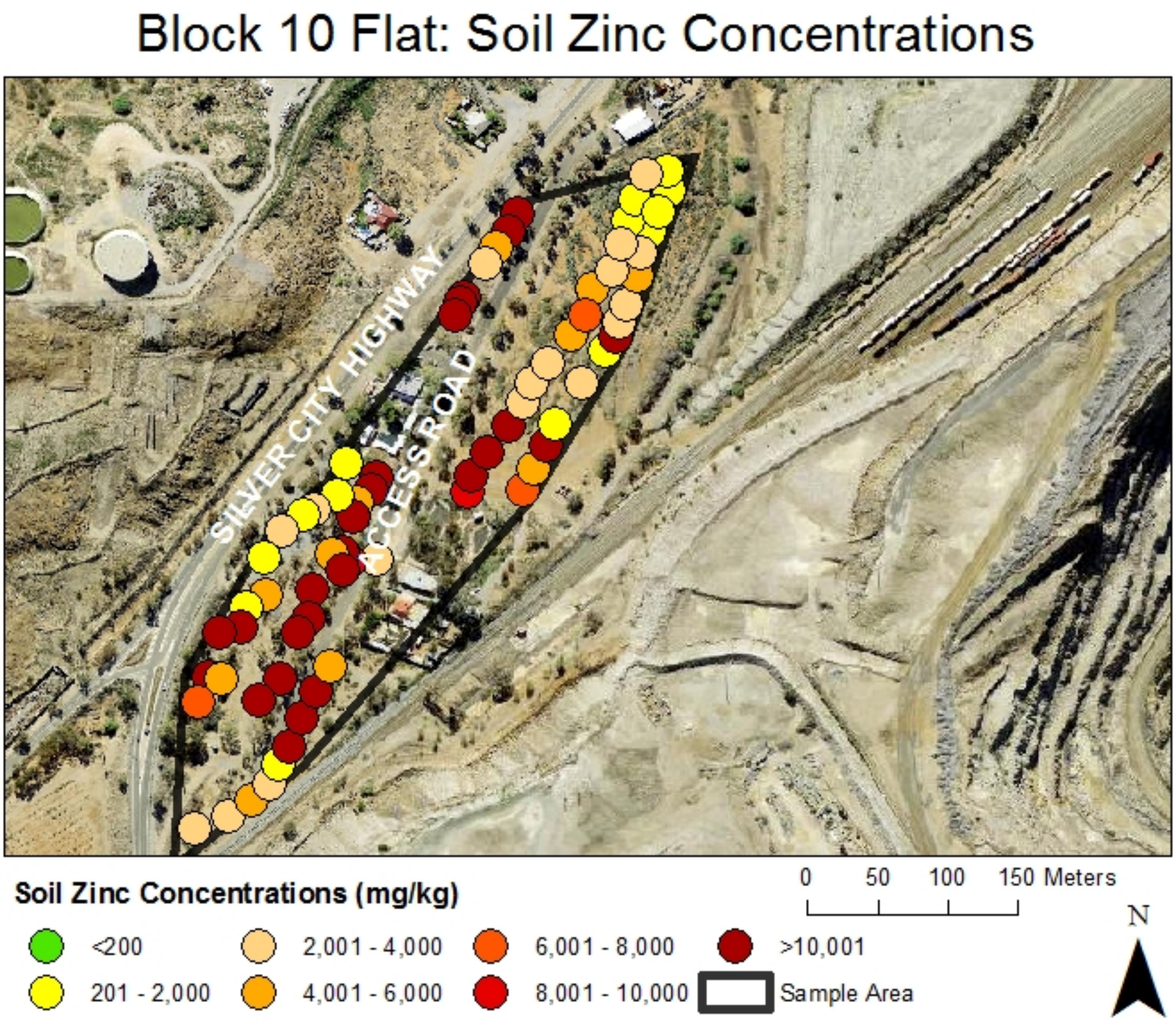

Figure 17. Soil zinc concentrations at Block 10 Flat.

Block 10 Flat was allocated the lowest priority for remediation due to its relatively moderate risk level in publically accessed areas and low risk to the general public due to low frequency use. Cars and cyclists were observed on the access road, however no children or adults were observed in the areas of high risk. The Block 10 Flat contains three houses and a commercial building that are frequented by residents and it is essential to consider the use of the area in regards to any remediation strategies suggested.

Remediation works have been done on the north-eastern section of the Block 10 Flat through the construction of shallow trenches (furrows) that run perpendicular to the slope on the site, thus decreasing the rate of runoff and promoting the retention of water on site (Frances Boreland 2016, pers.comm., 26 Sept.). This remediation strategy has allowed for vegetation to stabilise the ground surface and prevent aeolian and fluvial transport of soil lead. The vegetation cover was found to range from 0 to 50% with an average of 4.6% (Table 5.).

The low lying shrubs and tall grass are effective at reducing excessive aeolian and fluvial erosion. With mean lead concentrations being 3,417 mg/kg, suggested options for remediation are to excavate 50 mm of topsoil, replace with new topsoil and cover with turf or mulch in shady areas (Harvey *et al*., 2016). However, topsoil removal in an area of moderate vegetation would result in soil disturbance and dust.

Other short term alternatives are to lay 50 mm of clean gravel to stabilise the ground surface and prevent the movement of soil lead (Maynard *et al*., 2003). This ensures existing vegetation is not disturbed and water can continue to infiltrate into the subsurface. Mulch can provide the same benefits as gravel and contribute soil material under the right conditions.

Alternatively, fencing the high risk areas of the Block 10 Flat will reduce the potential risk of human exposure and enhance the growth of vegetation cover in the long term. There is no requirement for fence type, height or material as long as it informs the public through signage about the risks of entering into areas of high lead concentrations. The costs of installing fences around bare areas of the Block 10 Flat will need to account for materials and labour for construction. Log fences may be cheaper compared to metal grid fences and act as equally effective barriers. The locations that are in need of fencing are the north-east section of the sample area and to the south of the access road near the rail line.

The remediation strategies that have been suggested above aim to stabilise the ground surface and prevent the aeolian and fluvial erosion of soils with high lead concentrations. Any additional increases to the soil lead concentrations may be coming from windblown dust from the Line of Lode to the east of the Block 10 Flat. This pattern of distribution is reflected in the soil lead concentrations illustrated in Figure 14.

6.5 Further Discussion

6.5.1 Sources and Pathways of Lead Exposure

It is extremely important to identify the sources and pathways of lead exposure to inform decision making regarding suitable preventative measures and remediation works (Cao *et al.*, 2015). Multiple exposure pathways can be responsible for an elevated blood lead level, especially in children (Appendix 1.)(Cao *et al.*, 2015). Lead in soil and dust, and lead-based paint are the primary sources and pathways of lead exposure for children, as is the case for the residents of Broken Hill (CDC, 1991). Mining activity produces air pollution that contains lead which contaminates soil and dust in the surrounding area leading to higher levels of lead in in the environment, as is the case for Broken Hill (NHMRC, 2015). Lead deposited in soil and dust is a long-term source of exposure especially for children. Unless it is deliberately removed, due to its elemental stability it does not dissipate, biodegrade, or decay (NHMRC, 2015; CDC, 1991). When lead deposition ceases, remediation works will still have to be undertaken to reduce the exposure risk from contaminated soil and dust (CDC, 1991).

Children are commonly exposed to lead in dust, soil and flaking lead-based paint, and can also be exposed second-hand from family members who work with lead in mining or other industry (Kar-Purkayastha *et al.*, 2011). Lead dust can cling to hair, skin, clothing and shoes, so it is easily transported indoors and widely dispersed (NHMRC, 2015). Soils containing lead can also be brought inside on shoes and clothing and be spread to contaminate other areas (NHMRC, 2015). In environments with high lead exposure risk, such as Broken Hill, children should wash their hands and faces regularly to ensure that any lead contracted from soil or dust is not swallowed (NHMRC, 2015). In addition, play areas and indoor surfaces should be kept clean to reduce the likelihood of accidental ingestion of lead (NHMRC, 2015).

6.5.2 Case Studies

In similar historic and modern mining communities, elevated lead levels continue to pose a risk to people (Taylor *et al*., 2010), such as Port Pirie, Mount Isa, Esperance, Northampton and Boolaroo. With not many successful large-scale contamination cleanups in Australia (Heyworth *et al*., 2009; Harvey *et al*., 2016), examining previous remediation measures in other lead contaminated cities is an effective strategy to remediating Broken Hill.

The Port Pirie Lead Implementation Program was implemented in 1984 to identify children with high blood lead levels, houses requiring decontamination, soil treatment, family support and education, community education, and the development of heavily vegetated zones around the smelter (Maynard *et al*., 2003). Alternatively, Mount Isa remediation has been focused on community education via fact sheets, posters and stories, and the 'Living with Lead Alliance' group and Facebook page (Taylor *et al*., 2011; Sullivan & Green 2016). Additional remediation strategies have been suggested are adding clean topsoil and ground cover, geotextile fabric or capping to prevent airborne dust from spoil heaps, waste, ore piles and unsealed roads from entering the environment (Mackay *et al*., 2013; Sullivan & Green, 2016; Taylor *et al*., 2010; 2011). In Esperance, remediation was undertaken by the Western Australian Government via the Esperance Cleanup and Recovery Project and clean-up of rainwater tanks (McCafferty *et al*., 2013). In Northampton, tailings located in the school playground were removed and treated off-site and a disposal facility was proposed (Heyworth *et al*., 1981; Government of Western Australia Department of Lands, 2016). Lastly, the schools in Boolaroo underwent remediation to minimise lead access through soil removal, ceiling dust removal, improvements to surface cover, tree corridors surrounding the smelter, and cap and cover approaches to the urban environment through the Lead Abatement Strategy (McPhillips, 1995; Morrison, 2003; Harvey *et al*., 2016).

6.5.3 Lead in the Living Environment

There is evidence that lead affects nearly every system in the human body (CDC, 1991) and even at low levels in the environment, lead has a substantial impact on human health (Lanphear *et al*., 2005). Children, pregnant women and young women of childbearing age are more vulnerable to lead exposure (Kar-Purkayastha *et al*., 2011). In addition, Indigenous children are at a higher risk of elevated blood lead levels due to different lifestyle factors including housing and diet (McMannus, 2009). Aboriginal children are twice as likely to have blood lead concentrations above 10 μg/dL (Boreland & Lyle, 2014).

In 2009, the mean blood lead concentration for Indigenous children of 1 to 4 years of age was 9.1 µg/dL, whereas for non-Indigenous children the mean blood lead level was 5.7 µg/dL (GWAHS, 2010).

Since the 1970s, the blood lead level considered to indicate lead poisoning has fallen steadily as the adverse effects of lead have become more clear (CDC, 1991). A blood lead level of 60 µg/dL was considered toxic in the mid-1960s, but this was decreased to 40 µg/dL in 1971 (CDC, 1991; Lanphear *et al*., 2005). By 1978, the initial blood lead level was reduced by 50% to be 30 µg/dL before becoming 25 µg/dL by 1985 (CDC, 1991; Lanphear *et al*., 2005). In 1991, the Center for Disease Control and Prevention further reduced the blood lead value to 10 µg/dL and Australia followed in 1993 (CDC, 1991; Taylor *et al*., 2014; Lanphear *et al*., 2005). Though blood lead levels below 10 µg/dL have been considered normal for a time, new evidence has shown that contemporary blood lead levels in children are considerably higher than those found in pre-industrial humans (Patterson *et al.*, 1991; Lanphear *et al.*, 2005), which were 0.016 µg/dL (Taylor *et al*., 2014).

There is now evidence that suggests no level of lead exposure is safe (Boreland & Lyle, 2014). In 2009, the NHMRC noted that there is no threshold of lead exposure considered harmless, and that will not have adverse effects on cognitive abilities (NHMRC, 2009; Taylor *et al.,* 2014). Canada, the USA and Germany have all reduced their blood lead reference level to 5 µg/dL or lower for children (Boreland & Lyle, 2014) and Australia's NHMRC followed suit, also lowering the blood lead level to 5 µg/dL in 2015 (NHMRC, 2015; Kristensen & Taylor, 2016).

Lead became a community-wide concern during the 1970s as surface mining re-commenced and waste dumps were re-worked at Broken Hill (Boreland & Lyle, 2014). In 1982, a survey of children's blood lead levels found that none were above 40 µg/dL (the then level of concern) (Boreland & Lyle, 2009; 2014). It wasn't until later in the 1980s that lead was recognised as an issue after it became increasingly evident that blood lead levels previously thought safe were in fact a concern (Boreland & Lyle, 2009). These findings resulted in a blood lead survey of children aged 1 to 4 in 1991 which found that 1 in 5 had a blood lead level above 25 µg/dL (the then level of concern) (Boreland *et al*., 2002).

Further investigations followed and the government-funded Broken Hill Lead Management Program was established in 1994 after lead exposure was found to be a significant health issue for young children (Boreland & Lyle, 2009; 2014). The program consisted of screening blood lead levels, case finding and management, public education and some remediation of public areas with high lead levels (Boreland & Lyle, 2014).

By 2001, blood lead levels decreased causing the program to be integrated into the Child and Family Health Centre (CFHC) and funding was significantly reduced (Boreland & Lyle, 2014). Screening and educational activities were provided by the CFHC though it delivered minimal practical support for families affected by high blood lead levels that couldn't afford what was recommended (Boreland & Lyle, 2014). This is a significant issue given the high level of disadvantage preventing families from putting down clean soil, sealing gaps, and stabilising lead-based paint as minimal forms of remediation (ABS, 2008; Boreland & Lyle, 2014).

When lead management was integrated into the activities of other organisations, this meant that lead was less visible from the community's perspective (Boreland & Lyle, 2014). It was interpreted to mean that lead was no longer an issue or a government priority, and this may have been responsible for the decrease in annual participation in blood lead screening from 52% in 2005 to 38% in 2008 (Boreland & Lyle, 2014). In 2009, around 1 in 5 children had blood lead levels above the then intervention level of 10 µg/dL (Boreland & Lyle, 2009), and in 2014, 53% of children in Broken Hill had blood lead levels above 5 µg/dL which is the new reference level set by the NHMRC (Boreland & Lyle, 2014).

6.5.4 Current Action

The NSW Government has assigned AUD 13 million to go towards the restoration of the Environment Lead Program in Broken Hill (Kristensen & Taylor, 2016). This may result in some much needed remediation works to occur not only in public areas with high soil lead levels, but also in private dwellings for families in great need of assistance. In addition, the EPA has allocated AUD 225,000 in funding from the Environmental Trust through the Contaminated Land Management Program to address lead contamination in playgrounds that were identified in 2014 as being high risk (BH Annual Report, 2014/2015). This funding from the EPA is in addition to the AUD 13 million that will rejuvenate the Broken Hill Environment Lead Program over the next 5 years (BH Annual Report, 2014/2015).

6.5.5 Remediation and Community Engagement

In combination with the strategies listed in Section 6, it is also recommended that a number of community awareness strategies be implemented to further reduce the risk of lead to human health. As the main form of exposure to lead is ingestion (Appendix 2.) one of the best ways to reduce blood lead levels is to maintain good sanitation practices around food. To aid this recommendation, a fridge magnet (Appendix 5.) has been designed as a reminder for people to wash their hands before handling food. It has been branded with the ‘Lead Ted’ logo, which has been used on other community awareness projects around Broken Hill, including on the hand wash station in AJ Keast Park. In addition, three flyers have also been developed; one which describes foods which can assist in the reduction of lead absorption (Appendix 6.), one which details general health and safety information about lead (Appendix 7.) and the third is a template for recipes that use foods known to reduce lead absorption (Appendix 8.). It is recommended that all flyers be distributed to the public in supermarkets, community health centres and other public places. Some signs have also been designed to be placed around AJ Keast Park and on the fence (Appendix 9.). These have all also been branded with the ‘Lead Ted’ logo as a friendly reminder for children to stay lead safe.

7. Conclusion

Overall, the lead risk of the Broken Hill study area was found to be above the NEPM (2010) guidelines and of high risk to the Broken Hill public. The other elements measured, arsenic, manganese and zinc, were occasionally found to exceed the NEPM (2010) guidelines. Due to these findings, the sampling sites were listed in order of priority from highest to lowest risk; AJ Keast Park and surrounds, Residential Streets, Block 10 Hill and Block 10 Flat. The effectiveness of areas that were previously remediated to reduce lead risk, varied in preventing lead exposure to the public. In areas of high risk, recommendations for remediation were provided, including fencing of high risk areas, cracker dust placement, increased vegetation and signage. With the implementation of these remediation strategies, it is expected that the exposure of children to high concentrations of lead and other elements will be reduced.

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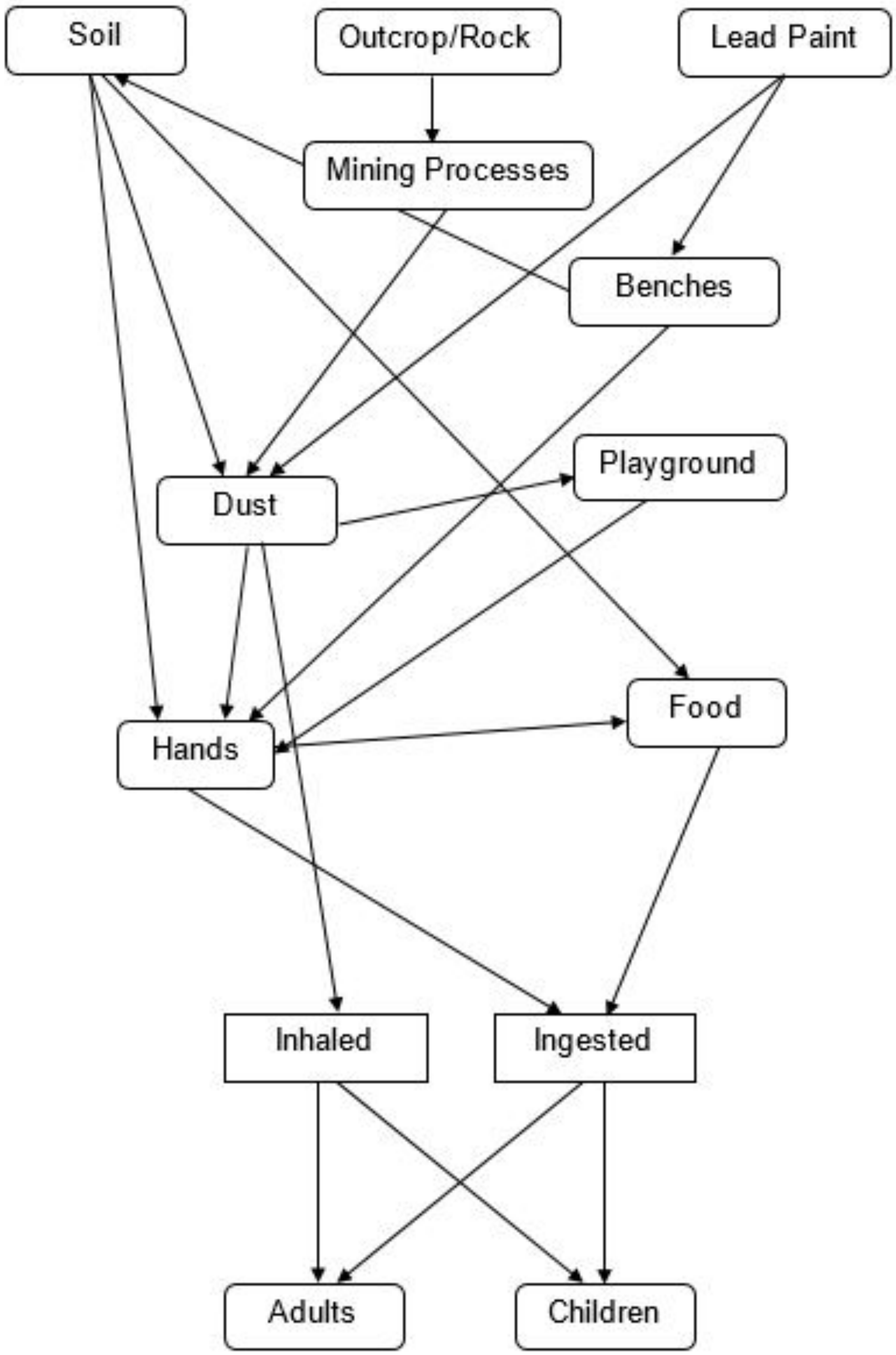
Appendix 1 – Historical Timeline

- **1844** — Charles Napier Sturt discovered Broken Hill
- **1883** — Charles Rasp discovered the Line of Lode
- **1892** — Howell conducted an enquiry into the prevalence of lead poisoning in Broken Hill
- **1895** — The Lead Poisoning Act 1895 (57 Vic No 18) was released
- **1991** — Sampling of ceiling dust in Broken Hill
  - Blood-lead survey of pre-school aged children in Broken Hill
- **1994** — NSW Lead Management Action Plan was formed
  - Broken Hill Environmental Lead Centre was established
- **2010** — Lead Health Operational Plan was created by the Greater Western Area Health Service

Appendix 2 – Lead Exposure Pathways

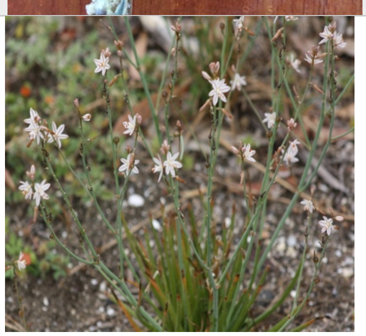
This flow chart describes the pathways of lead exposure in the Broken Hill community.



Appendix 3 – Vegetation Communities

The following species were all observed in the sample area behind AJ Keast Park.

Species Name	Photo	Description
***Cassia artemisioides* (Silver cassia)**		This shrub grows 1-2m high, and is mostly green-grey with downy cylindrical leaves. It is a quick growing shrub that is relatively short-lived (Cunningham *et al.,* 1981).
***Limonium thouinii* (Winged sea lavender)**		This species grows to approximately 40cm high. Its leaves arise in a rosette around the base of the plant. It is an annual species which flowers in winter/spring (Cunningham *et al.,* 1981).
***Eremophila* (Emu-bush)**		This plant was unable to be identified to species level, but is part of the *Eremophila* genus. This genus is mostly shrubs, with alternating leaves and flowers that are pollinated by birds or insects. These species are all native to Australia (PlantNET, 2016; Cunningham *et al.,*1981).
***Disphyma clavellatum* (Round-leaf pig face)**		This is a perennial species that acts as a robust groundcover, and is a succulent. It normally occurs in bladder saltbush communities, particularly those which have an overstorey of black box trees (Cunningham *et al*., 1981).

Species Name	Photo	Description
***Echium Plantaginaeum* (Paterson's curse)**		This plant is an annual or sometimes biennial plant which grows up to 1.2 m high. It is thought to be responsible for poisoning of sheep, and is considered a noxious weed throughout Victoria and much of NSW (Cunningham *et al.,* 1981)
***Acetosa vesicaria* (Wild hops)**		This plant is introduced to the Broken Hill area and is considered a weed. It grows to approximately 75 cm high, and prefers rocky or sandy soils (Cunningham *et al.,* 1981).
***Sida petrophila* (Rock sida)**		This shrub has one main stem with many smaller branches. It often grows to 1 m or taller. It prefers shallow sandy soils or stony ridges or hillsides with highly calcareous soils. They flourish in all but the driest seasons, where they will die back to the base. (Cunningham *et al.,* 1981)
***Asphodelus fistulosus* (Onion weed)**	 (Bailey, 2016)	This herb grows long thin, onion like leave about 10-25 cm long. When in flower, it grows a flower stem which can grow 20-30 cm high. This weed is unpalatable to stock, and its widespread distribution is largely a result of overgrazing. It is considered a weed throughout Victoria and parts of NSW (Cunningham *et al*., 1981*)*

Species Name	Photo	Description
Atriplex vesicaria **(Bladder salt bush)**		This shrub is a perennial species that grows to 70 cm in height. It is found on alluvial plains, especially those associated with black box or coolibah trees, as well as in rocky hills, ridges and communities of mulga, belah or bluebush. This plant is perceived to be extremely useful, as it has a high drought tolerance. In areas where this shrub has been removed, salt scalding has occurred in extreme cases. (Cunningham *et al.,* 1981)
Enchyleanma tomentosa **(Ruby saltbush)**		This perennial shrub is widespread throughout western NSW. It grows in most habitats and soil communities throughout the region and is very drought resistant making it a good choice for revegetation works. (Cunningham *et al.,* 1981)
Solanem ellipticum **(Velvet potato bush)**		This plant has a variety of common names including wild gooseberry, tomato bush, potato bush, hillside flannel bush and velvet nightshade. It grows to 40 cm and is common in mulga, bimble box and belah communities. It has also been found in bladder saltbush communities and on the fringe of mallee stands. It can withstand most soil types, but rarely clays. (Cunningham *et al.,* 1981)

Species Name	Photo	Description
Ptilotis atriplicifolius (Silver Tails)		This perennial shrub grows to approximately 1 m in height and diameter. It grows in a sandy or loamy or stony soil types. It is a hardy species and and recovers well from severe grazing and other threats (Cunningham *et al.,* 1981).
Sisymbrium irio **(London rocket)**	 (Cunningham *et al.,* 1981)	This plant grows to approximately 25-60 cm tall. It is an introduced species which has become naturalised throughout much of NSW (PlantNET, 2016). It is found in most soil types and is an annual species (Cunningham *et al.,* 1981)
Rhodanthe microglossa **(Clustered Sunray)**		Previously known as *Helipterum microglossum* (ALA, 2016). This annual plant grows 2-10 cm high. It grows in sandy, saline soils in bladder saltbush or black bluebush communities. This species is mostly found in the cooler seasons (Cunningham *et al.,* 1981)

Species Name	Photo	Description
Acacia aneura **Mulga**		This tree grows to 8 m high. It is found mostly on sandy plains, dunefields as well as stony soils. It has a shallow root system, and is therefore a good species for erosion control. (Cunningham *et al.,* 1981)
Brachyscome ciliaris **(Variable daisy)**		This perennial species grows to 40 cm high, with alternating leaves. It may have white or purple petals with a yellow centre. It is found in most soil types, however prefers red loamy soil types. (Cunningham *et al.,* 1981)
Cheilanthes lasiophylla **(Woolly cloak fern)**		This perennial fern has fronds which may grow to 15 cm long, however are usually shorter. It prefers rocky or stony soil types and is very drought resistant. (Cunningham *et al.,* 1981)

Species Name	Photo	Description
Lamarkia aurea **Golden top**		This is a small annual grass which grows to 15 cm tall. It grows in a wide variety of soil types, and is often found in shaded areas. It flowers in late winter or spring (Cunningham *et al.,* 1981)

Identification of these species was completed through consultation with Frances Boreland, as well as using ‘Plants of Western New South Wales’ (Cunningham et al., 1981), PlantNET (available at: http://plantnet.rbgsyd.nsw.gov.au) and the Atlas of Living Australia (available at: http://www.ala.org.au) to confirm species.

Appendix 4 – Field Measurements

This is the raw data from the two pXRF machines used for sampling. XRF code MQU is for the machine borrowed from Macquarie University (Machine 161), and the XRF code EPA is the machine borrowed from the Broken Hill Environmental Lead Program. Vege Cover is measured in %. Overall risk is based on the table presented in the methods section of this report. Each code is as follows: VL – Very low, L – Low, LM – Low-Moderate, M – Moderate, MH – Moderate-High, H – High, VH – Very High, EH – Extremely High.

AJ Keast Park												
Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
26/9/16	11:54:11	MQU	#7	1195	37	1685	3942	1	31.96836	141.44760	80	H
26/9/16	11:55:46	MQU	#8	667	52	1275	2179	2	31.69836	141.44759	60	M
26/9/16	11:58:02	MQU	#9	298	0	463	998	3	31.96834	141.44756	75	L
26/9/16	11:59:49	MQU	#10	899	26	1428	1763	4	31.96829	141.44751	70	M
26/9/16	12:01:25	MQU	#11	1399	22	1610	1211	5	31.96827	141.44748	30	H
26/9/16	12:05:01	MQU	#12	1874	87	2626	5898	6	31.96840	141.44762	30	EH
26/9/16	12:06:53	MQU	#13	134	19	318	919	7	31.96839	141.44757	35	L
26/9/16	12:09:05	MQU	#14	135	9	227	518	8	31.96839	141.44754	0	L
26/9/16	12:11:15	MQU	#15	904	20	1428	1150	9	31.96848	141.44763	80	M
26/9/16	12:12:57	MQU	#16	808	0	1867	1204	10	31.96846	141.44760	80	M
26/9/16	12:14:29	MQU	#17	1309	43	2015	2844	11	31.96846	141.44756	30	H
26/9/16	12:16:27	MQU	#18	1136	0	1563	2129	12	31.96846	141.44749	40	H
26/9/16	12:18:39	MQU	#19	484	0	635	1097	13	31.96869	141.44743	30	M
26/9/16	12:20:05	MQU	#20	649	0	758	1069	14	31.96868	141.44742	10	M
26/9/16	12:21:27	MQU	#21	835	0	1116	1479	15	31.96867	141.44742	<10	M
26/9/16	12:23:58	MQU	#22	775	39	1406	1070	16	31.96864	141.44745	45	M
26/9/16	12:26:01	MQU	#23	1183	32	1799	1564	17	31.96862	141.44742	40	H
26/9/16	12:28:14	MQU	#24	377	0	460	717	18	31.96861	141.44742	35	M
26/9/16	12:31:59	MQU	#25	560	0	950	1057	19	31.96857	141.44745	0	M
26/9/16	12:34:36	MQU	#26	822	0	1484	1375	20	31.96858	141.44745	10	M
26/9/16	12:36:35	MQU	#27	369	0	493	851	21	31.96856	141.44745	70	M
26/9/16	12:39:00	MQU	#28	642	0	1103	1151	22	31.96854	141.44745	0	M
26/9/16	12:40:35	MQU	#29	305	12	401	416	23	31.96855	141.44742	30	M
26/9/16	12:42:25	MQU	#30	964	17	1209	1370	24	31.96855	141.44740	10	M
26/9/16	12:44:13	MQU	#31	532	0	476	1006	25	31.96849	141.44742	10	M
26/9/16	12:46:07	MQU	#32	102	8	153	407	26	31.96851	141.44742	10	L
26/9/16	12:47:48	MQU	#33	472	0	587	1066	27	31.96853	141.44739	10	M

AJ Keast Park

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
26/9/16	12:51:26	MQU	#35	451	0	519	828	28	31.96841	141.44736	30	M
26/9/16	12:53:25	MQU	#36	340	0	422	858	29	31.96842	141.44733	5	M
26/9/16	12:55:37	MQU	#37	429	0	597	677	30	31.96844	141.44731	60	M
26/9/16	12:59:44	MQU	#38	443	0	482	638	31	31.96835	141.44731	50	M
26/9/16	13:01:26	MQU	#39	539	0	740	892	32	31.96832	141.44728	20	M
26/9/16	13:03:30	MQU	#40	453	22	798	1191	33	31.96834	141.44725	5	M
26/9/16	13:05:45	MQU	#41	805	0	1808	267	34	31.96823	141.44724	90	LM
26/9/16	13:07:20	MQU	#42	368	17	608	624	35	31.96823	141.44724	80	M
26/9/16	13:09:08	MQU	#43	137	0	295	80	36	31.96824	141.44719	100	VL
26/9/16	13:11:15	MQU	#44	1193	51	10175	1703	37	31.96816	141.44720	5	H
26/9/16	13:13:01	MQU	#45	842	0	1431	808	38	31.96815	141.44720	80	M
26/9/16	13:14:29	MQU	#46	389	0	611	419	39	31.96815	141.44719	80	M
26/9/16	13:16:58	MQU	#47	1584	0	6168	2249	40	31.96809	141.44717	30	EH
26/9/16	13:19:18	MQU	#48	1102	0	9165	1017	41	31.96807	141.44717	15	H
26/9/16	13:21:26	MQU	#49	469	0	680	568	42	31.96805	141.44713	80	M
26/9/16	13:24:18	MQU	#50	1676	57	3193	1127	43	31.96798	141.44716	40	EH
26/9/16	13:26:01	MQU	#51	638	31	939	920	44	31.96798	141.44716	5	M
26/9/16	13:27:46	MQU	#52	240	0	270	452	45	31.96798	141.44713	85	VL
26/9/16	13:29:48	MQU	#53	991	63	2629	2114	46	31.96790	141.44725	0	M
26/9/16	13:31:42	MQU	#54	1618	53	3194	840	47	31.96789	141.44722	100	MH
26/9/16	13:33:22	MQU	#55	1097	46	2282	1415	48	31.96790	141.44720	10	H
26/9/16	13:34:54	MQU	#56	809	0	1075	1792	49	31.96791	141.44716	5	M
26/9/16	14:09:55	MQU	#57	1792	0	2731	1771	50	31.96798	141.44725	5	EH
26/9/16	14:11:41	MQU	#58	2107	73	2714	1451	51	31.96799	141.44728	30	EH
26/9/16	14:13:33	MQU	#59	628	19	1722	1300	52	31.96803	141.44733	<5	M
26/9/16	14:15:45	MQU	#60	1017	26	1439	2105	53	31.96811	141.44737	50	MH
26/9/16	14:19:35	MQU	#61	1249	33	2038	2848	54	31.96810	141.44731	20	H
26/9/16	14:28:58	MQU	#62	498	0	902	1033	55	31.96822	141.44733	70	M
26/9/16	14:32:53	MQU	#63	1674	50	2027	2874	56	31.96830	141.44736	0	EH
26/9/16	14:48:12	MQU	#65	760	0	985	1076	57	31.96869	141.44753	60	M
26/9/16	14:50:48	MQU	#66	1112	31	1561	1836	58	31.96875	141.44757	40	H
26/9/16	14:53:56	MQU	#67	1489	0	1748	1989	59	31.96872	141.44777	100	M
26/9/16	14:54:22	EPA	#19	847	64	1334	1489	60	31.96891	141.44745	0	M
26/9/16	14:55:58	MQU	#68	1544	0	1984	2025	61	31.96862	141.44768	30	EH
26/9/16	14:58:16	EPA	#21	494	49	1077	450	62	31.96880	141.44733	100	L
26/9/16	15:00:39	EPA	#22	203	16	457	341	63	31.96871	141.44272	100	VL
26/9/16	15:02:39	EPA	#23	227	0	500	138	64	31.96856	141.44714	100	VL
26/9/16	15:06:17	MQU	#69	745	24	1138	1506	65	31.96897	141.44734	0	M

AJ Keast Park

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
26/9/16	15:04:53	EPA	#24	243	19	378	399	66	31.96843	141.44704	100	VL
26/9/16	15:06:47	EPA	#25	183	9.3	319	283	67	31.96830	141.44693	100	VL
26/9/16	15:09:03	MQU	#70	266	0	554	352	68	31.96887	141.44727	100	VL
26/9/16	15:09:21	EPA	#27	247	23	417	361	69	31.96814	141.44679	100	VL
26/9/16	15:12:09	EPA	#28	411	19	608	850	70	31.96825	141.44666	100	VL
26/9/16	15:11:17	MQU	#71	152	0	419	138	71	31.96873	141.44716	100	VL
26/9/16	15:13:42	MQU	#72	80.7	0	350	96	72	31.96861	141.44704	100	VL
26/9/16	15:14:14	EPA	#29	166	12.7	421	177	73	31.96834	141.44675	100	VL
26/9/16	15:16:01	MQU	#73	65.1	0	250	100	74	31.96847	141.44693	100	VL
26/9/16	15:16:00	EPA	#30	102	4.5	348	99	75	31.96847	141.44684	100	VL
26/9/16	15:18:02	MQU	#74	145	0	320	194	76	31.96833	141.44681	100	VL
26/9/16	15:17:35	EPA	#31	129	0	377	95	77	31.96859	141.44695	100	VL
26/9/16	15:19:54	MQU	#75	122	0	345	204	78	31.96826	141.44678	90	VL
26/9/16	15:21:47	MQU	#76	170	6.1	288	270	79	31.96822	141.44673	80	L
26/9/16	15:19:36	EPA	#32	281	28	539	302	80	31.96870	141.44702	100	VL
26/9/16	15:21:58	EPA	#33	131	12.9	496	117	81	31.96881	141.44710	100	VL
26/9/16	15:24:43	MQU	#77	95.7	0	227	163	82	31.96827	141.44662	100	VL
26/9/16	15:23:49	EPA	#34	340	23	812	379	83	31.96891	141.44719	100	VL
26/9/16	15:26:44	MQU	#78	200	22	521	380	84	31.96838	141.44670	100	VL
26/9/16	15:30:18	MQU	#79	161	7	298	330	85	31.96832	141.44653	100	VL
26/9/16	15:28:12	EPA	#35	1109	86	1647	2632	86	31.96906	141.44728	0	MH
26/9/16	15:35:04	MQU	#82	95	0	300	270	87	31.96856	141.44670	100	VL
26/9/16	15:33:06	MQU	#81	217	18	487	581	88	31.96845	141.44662	90	VL
26/9/16	15:35:16	EPA	#37	1062	86	1391	1384	89	31.96895	141.44695	0	MH
26/9/16	15:39:36	MQU	#83	673	0	997	1392	90	31.96909	141.44716	0	MH
26/9/16	15:42:40	MQU	#84	304	17	725	597	91	31.96896	141.44708	100	L
26/9/16	15:45:07	MQU	#85	52.3	0	156	52	92	31.96883	141.44696	100	VL
28/9/16	10:44:12	EPA	#9	2316	149	2830	2548	301	31.96743	141.44908	90	VH
28/9/16	10:45:23	MQU	#5	13646	0	7777	7207	302	31.96779	141.44902	80	EH
28/9/16	10:46:26	EPA	#10	3878	305	4457	3423	303	31.96753	141.44876	90	EH
28/9/16	10:47:55	MQU	#6	1005	0	1287	1211	304	31.96795	141.44887	90	MH
28/9/16	10:48:52	EPA	#11	4189	318	4097	4649	305	31.96767	141.44856	90	EH
28/9/16	10:49:50	MQU	#7	1656	81	2131	2954	306	31.96780	141.44838	50	VH
28/9/16	10:52:33	MQU	#8	1361	36	1868	3267	307	31.96817	141.44868	30	MH
28/9/16	10:51:39	EPA	#12	2058	57	2176	2540	308	31.96834	141.44847	90	VH
28/9/16	10:54:59	EPA	#13	1967	187	2096	5087	309	31.96800	141.44821	70	VH
28/9/16	10:54:39	MQU	#9	211	0	199	176	310	31.96821	141.44801	30	L
28/9/16	10:57:07	MQU	#10	2315	72	3138	3272	311	31.96837	141.44843	20	VH

AJ Keast Park

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
28/9/16	10:58:25	EPA	#14	1029	91	1271	1873	312	31.96854	141.44829	90	H
28/9/16	11:00:29	EPA	#15	1337	100	1718	2497	313	31.96862	141.44818	90	H
28/9/16	11:02:42	EPA	#16	3450	248	4047	3364	314	31.96832	141.44765	100	MH
28/9/16	10:59:45	MQU	#11	1619	88	2158	2936	315	31.96809	141.44746	90	VH
28/9/16	11:08:46	EPA	#17	986	81	1251	2385	316	31.96775	141.44739	70	M
28/9/16	11:09:10	MQU	#13	506	0	561	893	317	31.96772	141.44762	40	M
28/9/16	11:11:28	MQU	#14	1126	26	1328	2305	318	31.96802	141.44762	95	H
28/9/16	11:10:54	EPA	#18	209	31	238	489	319	31.96766	141.44780	60	L
28/9/16	11:13:41	MQU	#15	515	0	596	2290	320	31.96750	141.44806	20	M
28/9/16	11:16:24	MQU	#16	2420	77	2297	5677	321	31.96801	141.44781	60	VH
28/9/16	11:15:12	EPA	#19	272	29	225	502	322	31.96794	141.44807	20	L
28/9/16	11:18:46	EPA	#21	4189	368	4559	2899	323	31.96717	141.44843	40	EH
28/9/16	11:19:39	MQU	#17	908	0	1252	3013	324	31.96701	141.44868	10	M
28/9/16	11:21:57	MQU	#18	2533	41	2901	4705	325	31.96763	141.44849	20	EH
28/9/16	11:25:11	EPA	#23	1390	109	1851	2248	326	31.96763	141.44849	70	H
28/9/16	11:27:55	EPA	#24	707	98	807	2101	327	31.96745	141.44890	20	H
28/9/16	11:30:14	EPA	#25	1965	141	2235	3080	328	31.96741	141.44910	80	VH
28/9/16	15:29:58	EPA	#36	2974	110	180964	592		Bench Seat	Lead Paint		

Block 10 Hill

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
26/9/16	16:38:38	MQU	#89	2651	0	3691	29562	93	31.96720	141.45468	50	EH
26/9/16	16:38:55	EPA	#43	4271	381	6645	12106	94	31.96715	141.45459	80	EH
26/9/16	16:41:27	EPA	#44	3309	193	4219	12478	95	31.96721	141.45454	10	EH
26/9/16	16:42:04	MQU	#90	3225	183	5903	11665	96	31.96730	141.45462	80	EH
26/9/16	16:44:42	EPA	#45	2589	36	2095	2154	97	31.96732	141.45442	1	EH
26/9/16	16:44:19	MQU	#91	9449	0	8908	8200	98	31.96738	141.45453	0	EH
26/9/16	16:46:28	EPA	#46	1508	75	1643	5169	99	31.96736	141.45435	0	EH
26/9/16	16:47:09	MQU	#92	9906	259	7268	32628	100	31.96746	141.45441	0	EH
26/9/16	16:48:54	EPA	#47	3632	294	5465	55692	101	31.96744	141.45424	5	EH
26/9/16	16:49:31	MQU	#93	3561	82	5032	36042	102	31.96751	141.45430	10	EH
26/9/16	16:54:00	EPA	#48	4042	283	4677	107388	103	31.96745	141.45378	1	EH
26/9/16	16:56:38	MQU	#95	2613	72	3375	19500	104	31.96750	141.45377	5	EH
26/9/16	16:58:07	EPA	#49	901	81	1387	7915	105	31.96736	141.45381	30	MH
26/9/16	16:59:14	MQU	#96	400	0	1984	3361	106	31.96742	141.45393	0	M
26/9/16	17:01:15	EPA	#50	2919	237	3829	37956	107	31.96725	141.45393	30	EH
26/9/16	17:02:02	MQU	#97	1989	43	5307	75951	108	31.96728	141.45399	10	EH
26/9/16	17:03:33	EPA	#51	2847	145	2492	11519	109	31.96716	141.45396	3	EH
26/9/16	17:05:23	MQU	#98	839	46	1256	1796	110	31.96724	141.45407	45	M
26/9/16	17:06:19	EPA	#52	962	69	1178	2427	111	31.96700	141.45410	45	MH
26/9/16	17:08:04	MQU	#99	5255	125	7547	22257	112	31.96706	141.45419	5	EH
26/9/16	17:09:21	EPA	#53	1164	82	1313	1931	113	31.96692	141.45418	10	H
26/9/16	17:09:51	MQU	#100	1943	0	2711	5707	114	31.96700	141.45430	80	VH
26/9/16	17:12:05	EPA	#54	3900	211	4609	14119	115	31.96683	141.45427	60	EH
26/9/16	17:12:41	MQU	#101	530	16	1679	3283	116	31.96690	141.45436	30	M
26/9/16	17:14:13	EPA	#55	3481	161	5055	10571	117	31.96678	141.45430	40	EH
26/9/16	17:15:21	MQU	#102	669	0	1274	3305	118	31.96683	141.45439	70	M
26/9/16	17:16:36	EPA	#56	2688	183	3972	3342	119	31.96670	141.45438	90	EH
26/9/16	17:17:38	MQU	#103	3186	68	4833	21005	120	31.96676	141.45445	20	EH
26/9/16	17:22:22	EPA	#57	420	26	709	889	121	31.96674	141.45416	80	M
26/9/16	17:25:15	EPA	#59	649	54	1113	1689	122	31.96671	141.45415	80	
26/9/16	17:28:28	EPA	#60	573	43	847	1554	123	31.96678	141.45410	50	
26/9/16	17:30:00	EPA	#61	499	49	852	1602	124	31.96678	141.45404	50	
26/9/16	17:31:04	MQU	#107	1427	0	2362	2220	125	31.96661	141.45470	10	H
26/9/16	17:33:14	MQU	#108	383	17	529	981	126	31.96652	141.45465	5	M
26/9/16	17:28:35	MQU	#106	444	0	687	992	127	31.96675	141.45483	5	M
26/9/16	17:25:50	MQU	#105	655	42	1569	2142	128	31.96693	141.45503	5	M
26/9/16	17:23:44	MQU	#104	381	13	1223	3490	129	31.96699	141.45496	10	M

Block 10 Hill												
Sample Info				**Elements**				**GPS**			**Other**	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
26/9/16	17:39:17	MQU	#110	402	0	832	922	131	31.96653	141.45456	100	L
26/9/16	17:37:10	MQU	#109	307	0	567	616	132	31.96679	141.45471	100	L
26/9/16	17:43:35	MQU	#111	267	34	906	512	133	31.96697	141.45393	70	L
26/9/16	17:33:22	EPA	#62	635	42	332	944	134	31.96691	141.45384	50	MH
26/9/16	17:35:21	EPA	#63	370	44	807	457	135	31.96709	141.45387	40	M
26/9/16	17:43:24	EPA	#64	1326	132	2146	952	136	31.96708	141.45383	90	MH
26/9/16	17:45:26	EPA	#65	345	33	473	579	137	31.96716	141.45380	30	MH
26/9/16	17:48:31	EPA	#66	684	62	1148	1504	138	31.96717	141.45372	90	LM
26/9/16	17:50:06	EPA	#67	815	77	1205	1852	139	31.97065	141.45227	55	MH

Streets												
Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overal Risk
Gaffney Street												
27/9/16	9:31:31	EPA	#5	611	36	1315	1507	140	31.97069	141.45233	0	M
27/9/16	9:32:14	MQU	#5	798	0	1492	1530	141	31.97069	141.45218	5	M
27/9/16	9:33:50	EPA	#6	629	43	1422	2645	142	31.97075	141.45226	0	M
27/9/16	9:34:51	MQU	#6	2914	91	5610	10106	143	31.97076	141.45213	30	EH
27/9/16	9:35:21	EPA	#7	1001	76	2640	3304	144	31.97081	141.45219	0	MH
27/9/16	9:36:48	MQU	#7	1533	61	2796	2855	145	31.97083	141.45206	20	EH
27/9/16	9:36:51	EPA	#8	829	26	1985	3247	146	31.97087	141.45210	0	M
27/9/16	9:38:37	MQU	#8	964	66	2611	1932	147	31.97088	141.45198	15	M
27/9/16	9:38:22	EPA	#9	1061	31	3947	2671	148	31.97095	141.45204	0	MH
27/9/16	9:40:22	MQU	#9	3416	61	5472	8914	149	31.97950	141.45187	<5	EH
27/9/16	9:40:29	EPA	#10	1185	137	3357	7237	150	31.97102	141.45197	0	MH
27/9/16	9:41:54	MQU	#10	830	0	2365	4869	151	31.97182	141.45067	<5	M
27/9/16	9:44:28	EPA	#11	469	19	1114	1665	152	31.97194	141.45081	0	M
27/9/16	9:45:26	MQU	#11	391	0	1141	2516	153	31.97186	141.45062	0	M
27/9/16	9:45:53	EPA	#12	605	62	2053	5392	154	31.97197	141.45073	10	M
27/9/16	9:47:03	MQU	#12	376	0	1044	2537	155	31.97197	141.45047	0	M
27/9/16	9:47:41	EPA	#13	441	38	1232	1391	156	31.97211	141.45052	5	M
27/9/16	9:49:32	MQU	#13	856	30	1888	2797	157	31.97206	141.45029	5	M
27/9/16	9:49:36	EPA	#14	336	16	852	1498	158	31.97219	141.45041	0	M
27/9/16	9:51:17	MQU	#14	4619	69	8607	9572	159	31.97219	141.45009	0	EH
27/9/16	9:51:38	EPA	#15	1066	51	2250	5885	160	31.97231	141.45018	0	MH
27/9/16	9:53:27	MQU	#15	513	17	1817	1326	161	31.97238	141.44977	100	L
27/9/16	9:54:12	EPA	#16	883	46	1612	2485	162	31.97252	141.44987	0	M
27/9/16	9:55:22	MQU	#16	752	53	1728	541	163	31.97233	141.44965	20	M
27/9/16	9:57:16	EPA	#17	295	38	942	1500	164	31.97141	141.45032	0	L
Unnamed Lane												
27/9/16	10:00:55	EPA	#18	627	34	1031	2304	165	31.97142	141.45033	0	M
27/9/16	10:01:53	MQU	#17	322	30	959	1162	166	31.97144	141.45030	15	M
27/9/16	10:04:34	MQU	#18	568	0	1033	1475	167	31.97148	141.45015	1	M
27/9/16	10:04:35	EPA	#20	301	30	747	1084	168	31.97156	141.45007	5	M
27/9/16	10:06:41	MQU	#19	412	21	775	2096	169	31.97163	141.44995	5	M
27/9/16	10:08:29	MQU	#20	599	17	1454	1574	170	31.97172	141.44981	50	M
27/9/16	10:08:04	EPA	#21	620	53	1341	921	171	31.97182	141.44962	3	M
27/9/16	10:10:43	MQU	#21	2252	86	2627	4204	172	31.97195	141.44939	10	EH
27/9/16	10:10:23	EPA	#22	1961	135	4211	5471	173	31.97044	141.45085	1	VH
Carbon Street												

Streets

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overal Risk
27/9/16	10:16:53	MQU	#22	1023	45	1581	2354	174	31.97031	141.45065	0	MH
27/9/16	10:16:27	EPA	#23	256	34	484	1057	175	31.97056	141.45068	0	L
27/9/16	10:19:25	MQU	#23	139	0	283	733	176	31.97036	141.45056	0	L
27/9/16	10:18:10	EPA	#24	261	27	391	895	177	31.97055	141.45026	0	L
27/9/16	10:20:44	EPA	#25	233	37	336	999	178	31.97078	141.45036	0	L
27/9/16	10:21:49	MQU	#24	302	0	692	1264	179	31.97089	141.45016	0	M
27/9/16	10:23:50	MQU	#25	293	22	616	840	180	31.97080	141.44989	5	L
27/9/16	10:22:46	EPA	#26	194	11	282	680	181	31.97091	141.44969	30	L
27/9/16	10:24:38	EPA	#27	228	27	366	1158	182	31.97110	141.44983	2	L
27/9/16	10:25:59	MQU	#26	127	9	235	508	183	31.97127	141.44955	0	L
27/9/16	10:27:53	MQU	#27	329	0	512	1124	184	31.97112	141.44937	0	M
27/9/16	10:26:34	EPA	#28	74	0	149	925	185	31.97136	141.44893	0	L
27/9/16	10:28:52	EPA	#29	173	9	304	1474	186	31.97136	141.44937	0	L
27/9/16	10:29:43	MQU	#28	260	20	545	1226	187	31.97156	141.44908	0	L
27/9/16	10:31:50	MQU	#29	676	0	1846	5094	188	31.97014	141.45000	10	M
Carbon Lane												
27/9/16	10:38:34	MQU	#30	443	0	701	1150	189	31.97011	141.44997	90	L
27/9/16	10:38:12	EPA	#30	244	38	419	933	190	31.97035	141.44955	81	VL
27/9/16	10:42:08	MQU	#31	1674	92	2406	3163	191	31.97027	141.44963	15	EH
27/9/16	10:41:25	EPA	#31	274	45	814	943	192	31.97045	141.44937	10	L
27/9/16	10:43:39	EPA	#32	796	35	1438	1585	193	31.97049	141.44940	0	M
27/9/16	10:44:31	MQU	#32	660	0	1192	2444	194	31.97062	141.44908	35	M
27/9/16	10:46:17	EPA	#33	773	30	997	3007	195	31.97066	141.44910	5	M
27/9/16	10:47:08	MQU	#33	771	0	1468	1817	196	31.97084	141.44876	10	M
27/9/16	10:48:42	EPA	#34	378	30	751	1342	197	31.97086	141.44878	3	M
27/9/16	10:49:26	MQU	#34	767	23	1246	1890	198	31.97099	141.44858	5	M
27/9/16	10:51:15	MQU	#35	455	0	1982	1436	199	31.97096	141.44856	5	M
27/9/16	10:51:26	EPA	#35	478	41	1032	1975	200	31.96935	141.44974	25	M
Ryan Street												
27/9/16	10:59:01	MQU	#36	600	17	1544	4374	201	31.96951	141.44989	1	M
27/9/16	10:59:32	EPA	#36	390	44	3212	2303	202	31.96951	141.44948	0	M
27/9/16	11:01:44	MQU	#37	191	16	579	3027	203	31.96968	141.44958	0	L
27/9/16	11:00:39	EPA	#37	380	31	3052	2576	204	31.96969	141.44917	60	MH
27/9/16	11:03:53	MQU	#38	462	0	716	620	205	31.96985	141.44936	0	M
27/9/16	11:03:04	EPA	#38	1384	59	3219	10021	206	31.96987	141.44896	0	L
27/9/16	11:06:30	MQU	#39	512	0	808	1921	207	31.97000	141.44910	0	M
27/9/16	11:04:45	EPA	#39	254	0	455	2346	208	31.97004	141.44862	0	L
27/9/16	11:08:37	MQU	#40	234	0	436	2026	209	31.97019	141.44881	0	EH

Streets

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overal Risk
27/9/16	11:06:24	EPA	#40	198	11	794	2183	210	31.97032	141.44861	60	M
27/9/16	11:08:53	EPA	#41	568	27	1055	3236	211	31.97054	141.44824	65	M
27/9/16	11:10:51	EPA	#42	324	0	515	1199	212	31.97039	141.44812	0	MH
27/9/16	11:10:56	MQU	#41	76	0	140	488	213	31.96993	141.44778	5	L
27/9/16	11:49:56	EPA	#50	1179	54	3655	13154	225	31.96950	141.45006	0	MH
27/9/16	11:51:27	MQU	#48	775	28	6318	5424	226	31.96942	141.45000	0	M
27/9/16	11:51:27	EPA	#51	1016	45	2215	1348	227	31.96957	141.45015	0	MH
27/9/16	11:54:08	MQU	#49	1089	0	4836	1915	228	31.96954	141.44998	3	H
27/9/16	11:56:18	MQU	#50	343	34	974	1582	229	31.96954	141.45003	5	M
27/9/16	11:54:32	EPA	#52	845	37	3156	1956	230	31.97157	141.45296	10	M
Sampson Street												
27/9/16	11:18:10	MQU	#42	207	0	432	723	214	31.96979	141.44781	50	L
27/9/16	11:12:38	EPA	#43	1495	99	4103	8426	215	31.96981	141.44797	0	L
27/9/16	11:39:06	MQU	#43	365	0	719	973	216	31.96963	141.44800	0	M
27/9/16	11:38:15	EPA	#45	763	108	1117	1642	217	31.96971	141.44810	60	M
27/9/16	11:41:27	MQU	#44	246	0	421	826	218	31.96945	141.44835	85	L
27/9/16	11:41:07	EPA	#46	94	5.7	124	642	219	31.96955	141.44839	45	L
27/9/16	11:43:15	MQU	#45	189	0	253	625	220	31.96926	141.44868	0	L
27/9/16	11:43:14	EPA	#47	457	25	574	592	221	31.96938	141.44856	20	M
27/9/16	11:45:07	MQU	#46	240	21	686	1062	222	31.96913	141.44904	0	L
27/9/16	11:45:59	EPA	#49	1157	100	1698	2152	223	31.96899	141.44934	10	MH
27/9/16	11:47:47	MQU	#47	795	0	1225	2912	224	31.96938	141.44994	50	M

Block 10 Flat

Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
27/9/16	14:44:29	EPA	#56	2058	90	3087	3796	231	31.9715	141.45316	0	EH
27/9/16	14:46:22	MQU	#59	1652	0	2995	4221	232	31.97139	141.45331	1	EH
27/9/16	14:48:09	EPA	#57	2071	204	4206	3623	233	31.97129	141.45341	0	EH
27/9/16	14:49:42	MQU	#60	903	31	3476	2725	234	31.97116	141.45349	0	M
27/9/16	14:50:21	EPA	#58	124	0	301	787	235	31.97106	141.45355	0	L
27/9/16	14:51:49	MQU	#61	3309	106	10851	17881	236	31.97086	141.45363	2	EH
27/9/16	14:52:30	EPA	#59	3362	157	14083	19517	237	31.97069	141.45372	20	EH
27/9/16	14:54:29	MQU	#62	4591	95	13828	12201	238	31.97054	141.45381	5	EH
27/9/16	14:54:33	EPA	#60	2393	145	5372	6391	239	31.96985	141.45412	10	EH
27/9/16	14:58:38	MQU	#63	1360	59	3636	18540	240	31.96942	141.45470	0	H
27/9/16	15:01:50	MQU	#64	2466	75	9153	11867	241	31.96941	141.45505	0	EH
27/9/16	15:00:24	EPA	#61	4796	219	7181	8759	242	31.96931	141.45473	0	EH
27/9/16	15:04:16	MQU	#65	9480	0	22258	22763	243	31.96927	141.45511	0	EH
27/9/16	15:03:37	EPA	#62	2553	115	5216	6458	244	31.96917	141.45482	0	EH
27/9/16	15:06:21	MQU	#66	7907	0	13722	6662	245	31.96912	141.45520	0	EH
27/9/16	15:05:54	EPA	#63	3354	312	2368	2386	246	31.96900	141.45496	0	EH
27/9/16	15:08:51	MQU	#67	1525 1	266	23053	13149	247	31.96899	141.45525	0	EH
27/9/16	15:07:57	EPA	#64	960	21	1141	611	248	31.96873	141.45543	0	M
27/9/16	15:12:16	EPA	#65	4833	470	3367	5291	249	31.96885	141.45505	30	EH
27/9/16	15:11:00	MQU	#68	1780	28	2347	4391	250	31.96872	141.45511	1	EH
27/9/16	15:12:55	MQU	#69	1799	0	2862	6815	251	31.96860	141.45520	1	EH
27/9/16	15:14:49	MQU	#70	2532	0	2845	7669	252	31.96852	141.45558	1	EH
27/9/16	15:15:13	EPA	#66	2370	253	1381	3173	253	31.96842	141.45535	0	VH
27/9/16	15:29:30	MQU	#72	4049	57	5013	6246	254	31.96843	141.45563	1	EH
27/9/16	15:17:28	EPA	#67	1554	145	13578	9169	255	31.96834	141.45567	0	VH
27/9/16	15:20:38	EPA	#68	2019 9	2249	2952	4838	256	31.96822	141.45570	0	EH
27/9/16	15:22:35	EPA	#69	1350	164	2316	3464	257	31.96804	141.45578	40	MH
27/9/16	15:24:54	EPA	#70	2441	131	4309	2819	258	31.96775	141.45584	50	VH
27/9/16	15:30:00	EPA	#72	863	129	1528	1838	259	31.96789	141.45580	10	M
27/9/16	15:27:09	EPA	#71	1880	72	3254	5733	260	31.96813	141.45549	10	VH
27/9/16	15:34:55	MQU	#74	2334	0	4450	8385	261	31.96829	141.45544	0	EH
27/9/16	15:32:44	MQU	#73	4197	91	6539	8899	262	31.96801	141.45561	0	EH
27/9/16	15:36:51	MQU	#75	1888	0	3572	6521	263	31.96769	141.45572	1	EH
27/9/16	15:40:03	MQU	#76	592	20	2210	3105	329			20	M
27/9/16	15:48:12	MQU	#77	867	0	1676	3780	264	31.96755	141.45576	15	M
27/9/16	15:52:11	MQU	#78	552	55	1394	2112	265	31.9675	141.45598	30	M
27/9/16	15:38:48	EPA	#73	734	22	458	2030	330			40	M

Block 10 Flat												
Sample Info				Elements				GPS			Other	
Date	Time	XRF	Reading No.	Pb	As	Zn	Mn	Way-point ID	S	E	Vege Cover	Overall Risk
27/9/16	15:52:11	EPA	#74	381	56	1415	1911	266	31.96737	141.45596	30	M
27/9/16	15:56:53	EPA	#75	1080	80	1775	2880	267	31.96764	141.45502	5	MH
27/9/16	15:54:42	MQU	#79	1541	96	3632	3363	331			1	EH
27/9/16	16:02:12	EPA	#76	5047	294	27170	23424	268	31.96775	141.45496	0	EH
27/9/16	16:03:58	EPA	#77	2876	89	54513	12417	269	31.96786	141.45488	0	EH
27/9/16	16:07:13	EPA	#78	1380	75	4172	2851	270	31.96796	141.45480	0	MH
27/9/16	16:09:39	EPA	#79	970	70	2013	1627	271	31.96817	141.45467	0	M
27/9/16	16:11:58	EPA	#80	6105	280	33980	17435	272	31.96821	141.45465	5	EH
27/9/16	16:13:50	EPA	#81	357	0	233844	44121	273	31.96829	141.45461	0	M
27/9/16	16:17:00	EPA	#83	2376	157	18843	4053	274	31.96933	141.45412	0	VH
27/9/16	16:22:36	EPA	#85	9681	0	41786	19411	275	31.96941	141.45407	0	EH
27/9/16	16:24:19	EPA	#86	1055 5	768	26620	13855	276	31.96950	141.45398	0	EH
27/9/16	16:26:59	EPA	#87	3192	246	4714	5310	277	31.96958	141.45396	0	EH
27/9/16	16:29:15	EPA	#88	8238	249	32124	25714	278	31.96924	141.45392	0	EH
27/9/16	16:31:02	MQU	#80	163	0	383	1343	279	31.96986	141.45393	0	L
42640	0.68833 3333	EPA	#89	3880	246	8362	12150	280	31.96944	141.45386	0	EH
27/9/16	16:33:13	MQU	#81	814	0	1594	3600	281	31.96981	141.45389	0	M
27/9/16	16:33:25	EPA	#90	1101 9	238	39701	17873	282	31.96982	141.45383	0	EH
27/9/16	16:34:51	EPA	#91	2277	81	4550	7958	283	31.96953	141.45370	0	VH
27/9/16	16:34:54	MQU	#82	1352	49	2721	6155	284	31.96956	141.45366	0	H
27/9/16	16:36:49	MQU	#83	556	35	1169	2849	285	31.96992	141.45390	0	M
27/9/16	16:37:11	EPA	#92	5235	305	20129	14160	286	31.96967	141.45352	0	EH
27/9/16	16:38:36	MQU	#84	816	18	2085	3071	287	31.97004	141.45370	0	M
27/9/16	16:39:09	EPA	#93	1547	0	93423	14971	288	31.96984	141.45340	0	VH
27/9/16	16:40:23	MQU	#85	606	19	1363	2643	289	31.97023	141.45367	0	M
27/9/16	16:41:15	EPA	#94	3441	208	10669	7410	290	31.97008	141.45340	0	EH
27/9/16	16:41:59	MQU	#86	1790	68	4058	3837	291	31.97032	141.45361	5	EH
27/9/16	16:43:31	EPA	#95	8517	472	49169	19653	292	31.97016	141.45328	0	EH
27/9/16	16:43:48	MQU	#87	596	0	1273	956	293	31.97061	141.45349	0	M
27/9/16	16:45:49	EPA	#96	6533	606	18306	14270	294	31.97029	141.45325	0	EH
27/9/16	16:46:36	MQU	#88	5173	0	177067	28275	295	31.97076	141.45335	0	EH
27/9/16	16:48:58	EPA	#97	4483	300	11680	5851	296	31.97031	141.45311	0	EH
27/9/16	16:48:23	MQU	#89	760	0	16759	1998	297	31.97061	141.45305	0	M
27/9/16	16:51:10	MQU	#90	4631	107	18107	10099	298	31.97061	141.45312	1	EH
27/9/16	16:51:30	EPA	#98	1985	130	5566	9749	299	31.97076	141.45297	0	VH
27/9/16	16:53:46	MQU	#91	4086	0	7282	6355	300	31.96763	141.44926	0	EH

Appendix 5 – Fridge Magnet Design

The Lead Ted fridge magnet was produced to raise lead risk awareness and to remind people, including children, to wash their hands before eating. This reduces the intake of lead from dust on hands, gained from playgrounds and other outdoor activity.

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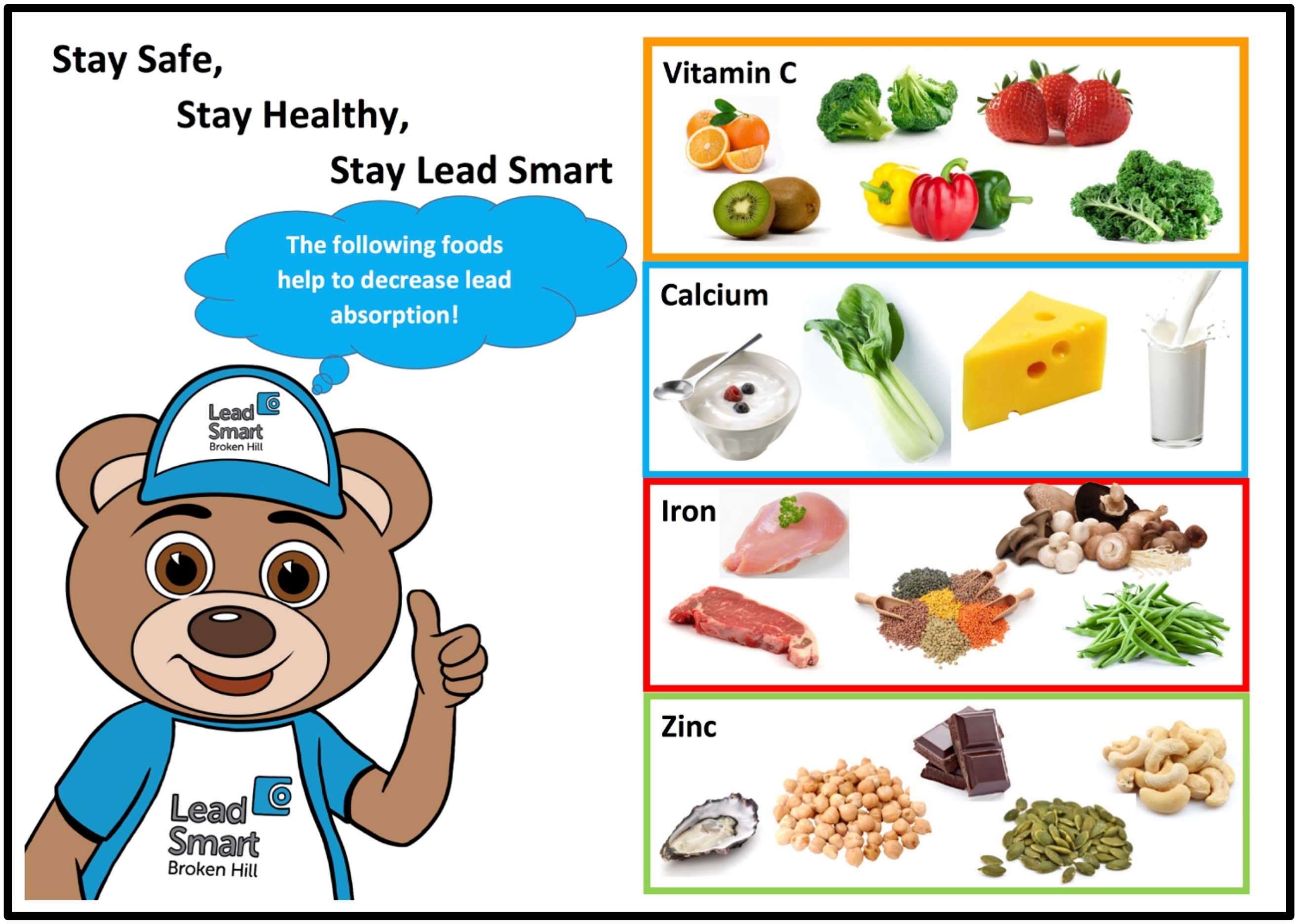
Appendix 6 – Lead Safe Foods Flyer

Studies have shown that there is a connection between dietary intake and blood lead levels. Results suggest zinc helps decrease the absorption of lead by reducing the amount of lead deposited in the bones along with resorption (The LEAD Group., 2010).



Appendix 7 – Lead Safe Communities Flyer

Lead Smart

How can we be Lead Smart?

Lead is not beneficial to human health and everyone in the community plays a part in Lead Smart practices.

Avoiding contact with lead by washing hands and keeping surfaces clean are necessary to avoid lead ingestion. In addition, avoiding spreading lead around in homes, workplaces and the wider community will help keep others Lead Safe.

Health Impacts

Children

Lead is a toxic heavy metal that can have significant physiological and neurological effects on humans, even at low levels.

Young children are particularly vulnerable to the adverse impacts of lead as their brains and nervous system are still developing.

Adults

There are adverse effects on cognitive function in children with low blood lead levels, and these may persist into adulthood and be irreversible.

Sources and Pathways of Lead

Lead in soil and dust, and lead-based paint are the primary sources of lead. In Broken Hill, mining produces air pollution containing lead which contaminates the soil and dust.

This is a long-term source of exposure, unless it is deliberately removed or covered over, as it does not biodegrade or decay.

Lead from the soil and dust, and lead-based paint can easily be ingested or inhaled if in the air or present on hands or food.

Who is Vulnerable to Lead?

The health effects of lead depend on a person's age, blood lead level and the amount of time they have been exposed to the toxic effects of lead.

Lead can have adverse health impacts on everyone. However, children, pregnant women and women of child bearing are more vulnerable to the harmful effects of lead.

Lead Smart
Broken Hill Lead Management Program

Appendix 8 – Lead Safe Recipes Flyer Template

Did you know that a diet high in iron, calcium, vitamin C and zinc can help to reduce the concentration of lead in the body?

Keep your family lead smart with this healthy recipe!

Broccoli & peas with a sesame dressing

Ingredients

1 tbsp sesame seeds, lightly toasted

1 tsp poppy seeds

1 head of broccoli, cut into florets

100g frozen peas

For the dressing

1 tbsp soy sauce

1tsp clear honey

¼ tsp sesame oil

Method

1. To make the dressing, mix the soy, honey and sesame oil together. Boil the broccoli and peas for 2 mins, then drain.
2. Tip the broccoli and peas back in the pan, pour half the dressing and half the seeds over, and shake for a few sec. Serve sprinkled with the remaining seeds and dressing.

Appendix 9 – Lead Safe Signs

We have designed signage for a multiple purposes including hand washing stations and warning signs for fenced off areas.

The hand washing station sign is designed for use in playgrounds to remind people to wash their hands after using the equipment.

We also designed a number of potential signs for fenced off areas, designed to alert people to why the area is fenced off, and to stay away from it. We have designed samples both with and without the Lead Ted branding.


CAUTION
Stay safe with LeadTed
Lead Smart Broken Hill
Lead contaminated area beyond