New Zealand Transport Agency

Te Onewa Point

Human Health Risk Assessment

August 2013

Executive summary

GHD was engaged by New Zealand Traffic Authority (NZTA) to undertake a health risk assessment for residential properties adjacent to the northern approach to Auckland Harbour Bridge (Te Onewa).

At Erin Point (the southern approach to the Auckland Harbour Bridge) soil investigations identified elevated concentrations of lead, copper and zinc in near surface soil samples collected from some locations, likely to be attributed to bridge maintenance activities (paint stripping). Historically lead was a common constituent in paint, and also in leaded fuels. Zinc and copper are still common components in paint.

Given the identified presence of contaminants in near surface soils on land adjacent to the southern approach to the harbour bridge, NZTA wished to evaluate the risks related to soil quality in residential properties adjacent to the northern approach to the bridge (Te Onewa).

NZTA has decided to undertake a review of existing information and soil data for Te Onewa area. This Human Health Risk Assessment (HHRA) for a residential land use scenario uses existing soil quality data from Te Onewa Reserve and soil quality data obtained by Opus that has been generated for NZTA bridge consent compliance monitoring.

The risk assessment has considered the potential effects on beneficial uses of land in the study area, and has particularly considered:

- The risks to residents within the study area from exposure to lead in soil resulting from deposition from operation and maintenance activities of the Auckland Harbour Bridge (AHB).
- Soil measurements have not been taken from within residential properties at Stokes Point. Therefore extrapolation of soil data from other locations close to the AHB has been selected as representative. These study areas are:
  - Corridor sites located on the southern approach of Auckland Harbour Bridge (GHD, 2012);
  - Stokes Point – Green Belt, south of residents (Opus, 2010); and
  - Stokes Point Reserve (T&T, 2011).

The important findings of this assessment were:

- A comparison of measured soil concentrations in three different study areas around the AHB indicated that lead is likely the only contaminant related to the AHB operation and maintenance activities which exceed the NZ NES soil guideline value.
- Other chemicals were found to exceed the NZ NES soil guideline values but these chemicals were likely from sources other than from AHB. These include PAHs, arsenic and cadmium.
- The USEPA lead biokinetics model (IEUBK) is used world-wide for assessing human health risks from lead exposure, particularly for children. The model estimates the blood lead level from lead exposure, and has been used in this assessment.
- In light that the NZ toxicological reference value for lead has halved and so has the recommended blood lead level as recommended by the US CDC, these two end points may be considered analogous to the findings of JECFA and the withdrawal of the old PTWI for lead.

- The acceptable blood lead level has been set at 5 µg/dL for the purposes of deriving a human health based soil criterion for residential land.
- The derived lead soil criterion for standard residential land (10% homegrown produce) was 500 mg/kg.
- Comparison of the derived criterion with the soil analytical results from the three studies indicates that the maximum reported lead concentration of 890 mg/kg is less than a factor of 2 above the derived criterion, and only 6 out of the total of 210 samples exceeded this criterion, This indicates that while there may be a few exceptions, the majority of the residential properties would likely be below the derived soil criterion for lead and therefore within acceptable health risk.
- As there has been no actual investigation within the residential properties, there is significant high uncertainty with respect to the results of this assessment. These include:
  - Extrapolation of data from other study areas to represent the residential properties;
  - No bioavailability testing of lead in soil has been undertaken in any of the studies;
  - No inspection of residential properties to determine the level of homegrown produce consumed at residential properties;
  - Contaminated fill was identified at Stokes Point Reserve, likely imported, and is possible that this fill is also present at the residential properties.

Based on the outcomes of the modelling and soil data obtained during the course of the investigations, the following recommendations are considered appropriate:

- Additional sampling in areas nearby the residential properties should be undertaken to further characterise the levels of contamination in soils;
- Bioavailability testing of lead should be considered for a number of soil samples to validate the bioavailability assumptions in this report;
- The health risk assessment should be reviewed and revised if required, once additional soil testing has been undertaken.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.4 and the assumptions and qualifications contained throughout the Report.

Glossary

AHB	Auckland Harbour Bridge
ANZECC	Australia and New Zealand Environment Conservation Council
ATSDR	Agency for Toxic Substances and Disease Registry
CDC	(US) Centers for Disease Control and Prevention
COPC	Chemicals of Potential Concern
DHHS	(US) Department of Health Services
FAO	Food and Agriculture Organisation
HHRA	Human Health Risk Assessment
IARC	International Agency for Research on Cancer
IEUBK	Integrated Exposure Uptake Biokinetic Model
JECFA	Joint FAO/WHO Expert Committee on Food Additives
NEPC	(Australia) National Environment Protection Council
NES	National Environment Standard
NHMRC	(Australia) National Health and Medical Research Council
NZTA	New Zealand Traffic Authority
PAH	Polycyclic Aromatic Hydrocarbon
PTWI	Provisional Tolerable Weekly Intake
USEPA	United States Environment Protection Agency
WHO	World Health Organisation

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1. Introduction

1.1 Background

GHD was engaged by New Zealand Transport Agency (NZTA) to undertake a health risk assessment for residential properties adjacent to the northern approach to Auckland Harbour Bridge (Te Onewa).

At Erin Point (the southern approach to the Auckland Harbour Bridge) soil investigations identified elevated concentrations of lead, copper and zinc in near surface soil samples collected from some locations, likely to be attributed to bridge maintenance activities (paint stripping). Historically lead was a common constituent in paint, and also in leaded fuels. Zinc and copper are still common components in paint.

Given the identified presence of contaminants in near surface soils on land adjacent to the southern approach to the harbour bridge, NZTA wished to evaluate the risks related to soil quality in residential properties adjacent to the northern approach to the bridge (Te Onewa).

NZTA commissioned GHD to undertake a review of existing information and soil data for Te Onewa area, adjacent to the Northern approach to Auckland Harbour Bridge. This Human Health Risk Assessment (HHRA) for a residential land use scenario uses existing soil quality data from Te Onewa Reserve and soil quality data obtained by Opus that has been generated for NZTA bridge consent compliance monitoring.

1.2 Purpose of this report

The purpose of this report is to:

- Assess potential risks to human health in the context of residential land use using existing soil quality data for Te Onewa reserve and other nearby study areas;
- Provide NZTA with information required to inform their decisions regarding the study area.

1.3 Scope of work

The following scope of work was proposed to undertake a health risk assessment for the study area:

- Review of available documentation including available investigation reports on study areas nearby;
- Undertake a Tier 1 screening assessment to identify contaminants of potential concern;
- Develop / refine a conceptual site model for the study area;
- Review of toxicological information for chemicals of potential concern;
- Assessment of exposure and estimation of chemical intake levels;
- Development health-based soil criteria for the chemicals of potential concern.

This work has been undertaken in conjunction with the report, *Te Onewa Point, Preliminary Site Investigation Report,* GHD, July 2013.

1.4 Limitations

This report has been prepared by GHD for NZTA and may only be used and relied on by NZTA for the purpose agreed between GHD and the NZTA as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than NZTA arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s). of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by NZTA and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

1.5 Assumptions

The methodology was developed with consideration given to the following assumptions:

- Information obtained from third parties and NZTA is complete and accurate.
- The observations made during the investigation are representative of the activities that have or are occurring on-site.
- The observable and inferred site condition is representative of the actual site condition.
- The soil quality data taken from nearby areas are representative of the study.

2. Hazard identification

Detailed information on site history and characterisation are presented in the Preliminary Site Investigation Report by GHD. The following sections are summaries of this information.

2.1 Site Location

The study area has been identified as the land adjacent aerial portions of the north landing of the Auckland Harbour Bridge, shown in Figure 1, below.

The area was delineated for the purposed of the current study by including an area of at least 55 meters, ‘as the crow flies’ from property boundary to the nearest point on the AHB.

Figure 1 Study area

2.2 Site History

Te Onewa Point is a historic headland Pa site and a number of archaeological features associated with the Pa are still visible including shell middens and a Maori trench.

More recently the site was used as a transport hub with both vehicular and ferry traffic. The first hotel to service the traffic in the area was built in the late 1850's. The surrounding land was largely developed for residential use by the end of the 19th Century.

The 1.2 km long AHB was opened in 1959. The bridge is an eight lane road bridge, comprising:

- the original four lane truss structure (completed in 1959);
- a four lane cantilever structure (clip-ons attached in 1969); and
- a central middle navigation span.

The central navigation span is 243 meters long with a height clearance of 43 meters for marine traffic.

2.3 Land Use

The study area includes a mixture of private and public land. Private land uses include residential and home businesses. Public land use includes bulk parking and recreational spaces. The following table describes the surrounding land uses:

Table 1 Summary of Land Uses Surrounding the Study Area

Direction	Land Use
North	Residential, small commercial and recreational land uses
South	Northcote Reserve and Waitemata Harbour
East	Stokes Point dry-dock and Waitemata Harbour
West	Northcote reserve, Northcote Point Ferry Terminal, and Waitemata Harbour

2.4 Zoning

The study area includes a mix of zones under the North Shore City District Plan[1] and includes:

- Recreation Zone 1 – Conservation
- Recreation Zone 2 – Neighbourhood Activities
- Residential Zone 3 – Built Heritage (Including subzones B and C relating to housing density)

2.5 AHB Operation and Maintenance

2.5.1 Operation

The daily average of vehicles crossing the AHB is estimated currently to be between 165,000 to 200,000 vehicles (NZTA 2013).

Contaminated traffic residues originate primarily from vehicle leaks and spillages as well as wear from exhausts, brake pads and tyres. Contaminants include Total Petroleum Hydrocarbons (TPH) (such as PAHs including BaP) and heavy metals, including copper, cadmium, lead and zinc (Kennedy and Sutherland 2008). Lead may also be present as a legacy of the use of leaded petrol.

[1] Auckland Council District Plan (north shore section) 2002

2.5.2 Maintenance

In a highly corrosive marine environment the structural integrity and the preservation of surface integrity of the bridge is paramount. The maintenance of the AHB can lead to contaminants being released as a result of:

- Surface preparation and cleaning;
- Painting; and
- Road repairs.

Sand abrasive blasting and water blasting are used to prepare steelwork for painting by removing old paintwork or any surface dirt, including traffic residues (TBS 2010).

Material and product use for maintenance activities have changed over the life of the bridge (e.g. type of paints including lead based), however, these past products remain as potential current and future contaminants. Historic paint materials of the AHB include lead based and zinc chromate paints. These materials contain heavy metal contaminants; predominantly zinc, lead and chromium (TBS 2010).

Bridge painting is the most common maintenance activity, occurring on a continual basis. Paint is applied using either a spray or by painting on with a brush. Painting activities include spray painting and treatment of paint surfaces with primers. Known materials used both historically and currently are listed in Table 5, below.

Table 2 Known Historic and Current Materials

Product Type	Key Ingredients of concern	Product Use	Historic or Current Usage
Altex Rust Barrier	Zinc	Spray painting the inside of the box girders (full containment)	Historic
Lead based and zinc chromate paints	Zinc, lead, chromium	Painting the bridge	Historic
MC 175 Thinners	*unknown*	Thinning paint and cleaning the lines	Historic
MC Zinc	Zinc, Xylenes	Painting the bridge – primer coat	Current
Wasser Miomastic	Zinc, Titanium oxide, Xylenes	Painting the bridge – intermediate coat	Current
MC Ferrox A	Isophorone diisocyanate, titanium oxide, xylenes.	Painting the bridge – top coat	Current
Spent Garnet Sand	-[2]	Blasting	Current

2.6 Previous Investigation Reports

2.6.1 Investigation of Soil Contamination at Three Auckland State Highway Corridor Sites (GHD, 2012)

NZTA commissioned GHD to undertake investigations of contaminants in soil potentially associated with aerial dispersion from three elevated sections of the State Highway Transport

[2] Garnet sand itself if not considered to be contaminated. However spend garnet sand is likely to be contaminated with the some of the other contaminants listed.

Corridor. These sites included Point Erin, on the southern approach to the Auckland Harbour Bridge. The information contained in this report which related to Point Erin, on the southern approach to the AHB was considered to be particularly relevant to the current assessment.

The investigations involved the collection of shallow (<100mm) soil samples. Results obtained were compared against the appropriate acceptance criteria for that site; Soil NES[3] contaminant standards for the protection of human health in the context of '*recreational land* use'. For this reason the conclusions described as a result of soil analysis on the southern approach are not directly relevant to the current investigation on the northern approach.

However, taking the Point Erin results and assessing them against the Soil NES standards for '*residential areas with 10% produce consumption'*, would result in exceedances being recorded for arsenic in 3 out of 11 samples analysed and for lead in 5 out of 11 samples analysed.

Linear regression analysis carried out by GHD on the results from testing carried out at Point Erin indicated that concentration distribution of copper and lead may be related. While Poly Aromatic Hydrocarbons (PAH's) were recorded in all samples at above the laboratory detection limits, levels were generally low. The results recorded for benzo(a)pyrene (BaP)TEQ were within the limits of the Soil NES standards for '*residential areas with 10% produce consumption'*.

The study found that in general, contaminant distribution at Point Erin appeared to be isolated to relatively discrete contaminant 'hotspots' which were located up to 50 meters from the motorway. The location of these hotspots tended to correlate with the prevailing wind direction.

2.6.2 AHB Maintenance Consent Renewal – Stokes Point Soil Sampling (Opus 2010)

The reports presents the results of a study carried out to support the Assessment of Environmental Effects (AEE) for the maintenance works discharge consent renewal. The investigation involved testing 20 soil samples for the presence of heavy metals. Seven of these samples were also tested for Total Petroleum Hydrocarbons) TPH, PAH and BTEX compounds[4].

Soil sampling was only carried out to 0.1m BGL due to the presence of historic features associated with the historic Pa site. Sampling locations are shown in **Figure 2**, below and were carried out in publicly available areas only. Sampling had been carried out in August 2010 and the report states that no abrasive sand blasting had been carried out in the previous 12 months, therefore the results were not considered to represent a 'worst-case scenario'.

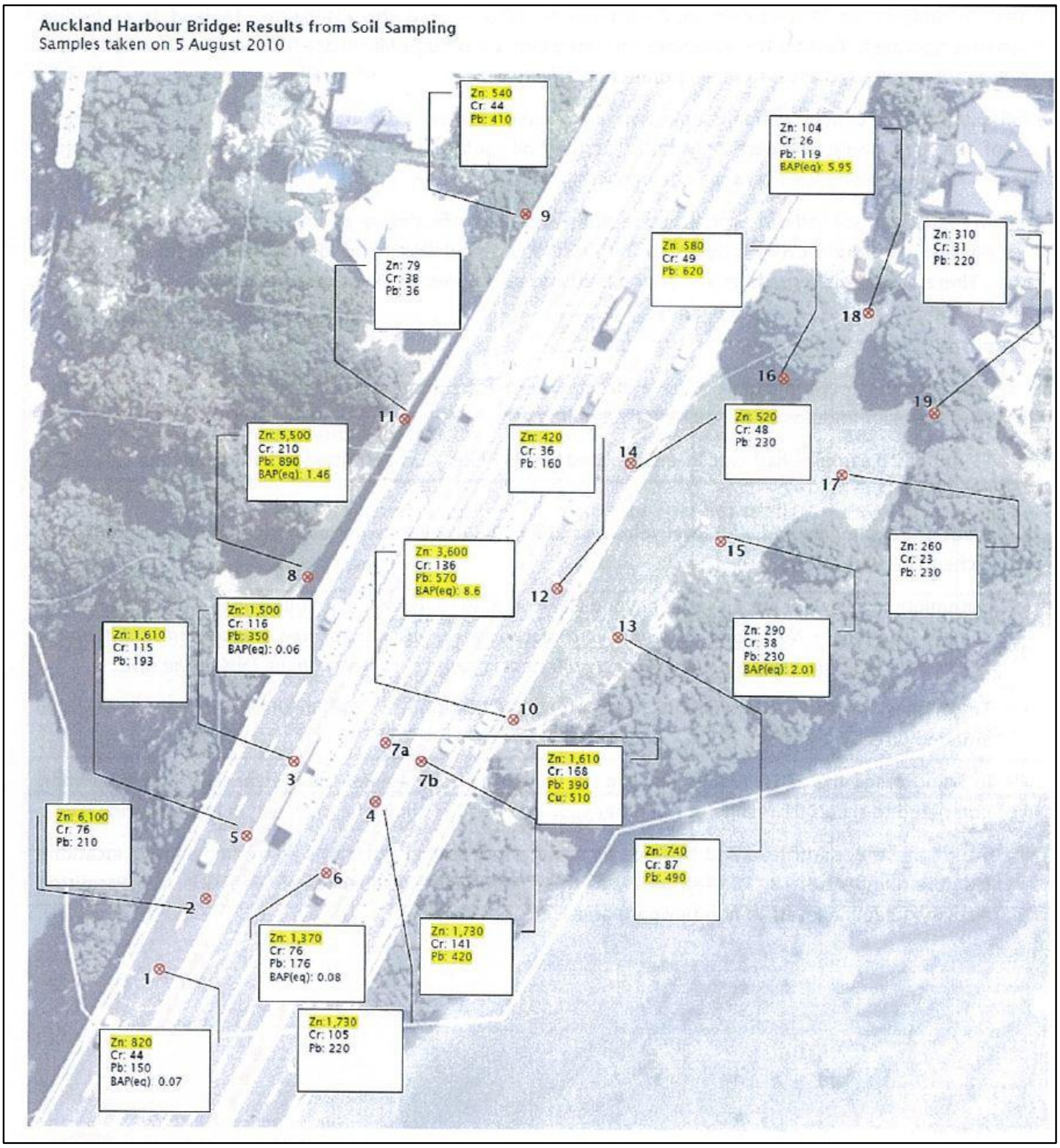
Results were compared against permitted activity criteria for contaminant levels in soil in the Proposed Auckland Regional Plan: Air, Land and Water (2010) (PARP:ALW)[5].

The main findings of the study were:

- 15 out of 20 samples had zinc levels elevated above PARP:ALW permitted activity guidelines;
- 8 out of 20 samples had lead levels elevated above PARP:ALW permitted activity guidelines;
- Chromium levels were not elevated beyond PARP:ALW permitted activity levels at any of the sample locations

[3] Soil NES Standards applies to assessing and managing the actual or potential adverse effects of contaminants in soil on human health
[4] BTEX is an acronym that stands for benzene, toluene, ethylbenzene, and xylenes. These compounds are some of the volatile organic compounds.
[5] The Proposed Auckland Regional Plan: Air, Land, Water permitted activity criteria apply to historical land uses only and relate to the discharge of contaminants to land or to water from land

- The highest levels of contaminants were found on the point of the Stokes Point Reserve which is situated directly under the AHB;
- In some cases, the 2010 results showed an increase in the contaminant levels for lead and zinc when compared to the 2001 results but in other cases the results showed a decrease in lead and zinc levels; and
- The highest levels of lead and hydrocarbons were in overland flowpaths (Figure 4, samples 8, 12, 16, 18) although there were lead exceedances above PARP:ALW permitted activity levels in non-flowpath areas.



Extract from Opus, 2010

Figure 2 Sampling locations used in 2010 investigation

2.6.3 Stokes Point Reserve, Northcote Soil Contamination – Human Health Risk Assessment (Tonkin & Taylor 2011)

This report was an updated version of the human health risk assessment for soil contamination at the Stokes Point Reserve. The report was intended to take into account the low usage rate of the reserve and to provide a more realistic understanding of the actual risk and the need for remediation works.

Soil sampling was carried out in February 2011 at locations shown in Figure 5, below. 49 soil samples were analysed. The report does not at what depth soil samples were taken but at least one sample was taken at 0.5m BGL. Results were compared against PARP:ALW and NES Soil criteria. NES Criteria for 'Recreation' were selected for this comparison, this criteria sets a lower standard than 'Residential 10% produce'. The potential adverse effects of PAH's were considered by calculating the Benzo(a)pyrene equivalent concentration (BaP eq.).

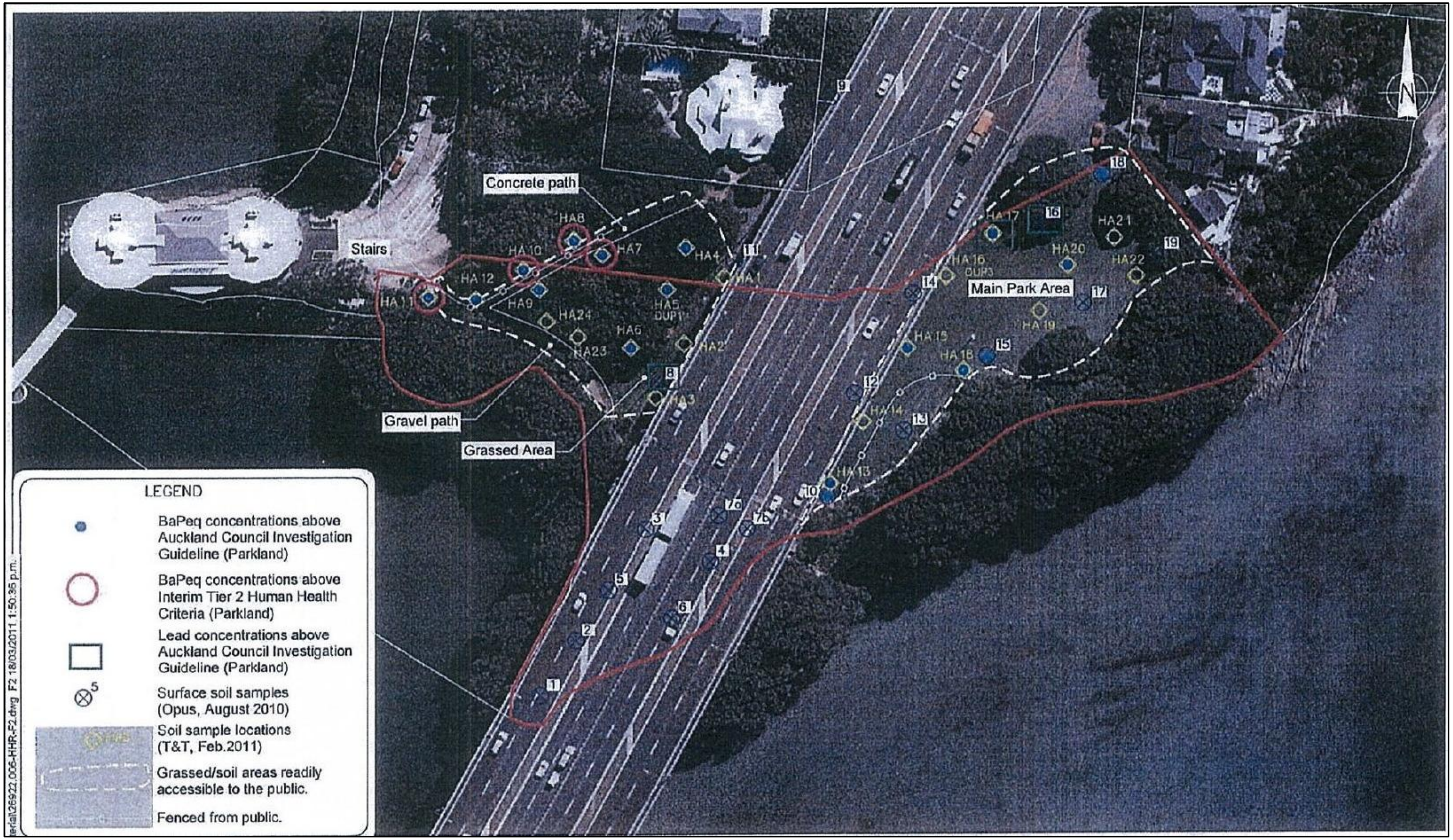
The following exceedances were found:

- 26 of 49 samples with BaP eq. concentrations between 2mg/kg and 83mg/kg, which exceed PARP:ALW permitted activity criteria of 2.15 mg/kg.
- 2 of the 49 samples had BaP eq. concentrations of 46mg/kg and 83mg/kg above Soil NES contaminant standards of 40mg/kg [however in residential scenarios with 10% produce consumption the BaP limit is 10mg/kg]; and
- All lead tests results are below the Soil NES contaminant value of 880mg/kg [however in residential scenarios with 10% produce consumption the lead limit is 210mg/kg].

In the context of the objectives of the assessment, the report found that lead and carcinogenic PAH's (measured as BaP eq.) were the contaminants of concern at the Stokes Point Reserve. A Human Health Risk Assessment was undertaken to evaluate the potential of adverse impacts on human health from residual lead and BaP eq. concentrations.

The report detailed measures carried out in June and July 2011 to isolate contaminated soils beneath a barrier system which was installed along both sides of the footpath. The objective of the barrier system was to prevent park users accessing contaminated soil by capping it with a combined geo-grid and geotextile layer and a 100mm layer of mulch.

Evaluation of the risk assessed against those standards applicable in New Zealand indicated that as a whole, contaminant levels do not pose and unacceptable risk to human health.



Extract from Tonkin & Taylor, 2011

Figure 3 Sampling locations used in 2011 investigation

3. Conceptual Site Model

3.1 Overview

For an exposure to occur, a complete pathway must exist between the source of contamination and the receptor. Where the exposure pathway is incomplete, there is no exposure, and hence no risk. An exposure pathway consists of the following elements:

- Source (eg spills);
- Release mechanism (eg leaching, volatilisation);
- Transport media (eg soil, groundwater, surface water, air);
- Exposure point, where the receptor comes in contact with the contamination (eg groundwater from an extraction bore, or soil under existing building); and
- Exposure route (eg inhalation, ingestion, dermal contact).

Where the pathway for a chemical from the source to the receptor is incomplete, there is no incremental risk due to the presence of contamination. A review of the possible exposure pathways has been undertaken for all receptors as part of the Conceptual Site Model (CSM).

3.2 Source-Pathway-Receptor

The key source-pathway-receptor linkages are described in **Figure 4**, below.

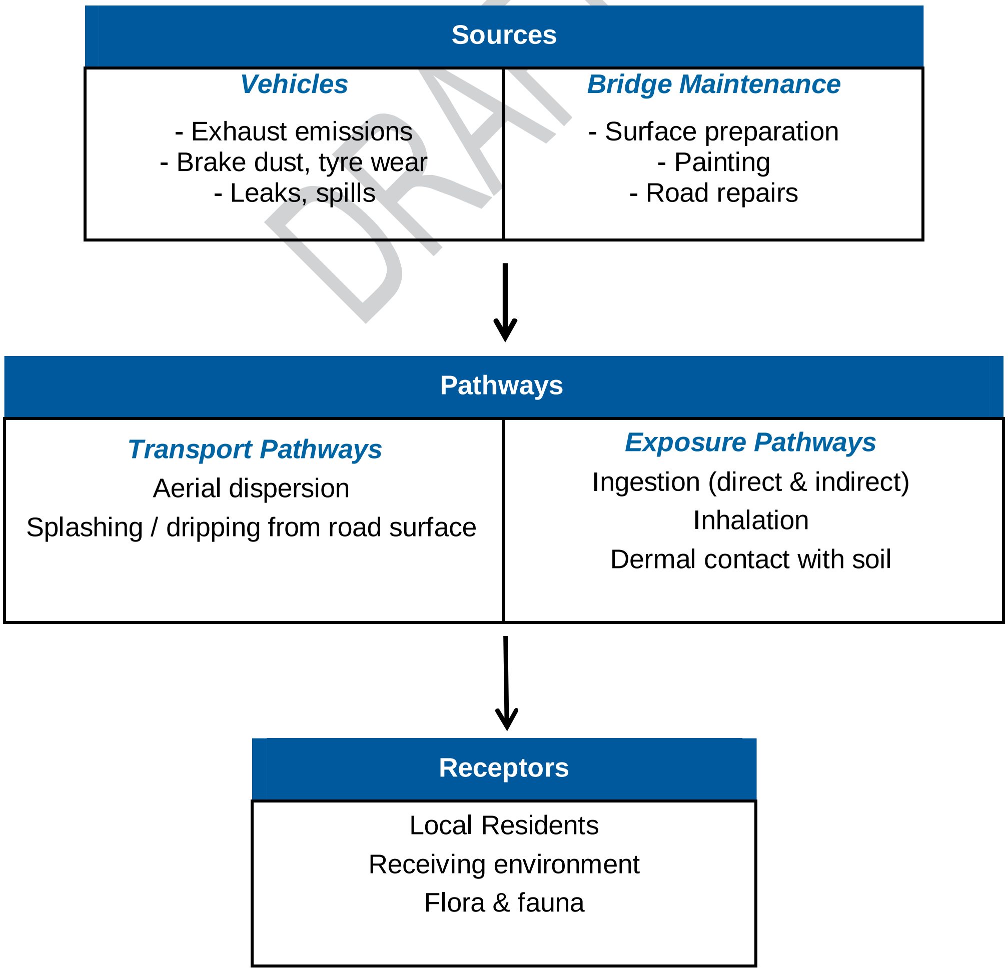


Figure 4 Source-Pathway-Receptor linkages

3.3 Exposure Pathways

The key exposure pathways are depicted in **Figure 5**, and are described in more detail in **Table 3**.

Table 3 Significance of exposure pathways

Exposure Pathway	Significance
Ingestion of Soil/Dust	Ingestion of soil and dust is the most significant exposure route for non-volatile chemicals, and is generally responsible for over 90% of the human health risks for non-volatile chemicals.
Dermal contact with soil/dust	Dermal contact with soils/dust is generally insignificant for most metals, but is a significant pathway for PAHs, which can readily absorb through the skin.
Inhalation of dust	Inhalation of dust is generally insignificant with regards to toxicity when compared to oral and dermal pathways, resulting in less than 1 % of the total risk. Inhalation of particulate matter (PM_{10} and $PM_{2.5}$) can be a significant risk contributor, however this study focuses on contaminated land, and there has not been an air quality assessment undertaken at the study area.
Inhalation of vapours	Volatile chemicals have not been identified in soil in the study area and therefore unlikely to pose a significant risk to local receptors. Inhalation of vapours from car fumes (BTEX) can be a significant risk contributor, however this study focuses on contaminated land, and there has not been an air quality assessment undertaken at the study area.
Uptake and consumption of contamination by fruit and vegetables	Based on visual inspection of properties in the study area, it is unlikely that any residential property contains significant produce gardens for homegrown produce consumption. For small gardens where residents consume homegrown produce which make up no more than 10% of their diet, health risks from uptake and consumption are generally low. Only a select number of chemicals are known to have strong uptake in plants/fruits/vegetables.
Uptake and consumption of contamination by livestock and eggs	Only a select number of chemicals are known to have strong uptake in animal products and eggs. Generally the health risks are quite low in comparison to direct consumption of soil.

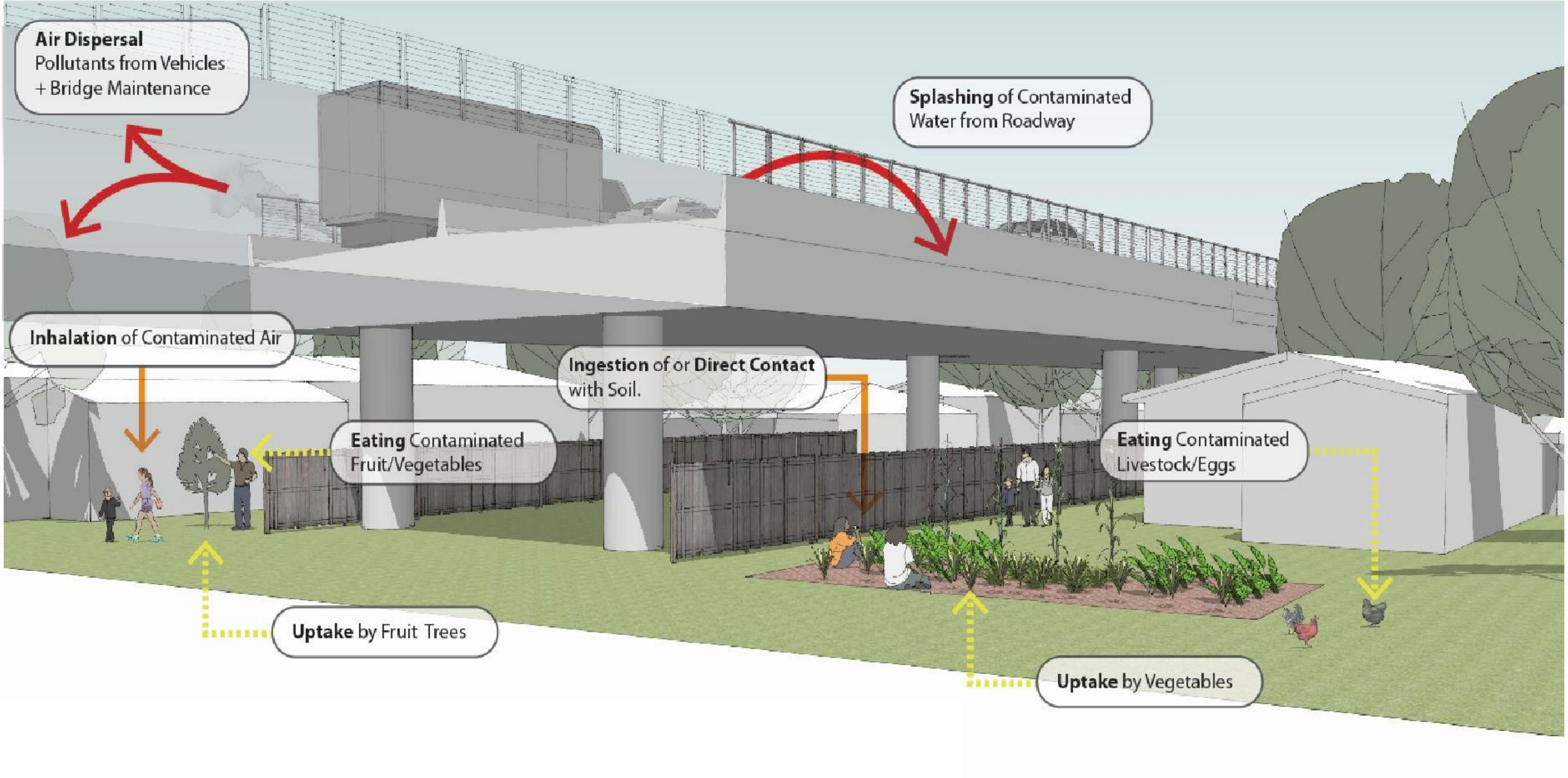


Figure 5 Conceptual site model

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3.4 Preliminary assessment of contamination

Based upon the information and observations outlined above, a list of the primary contaminants of interest to human health is listed in Table 4, below.

Table 4 Summary Primary Contaminants of Interest

Contaminant	Bridge Operation and Maintenance	Other Source
Arsenic		✓
Cadmium	✓	
Chromium	✓	✓
Copper	✓	✓
Lead	✓	✓
Nickel	✓	
TPH's (includes BaP)	✓	
Zinc	✓	

3.5 Screening assessment

No actual soil investigation has been undertaken to date at residential properties within the study area. Therefore soil investigations of nearby sites have been used as an indication of possible health risks at these locations. The nearby studies have been summarised in Section 2.6.

The National Environment Standards (NES) publish soil screening values for residential use, for a number of common contaminants in soil. These have been compared to the soil results from the various environmental studies undertaken for the area, and is summarised in Table 5.

Table 5 Reported range of contaminant concentrations in soil (mg/kg)

Chemical	Corridor Sites (south of bridge)(1)	Stokes Point(2)	Stokes Point Reserve(3)	NES Residential (<10% homegrown produce)
Arsenic	2 - 7.5	3 – 11	<2 - 7	20
Cadmium	0.1 – **59**	0.35 - 2.7	<0.1 - 1.5	3
Chromium	<1 – 125	23 – 210	9 – 220	460 (hex)
Copper	6 – 148	18 – 510	6 – 72	>10,000
Lead	4 – **507**	36 - **890**	12.4 – **840**	**210**
Nickel	<1 – 97	14 – 90	6 – 122	400 (4)
Zinc	8 – 882	79 - 6100	9 – 3300	7400 (4)
BaP	0.08 - 1.5	0.04 - 8.6	0.04 – **83**	10

Notes:

(1) Corridor sites located on the southern approach of Auckland Harbour Bridge (GHD, 2012)

(2) Opus, 2010

(3) Tonkin and Taylor, 2011

(4) NES do not present soil contaminant standard, Australia NEPM 2013 Residential land use (HIL-A) adopted.

Each of the three study locations are within the zone where bridge maintenance activities have occurred, and therefore the range of concentrations would be expected to be similar. This is apparent for chromium, copper, lead, nickel and zinc, which are the chemicals expected to be associated with sandblasting of metal structures, and lead-based paint.

The other chemicals have some inconsistencies between the datasets which are important to note:

- Arsenic was found to be elevated south of the bridge but not at stokes Point and Stokes Point Reserve studies. This would indicate that the arsenic south of the bridge is likely to be a separate source;
- Cadmium is similar to arsenic, in that it was only found to be elevated south of the bridge;
- Benzo(a)pyrene and PAHs were found only to be elevated at Stokes Point Reserve, and not at Stokes Point study, nor the corridors south of the bridge. Tonkin and Taylor (2011) state in their report that the elevated PAHs is likely to be sourced from contaminated imported fill, and not from activities associated with bridge operation and maintenance activities.

3.6 Chemicals of potential concern (COPC)

Based on the range of concentrations of contaminants in soil from various study areas around Auckland Harbour Bridge, it may be concluded that lead is the only chemical associated with bridge operation and maintenance activities, which reported concentrations exceeding soil contaminant standards consistently across all study areas. Therefore lead is considered to be the only COPC and has been the focus of this risk assessment.

4. Toxicity assessment

4.1 Overview

The purpose of this section of this report is to assess the potential effects of lead on human health and to determine the levels of exposure that could give rise to adverse effects.

Toxicity Assessment is defined as the process of determining whether human exposure to a chemical could cause an increase in the incidence of an adverse health condition (NEPC, 2013; ANZECC/NHMRC, 1992; USEPA, 1989; EnHealth, 2012). It considers:

- The nature of adverse effects related to the exposure;
- The dose-response relationship for various effects;
- The weight of evidence for effects such as carcinogenicity; and
- The relevance of animal data to humans.

Considerable research has been carried out recently on the risk resulting from lead exposure (including biokinetics and dose-response) by international organisations, including USEPA, ATSDR, WHO and CDC. The following sections summarise the current understanding of health effects from lead exposure. In this, GHD notes that the science of lead contamination is evolving, and depending on the policy position taken in New Zealand and Australia by the Health and Environmental regulatory agencies, there may be some change to the basis for assessment in the future.

4.2 Summary of health effects from lead exposure

The following is extracted from the US Agency for Toxic Substances and Disease Registry (ATSDR), recent update on lead (ATSDR, 2007).

4.2.1 General health effects

The effects of lead are the same whether it enters the body through breathing or swallowing. The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead exposure also causes small increases in blood pressure, particularly in middle-aged and older people. Lead exposure may also cause anaemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High level exposure in men can damage the organs responsible for sperm production.

There is currently no conclusive proof that lead causes cancer (is carcinogenic) in humans. Kidney tumours have developed in rats and mice that had been given large doses of some kind of lead compounds. The US Department of Health and Human Services (DHHS) has determined that lead and lead compounds are reasonably anticipated to be human carcinogens based on limited evidence from studies in humans and sufficient evidence from animal studies, and the USEPA has determined that lead is a probable human carcinogen. The International Agency for Research on Cancer (IARC) has determined that inorganic lead is probably carcinogenic to humans (Group 2B). IARC determined that organic lead compounds are not classifiable as to their carcinogenicity in humans based on inadequate evidence from studies in humans and in animals.

4.2.2 Health effects on children

Studies carried out by the US Centers for Disease Control and Prevention (CDC) show that the levels of lead in the blood of U.S. children have been reducing. This has been occurring because lead is now banned from gasoline, residential paint, and solder used for food cans and water pipes.

Children are more vulnerable to lead poisoning than adults. Children are exposed to lead all through their lives. They can be exposed to lead in the womb if their mothers have lead in their bodies. Babies can swallow lead when they breast feed, or eat other foods, and drink water that contains lead. Babies and children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground. These activities make it easier for children to be exposed to lead than adults. The dirt or dust on their hands, toys, and other items may have lead particles in it. In some cases, children swallow non-food items such as paint chips; these may contain very large amounts of lead, particularly in and around older houses that were painted with lead-based paint. The paint in these houses often chips off and mixes with dust and dirt. Some old paint contains as much as 50% lead. Also, compared with adults, a bigger proportion of the amount of lead swallowed will enter the blood in children.

Children are more sensitive to the health effects of lead than adults. No safe blood lead level in children has been determined. Lead affects children in different ways depending on how much lead a child swallows. A child who swallows large amounts of lead may develop anaemia, kidney damage, colic (severe “stomach ache”), muscle weakness, and brain damage, which ultimately can kill the child. In some cases, the amount of lead in the child’s body can be lowered by giving the child certain drugs that help eliminate lead from the body. If a child swallows smaller amounts of lead, such as dust containing lead from paint, much less severe but still important effects on blood, development, and behaviour may occur. In this case, recovery is likely once the child is removed from the source of lead exposure, but there is no guarantee that the child will completely avoid all long-term consequences of lead exposure. At still lower levels of exposure, lead can affect a child’s mental and physical growth. Foetuses exposed to lead in the womb, because their mothers had a lot of lead in their bodies, may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood also may slow mental development and cause lower intelligence later in childhood. There is evidence that these effects may persist beyond childhood.

4.2.3 Recent developments

The Joint FAO/WHO Expert Committee on Food Additives (JECFA) re-evaluated lead in 2010, finding that exposure to lead is associated with a wide range of effects, including various neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes. Impaired neurodevelopment in children is generally associated with lower blood lead concentrations than the other effects, the weight of evidence is greater for neurodevelopmental effects than for other health effects and the results across studies are more consistent than those for other effects. For adults, the adverse effect associated with lowest blood lead concentrations for which the weight of evidence is greatest and most consistent is a lead-associated increase in systolic blood pressure.

JECFA concluded that the effects on neurodevelopment and systolic blood pressure provided the appropriate bases for dose–response analyses. Based on the dose–response analyses, JECFA estimated that the previously established a provisional tolerable weekly intake (PTWI) of 25 µg/kg of body weight is associated with a decrease of at least 3 IQ points in children and an increase in systolic blood pressure of approximately 3 mmHg (0.4 kPa) in adults. These changes are important when viewed as a shift in the distribution of IQ or blood pressure within a population. JECFA therefore concluded that the PTWI could no longer be considered health protective, and it was withdrawn.

Similarly, The CDC identified **10 µg/dL** as the blood lead level of concern in children in their 1991 report "*Preventing Lead Poisoning in Young Children*" and provided risk management options for categories of blood lead levels higher than 10 µg/dL. In view of the recent information published by JECFA, the CDC no longer considers 10 µg/dL as a reference level for lead and is now using a reference level of **5 µg/dL** to identify children with blood lead levels that are much higher than most children's levels (CDC, 2013).

4.2.4 New Zealand position

The New Zealand National Environment Standards (NES) present screening levels for numerous chemicals including lead. The document, *Toxicological Intake Values for Priority Contaminants in Soil*, Wellington: Ministry for the Environment, 2011, presents the toxicological reference values used in the derivation of the screening criteria.

After the JECFA withdrew their provisional tolerable weekly intake for lead (ie. PTWI of 25 µg/kg bw/week), a toxicological intake of 1.9 µg/kg bw/day (or 13 µg/kg bw/week) was instead recommended to be used in the derivation of soil contaminant standards in New Zealand. This intake is based on dose-response modelling by JECFA and is the dietary intake at which the IQ decreases 3 points in the population. This is equivalent to approximately half the previous tolerable intake value.

4.3 Selected approach

GHD notes that while the NZ toxicological reference value for lead has halved, so has the recommended blood lead level as recommended by the US CDC. These two end points may be considered analogous to the findings of JECFA and the withdrawal of the old PTWI for lead.

The USEPA have a lead biokinetics model which is used world-wide for assessing human health risks from lead exposure, particularly for children. The model estimates the blood lead level from lead exposure.

The acceptable blood lead level should be set at 5 µg/dL for the purposes of deriving a human health based soil criterion for residential land.

5. Exposure assessment

5.1 Overview

The purpose of the exposure assessment is to assess the exposure that could potentially occur to lead.

The exposure assessment documents the selection of potentially exposed populations and exposure pathways used in estimating the potential health risks arising from exposure to lead.

Exposure dose estimation is included in the IEUBK model. The following sections describe the key assumptions used.

5.2 IEUBK model for lead

(Sourced from the USEPA IEUBK Guidance Manual, 2010)

Lead uptake rate and biokinetics is a complex series of biological reactions within the organs of the human body. In 1985, the USEPA Office of Air Quality Planning and Standards (OAQPS) initiated a project that would allow the calculation of blood lead concentrations in children exposed to differing arrays of concentrations of lead in air, soil, and dust. This model, called the Uptake/Biokinetic (or UBK) model for lead. The biokinetic parameters for the UBK model were extrapolated from long-term feeding studies on infant and juvenile baboons, autopsy data on human children, human infant feeding studies, and other sources. The exposure model that was coupled to the biokinetic model was developed by OAQPS. Model calibration and validation was done using data from the 1983 EPA/CDC/Montana study on children in East Helena, Montana, who lived in the vicinity of a large primary lead smelter. The modelling approach was reviewed and approved by EPA's Clean Air Science Advisory Committee (CASAC) in 1990.

The present version of the program is called the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (version 1.1, February 2010), which is an enhanced version of the UBK model, and is incorporated into a windows software package, available from the USEPA website. The IEUBK Model addresses three emerging paradigms of environmental risk assessment:

1. Assessments that recognize the multimedia nature of exposures to environmental toxicants are a significant improvement in assessing health risks. Assessments restricted to single pathways of exposure can overlook situations where integrated multimedia exposures are high enough to trigger health concerns. The lead model is structured to integrate exposures occurring through air, water, food, soil, and dust in estimating the blood lead levels in children in realistic environmental settings.

2. Pharmacokinetic information can strengthen the validity of environmental health assessments in comparison with more traditional methods that address only external dose or intake of a compound. Internal measures of dose that are pertinent to the biological effects exerted by a compound form an improved metric for risk assessment. The IEUBK estimates of blood lead concentrations as an internal indicator of potential health risk are based on pharmacokinetic modelling of lead absorption, transport, redistribution, and elimination.

3. Environmental assessments need to address the substantial variability in exposure and risk resulting from these factors. Single point estimates of exposure or risk are of limited utility. Individuals differ in their surroundings, behaviour, and physiological status. The Lead Model addresses variability through the estimation of probability distributions of blood lead levels for children exposed to similar environmental concentrations of lead. Through systematic application of the model, data on the variability of levels of

environmental lead contamination can be translated into estimates of the distribution of blood lead levels within populations of children.

The modules of the IEUBK model (i.e. environment media -> intake -> uptake -> biokinetics -> blood level) are presented in **Figure 6**.

(sourced from the USEPA IEUBK Guidance Manual, 2010)

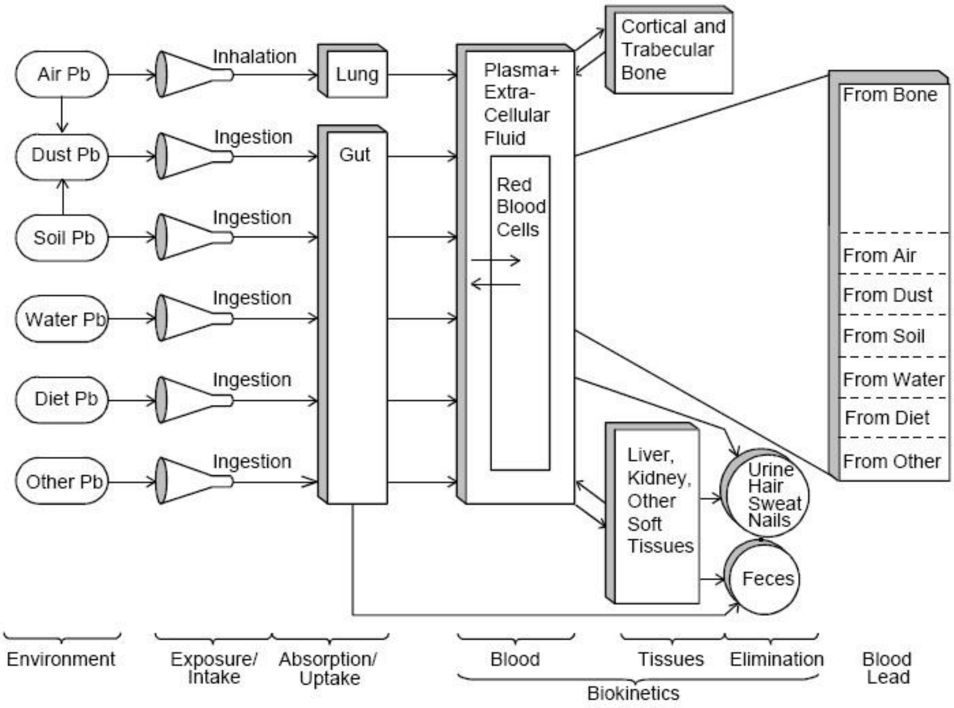

Figure 6 IEUBK conceptual diagram

The general term "biokinetic" is used to describe the movement of lead through various parts of the human body as a kinetic process. Current blood lead concentrations depend on prior exposure history as well as present exposure. With constant lead exposure, a near steady-state blood lead concentration level is achieved because there is a dynamic near-equilibrium between lead moving out (from blood plasma to peripheral tissues and through excretory routes), and lead moving in (to plasma from gastrointestinal uptake and remobilization into plasma from peripheral tissues and long-term bone storage).

The IEUBK Model assumes that skeletal lead turnover occurs relatively more rapidly in children than in adults. The lead in a child's blood is thus a mixture of lead taken up from recent environmental exposure and lead released from skeletal stores that reflect historical exposures. However, the faster turnover time assumed for children compared to adults implies that the lead burden in the skeleton is a smaller fraction of total body burden in children than in adults. The skeletal contribution to blood lead thus increases as the skeletal fraction of total body burden of lead increases.

The blood lead concentrations in children achieve nearly a steady state relationship with exposure within a period of months after changes in exposure. The situation in children is more complicated than in adults because the kinetic parameters also change with the child's growth and with changes in behaviour that affect lead intake, absorption, distribution, and elimination. The model is adequate to estimate childhood blood lead concentrations in near-equilibrium or in slowly changing exposure settings, as may be attained some time (months) after abatement occurs. The gradual phase down of lead in gasoline would be an example of changes that occurred slowly enough in most urban areas to permit accurate modelling of blood lead concentration changes accompanying the air lead concentration changes.

5.3 Populations of interest

The properties considered in the health risk assessment are the residential properties adjacent to the northern end of Auckland Harbour Bridge.

Receptors of interest include:

- Adult residents; and
- Children at residences.

The most sensitive age group for lead exposure is children from newborn to 7 years old. These are the age groups that are modelled by IEUBK. As well as higher intake per body weight, lead has a more significant toxic effect on young children than it does on adults. Therefore the derived criterion will be focused on children.

5.4 Exposure pathways

For exposure to occur, a complete pathway must exist between the source of contamination and the receptor. Where the exposure pathway is incomplete, there is no exposure, and hence no risk.

An exposure pathway consists of the following elements:

- Source (e.g. spills);
- Release mechanism (e.g. leaching, volatilisation);
- Retention of transport media (e.g. soil, groundwater, surface water, air);
- Exposure point, where the receptor comes in contact with the contamination (e.g. groundwater from an extraction bore, or soil under existing building); and
- Exposure route (e.g. inhalation, ingestion, dermal contact).

Where the pathway for a chemical from the source to the receptor is incomplete, there is no incremental risk due to the presence of contamination.

The primary exposure pathway is oral ingestion of dust/soil. Inhalation of dust as well as background sources in drinking water and food also contribute to overall lead exposure.

Note, a visual inspection has not been undertaken to determine whether there were any significant produce gardens in the surrounding residential properties, and therefore uptake and consumption of home grown produce has not been included in this assessment. If it is identified that a resident contains a significant produce garden and that if over 50% of the residents' fruit and vegetable consumption is home grown, then this risk assessment will need to be re-evaluated.

5.5 IEUBK Model Inputs

The IEUBK requires a number of parameters in order to estimate lead blood levels in children. The default parameters (sourced from the IEUBK Guidance manual) are attached in **Appendix A**.

The following parameters are those that relate directly to the assessment of residential properties adjacent to the northern approach to Auckland Harbour Bridge (Te Onewa).

5.5.1 Age Parameters

IEUBK models lead exposure in one year age blocks (eg 0-1 yr, 1-2 yr, 2-3 yr, etc) up to 7 year old child.

Parameters for inhalation rate, body weight, soil/dust ingestion rate, water ingestion rate, food consumption rate, and behavioural statistics such as time spent indoors, are all age specific. The default values for these parameters are based on statistical means from US Survey data. Limited age specific factors are available in New Zealand, however, the data available indicate similar values to those adopted in the IEUBK model. These default values are presented in **Appendix A**.

Some specific modifications to these parameters are discussed in the following sections.

5.5.2 Air Data

Historically, an ambient air concentration of lead was driven by lead in petrol, but since lead had been eliminated in fuels, ambient air concentrations of lead has dropped significantly.

Air quality monitoring has not been undertaken for the study area and hence the model default concentration of 0.1 µg/m^3 has been assumed.

5.5.3 Diet and water

Site-specific measurements of diet and water have not been taken as part of this assessment. The default concentration of lead in water is 4 µg/L (note the 2008 New Zealand Drinking water Guideline for lead is 10 µg/L). Mean dietary intakes for each age group are based on average diet consumption and levels of lead in tinned food from the USA.

5.5.4 Bioavailability

The concept of bioavailability is important for site-specific risk assessments for lead. The concept springs from the fact that lead potentially available to produce harm and found in exposure pathways or in body receiving compartments (lung, skin, gut) must reach the biological sites of action in order for an adverse health effect to occur in exposed humans or ecological biota.

The following is a section from the IEUBK Guidance document, Chapter 4.1.2.

A clear agreement on a definition of bioavailability should be established before one presents a detailed discussion of this topic. The difficulty here is that there are various definitions of bioavailability depending on the scientific discipline using the term and the technical context of use.

Typically, the pharmacologist or toxicologist or others in biomedical disciplines are concerned with measuring bioavailability as that fraction of the total amount of material in contact with a body portal of entry (lung, gut, skin) that then enters the blood. For the purpose of describing the Integrated Exposure Uptake Biokinetic (IEUBK) Model, this is the definition to be used in this manual. However, an aquatic biologist may define bioavailability as that fraction of material solubilized in the water column under certain conditions of hardness and pH. An aquatic toxicologist might consider contaminants which are soluble under specific stream conditions to be bioavailable to fish or benthic organisms. A biochemist or biochemical toxicologist would consider bioavailability with reference to that fraction of a toxicant which is available at the organ or cellular site of toxicity.

Keeping in mind the above statements, the bioavailability of lead does not relate to the soluble portion of lead in a soil/dust sample. The IEUBK Guidance document also presents the following:

Bioavailability factors can be validly adjusted to account for site-specific lead exposure characteristics in the IEUBK model. However, selection of a site-specific bioavailability parameter other than the model default value of 30% for soils and dusts requires considerable caution and warrants review by qualified technical experts.

Currently, in vivo bioassays are the only way to quantitatively measure and adjust default bioavailability to fit site soils……U.S. EPA Region 8 has conducted bioavailability studies of soil lead in an in vivo immature swine model. The results of these studies suggest possible trends in relative bioavailability related to the major form of lead in the soil samples (greater than 50% of total lead). For example, lead in soils containing predominantly galena (lead sulfide) has a relatively low bioavailability (RBA<25%, relative to lead acetate) in swine compared to soils containing predominantly cerrusite or lead manganese oxide (RBA>75%). Lead in soils containing mixtures of lead phosphates, sulfates, and/or lead oxides appears to have an intermediate bioavailability (RBA 25 - 75%). While lead speciation is not the sole factor influencing bioavailability, it may contribute to variability in soil lead bioavailability from site to site or at different locations within a given site.

The soil samples from the nearby sites have not been analysed for form of lead. However, it may be anticipated that the majority of the lead would be combination of historical deposition from leaded fuel vehicle emissions and leaded paint deposited during bridge maintenance (sand blasting).

Typically, the default position of regulators is to assume 100% bioavailability, but lead bioavailability is referenced against lead acetate. Lead acetate is absorbed 50% by children. Soil and paint particles are then assessed for bioaccessibility, that is, can the lead be extracted from the soil particle and then absorbed by the body's digestive system.

A report published by USEPA and University of Missouri (USEPA, 1998) published bioavailability test results for lead paint via animal testing (swine). In summary the study found that lead paint was 40% bioavailable, ie. 80% bioassessible relative to lead acetate, followed by 50% bioavailable. In the absence of actual bioavailability testing, this value has been adopted.

5.5.5 Dust to soil ratio

The IEUBK model allows for the concentration of lead in indoor dust to be directly entered, or to be calculated from outdoor media inputs. The default assumption is that the concentration of lead in indoor dust is 70% of the outdoor soil concentration. The default value has been selected in the absence of actual measurements.

5.5.6 Soil and dust ingestion rates

The soil/dust ingestion rates in the model by default are set up as 45% of total ingestion rate attributed to soil ingestion and 55% of the total ingestion attributed to dust ingestion.

The IEUBK model default soil ingestion rate are based on US population studies. For children aged between 1 and 4 years old, an ingestion rate of over 100 mg/d is presented.

The following is presented in the NZ NES, *Methodology for Deriving Standards for Contaminants in Soil to Protect Human Health* (2011):

As a pragmatic compromise, a value halfway between the median and mean has been employed as the residential childhood rate, that is, 50 mg/day (rounded up to the nearest 10 mg/day). This falls between the 75th and 80th percentiles of the distribution calculated by Stanek et al (2001) of 42 and 53 mg/day, respectively.

In comparison with the IEUBK default values, the NZ NES recommended value of 50 mg/d is less than the highest default value (135 mg/d for 2-3 year old) by more than a factor of 2. Therefore the selected values have been selected to be half of the model default values.

Table 6 Soil+dust ingestion rates by age group (g/day)

Age group	IEUBK Default residential	Selected value(1)
0-1	0.085	0.0425
1-2	0.135	0.0675
2-3	0.135	0.0675
3-4	0.135	0.0675
4-5	0.100	0.05
5-6	0.090	0.045
6-7	0.085	0.0425

Notes: Based on half of the IEUBK default values

6. Risk characterisation

6.1 Overview

The purpose of the risk characterisation is to combine the results of the toxicity assessment (i.e. the potential for health effects) with the predicted exposures to determine whether the chemicals of potential concern pose an unacceptable health risk and therefore what measures need to be taken to reduce the risk.

6.2 Assessment of lead exposure

Typically chemical exposure is assessed either using a cancer risk assessment approach based on cancer unit risks or slope factors to estimate the probability of cancer for an individual over a lifetime; or alternatively a threshold based approach whereby an exceedence of a daily intake level has been linked with possible health effects.

Assessment of lead falls under the threshold approach, but instead of comparing intake levels with a Tolerable Daily Intake (TDI) and calculating a Hazard Quotient (HQ), an estimate is made of the blood lead level and compared to the threshold guideline.

As discussed in Section 4.3 the acceptable blood lead level should be set at 5 µg/dL for the purposes of deriving a human health based soil criterion for residential land.

6.3 Results of risk assessment

An IEUBK model run has been undertaken for a range of concentrations of lead in soil, based on the assumptions described in Section 5.5.

The results of the model runs are presented in **Figure 7**.

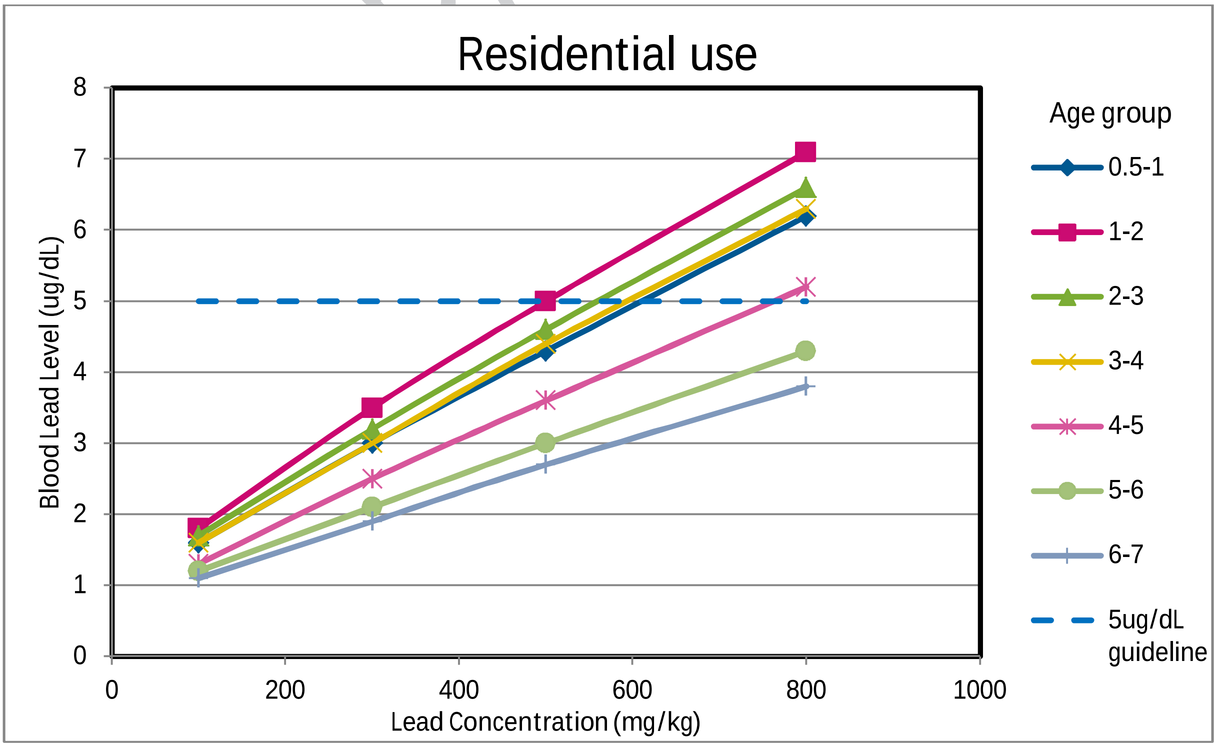

Figure 7 Results of lead criterion derivation

6.4 Discussion of results

Figure 7 presents the estimated blood lead levels for the different age groups in the IEUBK model. The age group of 1 to 2 years of age is the group with the highest risk, with the curve higher above all the other age groups. This is because the intake to body weight ratio is largest for this group.

The maximum allowed blood lead level of 5 µg/dL is crossed at a soil concentration of approximately **500 mg/kg**. This is the derived soil screening level for residential use with low levels of homegrown produce (10%).

6.5 Comparison with analytical results

A comparison of the **derived lead screening level of 500 mg/kg** has been made with the datasets described on Section 2.6 and is summarised in **Table 7**.

Table 7 Comparison of derived lead criterion with analytical results

Chemical	Units	Corridor Sites (south of bridge)(1)	Stokes Point(2)	Stokes Point Reserve(3)
Range of concentrations	mg/kg	4 – 507	36 - 890	12.4 – 840
Derived criterion	mg/kg	500	500	500
Total no samples	-	144	20	46
No of exceedences	-	1	3	2

Notes:

(1) Corridor sites located on the southern approach of Auckland Harbour Bridge (GHD, 2012)

(2) Opus, 2010

(3) Tonkin and Taylor, 2011

The total number of exceedences of the derived soil criterion is 6 from a total of 210 samples, and the level of exceedence is less than a factor of 2. This indicates that health risk from lead exposure is not considered to be high, with the exception of some isolated cases.

The derived lead soil criterion assumes standard residential level of homegrown produce consumption (10%) and no poultry and eggs. If it is identified that the residents in the study area consume significant amount of homegrown produce and eggs, then this assessment of risk should be revised.

It should be noted that this does not take into consideration any potential contamination from imported fill, which may be elevated with lead, PAHs and other contaminants.

6.6 Uncertainty assessment

Risk assessments involve a number of assumptions regarding site conditions, human exposure and chemical toxicity. It is not possible to fully describe site conditions and human activities at a site for the period of time considered in the risk assessment. The assumptions adopted for the risk assessment can be expected to be generally conservative in nature, to account for uncertainty in the parameter estimates and to protect public health by providing a deliberate margin of safety.

The aim of this section is to provide a qualitative evaluation of the sensitivity of the risk assessment to particular assumptions. Several of the most significant parameters were considered in this analysis to indicate how different assumptions may affect the outcome of the risk assessment.

Source Data

No soil analytical results have been taken from residential properties in the study area. Instead soil data has been taken from studies undertaken in nearby areas close to the AHB, which likely are similarly impacted by AHB operation and maintenance activities. In this scene, the soil data may be considered representative of the residential properties in the study area.

However, review of the soil data indicates that contamination in soil from imported fill has likely occurred at Stokes Point Reserve. It is not known whether similar contamination is present at the residential properties, which could potentially include elevated levels of carcinogenic PAHs. This assessment has assumed that residential properties do not contain imported contaminated fill.

Exposure Assumptions

A number of conservative assumptions were included in the risk assessment. For example, it was assumed that the residents would spend every day at home. Most of the exposure assumptions used in this assessment are default values in the IEUBK model and are generally regarded as “reasonable maximum” to give a plausible upper-bounds estimate of risk.

The exception to this is the soil/dust ingestion rates of children. The NZ NES soil guideline values were derived based on a soil ingestion rate of 50 mg/d. The default model soil ingestion rate is 135 mg/d for the 1-2 year old child. To keep consistency with the NES, The default model soil ingestion rates were halved, resulting in the 1 to 2 year old ingesting 65 mg/d.

Another uncertainty is with regards to the level of homegrown produce consumed by residents (including fruit, vegetable, poultry and eggs). Inspections of the properties have not been carried out. It has been assumed in this assessment that homegrown produce consumption conforms to the standard residential land use setting (less than 10%) which results in insignificant intake compared to soil/dust ingestion, with the exception of some chemicals with high plant uptake. If inspection of properties identifies significant gardens and poultry, then this assessment of health risk will need to be revised.

Bioavailability

Typically the default assumption for bioavailability is 100%, but lead is an exception due to the large amount of information available of lead bioavailability and the advancements of bioavailability tests. Lead acetate is the known standard with a bioavailability of 50% for children and less for adults.

Bioaccessibility further reduces the bioavailability as lead is bound within the soil matrix and not completely absorbed after ingestion. The IEUBK has a default bioaccessibility of 60%, resulting in a total bioavailability of 30%. However, this study has used a bioaccessibility of 80% resulting in a total bioavailability of 40%, based on bioavailability studies of lead paint. This is still a literature value, and only bioavailability testing can confirm the validity of this assumption. Having said this, the worst case would be a bioaccessibility of 100% which would decrease the derived soil criterion from 500 mg/kg to 400 mg/kg.

Toxicity

The toxicity of lead modelled is simulated in the IEUBK model based on measured biokinetic and chemical absorption studies on animals and humans, and is currently the most sophisticated model freely available for assessing risks from lead exposure.

There have been significant changes recently in understanding of observed effects of lead exposure, and consequently the withdrawal of JECFA's PTWI. US CDC has revised their recommended blood lead level from 10 µg/dL to 5 µg/dL. While other parts of the world have not made formal policies changes or are currently reviewing the old policy, this assessment has been based on the new CDC guideline value on the assumption that the rest of the world will soon follow.

7. Conclusions and recommendations

The risk assessment has considered the potential effects on beneficial uses of land in the study area, and has particularly considered:

- The risks to residents within the study area from exposure to lead in soil resulting from deposition from operation and maintenance activities of the Auckland Harbour Bridge (AHB).
- Soil measurements have not been taken from within residential properties at Stokes Point. Therefore extrapolation of soil data from other locations close to the AHB has been selected as representative. These study areas are:
  - Corridor sites located on the southern approach of Auckland Harbour Bridge (GHD, 2012);
  - Stokes Point – Green Belt, south of residents (Opus, 2010); and
  - Stokes Point Reserve (T&T, 2011).

The important findings of this assessment were:

- A comparison of measured soil concentrations in three different study areas around the AHB indicated that lead is likely the only contaminant related to the AHB operation and maintenance activities which exceed the NZ NES soil guideline value.
- Other chemicals were found to exceed the NZ NES soil guideline values but these chemicals may be from sources other than from AHB. These include PAHs, arsenic and cadmium.
- The USEPA lead biokinetics model (IEUBK) is used world-wide for assessing human health risks from lead exposure, particularly for children. The model estimates the blood lead level from lead exposure, and has been used in this assessment.
- In light that the NZ toxicological reference value for lead has halved and so has the recommended blood lead level as recommended by the US CDC, these two end points may be considered analogous to the findings of JECFA and the withdrawal of the old PTWI for lead.
- The acceptable blood lead level has been set at 5 µg/dL for the purposes of deriving a human health based soil criterion for residential land.
- The derived lead soil criterion for standard residential land (10% homegrown produce) was 500 mg/kg.
- Comparison of the derived criterion with the soil analytical results from the three studies indicates that the maximum reported lead concentration of 890 mg/kg is less than a factor of 2 above the derived criterion, and only 6 out of the total of 210 samples exceeded this criterion, This indicates that while there may be a few exceptions, the majority of the residential properties would likely be below the derived soil criterion for lead and therefore within acceptable health risk.
- As there has been no actual investigation within the residential properties, there is significant high uncertainty with respect to the results of this assessment. These include:
  - Extrapolation of data from other study areas to represent the residential properties;
  - No bioavailability testing of lead in soil has been undertaken in any of the studies;
  - No inspection of residential properties to determine the level of homegrown produce consumed at residential properties;

- Contaminated fill was identified at Stokes Point Reserve, likely imported, and is possible that this fill is also present at the residential properties.

Based on the outcomes of the modelling and soil data obtained during the course of the investigations, the following recommendations are considered appropriate:

- Additional sampling in areas nearby the residential properties should be undertaken to further characterise the levels of contamination in soils;
- Bioavailability testing of lead should be considered for a number of soil samples to validate the bioavailability assumptions in this report;
- The health risk assessment should be reviewed and revised if required, once additional soil testing has been undertaken.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.4 and the assumptions and qualifications contained throughout the Report.

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Appendices

Appendix A – IEUBK model output

LEAD MODEL FOR WINDOWS Version 1.1

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Model Version: 1.1 Build11
User Name:
Date:
Site Name:
Operable Unit:
Run Mode: Research

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****** Air ******

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100
4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

****** Diet ******

Age	Diet Intake(µg/day)
.5-1	2.260
1-2	1.960
2-3	2.130
3-4	2.040
4-5	1.950
5-6	2.050
6-7	2.220

****** Drinking Water ******

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 4.000 µg Pb/L

****** Soil & Dust ******

Multiple Source Analysis Used
Average multiple source concentration: 570.000 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.700
Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)

.5-1	800.000	570.000
1-2	800.000	570.000
2-3	800.000	570.000
3-4	800.000	570.000
4-5	800.000	570.000
5-6	800.000	570.000
6-7	800.000	570.000

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	0.000
1-2	0.000
2-3	0.000
3-4	0.000
4-5	0.000
5-6	0.000
6-7	0.000

****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 1.000 µg Pb/dL

****
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	0.990	0.000	0.350
1-2	0.034	0.839	0.000	0.856
2-3	0.062	0.931	0.000	0.909
3-4	0.067	0.907	0.000	0.943
4-5	0.067	0.901	0.000	1.016
5-6	0.093	0.960	0.000	1.087
6-7	0.093	1.047	0.000	1.113

Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	10.145	11.506	6.2
1-2	15.686	17.416	7.1
2-3	16.007	17.908	6.6
3-4	16.298	18.216	6.3
4-5	12.444	14.427	5.2
5-6	11.355	13.495	4.3
6-7	10.925	13.179	3.8

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