Intended for
Hydro Aluminium Kurri Kurri Pty Ltd

Document type
Final

Date
July 2016

HUMAN HEALTH RISK ASSESSMENT
FORMER HYDRO ALUMINIUM KURRI KURRI SMELTER DEMOLITION AND REMEDIATION

RAMBOLL ENVIRON

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DEMOLITION AND REMEDIATION

Revision	**Final**
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Ref AS130401

HHRA REA Report Final 2016_07_05

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EXECUTIVE SUMMARY

This Human Health Risk Assessment (HHRA) has been prepared by Ramboll Environ Australia Pty Ltd (Ramboll Environ) on behalf of Hydro Aluminium Kurri Kurri Pty Ltd (Hydro) to inform an Environmental Impact Statement (EIS) for submission to the Department of Planning and Environment prepared for the Demolition and Remediation Project (the Project) at the former Hydro Aluminium Kurri Kurri aluminium smelter at Hart Road Loxford (the Smelter).

This HHRA was completed to satisfy the requirements made by the Secretary's Environmental Assessment Requirements (SEARs), Hunter New England Local Health District and SafeWork NSW (formally WorkCover NSW). These requirements related to potential health risks associated with construction of the Containment Cell, remediation activities and demolition of Smelter structures; and the associated impacts these activities will have on the health of onsite workers and offsite sensitive receptors.

This HHRA was undertaken in accordance with Australian recommended guidance for performing human health risk assessments. This process involved:

1) Reviewing the project description provided in the EIS.

2) Identifying the source-pathway-receptor (SPR) linkages for each activity (i.e. developing a conceptual site model (CSM)).

3) Quantitatively and qualitatively assessing the potential health risk for all complete SPR linkages.

A summary of the CSM, which formed the basis of the HHRA, is provided below:

- *Health Impact Sources:* contamination sources such as particulates, groundwater and surface soil (including contaminants in the Capped Waste Stockpile) and noise and vibration from the Project Works.
- *Exposure pathways* and *receptors:* the table below summarises the human receptors and exposure pathways that were quantitatively assessed in the HHRA. The offsite residential property located at 6 Dawes Avenue, Loxford was considered to be the most sensitive offsite receptor because Project-generated dust concentrations were predicted to be the highest at this property. Both adults and children are considered to reside at this residential property.

Conceptual Site Model Summary

Project Activity	Exposure Pathway	Human Receptor	
		Works Personnel	Off-Site Residential Receptors
Onsite excavations; Transfer and handling of soils; Movement of contaminated soils to the Containment Cell; Demolition of structures.	Dermal contact with soil	✓	X
	Incidental ingestion of soil	✓	X
	Indoor inhalation of dust	X	✓
	Outdoor inhalation of dust	✓	✓
Removal of building footprints in areas of shallow groundwater.	Dermal contact with groundwater	✓	X
	Incidental ingestion of groundwater	✓	X
	Outdoor inhalation of groundwater vapours (within a trench)	✓	X
Dust generated from Project activities that may settle on nearby roof surfaces.	Potable use of tank rainwater collected from roof surfaces	X	X

Notes:
✓ indicates a potential exposure pathway is present which is assessed quantitatively in the HHRA
X indicates a potential exposure pathway is not present

On the basis of the available data, the assumptions and the quantitative risk estimates presented in this report, and with consideration of the identified uncertainties, it was considered that the potential health risks were low and acceptable for:

- onsite Works personnel conducting Project activities (excluding Works in the Capped Waste Stockpile area);
- offsite residential receptors exposed to Project-generated dust;
- offsite residential receptors exposed to Project-generated noise and vibration;
- offsite residential receptors exposed to site-derived soil impacts and groundwater beneath the Smelter; and
- use of tank rainwater and reticulated drinking water for offsite human receptors.

Potential health risks due to the Containment Cell were also considered to be low and acceptable because the proposed design excludes water from entering the cell, thereby stopping the generation of leachate and minimising the potential for gas generation. However, several contingency measures are proposed to mitigate exposure to offsite human receptors should leachate and gas be generated.

The health risks estimated for the Works personnel exposed to groundwater beneath the Capped Waste Stockpile exceed the acceptable limits indicating potential health risks associated with this activity. Management measures to eliminate direct contact exposure pathways, including use of personal protective equipment and real-time ambient air monitoring, are provided in the HHRA.

In addition to the environmental and noise/vibration controls that form part of the Project, the following mitigation measures would be implemented as part of a Work Health and Safety Management Plan that includes:

- The specific procedures to be implemented during activities at the Capped Waste Stockpile. This management plan would detail the personal protective equipment required to remove exposure pathways relating to dermal exposure, incidental ingestion and inhalation.
- Real-time ambient air monitoring at several locations around the Capped Waste Stockpile when waste from the Capped Waste Stockpile is exposed. At a minimum, the ambient air should be monitored for concentrations of ammonia and hydrogen cyanide gases.

1. INTRODUCTION

This Human Health Risk Assessment (HHRA) has been prepared by Ramboll Environ Australia Pty Ltd (Ramboll Environ) on behalf of Hydro Aluminium Kurri Kurri Pty Ltd (Hydro) to inform an Environmental Impact Statement for submission to the Department of Planning and Environment prepared to assess for the Demolition and Remediation Project (the Project) at the former Hydro Aluminium Kurri Kurri aluminium smelter at Hart Road Loxford (the Smelter).

1.1 Background

The former Hydro Aluminium Kurri Kurri Smelter (the Smelter) is located on Hart Road, Loxford near Kurri Kurri in New South Wales, Australia. The area owned and managed by Hydro incorporates the former smelter area comprising approximately 60 hectares, and the surrounding Hydro owned lands, comprising approximately 1,940 hectares (the Hydro land).

Smelting activities ceased in September 2012, and in May 2014 Hydro formally announced the closure of the Smelter.

It is Hydro's strategic vision for the Hydro land to play a key role in allowing the Hunter Region to achieve the economic, employment and environmental objectives identified in the NSW Government NSW State Plan 2021, the Hunter Regional Action Plan and the Draft Hunter Regional Plan. Hydro aims to achieve this strategic vision by facilitating the rezoning and development of the Project site for significant employment, residential, rural and biodiversity conservation purposes.

Hydro has commenced a number of decommissioning activities to facilitate demolition and remediation of the Smelter. In addition Hydro has submitted a Development Application to Cessnock City Council for the demolition of the majority of the Smelter (Stage 1 Demolition) excluding buildings used for material storage, various workshops, offices and storage sheds, the concrete stacks and the water tower.

The remaining activities that would make the Smelter suitable for future employment and industrial land uses are the following:

- The Works. The Works are the activities required to make the Project site suitable for future use. The key element of the Works is the construction of a waste management facility, comprising a state of the art, modern and purpose built Containment Cell. Other ancillary elements of the Works are:
  - Demolition of the remaining Smelter buildings and structures.
  - Site remediation.
  - Leachate and groundwater treatment.
- Containment Cell Management. Following completion of the Works, the Containment Cell would be subject to a monitoring and management program.

These activities form the Project, which is the subject of the Environmental Impact Statement and this HHRA.

1.2 Objectives

The purpose of the HHRA is to assist the Department of Planning and Environment in assessing the Project in accordance with Section 79(c)(1) of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

On 18 November 2014, NSW Department of Planning and Environment issued the Secretary's Environmental Assessment Requirements (SEARs) relating to the Project. Requirements specifically relating to the assessment of human health were:

- "2. Waste Containment Cell including….detail how contaminated material from the existing Containment Cell will be transported to the new proposed cell including measured to reduce…human health impacts;"

- "3. Contamination and Remediation including….[a Remedial Action Plan that will] justify the proposed treatment and remediation criteria based on the conclusions of a Human Health Risk Assessment prepared in accordance with the Environmental Health Risk Assessment – Guidelines for Assessing Human Health Risk from Environmental Hazards".
- "5. Demolition Management including….address…human health…impacts and how these impacts will be mitigated and managed"

The objectives of this HHRA are to:

- Assess the potential for unacceptable human health risks posed to on-site and off-site human receptors that may result from potential contact with or exposure to chemicals arising from the Project.
- Identify any additional management measures to mitigate impacts of the Project on workers and off-site sensitive human receptors including residents.
- Satisfy the HHRA requirements of the Secretary's Environmental Assessment Requirements (SEARs) issued by the NSW Department of Planning and Environment on 18 November 2014, in particular the issues raised by:
  - Hunter New England Local Health District, in a letter addressed to the Department of Planning and Environment dated 12 September 2014; and
  - WorkCover NSW, in an email sent to the Department of Planning and Environment on 16 September 2014.

1.3 HHRA Process and Methodology

HHRA is used to inform and assist decision-makers in managing contamination issues with careful consideration of site-specific circumstances. It is used to estimate, in a way that is adequately protective of health, the potential for site contamination to have an adverse effect on the health of those potentially exposed to it. This is achieved by modelling the dose that an individual may receive through incidental exposure to contaminated soil and/or water as a result of everyday activities. This estimated dose can then be compared against doses that are considered to result in no observable adverse impact to health, as published by authoritative bodies and health protection agencies.

HHRA is a tiered process that begins with a comparison of observed chemical concentrations in media of concern (e.g. groundwater and soil) at the site with conservative generic screening criteria, termed "Tier 1 levels". These levels are designed to identify chemical concentrations that are likely to require further site-specific consideration. If all observed concentrations of chemicals in media at the site are less than the Tier 1 screening levels, the assessment will not proceed any further. If the Tier 1 screening criteria are exceeded, then further site specific analysis at a higher tier of analysis, Tier 2, will be carried out to evaluate whether the risks from the contaminant concentrations observed on the site are significant.

This HHRA was undertaken in accordance with relevant Australian recognised guidelines for conducting human health risk assessment, including:

- National Environmental Protection Council (NEPC) (2013) *National Environment Protection (Assessment of Site Contamination) Amendment Measure (NEPM) 2013 (No. 1). Schedule B4, Guideline on Site-Specific Risk Assessment Methodology*.
- enHealth (2012) *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*. Commonwealth of Australia.

1.4 Report Structure

This HHRA follows the guidance listed in **Section 1.3** and the HHRA process illustrated in **Figure 1** on *Page 7*, and this HHRA report has been structured to reflect these risk assessment stages including:

- Section 2: Project Description
- Section 3: Existing Environment
- Section 4: Issues Identification
- Section 5: Data review and evaluation (including Conceptual Site Model)
- Section 6: Exposure assessment
- Section 7: Toxicity Assessment
- Section 8: Risk Characterisation
- Section 9: Uncertainty and Sensitivity Analysis
- Section 10: Mitigation Measures
- Section 11: Conclusions
- Section 12: References

Supporting risk assessment information used to form conclusions in this HHRA is provided in the following appendices:

- Appendix A: Tables
- Appendix B: Risk Assessment Algorithms
- Appendix C: Toxicological Profiles
- Appendix D: HHRA Sensitivity Analysis

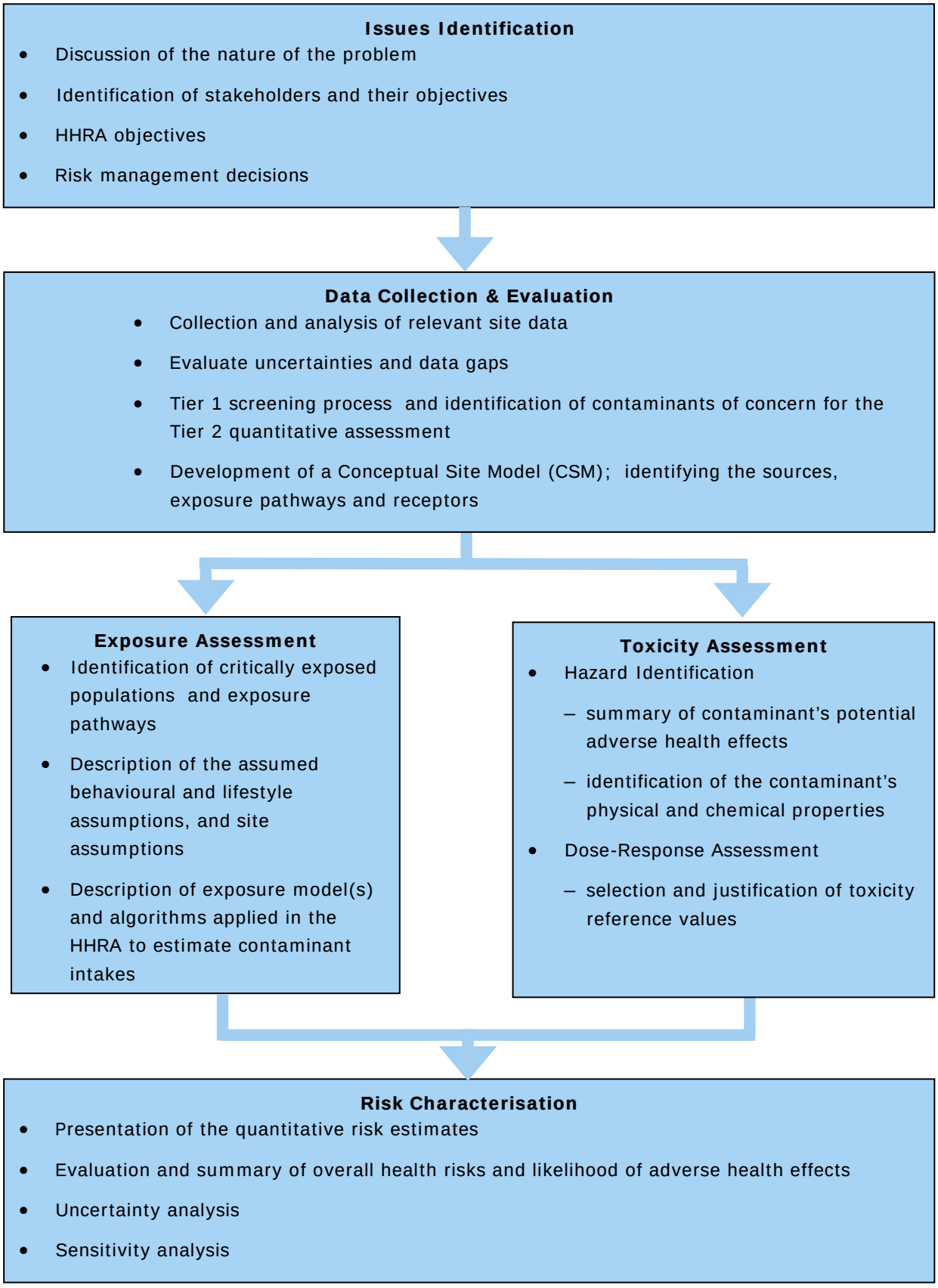


Figure 1: Human Health Risk Assessment Process

2. PROJECT DESCRIPTION

The Project will be located within the existing Hydro Aluminium Kurri Kurri Smelter site (the Smelter) at Hart Road Loxford. The Smelter location is shown in **Figure 2**. **Figure 3** shows the overall Project layout, including the locations of key activities.

Table 2.1 outlines the major elements of the Project and the key activities. A detailed description of the Project is provided in **Chapters 8** and **9** of the Environmental Impact Statement.

Table 2.1: Outline of the Project

Element	Key Activities
The Works	
Project Site Establishment	• Establishment of environmental controls (erosion and sediment controls, water quality controls). • Construction of the Containment Cell haul road. • Continued use of Stage 1 Demolition compounds. • Continued use of Stage 1 Demolition stockpile and storage areas.
Containment Cell Construction	• Vegetation clearance. • Site preparatory works. • Establishment and implementation of environmental controls (erosion and sediment controls, water quality controls). • Construction of the Containment Cell base layers. • Construction of internal cell walls within the Containment Cell. • Transport and placement of remediation and demolition materials to the Containment Cell. • Leachate and stormwater management. • Construction of the final Containment Cell capping layers.
Stage 2 Demolition	• Completion of hazardous materials removal. • Establishment and implementation of environmental controls (dust mitigation and water quality management). • Demolition of three concrete stacks and a water tower using detonation. • Mechanical demolition of remaining buildings and structures. • Material collection, separation, processing and storage. • Transportation of recyclable metals offsite. • Transport non-recyclable demolition material to the Containment Cell. • Grading of former building footprints.
Demolition Material Management	• Operation of a concrete and refractory crushing plant processing of up to 140 tonnes per day. • Manage a large stockpile area in the west of the Smelter. • Ferrous (steel) and non-ferrous (predominantly aluminium and copper) metals would be sorted and sized before being transported off site for recycling. It is anticipated that there would be up to 20 truck movements per day.
Contamination Remediation	• Removal of the Capped Waste Stockpile. • Excavation of the contaminated soils within the Smelter (including stockpiled soils sourced from other Hydro land). • Transport to the Containment Cell. • Filling and grading following removal of contaminated materials.
Leachate and Groundwater Treatment	• Establish and operate water treatment plants (Capped Waste Stockpile and Containment Cell). • Groundwater monitoring. • Water treatment plant, pumping well network and dam decommissioning.

Table 2.1: Outline of the Project

Element	Key Activities

Environmental Controls	• Dust controls during demolition would include:
	  • Accumulated fines from within the buildings would be removed where safe, reasonable and feasible to do so.
	  • Pre-wetting of buildings prior to undertaking the induced collapse and use of water sprays for dust suppression (as required due to wind conditions) during induced collapse.
	  • Ceasing activities that have the potential to generate significant dust that could have adverse impacts on sensitive receivers.
	• Watering of the demolition areas, unsealed access roads and other unsealed areas.
	• Vehicles would use (where possible) existing sealed roads.
	• Erosion and sediment controls would be installed, monitored and managed to reduce sediment run off entering the existing drainage system.
	• The existing site water management system would capture runoff.
	• Where possible, clean water would be diverted from Works areas.

Containment Cell Management	
Monitoring	• Monitoring of leachate generation within the Containment Cell.
Maintenance	• Mowing of the Containment Cell grass cover. • Maintenance (if required) of the capping layers.

The Works component of the Project would take approximately three years to complete.

Project traffic would predominantly travel to and from the Smelter via Hart Road and the Hunter Expressway (using the Hart Road interchange). A small number of vehicles (predominantly small vehicles used by Works personnel) are likely to continue to the intersection with Sawyers Gully Road, Gingers Lane and Government Road and along one of these roads.

Works activities that could generate an audible noise at the nearest sensitive receiver would be undertaken between 7:00 am to 6:00 pm, Mondays to Fridays and 7:00 am to 1:00 pm on Saturdays.

There are a number of Works activities that could be undertaken that would not exceed the Environment Protection Authority (EPA) *Interim Construction Noise Guideline* (DECC, 2009) or result in an adverse health impact to local residents (refer to **Section 5.4.2.4**).

2.1 Concurrent Activities

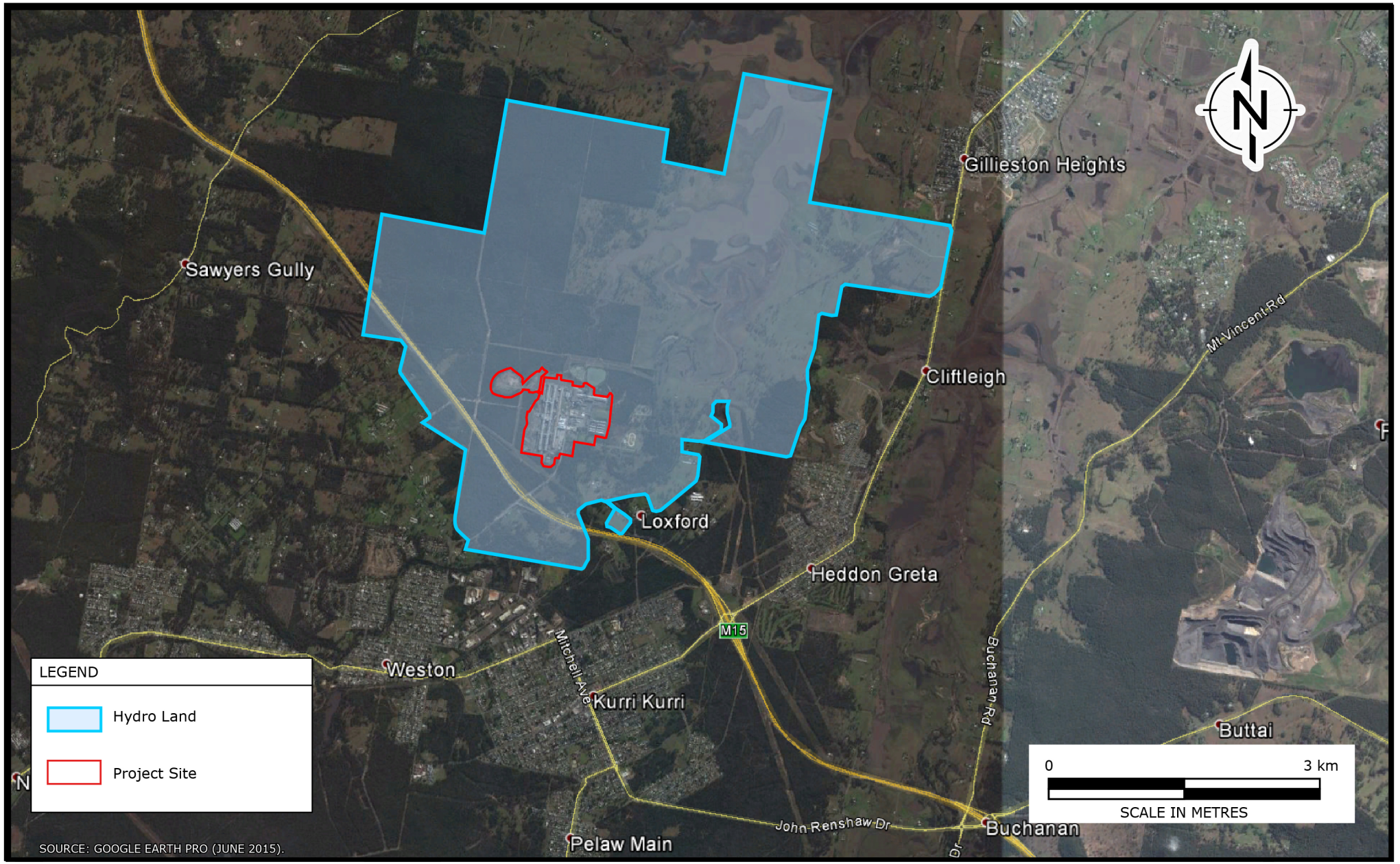
In March 2016 Hydro received Development Consent from Cessnock City Council for the following:

- Demolition of all buildings and structures at the Smelter excluding:
  - Buildings used for the storage of materials.
  - Three concrete stacks, and one concrete water tower (structures requiring the use of explosives for demolition).
  - The transformer yard and major power supply infrastructure in the north of the Smelter.
  - The administrative buildings, amenities building and various workshops and storage sheds.
- Establishment of a contractor's compound, either within an existing building located in the south of the Smelter (the former Building 77A Pot Rebuild building), or in the car park near the main entrance to the Smelter.
- A concrete and refractory crushing plant processing up to 28,000 tonnes per year or 140 tonnes per day.
- A demolition materials stockpile area.
- The sorting of recyclable metallic demolition materials and transportation to a metal recycling facility.

The activities addressed by the Development Consent from Cessnock City Council are known as Stage 1 Demolition.

It is proposed that the contractor's compound, the demolition materials stockpile area and the concrete and refractory crushing plant included in the Development Application to Cessnock City Council would continue to be used for the Project. It is anticipated that some Stage 1 Demolition activities would occur concurrently with the early stage of the Works.

So that the potential human health impacts of Stage 1 Demolition activities are considered when assessing the cumulative human health impacts, these activities have been included as appropriate in this report.



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LOCATION PLAN

FORMER HYDRO ALUMINIUM KURRI KURRI SMELTER
DEMOLITION AND REMEDIATION

FIGURE
2

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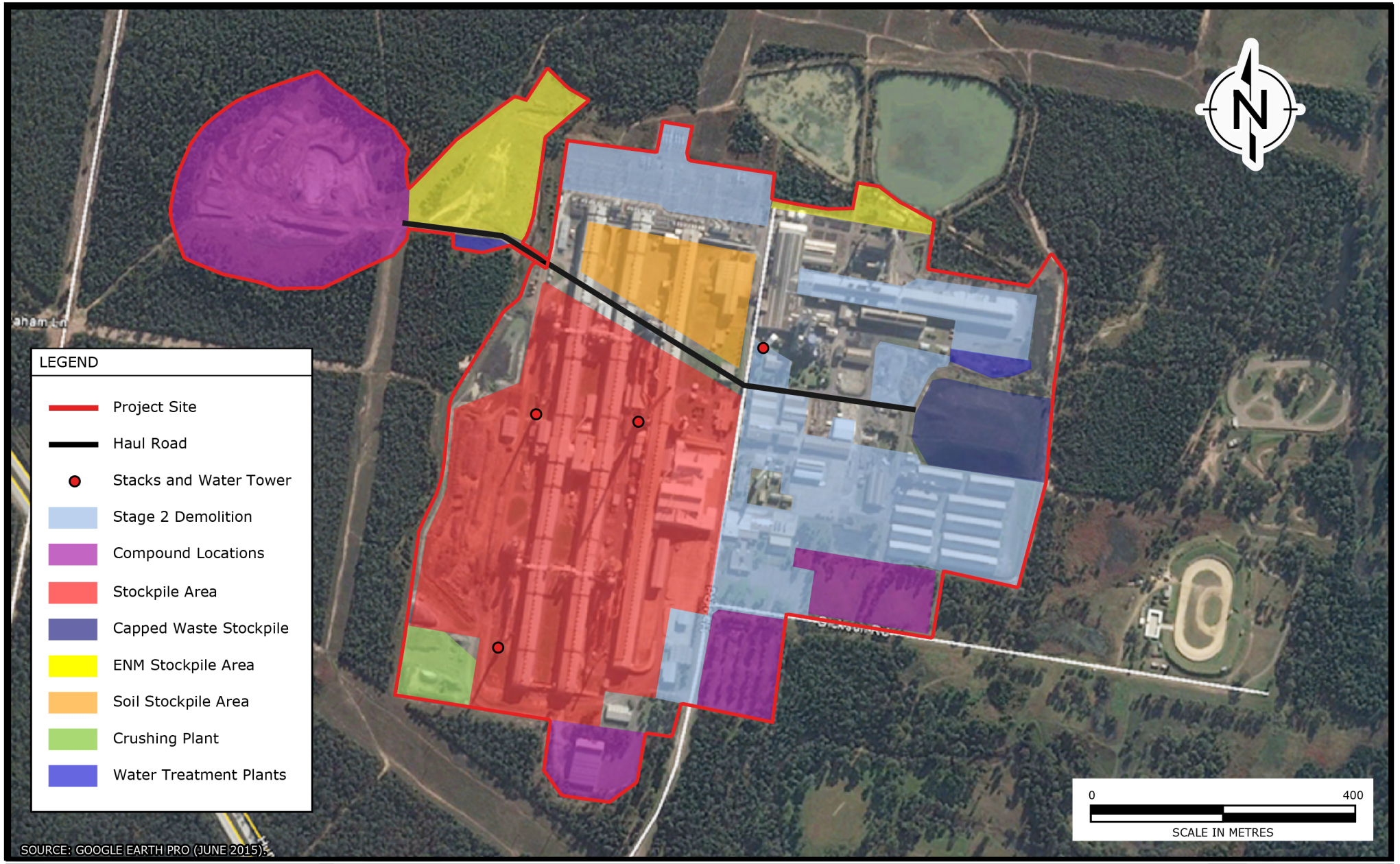

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PROJECT LAYOUT

FORMER HYDRO ALUMINIUM KURRI KURRI SMELTER
DEMOLITION AND REMEDIATION

FIGURE
3

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3. EXISTING ENVIRONMENT

3.1 General

As shown in **Figure 3**, the Project would impact the fenced Smelter footprint and the area currently known as the clay borrow pit to the immediate west.

Land uses in the vicinity of the Project include:

- Native vegetation: native ecological communities (with some cleared or disturbed areas) generally surround the Smelter and are within the Hydro owned land. Security fencing separates the Smelter from the vegetation.
- Electricity infrastructure: overhead power lines are located within easements to the north, west, southwest and northwest of the Smelter.
- Recreation: the Kurri Kurri Speedway and the Kurri Kurri Junior Motorcycle Club facility are approximately 500 metres to the east of the Project.
- Roads: The key roads in the vicinity of the Project are:
  - Hart Road is used to access the Smelter and is immediately adjacent to the western section of the Project.
  - Dickson Road intersects with Hart Road approximately 120 metres south of the Smelter security gate and immediately adjacent to the western section of the Project.
  - The Hunter Expressway is approximately 380 metres southwest of the Project.
- Residential: the Project is approximately 440 metres to the north of the nearest sensitive receiver, which is a rural residence owned by Hydro. The nearest rural residence not owned by Hydro is approximately 500 metres to the southeast, and the next nearest is approximately 750 metres to the southeast. There are approximately 24 rural residences within 1000 metres of the Project, of which 15 are on Hydro land.

  The nearest residential area to the Project is Weston, which is approximately 1800 metres to the southwest.
- Education: The Kurri Kurri TAFE is located approximately 1500 metres to the southeast of the Project and Kurri Kurri High School is approximately 1900 metres to the southeast of the Project.

3.2 Location and Size

The Smelter is located approximately 30km west of Newcastle and 150km north of Sydney in NSW, Australia. The Smelter address is Hart Road, Loxford, NSW, and is accessed through one main entrance located on the southern boundary of the site off Hart Road.

The Smelter covers an area of approximately 60 ha which is described by 10 different allotments, Lots 318, 319, 411, 413, 414, 415, 769, 776 in DP755231, and Lot 3 in DP456769.

The Smelter is located on approximately 2,000 hectares owned by Hydro (the Hydro land) which is described by approximately 75 different allotments. The Hydro land is used for primarily for agricultural purposes, with residential dwellings and commercial operations also present.

3.3 Current and Future Land Zoning

The Project site is currently zoned 'RU2 Rural Landscape' under the Cessnock Local Environmental Plan 2011. The objectives of the RU2 Rural Landscape zoning are:

- *To encourage sustainable primary industry production by maintaining and enhancing the natural resource base;*
- *To maintain the rural landscape character of the land;*
- *To provide for a range of compatible land uses, including extensive agriculture;*
- *To enable other forms of development that are associated with rural activity and require an isolated location or support tourism and recreation; and*
- *To ensure that the type and intensity of development is appropriate in relation to the rural capability and suitability of the land, the preservation of the agricultural, mineral and*

extractive production potential of the land, the rural environment (including scenic resources) and the costs of providing services and amenities.

It is noted the Smelter is permissible under existing use rights as established within the NSW *Environmental Planning and Assessment Act 1979.*

As noted in **Section 1.1** one purpose of the Project is to make the land suitable for future use. To facilitate a future land use the Project site is proposed to be subject to an LEP Amendment to rezone the Hydro land for conservation, residential, industrial and rural activities.

The proposed LEP Amendment includes the following zones within the Project site:

- IN1 General Industrial for the Smelter.
- IN3 Heavy Industrial for the Containment Cell.

The objectives of the IN1 General Industrial zone are:

- *To provide a wide range of industrial and warehouse land uses.*
- *To encourage employment opportunities.*
- *To minimise any adverse effect of industry on other land uses.*
- *To support and protect industrial land for industrial uses.*
- *To encourage sustainable major industrial development and major employment generating development.*

The IN1 General Industrial zoning is proposed to accommodate the future development permissible within the zone and consistent with the objectives of the zone.

The objectives of the IN3 Heavy Industrial are:

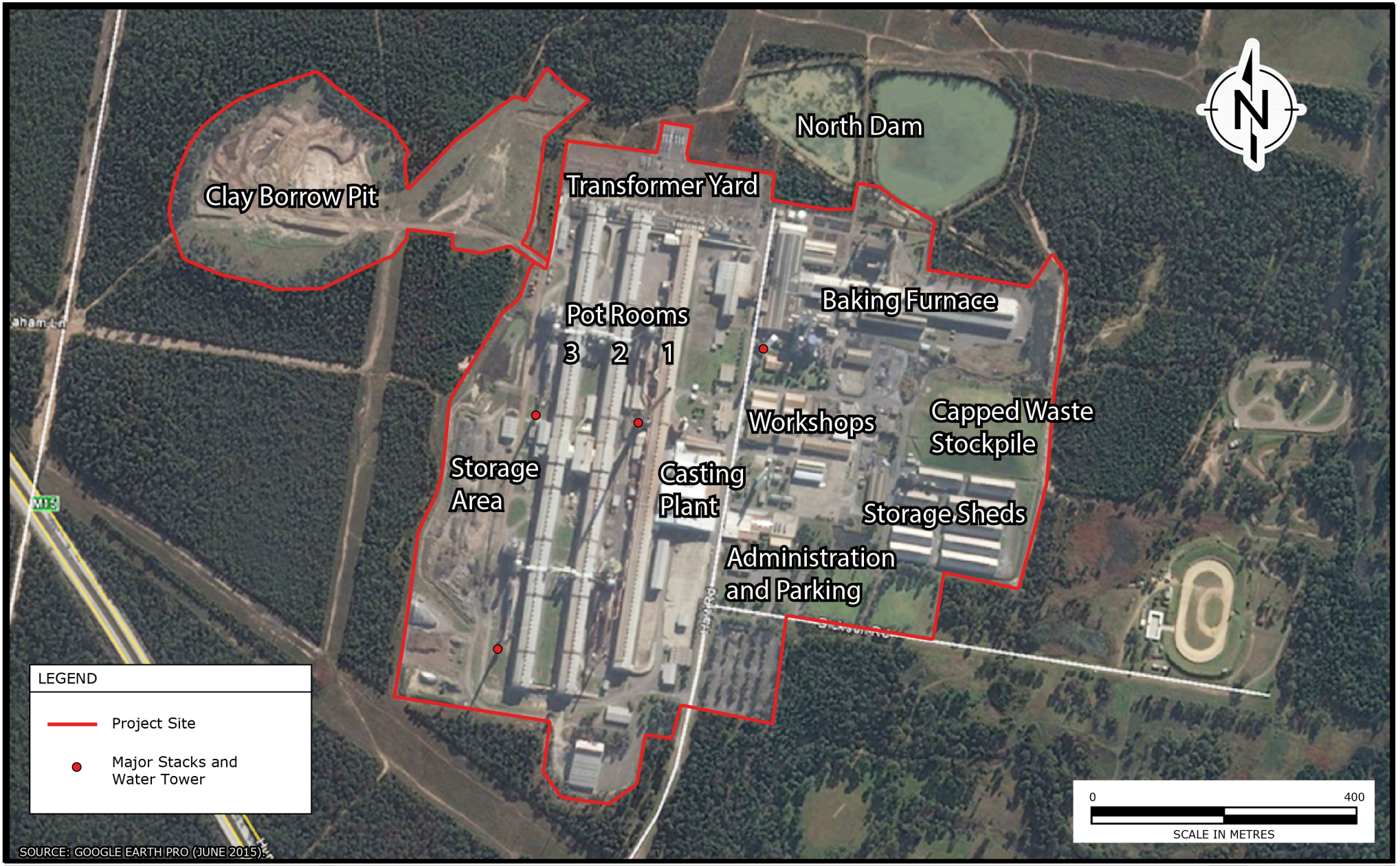
- *To provide suitable areas for those industries that need to be separated from other land uses.*
- *To encourage employment opportunities.*
- *To minimise any adverse effect of heavy industry on other land uses.*
- *To support and protect industrial land for industrial uses.*

The IN3 Heavy Industrial zoning is proposed to accommodate the Containment Cell and other future development permissible within the zone and consistent with the objectives of the zone.

3.4 Smelter Site Features

The key features of the Smelter, as shown in **Figure 4**, are as described below:

- Pot Rooms 1, 2 and 3 are located on the western portion of the Smelter. Alumina and cryolite were placed within pots and an electrical current applied. Molten aluminium was siphoned from each pot and taken to the Cast House.
- The Cast House is located immediately east of Pot Line 1 adjacent to the main entrance. The Cast House produced cast aluminium products to product specifications often including the addition of alloys. The Cast House utilised chlorine gas to avoid oxidation during the casting process. The gas was captured when the casting chamber is filled. Wastes from the Cast House included dross and swarf, which have a high aluminium content and were sent for recycling off-site.
- The Carbon Plant is located near the northern boundary of the Smelter to the east of the potlines. The Carbon Plant produced anodes from a mixture of coke, pitch and recycled anode butts to produce a green anode. This green anode was then baked within a bake furnace prior to the addition of a cast iron rod, and dispatched to the Pot Rooms. The bake furnace was gas fired however it was previously oil heated. Ancillary operations associated with the Carbon Plant include a liquid pitch tank, petroleum coke storage, the bake furnace scrubber, the rodding building, rodding mix storage building, baked anode storage.



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SMELTER SITE LAYOUT

FORMER HYDRO ALUMINIUM KURRI KURRI SMELTER
DEMOLITION AND REMEDIATION

FIGURE
4

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Infrastructure and ancillary structures located within the Smelter include:

- A transformer yard and substation are located in the north western corner of the Smelter.
- Stormwater on the Smelter's paved areas is directed via a drainage system to either the West Surge Pond, which is located on the western boundary of the Smelter or the East Surge Pond, which is located on the eastern boundary of the Smelter. Surface water runoff from the car park and administration areas is directed to the South Surge Pond. All ponds flow to the North Dam, located to the north of the Carbon Plant.
- Smelter wastes including spent pot lining were stockpiled on a low lying area of the Smelter near the eastern plant boundary between 1969 and the early 1990s. The smelter waste mound (known as the Capped Waste Stockpile) was capped with clay in 1995. Since this time smelter wastes have been stockpiled separately or recycled. Spent pot lining is now stored in purpose-built sheds, of which there are ten located to the south of the Capped Waste Stockpile.
- A maintenance compound is located in the centre of the Smelter, south of the Carbon Plant. The compound was and continues to be used for maintenance activities as well as storage of equipment and spare parts.
- A diesel refuelling area is located in the centre of the Smelter. The diesel refuelling area contains one above ground storage tank and a wash bay.
- A diesel spray area is located at the rear of the Carbon Plant on the northern smelter boundary, which was used to treat rust coatings from cathode rods prior to reuse.
- Offices, a security gate house, canteen, two playing fields and a gym are located in the central southern area of the Smelter.
- Storage area west of the Pot Rooms.
- The clay borrow pit.

The infrastructure and ancillary structures described above are included on **Figure 4**.

3.5 Surface Covering

The majority of the Smelter is developed with buildings and associated hardstand areas. Areas adjacent to the buildings are predominately sealed with concrete or bitumen (car parks, roadways and turning areas). Other areas are compacted gravel and fill material. Established garden beds and grassed areas surround some buildings at various locations throughout the Smelter.

3.6 Site Topography

The Smelter is located between low residual hills to the west and low lying swampy land to the north and east. Low lying areas were filled to create a flat, elevated platform at approximately 14m Australian Height Datum (AHD) for construction of the Smelter. The Smelter site is relatively flat with a gentle slope from west to east, from the Smelter towards the surrounding water courses.

Surrounding the Smelter site the landforms in the north and east comprise low-lying swamps, with many surface water drainage ponds and creeks, interspersed with topographical rises comprising residual soils. In the south and west, the landform is predominantly residual hills with gully formations draining to the north and east.

3.7 Surface Water and Drainage

There are five storage ponds located at the Smelter as shown on **Figure 4**. Surface water from the Smelter is directed to these storage ponds via open channels and some concrete subsurface drainage lines. Surface water ponds known as 'East' and 'West' are pumped to the North Dams where excess surface water is discharged to an irrigation area under licence from the Environment Protection Authority (EPA) (Environment Protection Licence No. 1548). Surface water dams were constructed by excavation into the residual underlying extremely weathered bedrock.

Currently, an active leachate interception trench placed at the toe of the Capped Waste Stockpile is intercepting leachate from below the Capped Waste Stockpile and diverting it to the East Surge Pond. Further down-gradient, a passive leachate interception trench intercepts groundwater

following rain events and diverts this groundwater to the East Surge Pond. Surface water quality data from the East Surge Pond and North Dams are monitored for pH, fluoride and cyanide. Data from 2014 monitoring indicates that pH is neutral at 6.5 to 7 in both dams, fluoride concentrations have varied between 5.6mg/L and 20mg/L in the East Surge Pond and 14.8mg/L to 18mg/L in North Dam. Free cyanide concentrations are generally less than the laboratory detection limit. These fluoride concentrations are elevated compared to background levels, which is likely due to the flow of stormwater past the anode waste pile (located to the northwest of the Capped Waste Stockpile) prior to pumping to the North Dam.

3.8 Geology

3.8.1 Regional Geology

According to the review of the regional geology described on the *Sydney Basin Geological Sheet*, the Smelter Site and the Hydro land are underlain by siltstone, marl and minor sandstone from the Permian aged Rutherford Formation (Dalwood Group) in the Sydney Basin.

The Sydney Basin is a sedimentary basin consisting of Permian and Triassic sedimentary rocks, which extends from Newcastle in the north to Batemans Bay in the south and to Lithgow, just west of the Blue Mountains. The basin overlies older basement rocks of the Lachlan Fold Belt. The sedimentary rocks of the basin generally consist of near horizontal sandstones and shales, with some recent igneous dykes. Only minor folding and faulting has occurred since these sedimentary rock sequences first formed. The Dalwood Group is stratigraphically located near the base of the Sydney Basin below both the Greta Coal Measures and Newcastle Coal Measures and was deposited in a marine environment.

Undifferentiated Quaternary alluvium occurs in the east and northeast in the Hydro land associated with surface water bodies. Quaternary sediments which are associated with Swamp Creek (located to the east of the site), Wentworth Swamps and the Hunter River consist of complex interbedded fluvial and marine sands and estuarine muds deposited within an estuarine environment during periods of sea level rise and fall.

3.8.2 Location and Extent of Fill

The Smelter is located in low lying land that was filled to create a level area for the construction of the Smelter. The fill material is generally understood to comprise locally derived fill. During the 2012 Phase 2 Environmental Site Assessment (ESA) investigations (ENVIRON, 2012b), crushed refractory brick fill was observed within fill material underlying the Carbon Plant and the Pot Lines.

Clay fill material from the clay borrow pit in the western portion of the Smelter was used to cap the Capped Waste Stockpile in the eastern portion of the Smelter in 1996. The excavated portion of the clay borrow pit was backfilled with refractory brick and concrete fill.

A portion of the Smelter between the north-western fence line and the clay borrow pit was also filled with material likely to include refractory bricks and concrete waste. This area was filled with excess Virgin Excavated Natural Material (VENM) from the construction of the Hunter Expressway immediately south of the Smelter.

3.8.3 Site Geology

Five geotechnical reports were prepared by Douglas Partners Pty Ltd in May 1993, September 2001, August 2002, December 2002 and January 2003 in relation to the bake furnace reconstructions within the Carbon Plant.

A summary of the subsurface conditions reported beneath the Carbon Plant is presented in **Table 3.1**.

Table 3.1: Subsurface Conditions beneath the Carbon Plant

Depth	Lithology
0m to 2m	Fill, gravelly sand/ sandy gravel
2m to between 4.2m and 6.5m	Fill, gravel/ sandy gravel with a trace of some clay
4.2m to 6.5m	Gravelly sand, loose to dense
6.2m to 11.7m	Clay, hard to very stiff
11.6m to 17.4m	Sand, dense to medium dense
17.4m to >24m	Siltstone, low to very low strength at top

During 2012 Phase 2 ESA, Ramboll Environ (formerly ENVIRON) supervised the drilling of 52 boreholes across the Smelter. These boreholes extended to a maximum depth of 16m below ground surface (bgs). The subsurface conditions varied across the Smelter, but generally comprised fill material overlying estuarine sediments. The fill material, where encountered, generally comprised clayey gravelly sand and included gravel brick fragments. The estuarine sediments generally comprised fine grained sand, with high plasticity clay encountered in some boreholes.

3.9 Hydrogeology

3.9.1 Regional Hydrogeology

Regionally groundwater is expected to follow the topography and flow northeast towards surface water bodies that feed into the Hunter River, located approximately 7km north east of the site.

The Hunter River Alluvium Groundwater Management Unit (GMU) is an important groundwater resource to the region. Groundwater extraction for irrigation, urban supply, drought supply, stock, domestic and commercial/ industrial use occurs, with volumes in excess of 10,000ML per annum extracted from the Hunter River Alluvium GMU. Aquifer storage and recovery is also an important use of this GMU.

According to the NSW Office of Industry and Investment there are 17 licensed groundwater abstractions (bores) located within the Hydro land. There are no other licensed groundwater bores within 2km of the Smelter. There is a group of seven groundwater bores located just over 2km to the northwest of the Smelter.

3.9.2 Local Hydrogeology

The general groundwater flow direction beneath the Smelter is understood to be towards the northeast, flowing towards the low lying Wentworth Swamp. Groundwater flow in the estuarine sands aquifer at the Smelter has been impacted by the construction of the Carbon Plant, which involved the excavation of sands to depths of 5.6m bgl and backfilling with granular material around the concrete lined pits containing the bake furnaces.

Groundwater flow occurs through two aquifers comprising a shallow sand channel aquifer that is underlain at depth by a separate and confined aquifer. Groundwater within the shallow aquifer is isolated from the deeper aquifer. Vertical groundwater flow is limited by both high plasticity clays and very dense fine grained sands (ENVIRON, 2015c).

Groundwater has been encountered within estuarine sands at depths ranging between 1m and 5m bgs beneath the Smelter Site during fieldworks conducted in 2012 and 2014 (ENVIRON, 2015b).

Groundwater flows within the estuarine sands of up to 14m/year have been estimated (ENVIRON, 2015b). Groundwater with the estuarine sands is not used at the Smelter and is not considered a suitable aquifer for use down-gradient of the Smelter.

4. ISSUES IDENTIFICATION

The Issues Identification process is intended to establish the context for the HHRA by a process of identifying the concerns that need to be addressed, such as '*what is causing the identified concern*?" and "*why is the concern an issue*?". It is a process of communication between stakeholders in the project, and its scope and complexity depends upon the scale of the project and the issues being dealt with.

4.1 Nature of the Problem

An Environmental Impact Statement (EIS) is being prepared for submission to the Department of Planning and Environment for the Demolition and Remediation Project (the Project) at the former Kurri Kurri Aluminium Smelter (The Smelter). This HHRA report was prepared to support requirements of the EIS.

4.2 HHRA Dimensions

This HHRA focuses on potential health risks to onsite (Works personnel) and offsite sensitive receptors (i.e. residents and other sensitive receptors) due to activities associated with the demolition and remediation of the Project site, including construction of the Containment Cell.

This HHRA does not assess future potential health risks following completion of the Works at the Project site, nor does it include an assessment of potential ecological risks to onsite or offsite ecological receptors.

The HHRA will be undertaken in accordance with relevant NSW and Australian guidance for performing human health risk assessments, and has been prepared to satisfy the requirements set by the SEARs, including the submissions made by the Hunter New England Local Health District and WorkCover NSW.

Predictive air quality and noise data are used in this HHRA to assess potential health risks, and these data were generated in parallel studies that accompany the EIS.

4.3 HHRA Objectives

As discussed in **Section 1.2**, the objectives of this HHRA are to:

- Assess the potential for unacceptable human health risks posed to on-site and off-site human receptors that may result from potential contact with or exposure to chemicals arising from the Project.
- Identify any additional management measures to mitigate impacts of the Project on workers and off-site sensitive human receptors including residents.

4.4 Risk Management Decisions

The results from this HHRA will be used to inform the Environmental Impact Statement (EIS) for the Project and to confirm and develop the detailed demolition and remediation methodology and associated management plans, including a Work Health and Safety Plan and Environmental Management Plan.

4.5 Project Stakeholders

Stakeholders to this HHRA include:

- *Hydro Aluminium Kurri Kurri*: applicant submitting the EIS for the demolition of redundant Smelter buildings and structures, remediation of impacted soil, and construction and operation of a Containment Cell.
- *NSW Department of Planning and Environment*: responsible for reviewing and approving the EIS.
- *Hunter New England Local Health District*: responsible for reviewing and providing comment to the HHRA which is provided as supporting information for the EIS.

- *WorkCover NSW*: responsible for reviewing and providing comment to the HHRA, with a focus on the potential health risk to workers undertaking the demolition and remediation activities on the Project site.
- *Local community*: the local community (including Loxford, Kurri Kurri, Weston, Sawyers Gully, Gillieston Heights and Heddon Greta) have been consulted throughout the Project planning process. It is a key objective of Hydro for the Project to not adversely impact the health of Works personnel and the local community.

5. DATA COLLECTION AND EVALUATION

5.1 Data Considered in the HHRA

Results and discussions of relevant works previously completed by Ramboll Environ at the Smelter considered within the HHRA are listed in **Section 5.2.** The data from these investigations were used to form conclusions regarding potential health risk presented in this HHRA.

In addition, this HHRA utilises data generated by Ramboll Environ and Vipac Engineers and Scientists Ltd (Vipac) which represents the predicted air quality data and noise levels likely to be generated by the Project. This data are provided in two separate studies prepared as supporting information for the EIS:

- Ramboll Environ (2015) *Former Hydro Aluminium Kurri Kurri Smelter Demolition and Remediation: Air Quality Impact Assessment*
- Vipac (2015) *Former Hydro Aluminium Kurri Kurri Smelter Demolition and Remediation: Noise and Vibration Impact Assessment*.

5.2 Previous Environmental Investigations Considered in this HHRA

The following environmental investigations have been performed on the Smelter, and are considered relevant to preparation of this HHRA:

- ENVIRON (2012a) *Application for Exemption – Refractory Brick*.
- ENVIRON (2012b) *Phase 2 Environmental Site Assessment, Kurri Kurri Aluminium Smelter*.
- ENVIRON (2013a) *Preliminary Screening Level, Health Risk Assessment for Fluoride and Aluminium*.
- ENVIRON (2013b) Phase 1 Environmental Site Assessment, Hydro Kurri Kurri Aluminium Smelter.
- ENVIRON (2014a) Hazardous Materials Audit Stage 1, Maintenance Workshops and Storage Sheds.
- ENVIRON (2014b) *Hazardous Materials Audit Stage 3, Cast House and Associated Buildings*.
- ENVIRON (2014c) *Hazardous Materials Audit Stage 5, Carbon Plant and Associated Buildings*.
- ENVIRON (Draft 2014d) *Application for Exemption – Refractory Brick Supplementary Testing*.
- ENVIRON (2015a) *Phase 2 Environmental Site Assessment, Smelter Site, Additional Investigations*.
- ENVIRON (2015b) *Hydro Aluminium Kurri Kurri Smelter, Capped Waste Stockpile, 12 Month Groundwater Monitoring Report*.
- ENVIRON (2015c) *Preliminary Geotechnical Investigation, Proposed Containment Cell Site, Clay Borrow Pit*.

A summary of the project objective, scope and conclusions for these investigations is provided below.

5.2.1 ENVIRON (2012a) Refractory Brick Exemption

Objective: to seek a resource recovery exemption from the NSW EPA for the reuse of refractory brick as a road construction material.

Scope: preparation of a document in accordance with the NSW EPA *Guidelines on Resource Recovery Exemptions (Land Application of Waste Materials as Fill) 2011*. Twenty composite samples of brick material was sampled and analysed for a range of contaminants including metals, fluoride, cyanide, sulphur and polycyclic aromatic hydrocarbons (PAH).

Conclusions: chemical concentration in the brick samples were below NEPM (2013) soil guidelines for residential land use. PAH concentrations were not detected above the laboratory limit of reporting (LOR). A maximum total fluoride concentration of 920 mg/kg was reported.

The request for exemption was granted by the NSW EPA in October 2012, and they requested a detailed characterisation of the refractory bricks which was carried out in August 2014 (refer to **Section 5.2.6**).

5.2.2 ENVIRON (2012b) Phase 2 Environmental Site Assessment

Objective: evaluate soil and groundwater concentrations at the Smelter that may represent a risk to human health at the Smelter, and human health and the environment in the surrounding Hydro land. Fieldworks were conducted during site operations and were considered to be a preliminary investigation.

Scope: review historical and background data; site inspections; drilling of 31 boreholes; installation of 21 groundwater monitoring wells; collection of 14 sediment, 45 surface soil and 28 groundwater samples; and soil and groundwater laboratory analysis.

Conclusions: the investigations 10 identified areas of potential environmental concern including the Capped Waste Stockpile, the Anode Waste Pile, East Surge Pond and associated drainage lines, Diesel Spray Area, Carbon Plant, Glen Ayr Drift, clay borrow pit, fluoride in soil and groundwater and aluminium in groundwater.

5.2.3 ENVIRON (2013a) Preliminary Screening Health Risk Assessment

Objective: develop preliminary screening level guidelines that are protective of human health for fluoride and aluminium under a range of current and possible future site uses.

Scope: the Health Risk Assessment was qualitative and involved a desktop evaluation of toxicity reference values for fluoride and aluminium, identified source exposure pathways and mechanisms and development of preliminary screening levels based on the compound's toxicity and the possible exposure routes.

Conclusions: preliminary screening levels for aluminium and fluoride were developed for residential, recreational and industrial soil, and surface water assuming recreational use. It was conservatively assumed that fluoride and aluminium are 100% bioavailable in soil and fluoride levels in drinking water are at the maximum target levels. The preliminary screening levels for fluoride are based on 'soluble fluoride' and not 'total fluoride'.

5.2.4 ENVIRON (2013b) Phase 1 Environmental Site Assessment

Objective: identify, review and report on the potential for historic and current site contamination.

Scope: review historical reports relating to land use and operations at the Smelter and Hydro land; review of historical aerial photographs; detailed site walk over; interview with Smelter environmental manager; and review of historical environmental investigations conducted since 2000.

Conclusions: Smelter operations on the Smelter and in the Hydro have potentially resulted in impacts to soil and water. ENVIRON has previously completed a number of investigations at the Smelter that identified and investigated potential areas of concern. Areas of potential concern identified previously and as part of this in-depth historical review have been listed in an Environmental Issues Register for Hydro land. This Environmental Issues Register is a live document used to document the issue identification and close out process and also to record new issues should they arise.

5.2.5 ENVIRON (2014a, b, c) Hazardous Materials Audits

Objective: undertake a Hazardous Materials Audit (HMA) and develop a hazardous materials register for the buildings and structures within the Smelter. This information will be used to assist contractors to scope and undertake the hazardous materials removal works.

Scope: amongst other activities such as site inspections, of relevance to this HHRA is the collection of dust and concrete samples for the analysis of metals, fluoride, cyanide, PAHs and TPH compounds. Concrete samples were collected from the Pot Rooms and Carbon Plant buildings, and

settled dust was collected from the spent potlining storage sheds, maintenance workshops, Carbon Plant and Cast House.

Conclusions: with respect to the dust and concrete samples, concentrations of metals, fluoride, cyanide PAHs and TPH were detected above the laboratory reporting limit. This information is discussed further in **Section 5.4.2.1**.

5.2.6 ENVIRON (Draft 2014d) Refractory Brick Exemption, Supplementary Testing

Objective: in response to NSW EPA's request the objective was to further characterise the refractory brick with the aim of seeking a resource recovery exemption for the reuse of refractory brick as a road construction material.

Scope: brick samples were collected on an approximate 20m grid from both stockpiled and buried material. Twelve brick samples were collected from 25 test pits and 24 brick samples were collected from above-ground stockpiles. Each sample was analysed for metals, fluoride, cyanide and 20% of the samples for PAHs.

Conclusions: chemical concentration in the brick samples were below NEPM (2013) soil guidelines for residential land use. A maximum fluoride concentration of 730mg/kg was reported.

5.2.7 ENVIRON (2015a) Phase 2 ESA, Additional Investigations

Objectives: complete Stage 2 of the Phase 2 ESA to build upon the results of Stage 1 in understanding the potential for soil and groundwater contamination at the site to impact on the use of the site for commercial/industrial land use. The initial Stage 1 phase of work was completed in November 2012.

Scope: review previous investigations and identify data gaps; soil sampling at five areas of concern and five new potential areas of environmental concern; install seven new groundwater wells at three areas of concern; sampling new and existing 17 groundwater wells; and analysis of soil and groundwater samples for metals, fluoride, PAHs and cyanide. Based on these results, refine the conceptual site model, identify additional site investigations and assess areas requiring remediation.

Conclusions: PAH impacts (primarily benzo(a)pyrene) to surface soils was identified in seven areas due to contamination in the fill material, which was not identified to extend into the underlying alluvial sands and not impact groundwater. Lateral delineation of soil contamination and hotspots was recommended prior to remediation efforts. Development of a Remediation Action Plan was recommended to develop remediation and validation plans for each of the seven areas identified with PAH soil impacts. It was acknowledged that remediation is likely to occur following or during demolition of the buildings on the Smelter.

5.2.8 ENVIRON (2015b) Capped Waste Stockpile, 12 Month Groundwater Monitoring Report

Objectives: monitor the groundwater leachate plume down-gradient of the Capped Waste Stockpile and compare the current status of the plume to historical data to assess its stability.

Scope: conduct five groundwater monitoring events at the leachate plume associated with the Capped Waste Stockpile between July 2013 and November 2014. Each groundwater monitoring event included the sampling and analysis of groundwater from 25 wells located on five sections along the length of the leachate plume down-gradient of the Capped Waste Stockpile. Groundwater samples were analysed for soluble fluoride, cyanide and aluminium. Field measurements of physio-chemical properties including pH.

Conclusions:

- Groundwater drawdown around the interception trench has occurred since the commissioning of the trench in May 2014.
- Fluoride concentrations are responding to the leachate interception trench with suggestions that undiluted leachate is being drawn into the trench, and concentrations beyond the trench are starting to decrease.

- Fluoride concentrations in the deep aquifer remain low and this aquifer appears un-impacted by leachate.
- Continued quarterly groundwater monitoring was recommended.

5.3 Data Gaps

An assessment of the data gaps identified for conducting the HHRA are presented in **Table 5.1**.

Table 5.1: Assessment of Data Gaps

Data Gaps	Potential Significance	Manner in which data gap is addressed in the HHRA
The concentration of dust likely to be generated via disturbance of soil and dust settled inside buildings during the Works is unknown.	Works personnel have the potential to inhale contaminated dust during the remediation and demolition works.	Dust concentrations were modelled by Ramboll Environ (2015) for the Project, and these predicted concentrations were used in the HHRA for Works personnel.
	Dust generated during Project activities have the potential to be transported offsite where sensitive receptors such as residents have the potential to inhale the dust particles	
Noise levels caused by Project activities that is experienced by offsite sensitive receptors is unknown.	Offsite sensitive receptors have the potential to be adversely affected by increased noise levels generated by the Project activities.	Noise levels predicted to be generated by the Project activities were modelled by Vipac (2015) and the results were used in this HHRA.
Soil concentrations within the Capped Waste Stockpile are unknown. However, the contents of waste within the Capped Waste Stockpile are reasonably well understood.	Works personnel have the potential to be exposed to impacted soil within the Capped Waste Stockpile during remediation activities.	Groundwater quality immediately down-gradient of the Capped Waste Stockpile is well characterised. Mitigation measures recommended to protect Works personnel from exposure to impacted groundwater within the Capped Waste Stockpile will also protect Works personnel from exposure to any impacted soil and waste.
Chromium concentrations in soil exceeded the adopted assessment criteria and was quantitatively assessed in the HHRA. It is unknown whether the chromium is present as III or VI.	Chromium VI is more toxic than chromium III.	Chromium was considered to be present on the site as chromium VI, the more toxic form. This is considered to be a health protective assumption.

5.4 Conceptual Site Model

A conceptual site model (CSM) is a site-specific qualitative description of the source(s) of contamination, the pathway(s) by which contaminants may migrate through the environmental media, and the populations (human or ecological) that may potentially be exposed. This relationship is commonly known as a Source-Pathway-Receptor (SPR) linkage. Where one or more elements of the SPR linkage are missing, the exposure pathway is considered to be incomplete and no further assessment is required.

The CSM for the Works phase of the Project is described in detail below.

5.4.1 Human Receptors

The human receptors of concern for the Works activities at the Smelter include the following:

- Works personnel: these receptors are adult workers employed to undertake the Works at the Project site. They are considered to spend the majority of the day working outdoors as they travel through the site, and may also undertake intrusive activities. Specific tasks may include:
  - Operation of trucks, excavators and other machinery.
  - Operation of the concrete crushers and mulching/composting machine.
  - Demolishing building structures, pavement, subsurface utilities and stacks.
  - Construction of the Containment Cell including removal of top soil and placement of cell infrastructure.
  - Excavation, transportation and placement of impacted material in the Containment Cell.
  - Crushing bricks, concrete, anode blocks and other large items from the Capped Waste Stockpile prior to transportation to the Containment Cell.
  - Supervisory and administrative tasks.
- Offsite human receptors including:
  - *Offsite residents*: these receptors are child and adult residents who live within the vicinity of the Project site and are potential receptors to particulates/vapour and noise generated by the Works.
  - *Offsite recreational users*: these receptors are children and adults who use passive and active recreational facilities such as parks, gold clubs and sporting venues.
  - *Offsite sensitive receptors*: these receptors are children and adults that use or reside in facilities such as childcare centers, educational facilities, places of worship, aged care facilities, immunocompromised and medical facilities.

When identifying the specific offsite human receptors for consideration in this HHRA, Ramboll Environ considered all sensitive receptor locations within a four kilometre radius of the Project site. The HHRA then considered potential health risks to the most sensitive human receptor which was considered to be the receptor location where predicted particulate concentrations, generated from Project activities, were the highest (as predicted by the Ramboll Environ AQIA, 2015 study).

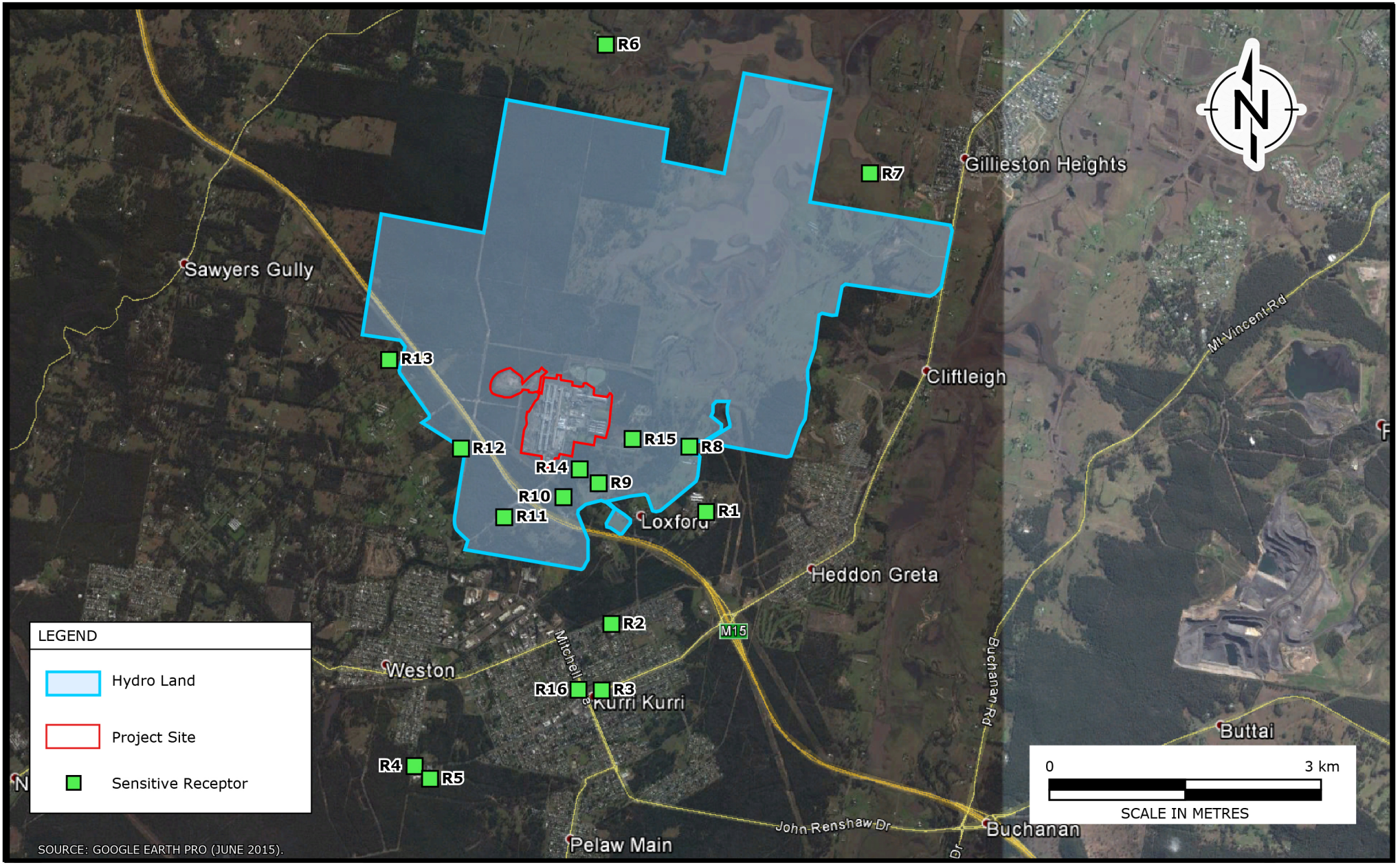
The offsite human receptors were separated into the following groups:

- *Educational Facilities*: including Hunter TAFE, local high schools, primary schools and preschools.
- *Childcare Facilities*: including early childhood centres, and before and after school care facilities.
- *Aged Care Facilities*: only one facility was identified located within the grounds of the Kurri Kurri Hospital.
- *Medical Care Facilities*: including hospitals and family medical centres.
- *Residential properties*: the nearest eight properties in each direction from the Project site, including properties owned by Hydro which will continue to be used as residential dwellings during the Works.
- *Recreational Facilities*: including parks, golf courses/clubs and sporting venues such as the Kurri Kurri Speedway and the Kurri Kurri Junior Motorcycle Club.
- *Places of Worship*: including local churches.

The human receptors of concern that were located closest to the Project site are presented in **Table 5.2**.

Table 5.2: Off-site Human Receptors

Sensitive Receptor	Address	Distance from Project (km)	Direction from the Project
Educational Facilities			
Hunter TAFE [R1]	McLeod Road, Kurri Kurri	1.4	Southeast
Kurri Kurri High School [R2]	Deakin and Standford Streets, Kurri Kurri	1.8	South/ southeast
Child-Care Facility			
Kurri Early Childhood Centre [R3]	107 Lang Street, Kurri Kurri	2.6	South/ southeast
Medical Facility			
Kurri Kurri Family Medical Centre [R4]	312 Lang Street, Kurri Kurri	3	South
Aged-Care Facility			
RFBI Kurri Kurri Masonic Village/Nursing Home [R5]	Hospital Road, Kurri Kurri	3.6	South/ southwest
Nearest Residential Property			
Private dwelling [R6]	685 Old Maitland Road, Bishops Bridge	4	North
Hydro-owned dwelling [R7]	464 Cessnock Road, Gillieston Heights	2.8	Northeast
Private dwelling [R8]	20 Bowditch Avenue, Loxford	1.0	East
Private dwelling [R9]	6 Dawes Avenue, Loxford	0.5	Southeast
Hydro-owned dwelling [R10]	Scales Avenue (Lot 444, DP755231), Loxford	0.35	South
Private dwelling [R11]	78 Hart Road, Loxford	0.8	Southwest
Private dwelling [R12]	103 Bishops Bridge Road, Sawyers Gully	0.7	West
Private dwelling [R13]	78 Lumby Land, Sawyers Gully	1.8	Northwest
Nearest Recreational Facility			
Hydro-owned Cricket Pitch Park, used by Scout clubs [R14]	Dawes Avenue, Loxford	0.15	Southwest
Kurri Kurri Speedway [R15]	73-81 Dickson Road, Loxford	0.2	West
Places of Worship			
Church of Christ [R16]	134 Maitland Street, Kurri Kurri	2.5	North



RAMBOLL ENVIRON

DRAFTED BY: KK | DATE: July 2016

LOCATION OF OFFSITE RECEPTORS (HUMAN HEALTH)

FORMER HYDRO ALUMINIUM KURRI KURRI SMELTER
DEMOLITION AND REMEDIATION

FIGURE
5

AS130401

5.4.2 Health Impact Source

The health impact sources assessed in this HHRA includes:

- Contamination sources including:
  - Particulates generated from surface soil and settled dust inside buildings.
  - Soil.
  - Groundwater.
- Noise and vibration.
- Smelter waste buried in the Capped Waste Stockpile including asbestos.

The 'contaminant source' is identified by comparison of observed chemical(s) of potential concern (CoPC) concentrations in the media of concern (soil, groundwater, and particulates) at the site against conservative generic screening criteria, termed "Tier 1 screening criteria". A potential 'source' is identified when the CoPC concentration is reported to be present in the environmental media at the site above Tier 1 screening criteria which have been derived based on protection of human health. Further assessment of the CoPC that exceed the Tier 1 screening criteria is undertaken in the Tier 2 HHRA.

Potential health risks due to the Containment Cell are discussed separately in **Section 0**. In addition, health risks due to potential impacts to tank rainwater quality and reticulated drinking water supplies are discussed in **Section 8.6** and **Section 8.7**, respectively.

5.4.2.1 Particulates

Particulate Sources

Air borne particulates are likely to be generated from a number of sources during the Works, and include:

- *Refractory bricks*: these were used as insulating material to line the bake furnace for baking of the anodes. The bricks are described as high temperature bricks comprising alumina (50%), iron oxide (2%) and silicate (48%). Laboratory analytical testing of the bricks reported concentrations below the NEPM (2013) soil guidelines for residential land use. PAH concentrations were not detected above the laboratory LOR; and a maximum fluoride concentration of 730 mg/kg was reported. Refractory bricks have been stockpiled around the site, placed in the clay borrow pit and some still remain in the bake furnace. The bricks will be crushed in the concrete crushing machine and used during construction of the haul road and Containment Cell; and these activities have the potential to create airborne particulates. The refractory brick analytical data is presented in **Table A1**, **Appendix A**.
- *Building concrete*: during demolition of the buildings, dust would likely be generated when the concrete structures are pulled down and during crushing of the concrete prior to disposal in the Containment Cell. Concrete samples were collected from the Pot Rooms and Carbon Plant buildings and concentrations of fluoride and carcinogenic PAHs were detected above the NEPM (2013) soil guidelines for residential land use. The concrete analytical data is presented in **Table A2**, **Appendix A**.
- *Surface soil*: surface soil would be disturbed during the Works activities such as the haul road construction and re-grading the Project site following remediation works. Surface soil data, excluding areas proposed to be remediated to commercial/industrial land use, from the two Phase 2 site investigations conducted in 2012 and 2014 where used to characterise soil concentrations. The surface soil analytical data is presented in **Table A3, Appendix A**.
- *Settled dust*: dust settled in onsite building surfaces is likely to be disturbed during building demolition. During hazardous materials audits, Ramboll Environ noted that settled dust was greater than 30cm in depth in some parts of the building (ENVIRON, 2014a,b,c). Settled dust samples were collected from the spent potlining storage sheds, Carbon Plant, Workshops and Cast House. Elevated concentrations of metals and PAHs were detected in the Carbon Plant building dust samples. The settled dust analytical data is presented in **Table A4** (Workshops), **Table A5** (Cast House) and **Table A6** (Carbon Plant), **Appendix A**.

Anodes are large carbon blocks which act as electrical conductors and comprise a blend of petroleum cokes, pitch and recycled anode. The mixed anode is baked in the bake furnace at a temperature of 1120°C. These anodes will be removed from the Smelter prior to the Works activities, and will therefore not be considered further in this HHRA. Similarly, the spent pot lining currently stored in the onsite sheds will be removed from the Smelter prior to, or following the Works activities, and will therefore not be considered further in this HHRA.

The analytical concentrations reported in surface soil, settled dust, concrete and refractory brick were screened against soil Tier 1 assessment criteria for *Residential land use* as provided in *NEPC (2013)*. This sensitive land use was adopted because the ultimate receptors to the dust generated during the Works activities are humans located off the Project site such as those listed in **Table 5.3**.

Table 5.3: Dust Generating Activities and Data Source

Activity No.	Activity	Dust Sources	Media	Chemicals in Dust (greater than HIL-A)	Data Source
Demolition Stage 1					
1	Demolition of Buildings (excluding buildings storing SPL, stacks, water tower, subsurface utilities and transformer yard)	Demolition of buildings (using induced techniques) including: - Pot rooms - Carbon plant - Work shops	Particulates from concrete and bricks	Fluoride and eight carcinogenic PAHs	Brick and concrete data collected from the Carbon Plant (ENVIRON, 2014c)
2		Dust settled inside buildings that escape during demolition	Dust settled inside building surfaces	As, Cd, Cr, Pb, Zn, F, pyrene and 8 carcinogenic PAHs	Dust collected from surfaces within the Carbon Plant, Workshops and Cast House (ENVIRON, 2014b).
3		Operation of trucks and excavators	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)
4		Operation of concrete crushing plant which crushes the concrete and refractory brick. Note PAH impacted concrete will be segregated.	Particulates, combustion emissions and vapour	- PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes - Fluoride - Eight carcinogenic PAHs (detected in concrete only)	- Air Quality Impact Assessment (Ramboll Environ, 2015) - Refractory brick (ENVIRON, 2012a, 2014d) and concrete data collected from the Carbon Plant (ENVIRON, 2014c)
Site Establishment					
5	Haul Road Construction	Operation of trucks and excavators	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)
6		Pre-fill earthworks including topsoil scraping and stockpiling	Particulates	Fluoride and eight carcinogenic PAHs	Surface soil data collected in the vicinity of the proposed haul road location (ENVIRON 2012b, 2015b)
7		Placement of crushed concrete along haul road Note PAH impacted concrete will be segregated.	Particulates	- Fluoride - Eight carcinogenic PAHs (detected in concrete only)	- Refractory brick (ENVIRON, 2012a, 2014d) and concrete data collected from the Carbon Plant and Pot Rooms (ENVIRON, 2014c)

Table 5.3: Dust Generating Activities and Data Source

Activity No.	Activity	Dust Sources	Media	Chemicals in Dust (greater than HIL-A)	Data Source
Demolition Stage 2					
8	Demolition of remaining structures including slabs, footings and subsurface utilities	Demolition of remaining buildings (using induced techniques and machines)	Particulates	Fluoride and eight carcinogenic PAHs	Brick and concrete data collected from the Carbon Plant and Pot Rooms (ENVIRON, 2014c)
9		Dust settled inside buildings that escape during demolition	Dust settled inside building surfaces	Cr, Ni, Fluoride and eight carcinogenic PAHs	Dust collected from surfaces within the SPL storage sheds (ENVIRON, 2014a).
10		Operation of trucks and excavators	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)
11		Detonation techniques to demolish stacks and water tower	Particulates	Refer to Ramboll Environ (2015) for a discussion regarding this dust source.	
12		Re-grading of ground surface following demolition activities	Particulates	Fluoride and eight carcinogenic PAHs	Site-wide soil concentrations excluding scheduled remediation areas for commercial/industrial land use (ENVIRON 2012b, 2015b)
13		Operation of concrete crushing plant which crushes the concrete and refractory brick	Particulates, combustion emissions and vapour	- PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes - Fluoride - Eight carcinogenic PAHs (detected in concrete only)	- Air Quality Impact Assessment (Ramboll Environ, 2015) - Refractory brick (ENVIRON, 2012a, 2014d) and concrete data collected from the Carbon Plant (ENVIRON, 2014c)
Construction of Containment Cell					
14	Construction of Containment Cell	Vegetation clearance and topsoil removal	Particulates from surface soil	PM_{10} and $PM_{2.5}$ (soil concentrations in this area are below residential screening criteria)	Surface soil data collected in the vicinity of the Containment Cell (ENVIRON 2012b, 2015b)
15		Operation of trucks and excavators	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)

Table 5.3: Dust Generating Activities and Data Source

Activity No.	Activity	Dust Sources	Media	Chemicals in Dust (greater than HIL-A)	Data Source
16		Operation of the mulching/composting machine	Particulates and vapour	Refer to Ramboll Environ (2015) for a discussion regarding this dust source.	
17		Excavation of material to make the cell	Particulates from soil	PM_{10} and $PM_{2.5}$ (soil concentrations in this area are below residential screening criteria)	Air Quality Impact Assessment (Ramboll Environ, 2015) Surface soil data collected in the vicinity of the Containment Cell (ENVIRON 2012b, 2015b)
18		Stockpiling of excavated material	Particulates from soil	PM_{10} and $PM_{2.5}$ (soil concentrations in this area are below residential screening criteria)	Air Quality Impact Assessment (Ramboll Environ, 2015) Surface soil data collected in the vicinity of the Containment Cell (ENVIRON 2012b, 2015b)
Removal of Waste from Capped Stockpile					
19	Removal of waste from Capped Waste Stockpile	Grass & top soil stripping	Particulates from surface soil	PM_{10} and $PM_{2.5}$	Air Quality Impact Assessment (Ramboll Environ, 2015) No topsoil analytical data available for this area
20		Excavation, transportation and placement of waste in Cell	Particulates from soils and materials in the waste	Cr, Ni, Fluoride and eight carcinogenic PAHs Asbestos and lead-based paints (suspected to be present in the Capped Waste Stockpile)	Dust collected from surfaces within the spent potlining storage sheds (ENVIRON, 2014a). This data is used in absence of spent potlining analytical data.
21		Operation of trucks and excavators	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)
Operation of Water Treatment Plant					
22	Operation of water treatment plan	Use of diesel pump to run the treatment plant	Combustion emissions and vapour	PM_{10}, $PM_{2.5}$, NO_2, SO_2, benzene, toluene, ethylbenzene, xylenes	Air Quality Impact Assessment (Ramboll Environ, 2015)

Air Quality Impact Assessment

Ramboll Environ completed an Air Quality Impact Assessment (AQIA) to assess (including air quality modelling) the potential air quality impacts of the Works activities (Ramboll Environ, 2015).

The intention of the air quality modelling was to capture the worst case 24-hour period of operational activity and then combine this with all likely meteorological conditions that would be experienced throughout a calendar year to predict maximum impacts. The worst case scenario was assumed to be the period involving concurrent:

- Stage 2 demolition activities;
- Soil excavation;
- Capped waste stockpile material excavation and processing;
- Haulage of Capped Waste Stockpile material to the Containment Cell; and
- Emplacement in the Containment Cell.

Particulate concentrations were predicted at the human receptor locations presented in **Table 5.3**. These are the same human receptors assessed in this HHRA and the Noise and Vibration Assessment (Vipac, 2015). Full details regarding the assumptions and methodology used to predict particulate concentrations at the Project site and off-site locations is presented in the AQIA (Ramboll Environ, 2015).

As identified in **Table 5.3**, the following constituents were assessed in the AQIA:

- Particulates: total suspended particles (TSP), PM_{10} and $PM_{2.5}$.
- Combustion emissions: NO_2, SO_2, CO, benzene, toluene, ethylbenzene and xylenes.
- Metals: arsenic, cadmium, chromium, lead, zinc, fluoride.
- PAHs.

Air Quality Results

Predicted dust concentrations were generated for a number of averaging periods including annual, eight hour periods and one hour period. Where data was available, the HHRA considered the 'cumulative' dust concentrations which include the measured background concentrations plus the dust concentrations predicted to be generated during the Works activities at the Project site.

The predicted cumulative maximum 'work area' dust concentrations were considered to represent the air quality onsite workers would be exposed to during the Works activities. This area was considered to be approximately 81 hectares. When assessing the offsite sensitive receptors, Ramboll Environ considered the residential property that had the highest predicted dust concentrations (maximum cumulative value). This residence was located 500m to the southeast at 6 Dawes Avenue, Loxford. This property returned higher dust concentrations than properties closer to the Project site due to factors relating to spatial distribution of emissions about the Project site and the general northwest-southeast alignment of wind direction (Ramboll Environ, 2015).

The predicted dust concentrations were screened against appropriate health-based air quality guidelines including:

- NEPC (2003) National Environmental Protection Measure (Ambient Air Quality) Measure, as amended. National Environmental Protection Council.
- DEC (2005) Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.
- World Health Organization. (WHO) (2000) Air Quality Guidelines for Europe, 2nd Edition.
- WHO (2000) Air Quality Guidelines.
- WHO (2005) Air Quality Guidelines Global Update 2005. Guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide.

Dust data for the Works personnel were screened against appropriate NSW EPA guidelines for air pollutants from industry-related stationary sources. Dust data for the off-site residents were screened against appropriate health-based guidelines including those recommended by the WHO.

A comparison of the predicted dust concentrations against the adopted health-based air quality guideline is presented in **Table 5.4** and **Table 5.5** for Works personnel and offsite residents, respectively. Those constituents with dust concentrations greater than the adopted screening criteria were assessed further in this HHRA.

Table 5.4: Predicted Dust Concentrations for On-Site Workers (µg/m^3) – Maximum Concentrations

Chemical	Averaging Period	Predicted Dust Concentration (µg/m^3)	Adopted Assessment Criteria	Assessed Further in HHRA?
Total Suspended Particles (TSP)	Annual	7.73	90 (a)	No
PM_{10}	24 hours	12.41	50 (a)	No
	Annual	4.65	30 (a)	No
$PM_{2.5}$	24 hours	9.26	25 (b)	No
	Annual	3.32	8 (b)	No
NO_2	1-hour	184.54	246 (a)	No
	Annual	10.89	62 (a)	No
SO_2	24 hours	0.02	228 (a)	No
	Annual	0.006	60 (a)	No
CO	1-hour	76.27	30,000 (a)	No
	8-hour	18.14	10,000 (a)	No
Benzene	1-hour	0.11	31 (a)	No
Toluene	1-hour	0.21	370 (a)	No
Ethylbenzene	1-hour	0.05	8,000 (a)	No
Total Xylene	1-hour	0.30	190 (a)	No
Arsenic	1-hour	0.001	0.09 (a)	No
Cadmium	1-hour	0.01	0.018 (a)	No
Chromium**	1-hour	0.05	0.09 (a)	No
Lead	Annual	0.01	0.5 (a)	No
Fluoride	1-hour	144.25	600 (d)	No
Zinc	1-hour	0.23	10,000 (c)	No
Total PAHs (as benzo(a)pyrene (BaP))	1-hour	0.53	0.4 (a)	**Yes**
Nickel	1-hour	0.11	0.18 (a)	No

Notes:

(a) DEC (2005) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW

(b) NEPC (2003) National Ambient Air Quality Measure (amended)

(c) SafeWork Australia TWA for Zinc oxide dust

(d) WHO (2000) Air Quality Guidelines for Europe, 2nd Edition.

Concentrations of PAHs (assuming present at benzo(a)pyrene) in dust exceeded the adopted air quality guideline for onsite Workers. Therefore, these PAHs in dust will be further assessed in this HHRA.

Table 5.5: Predicted Dust Concentrations for Residential Property with the highest predicted dust concentration (µg/m^3) – Maximum Cumulative Concentrations

Chemical	Averaging Period	Predicted Dust Concentration (µg/m^3)	Adopted Assessment Criteria	Assessed Further in HHRA?
TSP	Annual	48.5	90 (a)	No
PM_{10}	24 hours	46.9	50 (a,c)	No
	Annual	19.5	20 (c)	No
$PM_{2.5}$	24 hours	20.1	25 (b,c)	No
	Annual	7.3	8 (b)	No
NO_2	1-hour	99.6	200 (c)	No
	Annual	17.8	40 (c)	No
SO_2	10 minute	238.03	500 (c)	No
	24 hours	18.3	20 (c)	No
	Annual	3.3	60 (a)	No
CO	1-hour	9621.8	30,000 (a,d)	No
	8-hour	2762.4	10,000 (a,d)	No
Benzene	1-hour	0.015	31 (a)	No
	Annual	6.08E-04	1.337 (3)*	No
Toluene	1-hour	0.03	370 (a)	No
	Weekly	3.8E-03	260 (d,e)	No
Ethylbenzene	1-hour	0.007	8,000 (a)	No
	Annual	3.13E-04	22,000 (e)	No
Total Xylene	1-hour	0.042	190 (a)	No
	Annual	0.0017	870 (e)	No
Arsenic	1-hour	4.25E-04	0.09 (a)	No
	Annual	6.31E-05	0.0066 (d)*	No
Cadmium	1-hour	0.004	0.018 (a)	No
	Annual	6.32E-04	0.005 (d)	No
Chromium**	1-hour	0.02	0.09 (a)	No
	Annual	3.35E-03	2.5E-04 (d)*	**Yes**
Lead	Annual	4.99E-03	0.5 (a,d)^	No
Fluoride	1-hour	12.8	600 (d)	No
	Annual	2.63	1 (d)^^	**Yes**
Zinc	1-hour	0.083	1750 (f)	No
	Annual	0.012		No
Total PAHs (as BaP)	1-hour	0.034	0.4 (a)	No
	Annual	5.10E-03	1.2E-04 (d)*	**Yes**
Nickel	1-hour	0.041	0.18 (a)	No
	Annual	8.49E-03	0.025 (d)*	No

Notes:

(a) DEC (2005) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW

(b) NEPC (2003) National Ambient Air Quality Measure (amended)

(c) WHO (2005) Air Quality Guidelines Global Update

(d) WHO (2000) Air Quality Guidelines for Europe, 2nd Edition.

(e) WHO (2000) Guidelines for Air Quality.

(f) NEPM (2013) Schedule B7, Appendix 1A. Inhalation toxicity reference value.

* Based on an acceptable lifetime cancer risk of 1 in 100,000.

** Assuming chromium is present as Chromium VI (the more toxic form)

^ At this concentration the median blood lead level would not exceed 54µg/L.

^^ Guideline concentration to prevent effects on livestock and plants, and also sufficiently protects humans

Concentrations of chromium (assuming present as chromium (Cr) VI), fluoride and PAHs (assuming present as BaP) in dust exceeded the annual averaging period health-based air quality guidelines for the offsite residential receptors. Therefore, these chemicals in dust will be further assessed in this HHRA.

5.4.2.2 Soil

Soil samples were collected across the Smelter during two environmental investigations conducted in April 2012 and June 2014; and the results are reported in ENVIRON (2015b). Reported soil concentrations were compared against appropriate 'commercial/industrial' land use standards in accordance with the future anticipated site use. The environmental investigations identified PAH impacts (primarily BaP) to surface soils in seven areas due to contamination in the fill material.

During the remediation activities for the Project, the identified areas of PAH soil contamination would be excavated by the Works personnel. To assess the potential health risks associated with this activity, the maximum and average reported PAH soil concentrations were considered. The BaP NEPM (2013) HIL assessment criteria is based on eight carcinogenic PAHs and their toxic equivalents (potency relative to B(a)P). Therefore all eight carcinogenic PAHs will be considered in this HHRA when assessing potential health risk.

The maximum PAH concentrations reported in soil is summarised in **Table 5.6**. In addition, the average concentration for locations where BaP exceeded the adopted assessment criteria (n = 18 locations between 0 and 0.6 mbgl) is also presented. An assessment of potential health risk associated with these PAHs is assessed further in this HHRA.

Table 5.6: Maximum and Average Carcinogenic PAH Concentrations in Soil (mg/kg)

Chemical	Maximum Concentration (mg/kg)	Average Concentration at locations exceeding BaP TEQ criteria (mg/kg)	NEPM HIL-D
Benzo(a)pyrene (TEQ)	440	134	40
Benz(a)anthracene	300	72	-
Chrysene	490	91	-
Benzo(b)&(k)fluoranthene	990	183	-
Benzo(k)fluoranthene	47.7	30	-
Indeno(1,2,3-c,d)pyrene	190	65	-
Dibenzo(a,h)anthracene	60	15	-
Benzo(g,h,i)perylene	190	62	-

5.4.2.3 Groundwater

During the Works, offsite receptors would not have direct contact with groundwater originating from the Project site. Therefore, potential health risks associated with exposure to groundwater by offsite receptors is not assessed further.

Groundwater is unlikely to be encountered by Works personnel during construction of the Containment Cell. During geotechnical investigations conducted by Ramboll Environ in July 2014, free groundwater in the vicinity of the Containment Cell location was not encountered during the auger drilling of boreholes to a maximum depth of eight metres bgl (ENVIRON, 2015d). Groundwater measured in the installed wells was considered to represent an aquifer present in the secondary porosity of the underlying rock profile, confined by the overlying clays. In July 2015, standing water levels were measured in the installed wells between 0.84 and 12.47m bgl, and were considered to represent the piezometric pressure produced by groundwater at higher topographic levels, up-hydraulic gradient. Therefore, since the base of the Containment Cell would be approximately two metres minimum bgl, groundwater is unlikely to be encountered during construction.

However, Works personnel have the potential to contact groundwater under two exposure scenarios:

- Intrusive activities at the Capped Waste Stockpile; and
- During removal of building footings located across the Project site.

Groundwater beneath the Capped Waste Stockpile is more impacted than site-wide groundwater likely to be encountered during removal of building footprints, and therefore these areas are assessed separately in this HHRA in **Section 5.4.2.5**.

The maximum reported groundwater concentrations were compared against the following applicable human health criteria:

- National Health and Medical Research Council (NHMRC) (2011) *Australian Drinking Water Guidelines 6*, National Water Quality Management Strategy. Australian Government.
- WHO (2008*) Petroleum Products in Drinking-water. Background document for development of WHO Guidelines for Drinking-water Quality*.
- United States Environmental Protection Agency (USEPA) (2014) *Regional Screening Level (RSL) Resident Tapwater*, published online.

Works personnel would not be drinking the groundwater and therefore adoption of drinking water guidelines is an overly conservative approach. Therefore, as recommended in the *NHMRC (2008) Guidelines for Managing Risks in Recreational Water*, Ramboll Environ applied a factor of 10 to the drinking water guideline to derive the health-based groundwater screening criteria for the Project.

Groundwater Concentrations in areas of Building Footprints

Twenty-nine groundwater monitoring wells have been installed at the Smelter (excluding the Capped Waste Stockpile), and groundwater has been monitored from these wells in May 2012 and July 2014.

It is understood that Smelter buildings would be demolished down to 1.5m bgl, and therefore demolition works have the potential to intersect groundwater in areas where groundwater is shallower than 1.5m bgl. Some buildings have subsurface structures below 1.5m bgl (e.g. large tubs from the carbon plant and baking furnace), and voids from these structures would be filled with clean material.

Groundwater measured at, or shallower than, 1.5m bgl has been reported in monitoring wells MW04, MW06, MW08, MW13, MW16, MW17, S3A, MW105 and MW107 during 2012 and 2014 monitoring events; with depths ranging between 0.23 and 1.55 mbgl (ENVIRON, 2015b). These wells are located within the following areas:

- Refueling Area.
- Anode Waste Pile Area.
- Carbon Plant.

A summary of the groundwater analytical concentrations measured in these wells is presented in **Table A7, Appendix A**.

Chemicals detected in groundwater shallower than 1.5mbgl above the adopted health-based groundwater criteria is summarised in **Table 5.7.**

Table 5.7: Shallow (<1.5mbgl) Groundwater Concentrations exceeding health-based criteria (µg/L)

Chemical	Maximum Concentration (µg/L)	Health-based Groundwater Criteria (µg/L)
TPH C_6-C_9	240	10[a]
TPH C_{15}-C_{28}	1400	900[a]
Benz(a)anthracene	4	3.4[b]
Benzo(b)&(k)fluoranthene	10.8	3.4[b]
Benzo(a)pyrene	6.46	0.1[c]
Dibenz(a,h)anthracene	1	0.34[b]

Notes:

a) WHO (2008) with x10 factor applied as recommended by NHMRC (2008).

b) USEPA (2014) with x10 factor applied as recommended by NHMRC (2008). A cancer risk factor of 10^{-5} was adopted for the carcinogenic chemicals.

c) NHMRC (2011) with x10 factor applied as recommended by NHMRC (2008).

Further assessment of the potential health risks to Works personnel due to direct contact with shallow groundwater at the Capped Waste Stockpile and in areas of shallow groundwater is assessed further in this HHRA.

5.4.2.4 Noise and Vibration

A Noise and Vibration Impact Assessment (NVIA) was performed by Vipac to assess the potential noise and vibration impacts of the Works, and assess the potential traffic noise impact on public roads due to additional traffic generated by the Works (Vipac, 2015). The offsite sensitive receptors subjected to the noise were considered to be the same offsite sensitive receptors considered in the AQIA (Ramboll Environ, 2015); and are identified in **Table 5.3** of this report.

Methodology

A series of baseline noise surveys were undertaken by Vipac at the Project site and surrounding locations in order to determine background project-specific noise levels of the potentially affected areas at representative offsite locations. Noise modelling was performed by Vipac using the SoundPLAN computational noise prediction software package, which is accepted for use by the NSW EPA.

The predicted noise levels were based on the worst-case scenario for the demolition event where plant and equipment are placed closer to the noise sensitive receptors, at the southern end of the Pot Rooms and the northeastern corner of the demolition works area. The noise model also accounted for the operations of a concrete crushing plant located in the southwest of the Project site. Noise levels were predicted for “standard construction hours” (Monday to Friday 7am to 6pm, Saturday 8am to 1pm and no work on Sundays or public holidays) and outside standard construction hours. A full description of the methodology and underlying assumptions used to perform the noise modelling is provided in the NVIA (Vipac, 2015).

The noise levels were expressed at external $L_{Aeq\text{-}15}$ minutes (i.e. ambient noise levels over a 15-minute period) at the nearest boundary of the receptor properties. Vipac (2015) compared the modelled results against the following guidelines:

- *NSW DEC (2009) Interim Construction Noise Guideline*. These guidelines provide management levels for noise at residences and sensitive land uses such as recreation (active and passive), educational facilities, hospitals and aged care facilities.
- *NSW EPA (1999) Environmental Criteria for Road and Traffic Noise*.
- *NSW DECCW (2011) Road Noise Policy*.
- *NSW DEC (2006) Assessing Vibration: A Technical Guideline*
- *British Standard 6472*-1:2008 Guide to evaluation of human exposure to vibration in buildings, Part 1 – Vibration sources other than blasting

In addition to the above guidance, Ramboll Environ also considered the health-based recommended noise guidelines recommended by the World Health Organization in *WHO (1999)*

Guidelines for Community Noise. These guidelines are presented in Error! Reference source not found.

Table 5.8: WHO (1999) Guidelines for Community Noise

Specific Environment	Critical Health Effect(s)	LAeq(dB)	Time Base (hrs)	LAmax fast (dB)
Outdoor living area	Serious annoyance, daytime and evening	55	16	-
	Moderate annoyance, daytime and evening	50	16	-
Dwelling indoors	Speech intelligibility and moderate annoyance, daytime and evening	35	16	-
Inside bedrooms	Sleep disturbance, night-time	30	8	45
Outside bedrooms	Sleep disturbance, window open (outdoor values)	45	8	60
School class rooms and pre-schools, indoors	Speech intelligibility, disturbance of information extraction, message communication	35	During class	-
Pre-school bedrooms, indoors	Sleep disturbance	30	Sleeping time	45
School, playground outdoor	Annoyance (external source)	55	During play	-
Outdoors in parkland and conservation areas	Disruption of tranquillity	(a)	-	-
Hospital ward rooms	Sleep disturbance, night-time	30	8	40
	Sleep disturbance, daytime and evenings	30	16	-

Note: (a) Existing quite outdoor areas should be preserved and the ratio of intruding noise to natural background sound should be kept low

Demolition and Remediation Noise Results

The noise modelling indicated that the predicted noise levels associated with the worst-case scenario in terms of operational plant and machinery items that would be used for the Works would be within the applicable criteria adopted during standard construction hours at all assessed sensitive receptors. However, the predicted noise levels are expected to exceed the adopted noise criteria for outside standard construction hours (day, evening and/or night time) at the following sensitive receptors:

- Private residential property located 1km to the east;
- Private residential property located 0.5km to the southeast;
- Hydro-owned residential property located 0.35km to the south; and
- Private residential property located 0.7km to the west.

Therefore, in order to comply with the outside standard construction hours noise criteria during the neutral and worst-case conditions, the number of plant and equipment items operating at the Project site would be restricted. The restricted number and types of machinery for the Works activities, including additional noise reduction management recommendations, is detailed in Vipac (2015).

Assuming these noise reduction measures are implemented, the predicted noise levels were considered to be within the guidelines adopted by Vipac (2015). A comparison of the noise predictions (assuming restricted equipment is used) to the WHO (1999) health-based guidelines identified the following:

- No exceedences occur 'outside standard hours night time' (i.e. 10pm to 6am) when comparing the predicted noise levels to the "outside bedroom" sleep disturbance criteria of 45dB (compliance with the outside bedroom criteria indicates compliance with the indoor noise levels).
- No exceedences occur at educational, medical or recreational facilities.
- Under 'worst-case' weather conditions (rare events such as a temperature inversion) noise predictions exceeded the "outside bedroom" noise criteria at three residential properties. These exceedences were a maximum of 2dB above the WHO 'sleep disturbance' criteria and were predicted during outside standard hours evening (6pm – 10pm).
  It should be noted that the Works (noise reduction measures) would comply with the sleep disturbance criteria under the NSW EPA *Interim Construction Noise Guideline* (DEC, 2009), which develops receptor-specific sleep disturbance criteria based the existing noise levels.

Off-Site Traffic Noise Impact

Noise modelling was undertaken to assess potential noise impacts on existing noise sensitive receptors, associated with vehicle movements along Hart Road (south) and the Hunter Expressway (between the Allandale Road interchange and Kurri Kurri Interchange). The modelling accounted for all the sources associated with traffic that may be generated in conjunction with Project site activities, to determine the potential cumulative road traffic noise levels in the area.

Vipac (2015) concluded that the additional traffic generated by Project site activities along the Hunter Expressway and Hart Road is insignificant as the relative increase between the existing and future traffic noise levels is extremely low. Therefore, the predicted noise impact associated with site activities would comply with the adopted guidelines. Furthermore, the internal noise levels at the assessed properties were predicted to be below the applicable maximum internal noise level limits, which would not be expected to cause any awakening reactions to occupants and would be unlikely to cause sleep disturbance impacts.

Vibration Assessment

The vibration assessment estimated peak particle velocity (PPV) measured in mm per second associated with the plant equipment that is likely to be used during demolition and remediation works on the Project site. Vipac (2015) identified that vibration magnitudes would dissipate at varying levels dependent on ground conditions and source level variations associated with operational conditions of the plant and equipment.

It was concluded that based on the vibration levels estimated, it is unlikely that any vibration impacts generated by the Works equipment would give rise to annoyance at the closest sensitive receptor.

Conclusions

Assuming the recommended noise mitigation measures recommended by Vipac (2015) are adopted during the Works, the predicted noise and vibration levels are considered to be within the adopted guideline levels for the protection of human health.

The NVIA (Vipac, 2015) includes a noise complaints register and response system that defines how Hydro would respond to a noise complaint. This could include altering Works methodology and applying additional mitigation measures to reduce noise generation.

Based on the above screening assessment results, potential health risks associated with noise and vibration impacts from the Project will not be conducted further in this HHRA.

5.4.2.5 Capped Waste Stockpile Impacts

The Capped Waste Stockpile is located on the eastern portion of the Smelter and contains disposed materials associated with the smelting of aluminium. The Capped Waste Stockpile is located on low lying, relatively flat swampy land and was progressively filled with spent potlining and other materials between 1969 and 1992.

Aside from spent potlining, the following materials are understood to have been stockpiled in the Capped Waste Stockpile:

- Asbestos
- Lead-based paint
- Carbon Plant shot blast refuse, including grit and dust;
- Carbon Plant dust collector product;
- Collar filter spillage;
- Carbon Plant floor sweepings;
- Packing coke oversize;
- Contaminated bath;
- Rotary breaker oversize;
- Pot lining mix (hot ramming paste);
- Rodding mix (including anthracene oil);
- Stud joining mix;
- Pitch spills/ pencil pitch;
- Aluminium swarf;
- Scrap aluminium billets;
- Anode cover material;
- Butt from spent anodes;
- Ahead of schedule anodes;
- Dross;
- Pot bottom aluminium; and
- General rubbish, including plastic, wood and steel.

The majority of these materials are associated with the Carbon Plant, which produces carbon anodes from liquid pitch and coke. The main chemical of concern for these materials is Polycyclic Aromatic Hydrocarbons (PAHs). PAHs associated with pitch, coke and anodes have a low solubility in water and are unlikely to generate leachable concentrations.

Spent Potlining Waste and Gas Generation

Spent potlining was placed in the Capped Waste Stockpile up until 1992, after which the spent potlining waste was stored in an on-site environmentally secure storage facility comprised of purpose-built sheds.

Spent potlining, when in contact with moisture, has the potential to produce flammable, toxic and explosive gasses (e.g. ammonia, hydrogen, methane and phosphine). Spent potlining is a waste generated during aluminium smelting and is subject to the “Chemical Control Order (CCO) in Relation to Aluminium Smelter Wastes Containing Fluoride and/or Cyanide” under the *Environmentally Hazardous Chemicals Act 1985*.

At the Smelter, between 1969 and 1992 the process used to remove spent potlining from a pot involved the use of water to soak the pot linings. This resulted in the spent potlining cracking and breaking up, making it easier to remove, transport and stockpile. The use of water also created a reaction between the sodium, carbides and nitrides in the spent potlining to form sodium carbonate, hydrogen, methane and ammonia. Information from Dames and Moore (1992) *Environmental Impact Statement, Upgrades to Waste Storage Facilities at the Alcan Australia Limited Kurri Kurri Smelter* indicates that the gas generation rate is initially rapid for the three major gases of ammonia, hydrogen and methane, with the liberation of hydrogen and methane ceasing within a matter of hours. Ammonia continues to be generated for a longer time period. This soaking process is likely to have released the majority of any harmful gasses from the spent potlining waste prior to disposal into the Capped Waste Stockpile.

The use of water in the breakup the pot lining, the subsequent storage in a stockpile open to rain water and the rapid gas generation rate indicates that the spent potlining stored in the Capped Waste Stockpile is likely to have exhausted its gas generation potential.

Subsurface gas monitoring has been undertaken by Hydro from 12 gas vents installed within the cap of the Capped Waste Stockpile since its construction in 1995 (*n* = 22 sampling events). A summary of the gas data results collected between July 1996 and July 2012 is presented in **Table 5.9**. In June 2015, Ramboll Environ undertook an additional round of gas sampling from six newly installed vapour wells (VW01-VW06) to characterise current gas concentrations and confirm the presence of ammonia concentrations beneath the Capped Waste Stockpile. Boreholes were drilled into the Capped Waste Stockpile down to depths between 1.6 and 1.95mbgl so that the borehole intersected the gas-accumulating gravel layer beneath the clay cap. Geoprobe vapour implants were then inserted into the borehole prior to backfilling with a sand layer (to 10cm above the vapour implant) and bentonite to the surface. A week following installation, the vapour wells were purged and vapour samples were collected using a PID and LEL (lower explosive limit) meter, and Drager and Kitagawa gas detection tubes (with maximum detection rates of 3ppm and 260ppm, respectively). The PID and LEL results are summarised in **Table 5.10**.

Table 5.9: Capped Waste Stockpile Gas Concentrations (ppm/%) – 1996 to 2012 data

Chemical	Maximum Concentration (ppm/%)	Average Concentration (ppm/%)
Ammonia	800	55.6
Phosphine/Arsine	<0.1	<0.1
Hydrogen cyanide (HCN)	<1	<1
Hydrogen sulfide (H_2S)	<1	<1
Hydrogen	2.3%	0.45%
Methane	6.4%	0.67%

Table 5.10: Capped Waste Stockpile Gas Concentrations (ppm/%) – June 2015 PID and LEL data

Chemical	Maximum Concentration	Average Concentration
PID (ppm)	143	75
LEL (%)	71	43
O_2 (%)	1	0
CH_4 (%)	3	1
NH_3 (ppm)	Refer to Note 1	Refer to Note 1
CO (ppm)	1200	725

Notes: 1. Ammonia was recorded at the maximum concentration possible for the LEL meter of 500ppm at four sampling locations.

Results from the gas sampling tubes identified that hydrogen cyanide and hydrogen fluoride gasses were either not present or at concentrations not detected by either the Kitagawa gas sampling tubes. Ammonia concentrations were recorded at the maximum possible concentration of 900ppm at VW05, and detected at concentrations between 3 and 260ppm at all other locations.

The historical and newly collected gas data indicates that gases such as phosphine/arsine, hydrogen sulfide, hydrogen fluoride and hydrogen cyanide are either not present in the Capped Waste Stockpile or are present at very low concentrations below the laboratory limit of reporting.

The ammonia concentrations presented in **Table 5.9** and **Table 5.10** illustrate that ammonia concentrations are present beneath the Capped Waste Stockpile. Therefore, for the purposes of this HHRA and with the understanding that ammonia continues to be generated for longer periods of time, the potential health risks associated with exposure to ammonia gas will be assessed further in this HHRA in **Section 8.4**.

Groundwater Conditions

Since 1978, 25 monitoring wells were installed down hydraulic gradient of the Capped Waste Stockpile to assess and delineate a dissolved phase plume migrating approximately 250m northeast into the Hydro land. The leachate plume is characterised by alkalinity (pH> 9), elevated electrical conductivity, elevated fluoride and total cyanide. These impacts originated from material placed in the stockpile including cryolite, alumina, spent potlining, shot blast dust, floor sweepings and potlining mix.

Groundwater in the vicinity of the Capped Waste Stockpile is fairly shallow (approximately 2m bgl), and the impacts appear to be confined to the shallow semi-continuous sand aquifer (ENVIRON, 2015c). Furthermore, horizontal movement of the leachate plume appears constrained by a surrounding discontinuous clay aquitard (ENVIRON, 2015c). In April 2014, a groundwater interception trench was installed to intercept and collect shallow, perched impacted groundwater. A summary of the dissolved phase concentrations reported closest to the Capped Waste Stockpile is presented in **Table 5.11**. For the purpose of this HHRA, these concentrations are considered to be representative of concentrations in groundwater beneath the Capped Waste Stockpile.

Table 5.11: Capped Waste Stockpile Groundwater Concentrations (mg/L)

Chemical	Maximum Concentration (mg/L)	Average Concentration (mg/L)	Health-Based Groundwater Criteria (mg/L)
Soluble Fluoride	1080	520	15[b]
Total Cyanide	260	75	0.8[b]
Total Aluminium	415	65	Not available
pH	10.14	9.2	6.5-8.5

Notes:
a) Concentrations reported between July 2013 and November 2014 from monitoring wells W2S, W2D, E5, PUMP, W7S and W7M (located closest to the Capped Waste Stockpile).
b) NHMRC (2011) with x10 factor applied as recommended by NHMRC (2008)

The potential fluoride and cyanide impacts to Works personnel resulting from direct contact with impacted groundwater beneath the Capped Waste Stockpile is further assessed in Section 6 and Section 8.

5.4.3 Exposure Pathways

In order for a human receptor to be exposed to a chemical contaminant derived from a site, there should be an exposure pathway linking the source of contamination and the exposed population. An exposure pathway describes the course a chemical or physical agent takes from the source to the exposed individual and generally includes the following elements (USEPA, 1989):

- Source and mechanism of chemical release;
- Retention or transport medium (or media where chemicals are transferred between media);
- Point of potential human contact with the contaminated media; and
- Exposure route (e.g. ingestion, inhalation) at the point of exposure.

A detailed assessment of the potential exposure pathways for the receptors identified in **Section 0** is presented in **Table 5.12**.

Table 5.12: Exposure Pathways Assessment

Source	Potentially Occur? (Y/N)		Justification
	Works Personnel	Offsite Residential Receptors	
Dust (from soil and structure demolition)			
Dermal contact and incidental ingestion of soil	**Y**	N	Some Works personnel would have potential for direct contact with surface soil during activities such as haul road construction, Containment Cell construction and removal of waste from the Capped Waste Stockpile. Offsite receptors would not have access to soil on the Project site.
Dermal contact and incidental ingestion of dust	**Y**	**Y**	Works personnel have the potential to directly contact soil-derived dust, and dust that has accumulated inside buildings that would be demolished. Works personnel may also inhale airborne dust in outdoor and indoor environments. Site-derived dust has the potential to travel offsite where sensitive offsite receptors may be exposed to the dust in outdoor and indoor environments.
Outdoor dust inhalation	**Y**	**Y**	
Indoor dust inhalation	**Y**	**Y**	
Atmospheric deposition on roof catchments used to collect rainwater	N	**Y**	Two residents in the vicinity of the Project site have rainwater tanks installed on their properties. The end use of the collected rainwater is unknown but may be used for irrigation or domestic purposes. Rainwater collects on the roof catchment and appears to be funnelled to the rainwater tank for storage prior to use. Atmospheric deposition of dust generated during the Works has the potential to occur on the roof catchment and enter the rainwater tank. Therefore this exposure pathway is assessed further in Section 8.6.
Groundwater			
Dermal contact	**Y**	n/a	A small number of Works personnel have the potential to contact groundwater when working around the Capped Waste Stockpile, and shallow (<1.5mbgl) groundwater across the Project site when removing building footprints. Off-site receptors are not considered to be receptors to on-site groundwater.
Incidental ingestion	**Y**	n/a	
Potable ingestion	N	n/a	Groundwater beneath the Project site is not used for potable purposes.

Table 5.12: Exposure Pathways Assessment

Source	Potentially Occur? (Y/N)		Justification
	Works Personnel	Offsite Residential Receptors	
Outdoor inhalation of vapours (accumulated within building footprint trenches)	**Y**	n/a	Concentrations of the volatile TPH C6-C9 fraction were detected in shallow groundwater above the adopted health-based guideline. Those Works personnel who undertake excavation works that intersect shallow groundwater have the potential to inhale vapours generated in outdoor space. Vapours accumulated within a building footprint trench will be assumed as a conservative approach.
Indoor inhalation of vapours	N	n/a	On-site buildings would be demolished as part of the Works.
Surface water pathways	N	n/a	Surface water is collected on-site via the West Surge Pond, South Surge Pond, East Surge Pond and two North Dams. Storm water is managed on site via the three ponds and two dams and does not migrate off-site aside from the irrigation
Irrigation pathways	N	n/a	Water from the North Dams is irrigated to a paddock north of the North Dams under licence. Access to the paddocks is restricted. Water is irrigated at a rate that does not produce runoff.
Soil			
Dermal contact	**Y**	n/a	Some soils at the Project site have been detected to have PAH levels above 'commercial/industrial' health-based assessment criteria. These soils would be removed during the Works. Works personnel have the potential to directly contact PAH impacted soil.
Incidental ingestion	**Y**	n/a	
Indoor inhalation of vapours	N	n/a	No volatile contaminants have been detected in soil across Project site at concentrations greater than the adopted 'commercial/industrial' assessment criteria.
Outdoor inhalation of vapours	N	n/a	

5.4.4 CSM Summary

A summary of the pathway-receptor linkages that will be assessed further in this HHRA is provided in **Table 5.13**.

Table 5.13: Conceptual Site Model Summary

Exposure Pathway	Works Personnel	Offsite Residential Receptors[1]
Dermal contact with soil	✓	X
Incidental ingestion of soil	✓	X
Indoor inhalation of dust	X	✓
Outdoor inhalation of dust	✓	✓
Dermal contact with groundwater	✓	X
Incidental ingestion of groundwater	✓	X
Outdoor inhalation of vapours (within a trench)	✓	X
Potable use of rainwater tank collected from roof surfaces	X	X

Notes:
✓ indicates a potential exposure pathway is present which will be assessed further in the HHRA
1. The offsite residential property located at 6 Dawes Avenue, Loxford was considered to be the most sensitive receptor offsite because Project-generated dust concentrations were predicted to be the highest at this property. Both adults and children are considered to reside at this residential property.

The contaminant source for the Tier 2 HHRA comprises:

- *Dust*: PAHs to Works personnel, and chromium, fluoride and PAHs to off-site residential receptors.
- *Groundwater*: TPH C_6-C_{28} and PAHs in shallow groundwater to Works personnel. Fluoride and cyanide in groundwater beneath the Capped Waste Stockpile to on-site c workers.
- *Soil*: PAHs in surface soil to on-site workers.

6. EXPOSURE ASSESSMENT

Exposure assessment involves the estimation of the magnitude, frequency, extent and duration of exposures to contaminants, and identifies exposed populations and particularly sensitive sub-populations. The exposure assessment process involves:

- Identification of exposed populations;
- Identification of potential exposure pathways;
- Estimation of exposure concentrations for each pathway; and
- Estimation of contaminant intakes for each pathway for a range of scenarios.

6.1 Human Behavioural and Lifestyle Assumptions

Human behavioural and lifestyle assumptions adopted in the HHRA were obtained from Australian guidance and site-specific information, and where missing, from the following international resources:

- NEPM (2013) National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1)
  - Schedule B4, Site-Specific Health Risk Assessment Methodology.
  - Schedule B7, Derivation of Health-Based Investigation Levels.
- United States Environmental Protection Agency (US EPA) (2011) Exposure Factors Handbook: 2011 Edition.

The human behavioural and lifestyle assumptions adopted in this HHRA are presented in **Table 6.1** and **Table 6.2** for Works personnel and offsite residential receptors, respectively.

Table 6.1: Works Personnel Human Behavioural and Lifestyle Assumptions

Parameter	Works Personnel	Source
Exposure duration (years)	4	Assumes the demolition and remediation activities take four years to complete
Averaging time (carcinogens)	25,550	Assumes 365 days per year for 70 years (NEPM, 2013)
Body weight (kg)	70	NEPM (2013)
Outdoor Vapour and Dust Inhalation		
Exposure time spent in a trench (hours/day)	2	Conservative assumption based on an 8 hour working day
Exposure frequency, trench inhalation (days/year)	240	Assumes the worker performs the activity 5 days a week for 48 weeks per year. This exposure frequency was adopted for on-site construction workers exposure to benzo(a)pyrene in airborne dust detected site-wide.
Direct Contact with Groundwater		
Exposure frequency (days/year)	48 (site-wide) 80 (CWS)	Assumes the worker has contact with shallow groundwater within a building footprint excavation once per week for 48 weeks per year. Assumes remediation work at the Capped Waste Stockpile will take four months to complete.
Exposure time for dermal contact (hour/day)	2	Conservative site assumption – it is unlikely the worker will have contact with groundwater for long periods of time.
Exposed skin surface area (cm^2)	3,800	NEPM (2013) assumes the worker is wearing long sleeved pants and shirt, shoes, with face and hands exposed. Assumes worker is not standing in groundwater and they will not get their clothing saturated with groundwater.
Incidental ingestion rate (L/day)	0.004	a) Assumed to be 1/5th of the swimming incidental ingestion rate (21mL/hr) mean value for an adult (US EPA, 2011)

Table 6.1: Works Personnel Human Behavioural and Lifestyle Assumptions

Parameter	Works Personnel	Source
Direct Contact with PAH Impacted Soil		
Exposed skin surface area (cm^2)	3,800	NEPM (2013) assumes the worker is wearing long sleeved pants and shirt, shoes, with face and hands exposed. This is likely to be an overestimate as construction workers may be wearing gloves.
Soil to skin adherence (mg/cm^2)	0.9	CRC CARE (2011) value for a 'surface intrusion maintenance worker'
Exposure frequency to surface soil during remediation of PAH impacts (days/year)	40	Assumes the worker takes two months to remove the PAH impacted soil. This is likely to be an overestimate.
Soil Ingestion rate (mg/day)	330	CRC CARE (2011) value for a 'surface intrusion maintenance worker'

Table 6.2: Offsite Residential Receptor Human Behavioural and Lifestyle Assumptions

Parameter	Offsite Sensitive Receptor	Source
Exposure duration (years)	35	NEPM (2013) Resident
Averaging time (carcinogens)	25,550	Assumes 365 days per year for 70 years (NEPM, 2013)
Dust Inhalation		
Exposure time spent inhaling dust (hours/day)	24	NEPM (2013) Resident, value for combined indoor and outdoor hours
Exposure frequency, (days/year)	365	NEPM (2013) Resident, assumes resident is at home every day of the year

6.2 Exposure Point Concentrations

An exposure point concentration (EPC) is the estimation of the concentration of the source contaminant in the medium that the population is exposed to, at the location where exposure is predicted to occur. EPCs are identified for each site-impacted 'exposure unit', which is defined as the area throughout which a receptor moves and encounters an environmental medium for the duration of exposure. Typically, an individual receptor is assumed to be equally exposed to media within all portions of the exposure unit over the time frame of the risk assessment, which is often an overly conservative assumption.

There are a number of options for choosing the value to use as the EPC, and the most appropriate method will depend on the data set and site-specific exposure scenarios. These options include:

- *Maximum observed contaminant concentration*: this is often the most conservative option and is commonly used for groundwater sources where trends are poorly defined.
- *Mean concentration*: this is suitable for use as an EPC provided that it adequately represents the source being considered, and hotspot areas are not ignored. The mean value is more representative of the source as a whole, and may provide a better estimation of the actual concentration that a population would be exposed to over a period of time.
- *95% upper confidence limit (UCL) of the arithmetic mean contaminant concentration*: this provides a 95% confidence level that the true population mean will be less than, or equal to, this value. This is useful as an EPC in accounting for uncertainty in whether the data set is large enough for the mean to provide a reasonable measure of tendency.

For this HHRA, the maximum observed concentration in groundwater, dust and soil were adopted for the exposure modelling.

Where it is not possible to obtain direct measurements in the relevant media (such as water, dust and noise), EPCs can be estimated using modelling methods such as:

- *Particulate modelling* to estimate the indoor and outdoor concentrations of dust generated from surface soil and site activities;
- *Noise modelling* to estimate the indoor and outdoor noise level experienced at specific locations;
- *Groundwater fate and transport modelling* to estimate groundwater concentrations at a particular distance from the site; and
- *Plant uptake modelling* to estimate contaminant concentrations in crops, fruit and vegetables from soil and groundwater data.

For this HHRA, it was necessary to use particulate modelling (Ramboll Environ, 2015), noise modelling (Vipac, 2015) and outdoor vapour generation modelling (within a Works personnel's trench). Information regarding the dust and noise modelling methodology is provided in Ramboll Environ (2015) and Vipac (2015). Information regarding the outdoor vapour generation modelling within a worker's trench is provided below.

Vapour Estimation within a Worker's Trench

Estimation of vapour concentrations within the worker's trench (formed during removal of building footprints) was undertaken using the Virginia Department of Environmental Quality service trench model ("vrp38" spreadsheet). The modelling considers vapour emanating from a dissolved phase hydrocarbon source and not phase separated hydrocarbons. The modelling approach is based upon a combination of a vadose zone model to estimate volatilisation of gases from contaminated groundwater into a trench, and a box model to estimate dispersion of the contaminants from the air inside the trench into the above-ground atmosphere to estimate the EPC for air in a trench.

Table 6.3 presents the parameters adopted during vapour modelling for the Works personnel's trench.

Table 6.3: Worker's Trench Vapour Modelling Assumptions

Parameter	Value Adopted	Comment
Depth to groundwater (cm)	0	Groundwater assumed to seep into trench, direct contact therefore possible
Trench height (m)	1.5	Appropriate considering depth of the footprints is assumed to be 1.5m
Trench length (m)	2	
Trench width (m)	2	
Air exchange in trench (h^{-1})	360	VDEQ recommended value when the depth of the trench is less than the trench width
Fraction of floor through which groundwater can enter	0.9	Assumes a 1m trench intersects the groundwater
Water temperature (ºC)	25	VDEQ default value

6.2.1 Adopted Exposure Point Concentrations

The adopted dust EPCs are presented in **Table 6.4** and the data were obtained from the AQIA (Ramboll Environ, 2015). The dust concentrations for the Works personnel represent the work area maximum predicted concentration. The residential property with the highest predicted dust concentration was located 500m to the southeast of the Project site at 6 Dawes Avenue, Loxford.

Table 6.4: Predicted Dust Exposure Point Concentrations (µg/m3) – Annual Concentrations

Chemical	On-Site Workers (maximum concentrations)	Residential Property with the highest predicted dust concentration[1] (maximum concentrations)
Chromium VI	-	3.35E-03
Fluoride	-	2.63
Benzo(a)pyrene	2.435.3E-01	5.10E-03

Notes:
1. The residential property with the highest predicted dust concentration was located 500m to the south-east of the Smelter Site at 6 Dawes Avenue, Loxford.

The soil EPC are presented in **Table 6.5** and represent average reported PAH concentrations at locations where the 'commercial/industrial' assessment criteria were exceeded in soil across the Project site. These PAH impacts exceed the 'commercial/industrial' land use criteria and would therefore be excavated during remedial activities and placed in the Containment Cell. Potential health risks to Works personnel who perform this activity is assessed using these PAH concentrations.

Table 6.5: Soil Exposure Point Concentrations (mg/kg)

Chemical	Soil EPC (mg/kg)
Benzo(a)pyrene (TEQ)	134
Benz(a)anthracene	72
Chrysene	91
Benzo(b)&(k)fluoranthene	183
Benzo(k)fluoranthene	30
Indeno(1,2,3-c,d)pyrene	65
Dibenzo(a,h)anthracene	15
Benzo(g,h,i)perylene	62

The groundwater EPC are summarised **Table 6.6** and represent the maximum reported concentration in shallow (<1.5mbgl) groundwater across the Project site, excluding groundwater data collected in the Capped Waste Stockpile. The EPCs for groundwater in the Capped Waste Stockpile is presented in **Table 6.7**. When the groundwater EPC exceeded the solubility limit, the solubility limit was used as the EPC to estimate potential risk. Since the relative proportions of aliphatic and aromatic fractions within the TPH mixture is unknown, the HHRA assessed TPH twice, once assuming all TPH is present as aromatic fractions and once assuming TPH is present at aliphatic fractions. This is considered to be a conservative approach, and likely to overestimate potential health risks.

Table 6.6: Maximum Shallow (<1.5mbgl) Groundwater Exposure Point Concentrations (µg/L)

Chemical	On-Site Workers
TPH C_6-C_9	240
TPH C_{15}-C_{28}	1400* (1.5E-03 aliphatic) (290 aromatic)
Benz(a)anthracene	4
Benzo(b)&(k)fluoranthene	10.8* (1.5)
Benzo(a)pyrene	6.46* (1.62)
Dibenz(a,h)anthracene	1

Notes:
* indicates that the EPC exceeds the solubility limit and therefore the solubility limit was used as the EPC to estimate potential risk via direct contact with groundwater.
Value in brackets indicates the solubility limit that was adopted.

Table 6.7: Maximum Groundwater Concentrations beneath the Capped Waste Stockpile (µg/L)

Chemical	On-Site Workers
Fluoride	1,080,000
Cyanide	260,000

The vapour EPCs are presented **Table 6.8** and were estimated using the maximum reported groundwater TPH C_6-C_9 concentration presented in **Table 6.6**. These vapour concentrations were considered to be present within a Works personnel's trench when the depth of the trench intersects groundwater impacted with TPH C_6-C_9.

Table 6.8: Predicted Vapour Exposure Point Concentrations within a Worker's Trench (mg/m3)

Chemical	On-Site Workers
Aliphatic TPH C_6-C_9	1.66E-02
Aromatic TPH C_6-C_9	1.75E-02

Note: all other chemicals in shallow (<1.5mbgl) groundwater which exceeded the adopted health-based criteria are not considered volatile.

6.3 Estimation of Chemical Intakes

The chemical intakes are estimated for each receptor, chemical and pathway separately, and the methodology follows that described in NEPC (2013) *National Environment Protection (Assessment of Site Contamination) Amendment Measure 2013 (No. 1), Schedule B4, Site-Specific Health Risk Assessment Methodology*.

The equations used to estimate chemical intake are presented in **Appendix B** for the following exposure pathways:

- Inhalation of airborne particulates;
- Inhalation groundwater vapours within a worker's trench;
- Incidental ingestion of groundwater;
- Dermal contact with groundwater;
- Dermal contact with soil; and
- Incidental ingestion of soil.

7. TOXICITY ASSESSMENT

Toxicity assessment is typically divided into two stages: hazard identification; and dose-response assessment. The hazard identification stage is a qualitative description of the capacity of a contaminant or agent to cause harm. The dose-response assessment includes the selection of appropriate toxicity criteria from a hierarchy of published and reliable sources.

7.1 Hazard Identification

The hazard identification process provides a means in which to consider the capacity of a specific agent to produce adverse health or environmental effects. Hazard identification comprises the initial part of the toxicity assessment process involving the consideration of the types of adverse health effects that might be caused by a given agent and uncertainty analysis of toxicological data.

The hazard identification assessment is generally restricted to those compounds that were found to be present at the site in excess of the relevant screening criteria (i.e. quantitatively assessed in the Tier 2 HHRA).

7.2 Dose-Response Assessment

The objective of the dose-response assessment is to identify the toxicity values for each CoPC to be used for the quantification of human health risk. The numerical values derived from toxicity dose-response studies are referred to collectively as toxicity values. There are two basic approaches for the dose-response assessment that have been developed on the basis of the way in which chemicals cause toxicity: 1) threshold toxicity, and 2) non-threshold toxicity.

7.2.1 Threshold Toxicity

Threshold toxicity is exhibited by chemicals where there is an exposure level below which no toxic effect is thought to occur. Threshold substances are generally considered to include most non-carcinogenic chemicals and non-genotoxic carcinogens, however some carcinogenic chemicals act by both threshold and non-threshold toxicological modes of action (such as benzene).

Potential health effects that are assessed on the basis of a threshold dose response utilise a threshold value which is typically termed an acceptable or tolerable daily intake (ADI or TDI) or a reference dose (RfD) (expressed as mg of chemical/kg of body weight/day). For the purpose of this assessment, the threshold value adopted has been termed a TDI. A TDI is a chemical intake below which it is considered unlikely that adverse effects would occur in human populations, including sensitive sub-groups (such as the very young or elderly). Hence, the TDI relates to intakes from all sources, the site related impacts as well as background intakes (where relevant).

For inhalation exposures, the threshold value is typically termed a tolerable concentration in air (TC) or reference concentration (RfC) (expressed as mg of chemical/cubic meter of air), which is an estimate of a continuous inhalation exposure concentration to people (including sensitive subgroups) that is likely to be without risk of deleterious effects during a lifetime.

Exceedence of the threshold level does not imply that adverse effects will occur, as there are a number of uncertainties and safety factors incorporated into the threshold value, rather that exposure needs to be further evaluated.

7.2.2 Non-Threshold Toxicity

Non-threshold toxicity is exhibited by chemicals where there is considered to be no dose below which no adverse effect will occur. Genotoxic carcinogens comprise this group and they can potentially cause carcinogenesis at any level of exposure, with the probability of carcinogenesis increasing with dosage. These chemicals are therefore assessed on the basis of a non-threshold dose-response relationship.

The assessment of potential health effects associated with genotoxic carcinogens requires the use of non-threshold toxicity values. The values available are essentially the slope of the cancer dose-response curve for the chemical (based on relevant studies and approaches to extrapolate effects

from high doses to low doses) and are termed either a cancer slope factor ("CSF") or an inhalation unit risk ("IUR"). The CSF (expressed as $(mg/kg/day)^{-1}$), or IUR (expressed as $(\mu g/m^3)^{-1}$) is used to estimate the probability of an individual developing cancer at some point in a lifetime as a result of a specific exposure.

7.2.3 Adopted Dose-Response Values

The threshold and non-threshold dose-response values published in the follow guidance were adopted in this HHRA:

- NEPM (2013) Schedule B7, Appendix A1, The Derivation of HILs for Metals and Inorganics.
- NEPM (2013) Schedule B7, Appendix A2, The Derivation of HILs for PAHs and Phenols.
- Total Petroleum Hydrocarbon Criteria Working Group Series (1997), Volume 4 – Development of Fraction Specific Reference Doses and Reference Concentrations for Total Petroleum Hydrocarbons (TPH).
- US EPA (2015) Dose response values adopted by US EPA for derivation of the Regional Screening Levels (last updated January 2015). Available online.

The dose-response values adopted for this HHRA are presented in **Table 7.1**.

Table 7.1: Adopted Dose-Response Values

CoPC	Threshold Values		Non-Threshold Values	
	RfD (mg/kg-day)	RfC (mg/m^3)	SF oral ($mg/kg\text{-}day^{-1}$)	IUR (mg/m^3)
TPH C_6-C_9 aliphatic	5.0	18.4	-	-
TPH C_6-C_9 aromatic	0.04	0.18	-	-
TPH C_{15}-C_{28} aliphatic	2.0	not volatile	-	-
TPH C_{15}-C_{28} aromatic	0.03	not volatile	-	-
Chromium VI	n/a	1.0E-04[a]	-	-
Cyanide	0.006[a]	0.0008[a]		
Fluoride	0.04[d]	1.3E-02[b]	-	-
Benzo(a)pyrene	-	-	0.5[a]	0.143[a]
Benz(a)anthracene	-	-	0.05[a]	0.0143[a]
Benzo(b)&(k)fluoranthene	-	-	0.05[a]	0.0143[a]
Dibenz(a,h)anthracene	-	-	0.5[a]	0.143[a]
Chrysene	-	-	0.005[a]	0.00143[a]
Indeno(1,2,3-c,d)pyrene	-	-	0.05[a]	0.0143[a]
Benzo(g,h,i)perylene	-	-	0.005[a]	0.00143[a]

Notes:
RfD: reference dose
RfC: reference concentration
SF: slope factor
IUR: inhalation unit risk

a) NEPM (2013) Schedule B7, Appendix A1 and Appendix A2
b) US EPA (2015) Regional Screening Level, CAL EPA value
c) TPH (1997) Volume 4 – Development of Fraction Specific Reference Doses and Reference Concentrations for Total Petroleum Hydrocarbons (TPH)
d) NHMRC (2011) Australian Drinking Water Guidelines

Justification for adoption of the dose-response values in this HHRA is discussed in NEPC (2013) *Schedule B* for the PAH compounds, cyanide and chromium. ENVIRON conducted a toxicological assessment of fluoride in P*reliminary Screening Level, Health Risk Assessment for Fluoride and Aluminium* (ENVIRON, 2013a). Relevant portions of this assessment showing justification for the fluoride dose-response value adopted is provided in **Appendix C**. The toxicity profiles, including physico-chemical properties, for TPH C_6-C_{36} is also provided in **Appendix C**.

7.3 Background Exposure

Background levels of contamination comprise chemical concentrations present in the environment as a result of everyday activities or natural sources. These chemicals may be present in food, air, water and consumer products and represent the non-site sources of contamination exposure. This

is commonly referred to as background exposure which should be taken into account during the assessment of potential human health risk.

Background exposure is only applied to threshold contaminants (i.e. non-carcinogens) because intakes of non-threshold contaminants (i.e. carcinogens) are considered on the basis of an increase in risk, which is irrespective of background exposure. The allocation of background exposure is undertaken on a chemical-specific basis by applying a factor (%) to the threshold toxicity reference value (TRV or Reference Dose), as illustrated in the equation below:

$$TRV\ (adjusted\ for\ background\ exposure\ ) = \left(1 - Background\ (\%)\right)\ x\ TRV$$

In cases where background exposure is considered to be essentially negligible (contributing to less than 5% of the threshold TRV), no background exposure has been applied. Where background exposure is considered to comprise greater than 50% of the threshold TRV, the background exposure is considered to be 50% of the TRV.

The allocation of the TRV to background exposure for the chemicals assessed in this HHRA is presented in **Table 7.2**.

Table 7.2: Background Exposure Adopted for Non-Carcinogenic Chemicals

Chemical	Oral (%)	Inhalation (%)	Source
TPH C_6-C_9 aliphatic	0	10	CRC CARE (2011)
TPH C_6-C_9 aromatic	0	10	CRC CARE (2011)
TPH C_{15}-C_{28} aliphatic	0	Not volatile	CRC CARE (2011)
TPH C_{15}-C_{28} aromatic	0	Not volatile	CRC CARE (2011)
Chromium VI	n/a	0	NEPM (2013) Schedule B7, Appendix A1
Cyanide	50	0	NEPM (2013) Schedule B7, Appendix A1
Fluoride	10	10	ENVIRON (2013a) Preliminary Screening HHRA

8. RISK CHARACTERISATION

Risk characterisation is the final step in the risk assessment process whereby information gathered and derived from the toxicity assessment and exposure assessment are combined to derive numerical estimates of risk to human health. Conclusions reached during the risk characterisation process conveys the nature and existence of (or lack of) human health risks in a manner useful for decision makers.

8.1 Methodology

8.1.1 Threshold Risks

Non-carcinogenic or threshold risks are estimated in the form of Hazard Quotients ("HQs"), which are estimated for the dermal/oral pathways and the inhalation pathways as described below.

Oral/Dermal Pathways

$$Hazard\ Quotient\ (HQ) = \frac{Mean\ Daily\ Intake\ (MDI)\ \left(\frac{mg}{kg}\ day\right)}{Tolerable\ Daily\ Intake\ (TDI)\ \left(\frac{mg}{kg}\ day\right)}$$

Inhalation Pathways (dust and vapour)

$$Hazard\ Quotient\ (HQ) = \frac{Exposure\ Adjusted\ Air\ Concentration\ \left(\frac{\mu g}{m^3}\right)}{Tolerable\ Air\ Concentration\ \left(\frac{\mu g}{m^3}\right)}$$

Since an individual might be exposed to a substance or combination of substances via several exposure pathways, the HQs (for multiple exposure pathways and a combination of chemicals) can be summed to calculate an overall risk level, or Hazard Index (HI), as described below.

$$Hazard\ Index\ (HI) = \Sigma\ Hazard\ Quotients$$

It is important however to consider the reasonable exposure pathways combinations and to assess whether it is likely that the same individual would consistently face the reasonable maximum exposure by more than one pathway. Although often a conservative process, this procedure can be used to assess the additivity of effects from concurrent exposure to a mixture of chemicals.

8.1.2 Non-Threshold Risks

Carcinogenic or non-threshold risks are estimated in the form of Increased Lifetime Cancer Risks ("ILCR") which are estimated for the dermal/oral pathways and the inhalation pathways as illustrated below.

Oral/Dermal Pathways

$$ILCR = Chronic\ Daily\ Intake\ \left(\frac{mg}{kg}day\right) \times\ Slope\ Factor\ \left(\frac{mg}{kg}day\right)^{-1}$$

Inhalation Pathways (dust and vapour)

$$ILCR = Exposure\ Adjusted\ Air\ Concentration\ \left(\frac{\mu g}{m^3}\right) \times Inhalation\ Unit\ Risk\ \left(\frac{\mu g}{m^3}\right)^{-1}$$

Estimates from all pathways are summed to produce a total ILCR for each contaminant. ILCRs are evaluated against acceptability criteria set *a priori* to the risk assessment process, termed Maximum Acceptable Risk Levels ("MARLs").

8.2 Risk Acceptability Criteria

The MARL for non-carcinogenic risk is a HI of one (NEPM, 2013). A HI of less than one indicates that the estimated level of exposure is below that at which health risks are expected to occur. Should the HI exceed one then the 'risk driving' compounds and pathways need to be considered in more detail (such as segregating the pathways and/or different chemicals).

For non-threshold (carcinogenic) chemicals, the incremental lifetime cancer risk estimates for each receptor have been compared to an acceptable carcinogenic risk level of 1 in 100,000 (1×10^{-5}) in accordance with NEPM 2013 guidelines.

8.3 Summary of Risk Estimates

A summary of the risk calculation results for Works personnel and offsite sensitive receptors is presented in **Table 8.1** for the threshold risk estimates and in **Table 8.2** for the non-threshold risk estimates.

Table 8.1: Summary of Hazard Indices

Exposure Pathway	On-Site Worker	On-Site Worker at CWS	Off-Site Resident
Outdoor/trench dissolved phase vapour inhalation	5.4E-03	-	-
Dust inhalation	- *	-	0.26
Dermal contact with soil	- *	- (e)	-
Incidental ingestion of soil	-*	- (e)	-
Incidental ingestion of groundwater	1.3E-04 (d)	1.5	-
Dermal contact with groundwater	9.8E-02 (d)	2.8	-
Total HI	**0.10**	**4.2**	**0.24**

Notes:
a) Acceptable risk level of 1.0 was adopted (NEPM, 2013)
b) – indicates that the exposure pathway was not considered relevant for the HHRA
c) -* indicates that this pathway was assess for carcinogenic chemicals only (refer to Table 8.2)
d) Does not include groundwater beneath the Capped Waste Stockpile which is assessed separately
e) Soil data at the CWS is not available. Management measures to eliminate groundwater pathways will protect from exposure to soil impacts

Table 8.2: Summary of Increased Lifetime Cancer Risk (ILCR) Estimates

Exposure Pathway	Works Personnel	Offsite Nearest Sensitive Receptor
Outdoor/trench dissolved phase vapour inhalation	-	-
Dust inhalation	1.249.49E-07	3.65E-07
Dermal contact with soil	4.3E-07	-
Incidental ingestion of soil	6.8E-07	-
Incidental ingestion of groundwater (c)	5.4E-10	-
Dermal contact with groundwater (c)	2.5E-07	-
Total ILCR	**1.482.31E-06 (1 in 432,051)**	**3.65E-07 (1 in 2,739,726)**

Notes:
a) An acceptable cancer risk level of 1 in 100,000 was adopted in accordance with NEPM (2013) recommendations
b) – indicates that the exposure pathway was not considered relevant for the HHRA
c) Does not include groundwater beneath the Capped Waste Stockpile which is assessed separately. Note data indicating the presence of carcinogenic chemicals are not available for the CWS.

The risk estimates presented in **Table 8.1** and **Table 8.2** are based on a number of assumptions regarding human behaviour and the Project site, and were tailored to site-specific situations where this information was available. A review of the risk estimates indicates that:

- The potential threshold and non-threshold health risks for Works personnel (excluding the Capped Waste Stockpile) and offsite sensitive receptors are low and acceptable as indicated by HI values less than 1.0 and cancer risk estimates greater than 1 in 100,000.
- The health risks estimated for the Works personnel exposed to groundwater beneath the Capped Waste Stockpile exceeded the acceptable limits indicating potential health risks associated with this activity. This HHRA assumed that the Works personnel would have direct contact with the groundwater (to exposed hands and face) for two hours per day for 80 days (based on. four months to complete removal of the Capped Waste Stockpile material); which is likely to be an overestimate of actual exposure. Recommended management measures to eliminate direct contact exposure pathways, including use of personal protective equipment, is discussed in **Section 10**.
- The risk estimates for the offsite residential receptor represents the highest expected health risk for the off-site receptors via dust inhalation because they were considered to have the highest exposure (i.e. 24 hours per day every day of the year), and the risks were modelled based on the highest predicted offsite dust concentration (maximum cumulative annual average). Therefore, the health risks are likely to be lower for all other sensitive off-site receptors including recreational users. Site-derived dust was considered to be the only media that could potentially impact offsite sensitive receptors because any impacted soil and groundwater would be contained to the Project site.
- Potential health risk to Works personnel and offsite sensitive receptors via the inhalation of any site-derived vapours from the Capped Waste Stockpile is discussed in **Section 8.4**.

8.4 Health Risks Associated with the Capped Waste Stockpile

This HHRA has identified potential health risks to on-site workers via direct contact with groundwater beneath the Capped Waste Stockpile, due to fluoride and cyanide groundwater impacts. Although the waste contents within the Capped Waste Stockpile is relatively well known (refer to **Section 5.4.2.4**), soil analytical data was not available for use in this HHRA. However, the mitigation measures used to eliminate exposure pathways between impacted groundwater and the Works personnel (as outlined in **Section 10**) will protect the workers against any potential health risks associated with the Capped Waste Stockpile buried waste (including asbestos and lead-based paints) and associated soil impacts.

Gas monitoring data measured from the Capped Waste Stockpile indicates that ammonia gas has the potential to be released during removal of waste in the Capped Waste Stockpile; whilst concentrations of phosphine, hydrogen sulfide (H_2S) and hydrogen cyanide (HCN) were below detectable levels. Ammonia gas beneath the Capped Waste Stockpile are likely to dissipate and dilute in ambient air when released from the Capped Waste Stockpile; furthermore management measures (e.g. respiratory protection) to prevent any health risks associated with inhalation of waste gasses should be implemented (refer to **Section 10**).

The off-site sensitive human receptors, such as residents, are unlikely to have any exposure to impacted groundwater beneath the Capped Waste Stockpile or the waste that is to be removed during the remediation activities because soil/groundwater will not be transported off the Site. As discussed in **Section 5.4.2.5**, a groundwater plume emanating from the Capped Waste Stockpile has extended outside the Project site boundary. However it is contained and managed within the Hydro Land, and does not extend beneath residential properties.

Real-time ambient air monitoring for gases such as ammonia during removal of material from the Capped Waste Stockpile would reduce the likelihood that gases of detectable concentrations would be transported offsite and reach offsite sensitive receptors. Chapter 8 of the Environmental Impact Statement describes how the Capped Waste Stockpile activities would be undertaken and managed to minimise potential impacts.

8.5 Health Risks Associated with the Containment Cell

The Containment Cell is proposed to be constructed within the area currently known as the Clay Borrow Pit. This location provides the following benefits:

- It is an area underlain by suitable soils comprising low permeability residual clays and bedrock, and avoiding alluvial soils. Bedrock to be massive with minimal defects and fractures.
- An acceptable distance (a minimum of two metres) above the highest observed groundwater level.
- It minimises the vegetation clearance requirements.
- It is located:
  - Above the 1% Annual Exceedence Probability (AEP) flood level.
  - More than 100 metres from a watercourse.
  - A minimum of 500 metres from the nearest residence.
  - Within 500 metres of the Smelter and on the northern side of the Hunter Expressway.
  - A minimum of 20 metres from power line easements.

The Containment Cell includes the following elements:

- Containment cell base comprises the following layers (from the base to the waste material):
  - One metre thick base of compacted clay.
  - A high density polyethylene (HDPE) liner and filter fabric.
  - 300mm sand leak detection layer.
  - A HDPE liner and filter fabric.
  - 300mm gravel (or other suitable material) drainage detection layer.
  - Filter fabric.
- Containment cell contents segregated (through the use of crushed refractory) in the following categories:
  - Asbestos waste.
  - Contaminated soils.
  - Non-recyclable demolition materials.
  - Capped waste stockpile contents.
- Capping layer comprises the following layers (from lower layer to the surface):
  - Protection geotextile on top of waste material.
  - A 300mm sand gas collection layer.
  - Gas vents (from sand gas collection layer and through the following overlying layers).
  - A protection geotextile using excavator and spreader bars.
  - A 600mm compacted clay sealing layer. This layer would have a permeability of less than 1 x 10^{-9} m/s.
  - Geomembrane (HDPE or linear low-density polyethylene (LLDPE)) liner and protection geotextile.
  - A 300mm gravel layer or other suitable material for a drainage layer.
  - Protection geotextile using excavator and spreader bars.
  - A 300mm fauna barrier of crushed concrete.
  - A 800mm revegetation layer comprising of soil suitable to sustain plant growth.
  - 200mm topsoil and vegetation.
- Leachate contingency collection system.
- Water treatment plant (if required for treatment of collected leachate).
- Perimeter road. A sealed road and associated drainage would be constructed around the perimeter of the Containment Cell.

During community consultation, concern was raised over the potential health risks to the surrounding community in the event of cell failure.

The Containment Cell has been designed and would be constructed to incorporate best practice technology specifically designed to macro-encapsulate all the material streams and to mitigate and manage risks.

The proposed design contains the material and excludes water from entering the cell, thereby stopping the generation of leachate. However, as a contingency a leak detection layer and leachate collection system have been included in the design. If leachate is generated it would be collected and diverted to a water treatment plant.

Exclusion of water from the Containment Cell would also minimise the potential for gas generation. However in the event that gas is generated the vents would stop these concentrating below the containment layer.

Monitoring and management activities (as described in Chapter 9 of the Environmental Impact Statement) would continue during Containment Cell operation.

As discussed in **Section 5.4.2.3**, Works personnel are unlikely to be exposed to groundwater during construction of the cell and placement of material into the Containment Cell.

8.6 Health Impacts Associated with Impacts to Rainwater Tank Water Quality

Impacts to rainwater captured in tanks can occur by runoff to tanks from roofs washing off deposited particulates. The first flush concentration would be the major carrier of any deposited contaminants, as is commonly found in storm water. It should be noted that there are other contaminants that need to be avoided in roof runoff that are not associated with dust derived from the Project site such as microbial hazards (enHealth, 2010; NSW Health, 2007). The *Australian Drinking Water Guidelines* (2011) states that "*The principal sources of contamination* [for water collected in rainwater tanks] *are birds, small animals and debris collected on roofs*".

To assess the potential impacts to rainwater tank quality due to the Project activities, Ramboll Environ:

- Identified surrounding residential properties which contain a rainwater tank in the vicinity of the Project site; and
- Considered the potential for dust deposition to off-site properties due to Works activities.

In May 2015, Ramboll Environ observed two properties which contained rainwater tanks located at 22 Sawyers Gully Road, Sawyers Gully; and 2 Bowditch Avenue, Loxford. These properties are located approximately 1.1 km and 0.8 km from the Project site. It is recognised that other rainwater tanks may be located in the vicinity that were not visible during the inspection. The identified tanks were located close to shed roofs suggesting that rainwater collected on the roof is fed into the rainwater tank.

Nuisance dust deposition is regulated through the stipulation of maximum permissible dust deposition rates. The NSW EPA impact assessment goals for dust deposition (DECC, 2005) are given in **Table 8.3** illustrating the allowable increment in dust deposition rates above ambient (background) dust deposition rates which would be acceptable so that dust nuisance could be avoided.

Table 8.3: EPA Goals for Allowable Dust Deposition

Averaging Period	Maximum Increase in Deposited Dust Level	Maximum Total Deposited Dust Level
Annual	2 g/m^2/month	4 g/m^2/month

Source: Approved Methods for Modelling, DEC 2005

The AQIA (Ramboll Environ, 2015) reviewed data reported by Roads and Maritime Services (RMS) that was collected for the Hunter Expressway development. The RMS study identified that between January 2013 and January 2014 the annual average dust deposition at a background monitoring site near Heddon Greta (most applicable to the Project site) was 1.6g/m^2/month. Using this concentration as representative for background concentrations, Ramboll Environ (2015) estimated

that the cumulative dust deposition at the residential property with the highest predicted dust concentration (6 Dawes Avenue, Loxford located 500m to the south east) would be 1.7g/m^2/month. This is an increase of 0.1g/m^2/month due to the Works activities.

This increase in dust deposition is below the NSW Department of Environment and Conservation (NSW DEC) (2005) A*pproved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.*for allowable dust deposition, and is considered to be negligible. Therefore any potential health risks to users of rainwater tanks in the vicinity of the Project site are also considered to be negligible.

An information paper produced by the Health Department of NSW (NSW Health, 2007) and guidance provided by enHealth (*Guidance on the use of rainwater tanks*, 2010) describes steps that should be taken in the operation and maintenance of rainwater tanks to minimise the risks associated with consumption of rainwater. Such advice should be considered by off-site receptors which utilise rainwater collected in tanks.

8.7 Health Impacts Associated with Impacts to Reticulated Drinking Water Supplies

According to the Hunter Water Corporation, reticulated drinking water for the Loxford and Kurri Kurri areas is sourced from Chichester Dam located more than 60km to the north of the Project site. The Ramboll Environ AQIA (2015) predicted Project-generated concentrations of dust across a 10km x 10km area centered over the Smelter site dust. The model predictions showed that at the outer limits of this modelling domain, dust concentrations were negligible. Consequently, it is considered that dust deposition from Works activities are highly unlikely to impact the quality of water in Chichester Dam, located 60km from the Smelter.

The impacts of the Works activities to reticulated drinking water supplies will therefore not be assessed further.

9. UNCERTAINTY AND SENSITIVITY ANALYSIS

9.1 Analysis of Uncertainty

Inherent in each step of the risk assessment process are uncertainties that may ultimately affect the final risk estimates. Uncertainties may exist in many areas including the collection of samples used to identify contaminants, laboratory analysis of samples, estimation of potential exposures and derivation of toxicity criteria. These uncertainties may result in either an over or under-estimation of risks. However, for this HHRA, where uncertainties existed, a conservative approach was adopted, where appropriate, in order to overestimate rather than underestimate potential exposures and risks. Below is a discussion of the significant sources of uncertainty in the HHRA.

9.1.1 Conceptual Site Model Uncertainty

The CSM for the Project site is described in **Section 5.4** which outlines the contamination sources, exposure pathways and receptors for the Project site and surrounding sensitive receptors that have been assessed in this HHRA. A discussion of the uncertainties associated with the CSM is presented below.

- *Receptor uncertainty*: there is low uncertainty regarding the human receptors for the Project because the Environmental Impact Statement is applicable for the Works activities that will be carried out by workers. The offsite human receptors of concern were identified as nearby residents, educational facilities, medical facilities and recreational facilities. The offsite health risks were assessed for the most sensitive offsite receptor which was the residential dwelling that had the highest predicted Project-derived dust concentration. This exposure scenario is considered to be the most sensitive scenario which adequately addresses any offsite receptor uncertainty.
- *Source uncertainty*: there is moderate uncertainty regarding the contamination source that is assessed in this HHRA because:
  - Project-derived dust concentrations at the nearest offsite receptor were predicted using modelling techniques. However, conservative and EPA approved assumptions were use during the modelling with the aim of reducing any uncertainty in the predicted dust concentrations (Ramboll Environ, 2015). This HHRA also used the maximum cumulative dust concentration predicted off-site to assess health risks to the nearest resident.
  - It was unknown whether the chromium detected in soil and in the predicted dust concentrations was chromium III or the more toxic chromium VI. To account for this uncertainty, the HHRA assumed all chromium was present at chromium VI; which is likely to overestimate potential health risk.
  - Although the waste within the Capped Waste Stockpile is relatively well understood, no soil data was collected from the Capped Waste Stockpile to assess potential risks to workers. However, a large data set is available for groundwater located adjacent to the Capped Waste Stockpile and groundwater quality detected here was assumed to be beneath the Capped Waste Stockpile. The mitigation measured recommended to protect workers from direct contact with groundwater beneath the Capped Waste Stockpile are considered to be suitably protective of any health risks associated with exposure to impacted soil and waste within the Capped Waste Stockpile.
  - Since vapour concentrations in the subsurface were unknown (i.e. no soil gas data), vapour estimation models recommended by Virginia Department of Environmental Quality were used to estimate TPH vapours within building footprint excavations. These models are known to have the potential to over-estimate vapour concentrations and therefore may introduce uncertainty in the resulting risk estimates. In addition, in absence of site-specific subsurface oxygen data, biodegradation of hydrocarbon vapours was not included in the vapour modelling which has the potential to significantly overestimate vapour concentrations within a building.
  - The vapours and gases that are likely to be produced when Capped Waste Stockpile material is exposed and removed are unknown. However subsurface gas monitoring

indicates that generation of HCN, phosphine and H_2S vapours is unlikely. Ammonia gas emanating from the Capped Waste Stockpile has the potential to exceed Safe Work Australia exposure standards, and as a safety precaution management and mitigation measures would be implemented to protect workers from inhaling potentially harmful vapours.

- *Exposure pathway uncertainty*: there is low uncertainty regarding the exposure pathways adopted for the Works personnel because the Project activities to be undertaken are well known. The risk estimates presented in this HHRA has assumed that workers will be wearing boots, long pants and long sleeved shirts; with face and hands exposed. In reality, the workers are likely to be wearing gloves for the majority of Project activities and therefore the health risks are likely to be overestimated. There is also low uncertainty for the offsite sensitive receptor exposure pathways because site-derived soil and groundwater would not leave the Project site, and consideration of dust and vapours generated from Works activities have been assessed in the HHRA.

There is moderate uncertainty regarding the identification of rainwater tanks in the vicinity of the Smelter Site because not all properties were visited to inspect the presence of rainwater tanks. To compensate for this uncertainty, the HHRA has taken a conservative approach and assumed that the residential property with the highest predicted dust concentration had a rainwater tank.

9.1.2 Human Exposure Parameter Uncertainty

Risk assessment requires the adoption of several assumptions relating to human behaviour and characteristics in order to assess potential human exposure. However the exposure scenario for the assumed Works personnel has a degree of uncertainty associated with it. To account for this uncertainty, the assumptions used for the onsite receptors were conservative and developed to provide an estimate of reasonable maximum exposures rather than the actual exposures. For example, Works personnel not wearing gloves.

This approach tends to overestimate the associated risks because it is highly unlikely that this level of exposure could occur at the Project site and therefore this conservatism, or over prediction, of risk is considered to have more than catered for potential exposure uncertainty in the risk assessment. Uncertainty in the assessment is, therefore, taken into account by erring on the side of over estimation and health protection.

9.1.3 Toxicity Assessment Uncertainty

In general, the available scientific information is insufficient to provide a thorough understanding of all of the potential toxic properties of chemicals to which humans may be exposed. It is necessary, therefore, to extrapolate these properties from data obtained under other conditions of exposure and involving experimental laboratory animals. This may introduce two types of uncertainties into the risk assessment:

- Those related to extrapolating from one species to another; and
- Those related to extrapolating from the high exposure doses, usually used in experimental animal studies, to the lower doses usually estimated for human exposure situations.

The majority of the toxicological knowledge of chemicals comes from experiments with laboratory animals, although there may be interspecies differences in chemical absorption, metabolism, excretion and toxic response. There may also be uncertainties concerning the relevance of animal studies using exposure routes that differ from human exposure routes. In addition, the frequent necessity to extrapolate results of short-term or subchronic animal studies to humans exposed over a lifetime has inherent uncertainty.

In order to adjust for these uncertainties, ADIs and RfDs incorporate safety factors that may vary from 10 to 10,000. The US EPA assumes that humans are as sensitive to carcinogens as the most sensitive animal species. The policy decision, while designed to minimise the potential for underestimating risk, introduces the potential to overestimate carcinogenic risk. Conversely, it

also does not allow for the possibility that humans may be more sensitive than the most sensitive animal species.

The dose-response values recommended by NEPM (2013) and adopted in this HHRA have included additional safety factors. For example, free cyanide adopted the NHMRC (2011) oral reference dose which includes an additional 2-fold uncertainty factor for oral and dermal routes.

9.1.4 Risk Characterisation

Uncertainties can be introduced into the risk characterization stage of a HHRA when risk estimates are added for multiple chemicals across multiple exposure pathways. In some situations, chemicals may not affect similar target organs, may not act via similar mechanisms, or may interact in ways that are not additive. As a result, adding risk estimates may not appropriately reflect the potential risks associated with multiple chemical exposures. Similarly, the risks posed by a chemical following exposure via different pathways may differ in ways that are not adequately reflected by simple addition of the risk estimates derived for each individual pathway.

9.1.5 Summary of Uncertainties

Risk assessment methods are designed to be highly conservative to address the uncertainties associated with each step in the process. Thus, actual risks are not likely to be greater than (and may be significantly less than) the risks estimated, and for this HHRA key factors that are likely to have overestimated potential health risks include:

- Using the maximum predicted dust concentration as the EPCs for offsite residents and assuming that the maximum concentration remains constant throughout the entire period of exposure;
- Assuming all chromium detected in soil and dust is present as chromium VI, the more toxic form;
- Assuming that the residential receptors have exposure 24 hours a day for 365 days a year for the project duration (they never leave home during the project);
- Assuming that Works personnel would have direct contact with exposed hands and face to impacted groundwater beneath the Capped Waste Stockpile for two hours a day for 80 days (the entire duration of Capped Waste Stockpile material removal activities);
- Assuming the Works personnel would enter a trench made following removal of building footprints and that impacted groundwater would enter the trench;
- Assuming the non-carcinogenic chemicals assessed had a background exposure between 10% and 50% (i.e. reduce the adopted TDI/RfD); and
- Use of vapour estimation models to calculate the vapour concentrations within the building footprint trenches, and the exclusion of hydrocarbon biodegradation in the modelling process.

As indicated above, the HHRA presented in this report has adopted conservative or reasonable upper-bound values for a variety of variables. The compounding effect of utilizing multiple reasonable upper bound limits for quantitative parameters in the risk assessment is expected to give rise to an overestimation of actual exposure and associated health risk. Therefore, interpretation of the risk estimates should take this into consideration when deciding on risk management options for the Project.

9.2 Sensitivity Analysis

Sensitivity analysis provides a quantitative estimate of the effect of uncertainty and/or variability in the input parameters on the results of the risk assessment. The analysis should be performed when a risk assessment has been conducted using a deterministic exposure model where a single value has been used to represent likely exposure scenarios (such as ingestion rates). The process involves changing one variable at a time within a defined range while leaving the other variables constant and determining the effect on the output.

The results of the sensitivity analysis are used to identify important input variables (or groups of variables) and develop bounds on the distribution of exposure or risk. A sensitivity analysis can also estimate the range of exposures or risk that result from combinations of minimum and

maximum values for some parameters and mid-range values for others (US EPA, 1989). Effort may then be directed to the collection of additional data for these important variables; as additional data is collected, the uncertainty in the 'true' value is reduced (NEPC, 2013).

An assessment of the uncertainty inherent in the risk assessment is provided in **Appendix D**. The maximum exposure was adopted for all offsite resident variables (24 hours per day, 365 days per year) and the maximum predicted concentration was adopted in the HHRA. A reduction in any of these variables would result in a reduction of health risk. Therefore, a sensitivity analysis was not performed for this human receptor.

A review of the sensitivity analysis data presented in **Appendix D** identifies that the parameters most sensitive in influencing the resulting risk estimates are associated with skin exposure surface area and exposure time when assessing risks associated with dermal contact with groundwater beneath the Capped Waste Stockpile.

When assessing potential health risk associated with remediation of PAH surface soil, even if the maximum reasonable exposure variables were adopted for the on-site worker, the resultant risk estimates were still low and acceptable for that particular scenario.

10. MITIGATION MEASURES

In addition to the management measures described in **Table 2.1**, the following would be developed and implemented as part of a Work Health and Safety Management Plan prepared for the Works. These measures would mitigate the key human health impacts identified by this HHRA. The WHSMP would include

- The specific procedures to be implemented during activities at the Capped Waste Stockpile. This would include, but not be limited to:
  - Providing appropriate personal protective equipment to workers who are undertaking activities in or near the Capped Waste Stockpile. . The equipment would remove exposure pathways relating to dermal exposure, incidental ingestion and inhalation. This would include:
    - Waterproof boots, pants and long sleeved shirt as a minimum. Face shields would be required for personnel working in close proximity to exposed groundwater (when in locations and situations where splashing could result in incidental ingestion of groundwater and/or eye and skin contact).
    - Appropriate masks would be required to prevent dust (including asbestos) inhalation.
    - A respirator appropriate for ammonia, methane, hydrogen, hydrogen cyanide and hydrogen sulfide (available and ready to be used for all workers at the Capped Waste Stockpile).
- Real-time ambient air monitoring at several locations around the Capped Waste Stockpile when waste from the Capped Waste Stockpile is exposed. The ambient air would be monitored for concentrations of ammonia and hydrogen cyanide gases.
- Real-time ambient air monitoring should also be undertaken inside machinery housings, and workers within these housings should also have appropriate respirators on hand to use if necessary.

11. CONCLUSIONS

This Human Health Risk Assessment (HHRA) has been prepared by Ramboll Environ Australia Pty Ltd (Ramboll Environ) on behalf of Hydro Aluminium Kurri Kurri Pty Ltd (Hydro) to inform an Environmental Impact Statement (EIS) for submission to the Department of Planning and Environment prepared for the Demolition and Remediation Project (the Project) at the former Hydro Aluminium Kurri Kurri aluminium smelter at Hart Road Loxford (the Smelter).

This HHRA was completed to satisfy the requirements made by the Secretary's Environmental Assessment Requirements (SEARs), Hunter New England Local Health District and SafeWork NSW. These requirements related to potential health risks associated with construction of the Containment Cell, remediation activities and demolition of Smelter structures; and the associated impacts these activities will have on the health of onsite Workers and offsite sensitive receptors.

This HHRA was undertaken in accordance with Australian recommended guidance for performing human health risk assessments. This process involved 1) reviewing the project description provided in the EIS, 2) identifying the source-pathway-receptor (SPR) linkages for each activity (i.e. developing a conceptual site model (CSM)), and 3) quantitatively and qualitatively assessing the potential health risk for all complete SPR linkages.

A summary of the CSM, which formed the basis of the HHRA, is provided below:

- *Health Impact Sources:* contamination sources such as particulates, groundwater and surface soil (including contaminants in the Capped Waste Stockpile) and noise and vibration from the Project Works.
- *Exposure pathways* and *receptors:* **Table 11.1** summarises the human receptors and exposure pathways that were quantitatively assessed in the HHRA. The offsite residential property located at 6 Dawes Avenue, Loxford was considered to be the most sensitive offsite receptor because Project-generated dust concentrations were predicted to be the highest at this property. Both adults and children are considered to reside at this residential property.

Table 11.1 Conceptual Site Model Summary

Project Activity	Exposure Pathway	Human Receptor	
		On-Site Workers (Works personnel)	Off-Site Residential Receptors
Onsite excavations; Transfer and handling of soils; Movement of contaminated soils to the Containment Cell; Demolition of structures	Dermal contact with soil	✓	X
	Incidental ingestion of soil	✓	X
	Indoor inhalation of dust	X	✓
	Outdoor inhalation of dust	✓	✓
Removal of building footprints in areas of shallow groundwater.	Dermal contact with groundwater	✓	X
	Incidental ingestion of groundwater	✓	X
	Outdoor inhalation of groundwater vapours (within a trench)	✓	X
Dust generated from Project activities that may settle on nearby roof surfaces	Potable use of tank rainwater collected from roof surfaces	X	X

Notes:
✓ indicates a potential exposure pathway is present which is assessed quantitatively in the HHRA
X indicates a potential exposure pathway is not present

On the basis of the available data, the assumptions and the quantitative risk estimates presented in this report, and with consideration of the identified uncertainties, it was considered that the potential health risks were low and acceptable for:

- Onsite Works personnel conducting Project activities (excluding Works in the Capped Waste Stockpile area);
- Offsite residential receptors exposed to Project-generated dust;
- Offsite residential receptors exposed to Project-generated noise and vibration;
- Offsite residential receptors exposed to site-derived soil impacts and groundwater beneath the Smelter; and
- Use of tank rainwater and reticulated drinking water for offsite human receptors.

Potential health risks due to the Containment Cell were also considered to be low and acceptable because the proposed design excludes water from entering the cell, thereby stopping the generation of leachate and minimising the potential for gas generation. However, several contingency measures are proposed to mitigate exposure to offsite human receptors should leachate and gas be generated.

The health risks estimated for the Works personnel exposed to groundwater beneath the Capped Waste Stockpile exceed the acceptable limits indicating potential health risks associated with this activity. Management measures to eliminate direct contact exposure pathways, including use of personal protective equipment and real-time ambient air monitoring, are provided in the HHRA.

In addition to the environmental and noise/vibration controls that form part of the Project, the following mitigation measures would be implemented as part of a Work Health and Safety Management Plan that includes:

- The specific procedures to be implemented during activities at the Capped Waste Stockpile. This management plan would detail the personal protective equipment required to remove exposure pathways relating to dermal exposure, incidental ingestion and inhalation.
- Real-time ambient air monitoring at several locations around the Capped Waste Stockpile when waste from the Capped Waste Stockpile is exposed. At a minimum, the ambient air should be monitored for concentrations of ammonia and hydrogen cyanide gases.

12. REFERENCES

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13. LIMITATIONS

Ramboll Environ Australia prepared this report in accordance with the scope of work as outlined in our proposal to Hydro Aluminium Kurri Kurri Pty Ltd dated 28 October 2014 and in accordance with our understanding and interpretation of current regulatory standards.

Site conditions may change over time. This report is based on conditions encountered at the site at the time of the report and Ramboll Environ disclaims responsibility for any changes that may have occurred after this time.

The conclusions presented in this report represent Ramboll Environ's professional judgment based on information made available during the course of this assignment and are true and correct to the best of Ramboll Environ's knowledge as at the date of the assessment.

Ramboll Environ did not independently verify all of the written or oral information provided to Ramboll Environ during the course of this investigation. While Ramboll Environ has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll Environ was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

13.1 User Reliance

This report has been prepared exclusively for Hydro Aluminium Kurri Kurri Pty Ltd and may not be relied upon by any other person or entity without Ramboll Environ's express written permission.

APPENDIX A
TABLES

TABLE A1 Refractory Brick Wastes (mg/kg)

Sample Identification	HIL A[A]	PQL	RB2	RB3	RB4	RB9	RB10	RB11	RB12	RB13	RB14	RB15	RB17
Moisture Content			1.3	2.7	4.4	3.3	3.1	1.2	2.6	4.1	3.1	5.1	4.7
Metals													
Arsenic	100	4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Cadmium	20	1	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium (total)	100	3	2	13	<1	2	1	<1	<1	1	16	3	7
Copper	6000	0.5	<1	8	1	<1	2	<1	1	<1	4	3	5
Nickel	400	1	<1	6	2	<1	3	1	2	1	3	8	3
Lead	300	1	<1	<1	<1	<1	<1	<1	1	<1	1	2	<1
Zinc	7400	1	<1	2	1	<1	2	3	3	2	4	25	1
Mercury	40	1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Non Metallic Inorganics													
Total Fluoride	-	50	59	170	25	25	25	25	25	25	**730**	25	25
Total Cyanide	250	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Polycyclic Aromatic Hydrocarbons (PAH)													
Benzo(a)pyrene	3	0.05	NA	0.39	NA	NA	<0.05	NA	NA	<0.05	NA	NA	NA
Sum of reported PAH	300	--	NA	4	NA	NA	ND	NA	NA	ND	NA	NA	NA

All results are in units of mg/kg.

[A] NEPC (2013) Health Investigation Level 'A' (Low density residential)

Cells with '-' indicates testing was not completed or an appropriate screening criteria was not available

PQL = Practical Quantitation Limit.

Results shown in shading are in excess of the human health criteria

<LOR or <value = Less than the laboratory Limit of Reporting

* Site-specific fluoride (soluble) soil criteria for residental land use derived from 'Preliminary Screening Level Health Risk Assessment for Fluoride and Aluminium (ENVIRON 2013)'

** from Draft Hydro Aluminium Kurri Kurri Bake Ovens Refractory Brick Exemption 2012 (Table 2)

NA not analysed

RB18	RB24	RB26	RB27	RB28	RB29	RB30	RB31	RB32	RB33	RB34	RB35	RB35	RB36	RB37	RB38	RB39	RB40	RB41	RB42	RB43	RB44	RB45	RB46	RB47	RB48
8.8	6.8	2.5	3.1	2.3	5.3	2.5	4.5	3.9	2.1	3.5	3.1	-	4	3.4	3.9	4.5	3.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
2	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
6	1	20	<1	3	<1	6	1	<1	<1	<1	2	2	<1	<1	<1	14	<1	<1	<1	<1	<1	<1	<1	<1	<1
9	3	4	<1	3	3	3	3	1	<1	1	4	3	<1	<1	<1	8	<1	<1	<1	<1	2	<1	1	4	<1
3	3	3	2	3	4	2	1	2	<1	2	3	3	1	2	<1	2	<1	<1	<1	<1	2	<1	2	<1	<1
10	2	<1	<1	<1	<1	1	2	<1	<1	<1	<1	<1	2	<1	<1	<1	<1	<1	2	1	<1	1	1	1	2
10	3	1	<1	1	<1	1	2	1	<1	<1	2	1	<1	<1	<1	2	<1	<1	1	<1	<1	<1	<1	<1	<1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
470	500	25	210	25	25	25	25	25	25	25	25	25	25	25	200	25	25	25	25	25	25	25	25	25	25
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
NA	NA	NA	<0.05	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	<0.05	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05	NA
NA	NA	NA	ND	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	ND	NA

Table A2 Concrete Analytical Data (mg/kg)

Sample Identification	PQL		3A MAIN NORTH CONCRETE	3A BASEMENT NORTH CONCRETE	3A MAIN SOUTH CONCRETE	3A BASEMENT SOUTH CONCRETE	3B MAIN NORTH CONCRETE	3B BASEMENT NORTH CONCRETE	3B MAIN SOUTH CONCRETE	3B BASEMENT SOUTH CONCRETE	3C MAIN NORTH CONCRETE	3C BASEMENT NORTH CONCRETE	3C MAIN SOUTH CONCRETE	3C BASEMENT SOUTH CONCRETE
Building Number		HIL A[A]	3A	3A	3A	3A	3B	3B	3B	3B	3C	3C	3C	3C
Date			25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14
Metals														
Arsenic	1	100	9	<5	6	<5	6	<5	17	<5	7	7	7	7
Cadmium	0.1	20	4	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1
Chromium	1	100	24	18	11	20	16	63	9	14	13	14	13	11
Copper	2	6000	31	8	6	5	12	7	6	5	9	7	11	7
Lead	1	300	18	8	9	5	9	5	15	6	11	8	12	10
Nickel	2	400	49	15	39	15	23	22	143	7	18	10	24	11
Zinc	5	7400	1110	34	108	34	251	116	119	46	161	32	359	102
Mercury (inorganic)	0.1	40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hexavalent Chromium		100	0.7	0.9	1.3	<0.5	1.6	10.9	0.6	4.8	1.5	2.2	0.7	1
Fluoride (total)	40	-	10400	1250	9640	2490	4010	3540	56800	840	4140	360	5320	540
Non Metallic Inorganics														
Total Cyanide (free)	1	250	<1	<1	<1	<1	<1	1	<1	<1	<1	<1	<1	<1
Polycyclic Aromatic Hydrocarbons (PAH)														
Naphthalene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthylene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benz(a)anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b)&(k)fluoranthene	1	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(k)fluoranthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a) pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-c,d)pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a) pyrene TEQ		3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sum of reported PAH	--	300	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Petroleum Hydrocarbons (TPH)														
C10 - C14 Fraction	25	-	90	<50	<50	<50	<50	<50	<50	<50	<50	130	<50	<50
C15 - C28 Fraction	50	-	<100	<100	130	<100	<100	<100	<100	<100	100	<100	170	<100
C29 - C36 Fraction	100	-	<100	<100	280	<100	<100	<100	<100	<100	<100	<100	210	<100
C10 - C36 Fraction (sum)	100	-	90	<50	410	<50	<50	<50	<50	<50	100	130	380	<50

All results are in units of mg/kg.

[A] NEPC (2013) Health Investigation Level 'A' (Low density residential)

Cells with '-' indicates testing was not completed or an appropriate screening criteria was not available

PQL = Practical Quantitation Limit.

Results shown in shading are in excess of the human health criteria

<LOR or <value = Less than the laboratory Limit of Reporting

* Site-specific fluoride (soluble) soil criteria for residental land use derived from 'Preliminary Screening Level Health Risk Assessment for Fluoride and Aluminium (ENVIRON 2013)'

CONCRETE BTWN 5A+42B 25/09/14	5A GREENMIX OIL HEATER ROOM WA	5A GROUNDFLOOR GREENMIX CONCRE	6A ANODE COOLING WALL CONCRETE	6A VIBRATOR AREA CONCRETE	7A CONCRETE	7A CONCRETE (EAST)	7B/C ANADE HANDLING CONCRETE	8B OUTSIDE BUTT TUNNEL	8B RODDING CONCRETE	8B RODDING BUTT BREAKER CONCRE	8C CANDOE SHOT BLASTER CONCRET
	5A	5A	6A	6A	7A	7A	7B	8B	8B	8B	8C
25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14	25-Sep-14
<5	<5	<5	6	<5	<5	<5	<5	<5	<5	<5	7
<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
19	<2	18	18	22	14	17	12	16	18	20	20
14	<5	8	10	9	10	13	16	8	8	9	<5
8	<5	5	25	7	<5	16	13	<5	5	7	6
21	<2	14	13	17	12	9	8	12	14	17	8
79	36	46	74	96	61	103	100	92	148	101	107
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.5	<0.5	1.5	1.4	1.6	1.5	32.8	0.8	1.3	<0.5	<0.5	6.8
750	390	880	620	1190	80	330	200	1690	440	920	340
<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
4.7	<0.5	3.9	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
4.4	<0.5	85.5	1.2	14.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
0.5	<0.5	3.6	<0.5	1.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
8.8	0.6	129	4.8	55.2	0.7	1.5	<0.5	0.6	<0.5	0.7	<0.5
6.6	<0.5	92.7	3.2	44.8	<0.5	1	<0.5	0.6	<0.5	<0.5	<0.5
1.2	<0.5	29.7	2.2	21.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
1.4	<0.5	23.1	2.9	34	<0.5	2.1	<0.5	<0.5	<0.5	<0.5	<0.5
1.1	<0.5	15.4	3.9	24.7	<0.5	1.6	<0.5	0.7	<0.5	<0.5	<0.5
0.7	<0.5	8.5	1.9	12.1	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	<0.5
0.5	<0.5	4.8	2.7	10.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.5	<0.5	2.7	1.4	4.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.5	<0.5	0.6	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
<0.5	<0.5	2.3	1.5	4.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
0.8	<0.5	11.3	3.7	18.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
31.6	0.6	402	25.7	230	0.7	7	<0.5	1.9	<0.5	0.7	<0.5
<50	<50	160	<50	<50	<50	<50	<50	<50	<50	<50	<50
220	<100	2360	390	8680	260	<100	<100	240	220	3360	<100
720	140	1660	110	7250	360	<100	<100	220	<100	3820	<100
940	140	4180	500	15900	620	<50	<50	460	220	7180	<50

Table A3 Surface Soil Data (mg/kg)

Sample Identification	PQL		MW12	MW12	MW13	SB103	SB103	SB104	SB104	SB105	SB105	MW103	MW103	MW104
Sample Depth (m)		HIL A[A]	0-0.2	0.4-0.6	0.2-0.4	0-0.1	0.3-0.4	0-0.1	0.3-0.4	0-0.1	0.3-0.4	0-0.1	0.3-0.4	0-0.1
Date			17-Apr-12	17-Apr-12	17-Apr-12	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14
Sample Profile			FILL	FILL	FILL	FILL	ESTUARINE	FILL	FILL	FILL	FILL	FILL	FILL	FILL
PAEC Sampled			AWP	AWP	AWP	AWP	AWP	AWP	AWP	AWP	AWP	AWP	AWP	AWP
Sample collected by			KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
Metals														
Aluminium	50	NL*	55800	3260	36700	-	-	-	-	-	-	-	-	-
Arsenic	1	100	10.1	1	10.5	-	-	-	-	-	-	-	-	-
Cadmium	0.1	20	1.4	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Chromium	1	100	46.8	4.4	10.9	-	-	-	-	-	-	-	-	-
Copper	2	6000	41.1	0.3	6.7	-	-	-	-	-	-	-	-	-
Nickel	1	400	103	3.4	79.9	-	-	-	-	-	-	-	-	-
Lead	2	300	34.1	2.6	7.5	-	-	-	-	-	-	-	-	-
Zinc	5	7400	304	1	21.3	-	-	-	-	-	-	-	-	-
Mercury (inorganic)	0.1	40	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-
Fluoride (soluble)	40	440*	-	-	-	890	24	1077	270	970	110	410	430	64
Fluoride (total)	40	-	47100	1010	17700	-	-	-	-	-	-	-	-	-
Non Metallic Inorganics														
Total Cyanide (free)	1	250	<1	1	<1	-	-	-	-	-	-	-	-	-
Polycyclic Aromatic Hydrocarbons (PAH)														
Naphthalene	0.5	-	<0.5	<0.5	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthylene	0.5	-	<0.5	<0.5	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Acenaphthene	0.5	-	1.4	<0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Fluorene	0.5	-	0.9	<0.5	<0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Phenanthrene	0.5	-	15.2	<0.5	5	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Anthracene	0.5	-	4.1	<0.5	1.1	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Fluoranthene	0.5	-	56.5	<0.5	20.4	13	13	13	13	13	13	13	13	13
Pyrene	0.5	-	52.2	<0.5	20.5	12	12	12	12	12	12	12	12	12
Benz(a)anthracene	0.5	-	52.6	<0.5	17.3	11	11	11	11	11	11	11	11	11
Chrysene	0.5	-	74.3	<0.5	17	11	11	11	11	11	11	11	11	11
Benzo(b)&(k)fluoranthene	1	-	88.6	<0.5	26.6	25	25	25	25	25	25	25	25	25
Benzo(k)fluoranthene	0.5	-	31.2	<0.5	11.8	-	-	-	-	-	-	-	-	-
Benzo(a) pyrene	0.5	-	29.4	<0.5	16.1	15	<0.05	18	21	37	12	28	160	24
Indeno(1,2,3-c,d)pyrene	0.5	-	20.7	<0.5	11.4	14	<0.1	16	18	32	8.2	27	120	18
Dibenz(a,h)anthracene	0.5	-	7.2	<0.5	2.5	1.4	<0.1	2	1.7	5.2	0.9	4.1	22	2.7
Benzo(g,h,i)perylene	0.5	-	24	<0.5	14.5	12	<0.1	13	16	27	6.6	21	100	15
Benzo(a) pyrene TEQ		3	56.9	<0.5	25.6	21	<0.5	26	30	55	16	42	250	34
Sum of reported PAH	--	300	458	<0.5	165	120	NIL (+)VE	140	180	300	85	210	1400	150

All results are in units of mg/kg.

[A] NEPC (2013) Health Investigation Level 'A' (Low density residential)

Cells with '-' indicates testing was not completed or an appropriate screening criteria was not available

PQL = Practical Quantitation Limit.

Results shown in shading are in excess of the human health criteria

<LOR or <value = Less than the laboratory Limit of Reporting

* Site-specific fluoride (soluble) soil residential landuse criteria derived from 'Preliminary Screening Level Health Risk Assessment for Fluoride and Aluminium (ENVIRON 2013)'

MW104	SB17	SB18	MW19	MW19	SB111	SB111	SB112	SB112	SB112	SB113	SB113	SB114	SB114	SB11	SB12
0.3-0.4	0.3-0.4	0.5-0.6	FILL 1	FILL 2	0.0-0.1	0.4-0.5	0.0-0.1	0.4-0.5	0.8-0.9	0.0-0.1	0.4-0.5	0.0-0.1	0.4-0.5	0.2-0.4	1.8-1.9
30-Jun-14	18-Apr-12	18-Apr-12	19-Apr-12	19-Apr-12	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	17-Apr-12	18-Apr-12
FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL
AWP	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	DSA	Carbon Plant	Carbon Plant
KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
-	-	-	-	-	-	-	-	-	-	-	-	-	-	9550	10300
-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.9	16.5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.3	7.9
-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.6	14.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	12.4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.3	6.5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	51.6	53.4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	240	150
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	<1
<0.1	<0.5	<0.5	<4.0	<0.5	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5
<0.1	<0.5	<0.5	<4.0	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5
0.6	<0.5	3.8	8.4	1.6	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5
0.3	<0.5	2.2	4.2	0.8	<0.1	<0.1	<0.1	0.9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5
3.8	<0.5	30.2	46.7	7.8	<0.1	0.4	<0.1	8.1	<0.1	0.2	<0.1	0.1	<0.1	<0.5	<0.5
0.7	<0.5	6.3	9.6	1.6	<0.1	<0.1	<0.1	1.7	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5
13	<0.5	59.7	137	21.6	0.4	1.5	<0.1	30	<0.1	0.4	0.1	1	0.2	<0.5	<0.5
12	<0.5	59.1	133	21.7	0.5	1.6	<0.1	32	<0.1	0.4	0.1	1	0.2	<0.5	<0.5
11	<0.5	46.7	103	24.3	0.3	1.2	<0.1	29	<0.1	0.3	<0.1	1.4	0.2	<0.5	<0.5
11	<0.5	45.6	97.3	23.5	1	1.1	<0.1	29	<0.1	0.6	0.1	2.7	0.2	<0.5	<0.5
25	<0.5	60.3	140	31	0.9	2.3	<0.2	64	<0.2	0.9	0.2	4.1	0.5	<0.5	<0.5
-	<0.5	21.2	47.7	10	-	-	-	-	-	-	-	-	-	<0.5	<0.5
0.21	<0.5	43.4	101	19.2	0.48	1.5	0.06	38	<0.05	0.42	0.12	0.96	0.16	<0.5	<0.5
0.2	<0.5	41.6	57.5	17.5	0.3	1.1	<0.1	28	<0.1	0.3	<0.1	0.6	0.1	<0.5	<0.5
<0.1	<0.5	8.8	12.8	4.6	<0.1	0.1	<0.1	3.8	<0.1	<0.1	<0.1	0.1	<0.1	<0.5	<0.5
0.2	<0.5	46.1	65	19.9	0.4	1	<0.1	23	<0.1	0.3	<0.1	0.8	0.1	<0.5	<0.5
<0.5	<0.5	70.1	150.2	31.6	1	2	<0.5	55	<0.5	1	<0.5	2	<0.5	<0.5	<0.5
1.7	<0.5	475	963	205	4.3	12	0.06	290	NIL (+)VE	3.7	0.66	13	1.7	<0.5	<0.5

SB13	MW14	MW15	MW16	MW16	MW17	MW17	MW18	MW18	SB108	SB109	SB110	MW105	MW105	MW106	MW107
1.0-1.2	0-0.4	0.1-0.4	0.2-0.4	1.8-2.0	0.2-0.4	0.8-1.0	0-0.2	0.8-1.0	0-0.1	0-0.1	0-0.1	0.15-0.25	0.3-0.4	0.0-0.1	0.15-0.25
18-Apr-12	19-Apr-12	19-Apr-12	18-Apr-12	18-Apr-12	18-Apr-12	18-Apr-12	19-Apr-12	19-Apr-12	30-Jun-14	01-Jul-14	01-Jul-14	30-Jun-14	30-Jun-14	30-Jun-14	30-Jun-14
FILL	FILL	FILL	FILL	ESTUARINE	FILL	ESTUARINE	FILL	ESTUARINE	FILL	FILL	FILL	FILL	FILL	FILL	FILL
Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant
KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
14200	14700	13800	7740	3180	6740	1310	32700	8210	-	-	-	-	-	-	-
3.4	6.3	5.1	0.9	1.2	0.8	0.2	12	1.8	-	-	-	-	-	-	-
0.1	0.1	2.4	<0.1	<0.1	<0.1	<0.1	0.4	<0.1	-	-	-	-	-	-	-
52.1	25.5	18	5	3.2	5.3	1.4	26.9	6	-	-	-	-	-	-	-
16	15.6	44.5	7.8	0.2	4.2	0.3	21.9	0.3	-	-	-	-	-	-	-
34.4	53	27.8	6.4	1.8	2	0.6	51.6	4.6	-	-	-	-	-	-	-
25.8	9.2	44.4	3.6	1.8	37	0.6	20.6	3.3	-	-	-	-	-	-	-
178	70.4	115	18.8	0.6	43.4	0.5	288	1.4	-	-	-	-	-	-	-
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1960	2350	3950	700	60	200	80	7740	650	-	-	-	-	-	-	-
<1	<1	<1	3	<1	<1	<1	<1	<1	-	-	-	-	-	-	-
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.1	4	0.2	<0.1	<0.1
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.5	<0.5	<0.5	0.8	<0.5	<0.5	<0.5	1.9	<0.5	0.1	0.1	<0.1	7.3	0.4	<0.1	<0.1
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1.1	<0.5	<0.1	<0.1	<0.1	2.7	0.2	<0.1	<0.1
<0.5	<0.5	0.8	<0.5	<0.5	<0.5	<0.5	16.6	<0.5	1.3	0.7	<0.1	3.4	0.2	0.1	<0.1
<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	3.4	<0.5	0.3	0.3	<0.1	0.9	<0.1	<0.1	<0.1
<0.5	0.7	3.8	<0.5	<0.5	<0.5	<0.5	41.2	<0.5	6	2.2	<0.1	5.9	0.1	0.6	<0.1
<0.5	0.7	3	<0.5	<0.5	<0.5	<0.5	38.3	<0.5	6	2	<0.1	4.6	0.1	0.6	<0.1
<0.5	0.7	5.3	<0.5	<0.5	<0.5	<0.5	47.1	<0.5	3.4	0.8	<0.1	0.8	<0.1	0.7	<0.1
<0.5	0.8	8.1	<0.5	<0.5	<0.5	<0.5	50.3	<0.5	3.8	0.8	0.1	0.9	<0.1	0.9	<0.1
<0.5	1.1	9.6	<0.5	<0.5	<0.5	<0.5	67.2	<0.5	10	1.5	<0.2	1.3	<0.2	2.4	<0.2
<0.5	<0.5	2.1	<0.5	<0.5	<0.5	<0.5	20.4	<0.5	-	-	-	-	-	-	-
<0.5	0.6	2.1	<0.5	<0.5	<0.5	<0.5	33.6	<0.5	4.9	0.88	<0.05	0.44	<0.05	0.72	<0.05
<0.5	0.6	1.5	<0.5	<0.5	<0.5	<0.5	29.2	<0.5	4.7	0.6	<0.1	0.4	<0.1	0.7	<0.1
<0.5	<0.5	0.5	<0.5	<0.5	<0.5	<0.5	7.7	<0.5	0.5	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
<0.5	0.6	1.8	<0.5	<0.5	<0.5	<0.5	28.8	<0.5	4.1	0.6	<0.1	0.3	<0.1	0.7	<0.1
<0.5	1.87	4.5	<0.5	<0.5	<0.5	<0.5	58.5	<0.5	7	1	<0.5	1	<0.5	1	<0.5
<0.5	5.8	38.6	0.8	<0.5	<0.5	<0.5	387	<0.5	46	10	0.1	33	1.2	7.6	NIL (+)VE

HA106	HA106	HA107	HA107	HA108	HA109	HA109	HA110	HA110	HA111	HA111	HA112	SB9	SB9	MW11	SB101
0.1	0.15	0.1	0.2	0-0.1	0-0.1	0.3-0.4	0-0.1	0.3-0.4	0-0.1	0.3-0.4	0.1	0.3-0.4	0.6-0.8	0-0.2	0.0-0.1
25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	16-Apr-12	16-Apr-12	16-Apr-12	30-Jun-14
FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL
Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Washbay	Washbay	Washbay	Washbay
KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
-	-	-	-	-	-	-	-	-	-	-	-	39800	12600	15000	-
-	-	-	-	-	-	-	-	-	-	-	-	17.1	23.9	5.8	-
-	-	-	-	-	-	-	-	-	-	-	-	11.1	0.2	0.2	-
-	-	-	-	-	-	-	-	-	-	-	-	59.5	18.8	23.7	-
-	-	-	-	-	-	-	-	-	-	-	-	82	62	36.3	-
-	-	-	-	-	-	-	-	-	-	-	-	152	29.4	24.5	-
-	-	-	-	-	-	-	-	-	-	-	-	185	66.4	48	-
-	-	-	-	-	-	-	-	-	-	-	-	578	621	420	-
-	-	-	-	-	-	-	-	-	-	-	-	0.2	<0.1	<0.1	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	94
-	-	-	-	-	-	-	-	-	-	-	-	39000	1230	960	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1	-
<0.1	<0.1	1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-
<0.1	<0.1	0.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	-
0.6	0.7	4.3	8.3	0.4	0.4	0.2	1.5	0.1	1.2	1.1	0.2	-	-	-	-
0.3	0.3	2.6	3.6	0.2	0.2	<0.1	1	<0.1	0.8	0.4	0.1	-	-	-	-
5.5	6.3	24	68	3.5	3.4	1.5	15	1.8	12	12	2.4	-	-	-	-
1.2	1.3	5.7	11	0.8	0.9	0.4	3.8	0.5	3.1	3.7	0.6	-	-	-	-
19	20	76	220	12	11	4.5	43	7.8	37	46	9.3	-	-	-	-
19	19	72	220	12	10	4.5	40	7.8	35	46	9	-	-	-	-
18	14	70	150	9	10	2.6	40	5.5	36	34	9.3	-	-	-	-
19	13	70	130	9.3	10	2.5	41	5.5	37	34	9.8	-	-	-	-
46	30	170	290	22	25	5.6	96	13	86	76	25	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	18	98	180	13	14	3.7	55	8.1	50	47	14	-	-	-	-
19	15	63	150	9.1	10	2.4	41	5.8	38	36	10	-	-	-	-
2.7	2	15	16	0.9	1.7	0.3	9.4	0.7	8.4	4.4	1.4	-	-	-	-
18	14	59	130	8.9	9.7	2.3	37	5.5	33	32	9.2	-	-	-	-
36	26	140	260	18	21	5	82	11	75	67	20	-	-	-	-
190	150	730	1600	100	110	30	420	63	380	370	100	-	-	-	-

SB101	SB1	SB2	SB3	SB4	SB115	SB116	SB116	SB117	SB117	SB118	SB118	SB119	SB119	SB120	SB121	SB121
0.3-0.4	0-0.05	0-0.05	0-0.05	0-0.05	0.0-0.1	0.0-0.1	0.1-0.2	0.0-0.1	0.1-0.2	0.0-0.1	0.2-0.3	0.0-0.1	0.3-0.4	0.0-0.1	0.0-0.1	0.1-0.2
30-Jun-14	12/04/2012	12/04/2012	12/04/2012	12/04/2012	01-Jul-14	01-Jul-14	01-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14
FILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL
Washbay	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers
KJG	FR	FR	FR	FR	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG
-	53300	139000	138000	41700	-	-	-	-	-	-	-	-	-	-	-	-
-	4.5	28.9	8.8	14.6	-	-	-	-	-	-	-	-	-	-	-	-
-	0.7	1.8	1.4	0.8	-	-	-	-	-	-	-	-	-	-	-	-
-	26.8	35	14.8	36	-	-	-	-	-	-	-	-	-	-	-	-
-	21.1	280	18.9	89.8	-	-	-	-	-	-	-	-	-	-	-	-
-	98	159	166	65.7	-	-	-	-	-	-	-	-	-	-	-	-
-	25	430	28.7	247	-	-	-	-	-	-	-	-	-	-	-	-
-	229	5400	444	1210	-	-	-	-	-	-	-	-	-	-	-	-
-	<0.1	<0.1	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
73	-	-	-	-	73	140	48	13	24	17	29	55	36	3.1	20	7.8
-	13400	26400	41900	20900	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SB122	SB123	SB123	SB124	SB125	SB126	SB127	SB127	SB127	SB128	SB129	SB129	SB129	SB131	SB131	SB132	SB133	SB133
0.0-0.1	0.0-0.1	0.1-0.2	0.0-0.1	0.0-0.1	0.0-0.1	0.0-0.1	0.1-0.2	0.4-0.6	0.0-0.1	0.0-0.1	0.1-0.2	0.9-1.0	0.0-0.1	0.3-0.4	0.0-0.1	0.2-0.3	0.3-0.4
01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	01-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14	02-Jul-14
FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	ALLUVIAL	FILL	FILL	FILL	FILL	FILL	ALLUVIAL	FILL	ALLUVIAL	ALLUVIAL
Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Dry Scrubbers
KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG	KG
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	87	140	87	210	250	7.5	14	0.6	23	23	16	2.7	10	52	2.3	5	27
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-																
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

SB134	SB135	SB135	HA101	HA101	HA101	HA102	HA102	HA102	HA103	HA103	HA104	HA104	HA105	HA105	HA105	HA113	HA113
0-0.1	0-0.1	0.3-0.4	Surface	0.1	0.2	Surface	0.1	0.15	Surface	0.1	Surface	0.1	Surface	0.1	0.2	0-0.1	0.3-0.4
02-Jul-14	02-Jul-14	02-Jul-14	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	26/06/2014	27-Jun-14	27-Jun-14
FILL	FILL	FILL														FIILL	FIILL
Dry Scrubbers	Dry Scrubbers	Dry Scrubbers	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	Pot Lines	27/06/2014	27/06/2014
KG	KG	KG	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.3	22	36	28	180	62	53	78	120	140	180	90	82	100	120	67	40	130
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7	0.9
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	0.3
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	3.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	3.1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.5	1.5
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	1.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	3.6
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.6	1.9
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.4	1.3
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	0.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	1.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	3
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	110	19

HA114	HA115	HA115	HA116	HA116	HA117	HA117	HA119	HA119	HA120	HA121	HA122	HA122	SB106	TP101	TP104	TP107
0-0.1	0-0.1	0.2-0.3	0-0.1	0.3-0.4	0-0.1	0.25-0.35	0-0.1	0.3-0.4	0-0.1	0-0.1	0-0.1	0.3-0.4	0.0-0.1	0.2	0-0.2	0.5
27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	27-Jun-14	30-Jun-14	23-Jun-14	23-Jun-14	23-Jun-14
FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	FIILL	Estuarine	Estuarine	Estuarine
27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	27/06/2014	30/06/2014	Playing Fields	Playing Fields	Playing Fields
KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KG	KW	KW	KW
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<4	<4	<4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.4	<0.4	<0.4
-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	12	<1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	<1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	5	1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10	1
-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	36	3
-	-	-	-	-	-	-	-	-	-	-	-	-	-	<0.1	<0.1	<0.1
29	7.9	-	28	-	13	-	76	130	13	17	39	68	38	45	16	19
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.9	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.4	16	2.2	4.2	0.2	4	<0.1	5.6	1.5	1.4	0.1	0.4	0.7	<0.1	<0.1	<0.1	<0.1
<0.1	3.5	0.6	0.8	<0.1	1.3	<0.1	1	0.4	0.4	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
3.1	210	40	41	3.4	38	0.3	17	5.8	12	1.2	2.4	2.6	0.2	0.1	0.2	<0.1
3	240	50	41	3.4	38	0.3	16	5.6	11	1.2	2.3	2.5	0.3	0.1	0.2	<0.1
4.4	300	61	57	3.1	52	0.2	16	3.2	14	1.5	2.4	1.4	0.3	<0.1	<0.1	<0.1
8.1	490	110	110	5.8	110	0.3	21	3.3	26	2.8	4.2	1.7	0.3	<0.1	<0.1	<0.1
18	990	230	240	12	300	0.8	53	7.4	69	7.4	8.8	3.8	0.7	<0.2	0.2	<0.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.7	230	44	42	1.7	47	0.26	19	4.3	12	1.4	2.2	1.7	0.3	0.07	0.12	<0.05
3.1	190	44	48	2.9	76	0.3	17	3.1	20	2.2	2.1	1.2	0.3	<0.1	<0.1	<0.1
0.8	60	15	12	0.7	25	<0.1	3	0.3	4.9	0.5	0.4	0.2	<0.1	<0.1	<0.1	<0.1
3.3	190	42	53	2.9	81	0.3	16	2.9	21	2.4	2.1	1.3	0.3	<0.1	<0.1	<0.1
7	440	94	90	4	120	<0.5	31	6	28	3	4	3	<0.5	<0.5	<0.5	<0.5
47	2900	640	640	37	770	2.8	190	38	190	21	27	17	2.7	0.35	0.69	NIL (+)VE

TP111	TP113	TP115	TP116	TP117	TP118	TP119	TP120	TP122	TP123	TP124	TP125	TP126	TP127	TP128	TP128
0-0.3	0.4-0.5	0.4-0.5	0.1-0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.2
23-Jun-14	23-Jun-14	23-Jun-14	23-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14
Fiill	Estuarine	Estuarine	Fill	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL
Playing Fields	Playing Fields	Playing Fields	Playing Fields	EPF	EPF	EPF	EPF	EPF	EPF	EPF	EPF	EPF	EPF	SAPL3	SAPL3
KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<4	<4	<4	63	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	30	6
<0.4	<0.4	<0.4	0.5	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
23	17	11	12	11	5	3	3	5	7	7	7	5	6	17	8
2	<1	<1	590	17	4	3	2	1	2	3	2	5	3	94	12
6	3	1	5	18	6	4	4	3	7	5	6	4	4	18	14
12	24	4	1600	23	7	8	18	6	9	7	8	6	6	120	8
35	5	2	5600	51	41	20	22	14	26	12	57	23	13	510	48
<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
22	<0.5	2.1	31	340	22	28	17	26	23	17	27	15	19	220	800
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<0.1	<0.1	<0.1	<0.1	1.6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	7.6	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	2.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	130	0.2	0.1	<0.1	0.1	0.2	<0.1	0.1	0.1	0.2	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	33	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	390	0.5	0.5	0.2	0.5	0.7	0.1	0.4	0.4	0.6	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	380	0.4	0.5	0.2	0.5	0.7	<0.1	0.4	0.4	0.5	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	180	0.2	0.4	0.1	0.3	0.4	<0.1	0.3	0.2	0.2	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	170	0.2	0.4	0.1	0.4	0.4	<0.1	0.3	0.2	0.2	<0.1	<0.1
<0.2	<0.2	<0.2	<0.2	320	0.4	1.2	0.2	0.8	1	<0.2	0.8	0.4	0.3	<0.2	<0.2
-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	<0.05
<0.05	<0.05	<0.05	<0.05	220	0.23	0.58	0.13	0.47	0.56	0.06	0.41	0.21	0.17	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	120	0.2	0.5	0.1	0.4	0.5	<0.1	0.4	0.2	0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	26	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<0.1	<0.1	<0.1	<0.1	120	0.2	0.4	0.1	0.4	0.4	<0.1	0.3	0.1	0.1	<0.5	<0.5
<0.5	<0.5	<0.5	<0.5	310	<0.5	1	<0.5	1	1	<0.5	1	<0.5	<0.5	0.08	NIL (+)VE
NIL (+)VE	NIL (+)VE	NIL (+)VE	NIL (+)VE	2100	2.5	4.8	1	4	4.8	0.18	3.5	2.3	2.2	-	-

TP129	TP130	TP130	TP131	TP132	TP132	TP133	TP134	TP135	TP135	TP136	TP137	TP137	TP138	TP139	TP140
0-0.3	0-0.3	0.6-0.7	0.1-0.3	0.1	0.4	0.1-0.2	0.2	0.1	0.4	0.1	0.1	0.4	0.2	0.1	0.1
25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14	25-Jun-14
FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL	FILL
SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3	SAPL3
KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW	KW
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	<4	<4	7	20	<4	8	7	9	6	6	<4	5	<4	4	<4
<0.4	<0.4	<0.4	4.3	<0.4	<0.4	<0.4	0.4	0.6	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
15	9	29	29	33	15	11	10	19	13	6	20	18	7	17	7
8	12	1	48	44	2	22	28	140	12	10	24	<1	<1	26	1
47	54	8	130	27	3	16	21	17	6	10	12	4	3	15	5
9	11	8	23	13	10	21	47	38	16	7	29	17	8	33	13
47	86	15	240	130	8	140	220	210	47	42	76	22	41	280	7
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
200	1463	120	87	58	0.9	1.1	110	110	4.6	13	2.2	7	5.5	79	50
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	<0.1
0.4	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.3	<0.1
0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1
1	1	<0.1	0.2	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	3.8	<0.1
0.9	1	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	3.4	<0.1
0.5	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.4	<0.1
0.5	0.6	<0.1	0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.7	<0.1
1.1	1	<0.2	0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.6	<0.2
0.64	0.56	<0.05	0.11	0.06	<0.05	0.11	<0.05	0.05	<0.05	<0.05	0.08	<0.05	<0.05	2.9	<0.05
0.5	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	2.1	<0.1
<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1
0.5	0.4	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	1.9	<0.1
1	1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4	<0.5
6.2	5.7	NIL (+)VE	0.76	0.06	0.13	0.84	NIL (+)VE	0.05	NIL (+)VE	NIL (+)VE	0.18	NIL (+)VE	NIL (+)VE	29	NIL (+)VE
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table A4 Settled Dust Analytical Concentrations (mg/kg) - Workshops

Sample Identification	PQL		56C/U/28/F	64C Mobile Floor	26A Mezzanine	83A/7 FW	83A/2 FW SLAB	83A/1 FE	83A/10 WE	83A/8WW	83A/5 FE	83A/8 FE	67C/FS	83A/1 FW	PAINT STORE EX F	PAINT STORE INT F	83A/3 WE	WASHBAY SLUDGE
Building Number		HIL A[A]	56C	64C	26A	83A	83A	83A	83A	83A	83A	83A	67C	83A	near 19A	near 19A	83A	Washbay
Date			18-Jun-14	18-Jun-14	18-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	12-Jun-14	13-Jun-14	13-Jun-14
Sample Profile			Floor dust on mezzanine	Sample of concrete from floor	Dust from wall on mezzanine level	Dust sample from western end floor, Shed 7	Dust sample from western end floor, Shed 2	Dust sample from eastern end floor, Shed 1	Dust sample from eastern end wall, Shed 10	Dust sample from western end wall, Shed 8	Dust sample from eastern end floor, Shed 5	Dust sample from eastern end floor, Shed 8	Residue on floor around the edge of the building (internal)	Dust sample from western end floor, Shed 1	Residue on floor outside Paint Store	Residue on floor inside Paint Store	Dust sample from eastern end wall Shed 3	Sludge in wash bay
Location			NE corner	N end	S end													
Sample collected by			KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
Metals																		
Arsenic	1	100	8	8	<5	32	8	7	32	21	19	20	8	69	383	9	31	11
Cadmium	0.1	20	7	<1	<1	3	<1	<1	2	1	2	1	<1	3	8	4	<1	<1
Chromium	1	100	19	15	35	4	19	157	44	22	89	56	37	148	1300	60	72	43
Copper	2	6000	126	17	40	10	15	61	30	13	112	47	28	2650	1540	147	81	58
Nickel	1	400	36	11	9	23	11	48	30	32	34	40	48	159	5680	245	19	27
Lead	2	300	323	17	22	296	89	78	413	270	184	163	97	74	57	90	466	144
Zinc	5	7400	1350	84	145	101	40	675	292	510	596	302	371	4610	37500	1360	1540	162
Mercury (inorganic)	0.1	40	<0.1	0.2	<0.1	0.1	<0.1	0.1	0.1	<0.1	0.1	0.2	0.1	0.3	0.5	0.1	0.3	0.3
Hexavalent Chromium		100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	620	8.1	<0.5	<0.5
Fluoride (total)	40	-	35600	1230	1360	146000	84900	48500	65800	49200	51600	64900	56300	19100	7860	26800	71300	40400
Non Metallic Inorganics																		
Total Cyanide (free)	1	250	<1	<1	<1	1	13	94	34	20	67	173	11	62	<1	1	22	4
Polycyclic Aromatic Hydrocarbons (PAH)																		
Naphthalene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	6.4	<0.5	<0.5	<0.5	<2.0	<0.5	<0.5
Acenaphthylene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<2.0	<0.5	<0.5	<0.5	<2.0	<0.5	<0.5
Acenaphthene	0.5	-	<0.5	<0.5	<0.5	<0.5	2.9	0.6	1.1	<0.5	<0.5	51.4	<0.5	2.4	<0.5	<2.0	1.1	3.8
Fluorene	0.5	-	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	20.4	<0.5	1.9	<0.5	<2.0	0.5	1.2
Phenanthrene	0.5	-	2.1	2.5	0.7	<0.5	11.7	2.4	7.3	0.9	4.2	88.5	2.2	6	1.6	47.2	4.9	11.2
Anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	2.4	0.6	0.8	<0.5	0.5	9.7	<0.5	1.5	<0.5	<2.0	0.5	1.3
Fluoranthene	0.5	-	5.3	1.5	0.5	<0.5	27.1	10.2	12.5	2.2	10.2	87.4	2.4	12.6	5.7	14.4	5	11.8
Pyrene	0.5	-	4.5	2.4	<0.5	<0.5	24.3	9.3	8.2	1.4	7	68.2	1.5	11.2	4.2	15.3	3.8	9
Benz(a)anthracene	0.5	-	4.4	<0.5	<0.5	<0.5	21.9	11.8	6.5	1.1	6.5	61.2	0.6	10.4	1.8	2.9	2.8	3.6
Chrysene	0.5	-	4.9	1	<0.5	<0.5	19.9	19.9	11	2	13.9	90.5	1	14.2	8.1	8.7	3.4	3.3
Benzo(b)&(k)fluoranthene	1	-	8.7	0.7	<0.5	<0.5	39.4	37.6	15.4	2.8	22.9	149	0.9	26.5	9.6	11.1	4.8	5.8
Benzo(k)fluoranthene	0.5	-	2.7	<0.5	<0.5	<0.5	13.2	9.5	5.4	0.8	5.9	39	<0.5	8	3.2	4.2	1.4	1.6
Benzo(a) pyrene	0.5	-	5.3	<0.5	<0.5	<0.5	27.1	13	6.9	0.8	5.7	61	<0.5	11.4	1.4	<2.0	2.3	3.8
Indeno(1,2,3-c,d)pyrene	0.5	-	3.3	<0.5	<0.5	<0.5	13.7	8.4	4	0.6	4.1	38.1	<0.5	6.7	2.9	2.4	0.9	2.1
Dibenz(a,h)anthracene	0.5	-	0.8	<0.5	<0.5	<0.5	3.8	2.9	1.2	<0.5	1.4	13.2	<0.5	2.2	0.7	<2.0	<0.5	0.5
Benzo(g,h,i)perylene	0.5	-	4.1	<0.5	<0.5	<0.5	18	11.8	5.5	0.9	5.7	50.3	<0.5	9.2	3.7	3.2	1.1	3.1
Benzo(a) pyrene TEQ		3	8.1	<0.5	<0.5	<0.5	40.1	22.9	11.4	1.4	11.2	104	<0.5	19	4	2.2	3.3	5.7
Sum of reported PAH	--	300	46.1	8.1	1.2	<0.5	226	138	85.8	13.5	88	834	8.6	124	42.9	109	32.5	62.1
Total Petroleum Hydrocarbons (TPH)																		
C10 - C14 Fraction	25	-	<50	100	80	<50	<50	<50	<50	<50	<50	160	<50	<50	5700	650	<50	<50
C15 - C28 Fraction	50	-	600	6080	170	<100	390	250	290	<100	220	1970	<100	330	3430	49500	180	330
C29 - C36 Fraction	100	-	310	5820	<100	<100	300	160	200	<100	120	900	<100	220	4930	1880	120	290
C10 - C36 Fraction (sum)	100	-	910	12000	250	<50	690	410	490	<50	340	3030	<50	550	14100	52000	300	620

All results are in units of mg/kg.

Table A5 Settled Dust Analytical Concentrations (mg/kg) - Cast House

Sample Identification	PQL		4A UM S OF FURNACE 3	4A M E OF FURNACE 6	4A OPEN N OF SWITCH RM	4A M W OF FURNACE 4	4A M E OF FURNACE 3	4A M N OF FURNACE 3	4B UM UNDER FURNACE 6	4B OPEN S OF HOMO 3	4B M SW OF FURNACE 3	4B M FURNACE 7 EXHAUST	4B M EXHAUST DUCT DC2/DC3	4C OPEN SOUTH OF SAW OLIVER
Building Number		HIL A[A]												
Date			11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14	11-Aug-14
Sample Profile			Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	Dust on concrete	RESIDUE	RESIDUE	Dust on concrete
Location			4A	4A	4A	4A	4A	4A	4B	4B	4B	4B	4B	4C
Sample collected by			NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW	NW
Metals														
Arsenic	1	100	<5	6	6	<5	13	<5	7	8	7	20	10	<5
Cadmium	0.1	20	<1	<1	<1	<1	1	<1	<1	<1	<1	51	<1	<1
Chromium	1	100	48	42	29	21	213	26	44	37	128	54	53	57
Copper	2	6000	16	10	6	26	7	6	9	17	9	95	64	9
Nickel	1	400	10	9	8	5	9	6	10	10	5	18	137	<5
Lead	2	300	31	13	11	40	98	13	13	18	62	34	37	14
Zinc	5	7400	538	142	524	53	29	50	90	92	94	132	522	45
Mercury (inorganic)	0.1	40	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
Hexavalent Chromium		100	0.6	6.6	<0.5	0.9	7.8	0.9	<0.5	2	3.8	<0.5	2.2	1.8
Fluoride (total)	40	-	2720	1000	420	740	140	270	500	840	760	75100	390	230
Non Metallic Inorganics														
Total Cyanide (free)	1	250	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	<1
Polycyclic Aromatic Hydrocarbons (PAH)														
Naphthalene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthylene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Acenaphthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluorene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Phenanthrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Fluoranthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benz(a)anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chrysene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(b)&(k)fluoranthene	1	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5
Benzo(k)fluoranthene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a) pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Indeno(1,2,3-c,d)pyrene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dibenz(a,h)anthracene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(g,h,i)perylene	0.5	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a) pyrene TEQ		3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Sum of reported PAH	--	300	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5
Total Petroleum Hydrocarbons (TPH)														
C10 - C14 Fraction	25	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	50	-	190	4540	1860	1550	<100	3300	<100	140	3460	<100	450	3960
C29 - C36 Fraction	100	-	110	5640	2380	1830	<100	3710	<100	180	5270	<100	570	3310
C10 - C36 Fraction (sum)	100	-	300	10200	4240	3380	<50	7010	<50	320	8730	<50	1020	7270

All results are in units of mg/kg.

[A] NEPC (2013) Health Investigation Level 'A' (Low density residential)

Cells with '-' indicates testing was not completed or an appropriate screening criteria was not available

PQL = Practical Quantitation Limit.

Results shown in shading are in excess of the human health criteria

<LOR or <value = Less than the laboratory Limit of Reporting

Table A6 Settled Dust Analytical Concentrations (mg/kg) - Carbon Plant

Sample Identification	PQL		5A L6 Lift Room Floor	5A L5 Screen FD101 Dust	5A L4 East Wall Dust	5A L2 Floor Dust	5A L2 HTM Tank Dust FE602	5A L2 Pitch Weigh Tank FE901W	5A L1 GD601E mixer	5A HTM Gas Boiler Floor	5A External Stack HTM	6A Reject Anode Collector	6A Eriez Feeder	pitch conduit	7A Exhaust Ramp Dust	7A Refractory Mud Cap	7A Refractory Brick	7B Anode Handling Conveyor	8A Short Trench Adj Butt Breaker	8A Stub Dipping North	8B Cast Iron Ladle Heater	8B Cast Iron Ladle Pouring	8B Cast Iron Yellow Drip Tray	9A Dust Collector Ground	60C Ring Furnace Scrubber	60C Redunant Ring Furnace
Building Number		HIL A[A]	5A L6	5A L5	5A L4	5A L2	5A L2	5A L2	5A L1	5A	5A	6A	6A	pitch conduit	7A	7A	7A	7B	8A	8A	8B	8B	8B	9A	60C	60C
Date			16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	16-Sep-14	17-Sep-14	17-Sep-14
Sample Profile			Dust from the floor of the lift room	Dust caught in the screen on FD101	Dust collected on wall	Dust collected on floor	Dust collected on top of tank	Residue collected on Pitch Weigh Tank	Residue collected on mixer	Residue on Bgas oiler Room floor	Residue collected from base of stack	Residue collected beneath anode collector	Residue attached to Eriez Feeder	Pitch residue	Dust collected on Exhaust Ramp		Chipped piece of refractory brick	Residue beneath Anode Handling Conveyor	Residue collected in floor trench	residue at the dipping stub	residue at the ladle heater	Residue from ladle pouring	Residue in yellow drip tray	Dust/ residue on ground outside 9A	Recycled alumina (RFRA)	Recycled alumina (RFRA)
Location			Level 6	Level 5	Level 4	Level 2	Level 2	Level 2	Level 1	Ground Floor	External East	Internal east	Top floor of 6A		Ground		In ground	Ground	in ground	West	West	West	West	External	Inside waste bin	Inside conduit
Sample collected by			KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
Metals																										
Arsenic	1	100	6	<5	6	<5	8	<5	<5	9	64	<5	<5	<5	26	<5	<5	<5	17	6	52	8	<5	5	10	<5
Cadmium	0.1	20	2	<1	3	<1	4	<1	<1	3	3	<1	<1	<1	258	<1	1	<1	<1	1	4	<1	6	<1	241	9
Chromium	1	100	23	<2	44	<2	18	<2	2	21	87	3	4	3	509	8	8	3	61	91	295	121	10	13	162	6
Copper	2	6000	27	<5	105	<5	34	<5	<5	83	153	<5	5	12	496	14	12	<5	52	270	673	230	8	26	46	13
Nickel	1	400	16	<5	102	<5	33	<5	<5	62	67	<5	8	6	2370	37	5	<5	22	6	9	7	<5	17	2270	211
Lead	2	300	127	2	36	8	130	<2	10	89	182	4	10	6	262	38	20	16	185	76	314	116	10	15	90	15
Zinc	5	7400	1100	<5	1280	14	189	76	<5	1960	453	21	41	57	8760	93	23	28	280	97	28	59	348	837	1450	91
Mercury (inorganic)	0.1	40	<0.1	5.3	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	<0.1
Hexavalent Chromium		100	<0.5	<0.5	10.4	<0.5	<0.5	<0.5	<0.5	9.6	1.2	<0.5	<2.5	<0.5	1.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	20.4	<5.0
Fluoride (total)	40	-	17700	970	6730	160	12200	120	850	8280	1120	1020	1280	350	1100	3030	1420	140	27300	15200	2020	1470	180	2680	16000	3650
Non Metallic Inorganics																										
Total Cyanide (free)	1	250	<1	<1	<1	<1	<1	<1	<1	<1	1	<1	<1	<1	<10	<1	<1	<1	<1	<1	<1	<1	<10	<1	<10	<1
Polycyclic Aromatic Hydrocarbons (PAH)																										
Naphthalene	0.5	-	<0.5	2.3	<8.0	0.6	<8.0	<8.0	15.4	<0.5	8.5	<0.5	<80.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<8.0	9.6
Acenaphthylene	0.5	-	<0.5	<0.5	<8.0	<0.5	<8.0	<8.0	12	1	0.6	<0.5	<80.0	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<8.0	22.2
Acenaphthene	0.5	-	0.6	0.7	37.8	2.5	<8.0	140	218	<0.5	3.8	3.7	413	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	1.1	<8.0	<8.0
Fluorene	0.5	-	0.5	<0.5	18.4	<0.5	<8.0	104	65.6	<0.5	3.2	2.6	4120	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	<8.0	<8.0
Phenanthrene	0.5	-	15.3	3	727	5.1	134	1360	1260	10.3	22.2	30.3	55700	3.6	<0.5	<0.5	<0.5	<0.5	10.4	0.9	<0.5	<0.5	<0.5	11.3	69.3	1110
Anthracene	0.5	-	2.7	<0.5	187	0.6	30	452	189	4.1	7	8.7	27500	1.9	<0.5	<0.5	<0.5	<0.5	1.4	<0.5	<0.5	<0.5	<0.5	2.7	25.1	215
Fluoranthene	0.5	-	59.7	2.2	2150	6.1	762	3530	1190	32.2	91	80	48800	10.6	0.9	<0.5	<0.5	<0.5	28	<0.5	<0.5	<0.5	<0.5	31.2	620	4590
Pyrene	0.5	-	40.4	1.8	2060	4.2	658	3310	844	21.5	81.1	76.6	36300	9.5	0.7	<0.5	<0.5	<0.5	23	<0.5	<0.5	<0.5	<0.5	30.1	403	5900
Benz(a)anthracene	0.5	-	23.1	0.7	1260	0.8	398	2940	216	10.5	53	76.5	3840	6.2	0.7	<0.5	<0.5	<0.5	3.3	<0.5	<0.5	<0.5	<0.5	30.1	678	5160
Chrysene	0.5	-	34.6	0.8	1230	1.4	469	3000	239	22.2	89.2	73.4	4360	8.3	1.3	<0.5	<0.5	<0.5	4.9	<0.5	<0.5	<0.5	<0.5	29.8	1780	8700
Benzo(b)&(k)fluoranthene	1	-	44.4	0.6	1910	0.5	684	4470	182	12.8	85.8	125	1590	10.6	2.6	<0.5	<0.5	<0.5	2.6	<0.5	<0.5	<0.5	<0.5	46	1900	11700
Benzo(k)fluoranthene	0.5	-	16.2	<0.5	626	<0.5	264	1320	58.5	15.2	23.8	41.9	654	4.5	0.7	<0.5	<0.5	<0.5	2.8	<0.5	<0.5	<0.5	<0.5	17.1	886	2850
Benzo(a) pyrene	0.5	-	21.5	<0.5	1300	<0.5	408	3330	76	26.4	41.7	75.4	699	6	0.7	<0.5	<0.5	<0.5	13.7	<0.5	<0.5	<0.5	<0.5	33.7	187	3540
Indeno(1,2,3-c,d)pyrene	0.5	-	14.5	<0.5	910	<0.5	322	1760	47.2	<0.5	33.1	49	357	3	0.7	<0.5	<0.5	<0.5	3.4	<0.5	<0.5	<0.5	<0.5	18.2	284	2330
Dibenz(a,h)anthracene	0.5	-	4.2	<0.5	262	<0.5	82.3	690	15.2	<0.5	9.7	20.7	95.6	1.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	155	835
Benzo(g,h,i)perylene	0.5	-	16.9	<0.5	1060	<0.5	374	1960	49.9	<0.5	53.4	54	400	3.4	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	19.6	280	2980
Benzo(a) pyrene TEQ		3	36	<0.5	2060	<0.5	666	5120	144	30.5	72.4	127	1490	10.1	1.2	<0.5	<0.5	<0.5	15	<0.5	<0.5	<0.5	<0.5	50.3	737	6700
Sum of reported PAH	--	300	295	12.1	13700	21.8	4580	28400	4680	156	607	718	185000	69.2	9.1	<0.5	<0.5	<0.5	94.1	0.9	<0.5	<0.5	<0.5	277	7270	49900
Total Petroleum Hydrocarbons (TPH)																										
C10 - C14 Fraction	25	-	<50	<50	<50	<50	<50	<50	<50	280	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	-	-
C15 - C28 Fraction	50	-	970	<100	17000	<100	6800	25400	6260	15200	950	18000	382000	1160	<100	<100	<100	<100	42600	230	<100	<100	590	320	-	-
C29 - C36 Fraction	100	-	2080	<100	18600	<100	8440	31800	1550	44300	890	21500	19400	7060	<100	<100	<100	<100	85800	<100	<100	<100	150	430	-	-
C10 - C36 Fraction (sum)	100	-	3050	<50	35600	<50	15200	57200	7810	59800	1840	39500	401000	8220	<50	<50	<50	<50	128000	230	<50	<50	740	750	-	-

All results are in units of mg/kg.

[A] NEPC (2013) Health Investigation Level 'A' (Low density residential)

Cells with '-' indicates testing was not completed or an appropriate screening criteria was not available

PQL = Practical Quantitation Limit.

Results shown in shading are in excess of the human health criteria

<LOR or <value = Less than the laboratory Limit of Reporting

Table A7 Groundwater Analytical Results (ug/L)

Sample Identification	PQL	Guidelines		MW06	MW06	MW102	MW08	MW08	MW13	MW13	MW16	MW16	MW17	MW17	MW105	MW107	S3A	S3A
Date		Drinking Water[A]	Recreational[B]	2/5/12	10/7/14	9/7/14	1/5/12	9/7/14	1/5/12	9/7/14	3/5/12	10/7/14	3/5/12	10/7/14	10/7/14	11/7/14	3/5/12	10/7/14
PAEC Sampled				Background	Background	Refuelling	Refuelling	Refuelling	AWP	AWP	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant	Carbon Plant
Sample Appearance				Clear	Clear	Clear	Clear	Clear	Cloudy	Brown	Clear	Clear	Cloudy	Clear	Clear	Clear	Clear	Clear
Sample collected by				KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG	KJG
Metals																		
Aluminium pH>6.5	10	200	2000	10	180	<10	150	1200	2,150	2,500	100	<10	3,260	3,800	20	5,000	50	630
Arsenic	1	10	100	<10	1	1	3	<1	4	<1	4	<1	12	12	1	<1	5	1
Cadmium	0.1	2	20	<1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	0.2
Chromium	1	50	500	<10	<1	<1	2	1	4	6	1	<1	<1	4	2	2	<1	1
Copper	1	2	20	<10	1	2	<1	<1	1	<1	4	2	10	1	1	<1	4	<1
Nickel	1	20	200	22	20	2	2	<1	2	<1	6	<1	14	8	4	3	6	2
Lead	1	10	100	<10	<1	<1	<1	<1	<1	<1	<1	<1	34	1	<1	<1	<1	1
Zinc	5	300	3,000	78	16	4	12	<1	25	2	57	1	40	6	4	7	31	64
Mercury	0.1	1	10	<0.1	<0.05	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05	<0.1	<0.05	<0.05	<0.05	<0.1	<0.05
Fluoride	100	1500	15000	1000	220	3200	4900	6700	43000	40000	1500	2300	800	1100	1100	10000	12000	8200
Non Metallic Inorganics																		
Free Cyanide	4	80	800	<4	-	-	-	-	7	-	<8	-	<8	-	-	-	<4	-
Total Cyanide	4	80	800	<4	-	-	-	-	40	-	<8	-	<8	-	-	-	<4	-
Total Petroleum Hydrocarbons (TPH)																		
TPH C6-C9	20	1	10	-	-	18	<20	<10	-	-	-	<10	-	-	240	-	-	-
TPH C10-C14	50	90[C]	900	-	-	<50	<50	<50	-	-	-	<50	-	-	180	-	-	-
TPH C15-C28	100	90[C]	900	-	-	<100	330	<100	-	-	-	<100	-	-	1400	-	-	-
TPH C29-C36	100	90[C]	900	-	-	<100	<50	<100	-	-	-	<100	-	-	<100	-	-	-
TPH C6-C36		-	-	-	-	18	330	<100	-	-	-	<100	-	-	1820	-	-	-
Polycyclic Aromatic Hydrocarbons (PAH)																		
Naphthalene	0.1	6.1[D]	61	<0.1	-	-	<0.1	-	<0.1	<0.1	5.2	<0.1	0.2	<0.1	-	-	<0.1	-
Acenaphthylene	0.1	-	-	<0.1	-	-	<0.1	-	<0.1	<0.1	<0.1	<0.1	22.9	<0.1	-	-	<0.1	-
Acenaphthene	0.1	530[D]	5300	<0.1	-	-	<0.1	-	0.2	<0.1	9.4	<0.1	<0.1	<0.1	-	-	<0.1	-
Fluorene	0.1	290[D]	2900	<0.1	-	-	<0.1	-	<0.1	<0.1	1.1	<0.1	2	<0.1	-	-	<0.1	-
Phenanthrene	0.1	-	-	<0.1	-	-	<0.1	-	0.9	<0.1	0.6	<0.1	0.4	<0.1	-	-	<0.1	-
Anthracene	0.1	1800[D]	18000	<0.1	-	-	<0.1	-	0.2	<0.1	0.6	<0.1	0.1	<0.1	-	-	<0.1	-
Fluoranthene	0.1	800[D]	8000	<0.1	-	-	<0.1	-	4.8	<0.1	1	<0.1	0.2	<0.1	-	-	<0.1	-
Pyrene	0.1	120[D]	1200	<0.1	-	-	<0.1	-	5	<0.1	0.7	<0.1	0.1	<0.1	-	-	<0.1	-
Benz(a)anthracene	0.1	0.34[D]	3.4	<0.1	-	-	<0.1	-	4	<0.1	0.2	<0.1	<0.1	<0.1	-	-	<0.1	-
Chrysene	0.1	34[D]	340	<0.1	-	-	<0.1	-	3.6	<0.1	0.2	<0.1	<0.1	<0.1	-	-	<0.1	-
Benzo(b)&(k)fluoranthene	0.2	0.34[D]	3.4	<0.2	-	-	<0.2	-	10.8	<0.2	0.3	<0.2	<0.2	<0.2	-	-	0.2	-
Benzo(a) pyrene	0.05	0.01[A]	0.1	<0.05	-	-	<0.05	-	6.46	<0.05	0.22	<0.05	<0.05	<0.05	-	-	0.14	-
Indeno(1,2,3-c,d)pyrene	0.1	0.34[D]	3.4	<0.1	-	-	<0.1	-	3	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	-
Dibenz(a,h)anthracene	0.1	0.034[D]	0.34	<0.1	-	-	<0.1	-	1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	<0.1	-
Benzo(g,h,i)perylene	0.1	-	-	<0.1	-	-	<0.1	-	2.6	<0.1	0.1	<0.1	<0.1	<0.1	-	-	<0.1	-
Organochlorine Pesticides (OCP)																		
alpha-BHC	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HCB	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
delta-BHC	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptachlor	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aldrin	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptachlor epoxide	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlordane	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dieldrin	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDE	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endrin	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDD	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endrin aldehyde	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan sulfate	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDT	4	-	-	<4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Organophosphorous Pesticides (OPP)																		
Dichlorvos	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dimethoate	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diazinon	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorpyrifos-methyl	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malathion	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fenthion	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorpyrifos	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bromophos-ethyl	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorfenvinphos	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Prothiofos	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethion	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phenols																		
Total Phenolics	4	-	-	<4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Phthalate Esthers																		
Dimethylphthalate	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diethylephthalate	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitrosamines																		
Total Nitrosamines	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitroaromatics and Ketones																		
Total Nitroaromatics and Ketones	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haloethers																		
Total Haloethers	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorinated Hydrocarbons																		
Total Chlorinated Hydrocarbons	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anilines and Benzidines																		
Total Anilines and Benzidines	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous Compounds																		
Total Misscellaneous Compounds	2	-	-	<2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

All results in ug/L

PQL = Practical Quantitation Limit.

A NHMRC Australian Drinking Water Guidelines, 2011

B NHMRC (2008) Guidelines for Managing Risks in Recreational Water. Application of a x10 factor to the drinking water guidline.

C WHO (2008) Petroelum Products in Drinking-water.

D USEPA (2014) Regional Screening Level, Residental Tapwater value.

APPENDIX B
RISK ASSESSMENT ALGORITHMS

1 Estimation of Chemical Intakes

The algorithms used to estimate chemical intakes for each receptor and chemical of potential concern are presented below, and the definitions for the variables are presented in Table B1.

1.1 Incidental Soil Ingestion (US EPA, 1989)

$$Soil\ Ingsetion\ Intake\ \left(\frac{mg}{kg}\ day\right) = \frac{Cs\ \times \mathrm{IRs}\ \times CF\ \times FI\ \times EF\ \times ED}{BW\ \times AT}$$

1.2 Incidental Groundwater Ingestion (US EPA, 1989)

$$Groundwater\ Ingestion\ Intake\ \left(\frac{mg}{kg}\ day\right) = \frac{Cw\ \times IRw\ \times CF\ \times EF\ \times ED}{BW\ \times AT}$$

1.3 Dermal Contact with Soil (US EPA, 2004)

The dermal absorbed dose or dermal intake is estimated using the concept of absorbed dose per event (US EPA, 2004), where the overall absorbed dose depends on the number of events, the adherence factor and the fraction of contaminant absorbed.

$$Soil\ Dermal\ Contact\ Intake\ \left(\frac{mg}{kg}\ day\right) = \frac{Cs\ \times CF \times AF\ \times ABS\ \times EF\ \times EV\ \times ED\ \times SA}{BW\ \times AT}$$

1.4 Dermal Contact with Water (US EPA, 2004)

The chemical intake via dermal absorption with water is calculated depending on the exposure duration as follows:

$$Water\ Dermal\ Contact\ Intake\ \left(\frac{mg}{kg}\ day\right) = \frac{DAevent\ \times EF\ \times EV\ \times ED\ \times SA}{BW\ \times AT}$$

For short duration exposures with organic compounds in water ($t_{event} \leq t^*$):

$$DAevent = 2\ \times FA\ \times Kp\ \times Cw\ \times \sqrt{\frac{1+3B+3B^2}{(1+B)^2}}$$

For long duration exposures with organic compounds in water:

$$DAevent = FA \times Kp \times Cw \times \left[\frac{tevent}{1+B} + 2\tau event \left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

For exposure to inorganic or highly ionized organic chemicals in water:

$$DAevent = Kp \times Cw \times tevent$$

1.5 Dust Inhalation (US EPA, 2009)

The US EPA (2009) RAGS-F guidance recommends that when estimating risk via inhalation pathways, the concentration of the chemical in air should be used as the exposure metric (e.g. mg/m^3), rather than inhalation intake of a contaminant in air based on inhalation rate and body weight (e.g. mg/kg-day). This is known as the *Inhalation Dosimetry Methodology* which supersedes the previous US EPA (1989) RAGS, Part A inhalation methodology because "*the internal dose to a chemical from the inhalation pathway is not a simple function of the inhalation rate and body weight….* [and therefore the US EPA (1989) inhalation equation] *does not comply with the principles of EPA's inhalation dosimetry procedures used to determine the human equivalent concentration (HEC) for calculating a Reference Concentration (RfC) or Inhalation Unit Risk (IUR)*") (US EPA, 2003).

The updated inhalation dosimetry methodology calculates a modified exposure concentration (EC, mg/m^3) which is then directly compared with a Reference Concentration (RfC, mg/m^3) or Inhalation Unit Risk (IUR, per mg/m^3) that is derived from toxicological studies.

$$ECdust\ (indoors)\ \left(\frac{\mu g}{m^3}\right) = \frac{Ca_{indoors} \times RF \times ETindoors \times Bio \times EF \times ED}{AT}$$

$$EDdust\ (outdoors)\left(\frac{\mu g}{m^3}\right) = \frac{Ca_{outoors} \times RF \times EToutdoors \times Bio \times EF \times ED}{AT}$$

Table B1 Variables description for Estimation of Chemical Intakes

Variable	Units	Description
Cs	mg/kg	Concentration in soil
Cw	mg/L	Concentration in groundwater
IRs	mg soil/day	Soil ingestion rate
IRw	L/day	Groundwater ingestion rate
CF	10^{-6} kg/mg	Unit conversion factor
FI	-	Fraction ingested from contamination source
EF	days/year	Exposure frequency
ED	years	Exposure duration
BW	kg	Body weight
AT	days	Averaging time Non-carcinogenic effects AT= ED (yr) x 365 d/yr Carcinogenic effects AT = 70yr x 365 d/yr
DAevent	mg/cm^2 - event	Dermally absorbed dose per event per unit exposed skin area
EV	events/day	Event frequency
SA	cm^2	Skin surface area available for contact

Cw	mg/L	Concentration in water
AF	mg/cm^2 - event	Adherence factor of soil to skin
ABS	-	Dermal absorption fraction (chemical-specific)
FA	-	Fraction absorbed from water
Kp	cm/hour	Dermal permeability coefficient of compound in water (chemical-specific)
τevent	hours/event	Lag time per event (chemical-specific, refer to Appendix B of US EPA (2004))
t*	hours	Time to reach steady state = 2.4 τevent
t_{event}	hours/event	Event duration
B	-	Ration of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across viable epidermis (refer to Equation A.1 in Appendix A of US EPA (2004)).
Bio	-	Bioavailability
ECdust	$\mu g/m^3$	Exposure concentration (a time-weighted average concentration) relevant to chemicals present as dust
$C_{A\ indoors}$	$\mu g/m^3$	Concentration in indoor air (exposure point concentration which has been measured or modeled)
$C_{A\ outdoors}$	$\mu g/m^3$	Concentration in outdoor air (exposure point concentration which has been measured or modeled)
RF	-	Lung retention factor relevant to the inhalation of dust and includes consideration of a deposition fraction and ciliary clearance
ETindoors	hours/event	Exposure time spent indoors
ETоudoors	hours/event	Exposure time spent outdoors
F_{SD}	-	Fraction of site-derived fruit
CF_{fruit}	mg/kg fresh weight produce to mg/kg dry weight soil	Plant concentration factor for fruit (chemical specific, adopted from EA (2009)).
IR_{fruit}	kg/day	Fruit consumption rate

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APPENDIX C
TOXICOLOGICAL PROFILES FOR TOTAL PETROLEUM HYDROCARBONS AND FLUORIDE

Total Petroleum Hydrocarbon (TPH) Toxicological Profile

General

Total Petroleum Hydrocarbons (TPH) is the collective name given to approximately 250 hydrocarbon based compounds which are derived from crude oil (ATSDR, 1999). This should not be confused with the generic term 'petroleum hydrocarbons'. The generic term refers to hydrogen and carbon containing compounds originating from crude oil, whereas the term TPH is specifically associated with environmental sampling and analysis. TPH is essentially a type of analytical method used to estimate the concentration of petroleum hydrocarbons in environmental media. Note that it does not imply a specific analytical method, and estimates of TPH concentration can often vary depending on the analytical method used (ATSDR, 1999). Non-petroleum hydrocarbons are typically removed from a soil solvent extract by passing the extract through a silica gel column.

There are several hundred compounds defined as petroleum-based. Aromatic TPH compounds typically include benzene, toluene, ethylbenzene and xylene (BTEX), a number of other monoaromatic hydrocarbons, and polycyclic aromatic hydrocarbons (PAHs). Typical aliphatic TPH compounds are the alkanes, also referred to as paraffins (eg, pentane, hexane) (ATSDR, 1999).

TPH Fractions

It is rarely practicable to quantify each chemical constituent contained within a hydrocarbon fuel or oil, and toxicological information is only available for around one tenth of TPH compounds. In order to assess health risks from TPH, it is necessary to group the TPH compounds.

The Massachusetts Department of Environmental Protection (MA DEP) originally introduced a solution to this problem. MA DEP split TPH into a relatively small number of fractions with similar physical-chemical properties, simplifying modelling of their movement in the environment and allowing toxicity characteristics to be assigned to the fractions (MA DEP, 1994).

Independently the TPHCWG, (TPHCWG, 1997a) developed with a similar methodology and grouping, adding support to their conclusions. The MA DEP report was state-specific and has since been updated, whereas the TPHCWG work was more generically applicable and now forms an international basis for TPH evaluation. Thus the TPHCWG volumes (TPHCWG, 1997a; 1997b; 1998) form the basis for the remainder of this toxicity profile.

TPHCWG recommends that TPH be broken down into its aromatic and aliphatic fractions with different toxicity and mobility characteristics. TPHCWG divided TPH compounds into the fractions listed below, and provided physical and chemical data, and toxicological data that the Criteria Working Group considered representative of each fraction. TPHCWG did not consider TPH compounds with carbon numbers greater than 34.

Aliphatic TPH: C_5-C_6, $C_{>6}$-C_8, $C_{>8}$-C_{10}, $C_{>10}$-C_{12}, $C_{>12}$-C_{16}, $C_{>16}$-C_{21}, $C_{>21}$-C_{34}

Aromatic TPH: C_7-C_8, $C_{>8}$-C_{10}, $C_{>10}$-C_{12}, $C_{>12}$-C_{16}, $C_{<16}$-C_{21}, $C_{<21}$-C_{34}

TPHCWG Fractions

More than 200 hydrocarbons were considered by TPHCWG in the development of fraction specific properties. A simple screening-level partitioning model, based on the ASTM Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, "RBCA" (ASTM, 1995) was applied to each chemical in order to quantify, individually, the chemical's relative ability to leach from soil to groundwater and volatilise from soil to air. Based on the modelling results, the chemicals were grouped into fractions (using an order of magnitude as the cut-off point) (TPHCWG, 1997a).

Within each of the initial fractions the hydrocarbons were then grouped relative to their equivalent carbon (EC) number. The equivalent carbon number, EC, is related to the boiling point of a chemical normalised to the boiling point of the n-alkanes. This can also be determined from

retention time in a boiling point gas chromatographic (GC) column. This relationship was empirically determined. Thus, for chemicals where only boiling points are known, an equivalent carbon number can be easily calculated (TPHCWG, 1997a).

For example, hexane contains six carbons and has a boiling point of 69°C. Its equivalent carbon number is six. Benzene, also containing six carbons, has a boiling point of 80°C. Based on benzene's boiling point and its retention time in a boiling point GC column, benzene's equivalent carbon number is 6.5. This approach is consistent with methods routinely used in the petroleum industry for separating complex mixtures and is a more appropriate differentiation technique than the carbon number of the chemical. Additionally this is consistent with the way analytical laboratories report carbon numbers when chemicals are evaluated on a boiling point GC column (TPHCWG, 1997a).

Once the fractions were defined, typical fate and transport properties were assigned to each fraction based on an empirical relationship between fate and transport properties of chemicals within each fraction and boiling point. These properties could be used to estimate fraction-specific exposure potential at petroleum hydrocarbon contaminated sites (TPHCWG, 1997a).

Volume 3 of the TPHCWG series (TPHCWG, 1997a) describes the process of defining the fractions. Fraction-specific properties can then be used to estimate the partitioning of the specific fraction in soil-water-air systems. Fate and transport models (either simple or complex) can then be applied as well. This revolutionary approach is now the accepted international basis for TPH evaluation.

Table 7 in Volume 3 (TPHCWG, 1997a) presents physical parameters for fractions based on simple averaging, composition-weighted averaging, and correlation to relative boiling point index. Although each method yields similar results, the 'averaging of fractions' method to be consistent with the CRC CARE methodology has been adopted. Note that consistent with paragraph 4.3.5 in Volume 3 (TPHCWG, 1997a), the diffusivity in air should be set to 0.1 cm^2/sec for all fractions, and the diffusivity in water should be set to 0.00001 cm^2/sec for all fractions.

Physical and Chemical Properties

The physical and chemical properties of the various TPH fractions are presented in **Table C1**, and were sourced from Table 7 (averaging of fractions) in TPHCGW (1997a).

Table C1 Physical and Chemical Properties of Total Petroleum Hydrocarbons

Variable	Symbol	Unit	Aliphatic C6-C10[a]	Aliphatic >C10-C16[b]	Aliphatic C>16-C34[c]	Aliphatic >C34-C40[c]	Aromatic C6-C10[d]	Aromatic >C10-C16[e]	Aromatic >C16-C34[f]	Aromatic >C34-C40[g]	Reference
Molecular Weight	MW	g/mole	120	185	280	280	106	145	215	250	TPHCWG
Henry's Law Constant @ 25°C	H'	unitless	190	160	110	110	0.345	0.219	4.99E-03	8.2E-05	TPHCWG
Henry's Law Constant @ 25°C	H'	atm-m^3/mol	2.89	3.90	2.68	2.68	8.41E-03	5.34E-03	1.22E-04	2.0E-06	TPHCWG
Vapour Pressure	ρ	mmHg	29.2	0.288	8.36E-04	8.36E-04	16.7	0.38	8.8E-04	1.2E-05	TPHCWG
Aqueous solubility	S	mg/L	0.83	0.053	1.5E-06	1.50E-06	315	20.2	0.29	2.9E-02	TPHCWG
Soil-water partition coefficient	Kd	cm^3/g	-	-	-	-	-	-	-	-	-
Organic carbon partition coefficient	Koc	cm^3/g	1.0E+04	1.26E+06	3.98E+08	3.98E+08	562	4.47E+03	4.47E+04	1.26E+5	TPHCWG
Log of octanol-water partition coefficient	log Kow	-	3.9	5.65	6.0	6.0	2.13	3.58	5.16	5.16	RAIS
Dermal permeability constant	Kp	cm/hr	0.201	1.7	1.96	1.96	1.49E-02	6.92E-02	0.308	0.308	RAIS
Soil dermal absorption factor	DAF	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	CCME (2008)
Oral bioavailability in soil	Bio	-	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	-
Diffusivity in air	Dair	cm^2/sec	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	TPHCWG
Diffusivity in water	Dwater	cm^2/sec	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	TPHCWG

ND: No data available

a) Represents the average value of EC>C6-C8 and EC>C8-C10
b) Represents the average value of EC>C10-C12 and EC<C12-C16
c) Represents the EC>C16-C35 value
d) Represents the average value for EC>C7-C8 and EC>C8-C10
e) Represents the average value for EC>C10-C12 and EC>C12-C16
f) Represents the average value for EC>C16-C21 and EC>C21-C35
g) Represents the EC>C21-C35 values

Presence in the Environment

TPH are used extensively and are used in a wide variety of industries. Their main use is as fuel, and they are primarily found in petroleum products including petrol, diesel, fuel and motor oils, household solvents, cleaners and asphalt (ATSDR, 1999).

TPH enters the environment via leaking underground fuel tanks, industrial releases, volatilisation during transport, handling and use, and from accidental spillage of petroleum products during commercial or private uses (ATSDR, 1999). TPH (particularly the PAH compounds) are also released to the atmosphere as a result of incomplete combustion of fuels in boilers, motor vehicles and other petroleum –fueled machinery (ATSDR, 1999).

Environmental Fate and Transport

The fate of TPH compounds varies by fraction: when spilled onto or into soils, lighter fractions are prone to volatilisation. On water, spilled oil will quickly spread out, forming a film less than 1mm thick. In this way the oil may cover a large area very quickly. Some of the heavier fractions, for example some of the PAH compounds are denser than water, making them likely to sink and accumulate in sediments (ATSDR, 1999).

Over time, petroleum products in the environment are broken down by chemical, physical and biological processes, which generally results in a gradual lower of toxicity. This weathering effect is relatively rapid in surface waters and surface soils, however at depth, and particularly in groundwater, weathering processes may operate very slowly (ATSDR, 1999). TPH compounds are variably biodegradable, however as a general rule the lower carbon numbers are likely to biodegrade more quickly, and aerobic degradation is likely to be the dominant process. Anaerobic degradation of TPH is not likely to be significant (ATSDR, 1999). Shorter chain TPH are not likely to bioaccumulate, however some heavier compounds, particularly the PAHs may do so (ATSDR, 1999).

When oil is spilled into the ground it flows as a bulk product with little separation of the various components. In soils, the oil will migrate downwards under the influence of gravity. It leaves behind a residual amount adsorbed to soil particles, which may persist for many years and which is generally immobile. Oils reaching the water table will spread out (most petroleum mixtures are less dense than water and are often referred to as LNAPLs – 'light non-aqueous phase liquids) and may travel some distance on groundwater. The behaviour of LNAPL in groundwater is influenced by the head of the LNAPL, which may force the product to some metres below the water table, where it forms a 'plug' that gradually spreads laterally both beneath and at the water table (LSP, 2005).

From the bulk oil spill, TPH compounds may migrate into the atmosphere through volatilisation. Volatile TPH may also move through unsaturated soils in the vapour phase, and can move laterally in response to pressure gradients. Although the TPH compounds are generally of low water solubility, dissolution of the BTEX and some other short chain compounds does take place and dissolved phase TPH compounds can be mobile in groundwater (ATSDR, 1999).

Toxicokinetics

As the petroleum products are highly volatile, inhalation is the primary route of exposure. However ingestion and dermal absorption of TPH via contact with fuel, and contaminated soil and groundwater are also possible routes of exposure to TPH. Little information is available regarding the toxicokinetics of TPH mixtures because the majority of studies focus on individual components of TPH. Human and animal studies indicate that benzene, toluene, ethylbenzene and xylene (BTEX) which are components in the lighter aromatic TPH fractions ($>C_5$-C_8) are readily absorbed via inhalation and ingestion. BTEX compounds are also absorbed following dermal exposure to a lesser extent (ATSDR, 1999). These compounds are widely distributed in tissue and organs, metabolised via oxidative metabolic pathways to more soluble metabolites and excreted primarily in the urine. Metabolism of BTEX can produced more toxic or less toxic metabolites (ATSDR, 1999).

The absorption of heavy aromatic TPH fractions decreases with increasing weight, however lipophillic delivery vehicles can increase the degree of absorption. The metabolism of polycyclic

aromatic hydrocarbons (PAHs), which are components in heavier aromatic TPH fractions (>C_{17}-C_{36}) produce arene oxide, phenols, phenol-diol and phenol-epoxide (ATSDR, 1999). Absorption of aliphatic TPH fractions decreases with increasing weight and aliphatic TPH (>C_{16}-C_{35}) are poorly absorbed regardless of the route of exposure. Aliphatic TPH are preferentially distributed and stored in fatty tissue in the body (ATSDR, 1999). Hexane which is a component of aliphatic TPH (>C_5-C_7) is metabolised oxidatively to alcohol, ketone, carboxylic acid and dihyrodiol whereas aliphatic TPH (>C_{16}-C_{35}) are slowly metabolised to fatty acids and triglycerides (ATSDR, 1999).

In the absence of evidence to the contrary 100% bioavailability via ingestion and inhalation has been assumed. Dermal bioavailability was estimated at 20% for all TPH fractions in accordance with CCME (2008) methodology.

IARC Toxicity Classification

The International Agency for Research on Cancer (IARC) has determined that the TPH compounds benzene and benzo(a)pyrene are carcinogenic to humans. Most of the other TPH compounds are considered not to be classifiable by IARC (IARC, 1989; ATSDR, 1999).

Threshold (non-carcinogenic) Health Effects (ATSDR, 1999)

As TPH consists of a vast number of compounds, many different health effects are possible including: central nervous system effects, blood effects, immune effects, lung effects, skin effects, eye effects, reproductive effects, liver effects and kidney effects. The toxicity criteria adopted primarily focuses on liver, kidney, body weight and blood effects.

Generally, the body system most affected by TPH compounds is the central nervous system; other body systems affected include the blood, immune system, lungs, skin and eyes. Effects of TPH compounds include dizziness, headaches, peripheral neuropathy and reproduction impairment. Allergic or idiosyncratic effects may include skin disorders such as dermatitis upon dermal contact. The swallowing of some petroleum products such as gasoline and kerosene causes irritation of the throat and stomach, central nervous system depression, difficulty breathing, and pneumonia from breathing liquid into the lungs.

Children and foetuses may be at increased risk to benzene toxicity because their haematopoietic cell populations are expanding and dividing cells are at greater risk than quiescent cells. In addition, people with sub-clinical and clinical epilepsy are considered at increased risk of seizures from exposure to xylene because of its central nervous system effects. Additional chronic health effects that are specific to particular fractions are summarised in **Table C2** (ATSDR, 1999; TPHCWG, 1998).

Table C2 Health Effects of Aliphatic and Aromatic TPH Fractions

Aromatic or Aliphatic Fraction	Chemical of Concern	Health Effects
Aromatic C_6 – C_9	BTEX	Central Nervous System (CNS) depression, skin/eye irritation, renal & hepatic effects.
Aromatic C_{10} – C_{14}	Naphthalene, Isopropylbenzene, methylbenzene, butyl.	Anaemia, renal effects & hepatic effects, skin irritation.
Aromatic >C_{15}	Pyrene, various Polycyclic Aromatic Hydrocarbons	Anaemia, immunological effects,
Aliphatic C_6 – C_9	n- hexane, n-pentane, n-octane.	Neurological and respiratory effects, peripheral neuropathy, reproductive effects, skin and eye irritation.
Aliphatic C_{10} – C_{14}	Kerosene, nonane, JP-8.	CNS depression, neuropathy, renal and hepatic effects, skin and eye irritation.

Table C2 Health Effects of Aliphatic and Aromatic TPH Fractions

Aromatic or Aliphatic Fraction	Chemical of Concern	Health Effects
Aliphatic >C_{15}	Elcosane, hydraulic fluids, mineral oils.	Hepatic and lymph node effects,

Carcinogenic (genotoxic) Health Effects (ATSDR, 1999)

Carcinogenic effects cannot be applied to TPH in general however multiple individual compounds (e.g., benzene and benzo(a)pyrene) have been positively linked to human carcinogenic effects. Benzene is a known human genotoxic carcinogen for all routes of exposure, with epidemiological studies and case reports providing clear evidence of a causal relationship between occupational exposure to benzene and an increase in the occurrence of certain types of leukaemia.

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Fluoride

General

Under standard conditions of temperature and pressure, fluorine is a halogen that exists as a light yellow-green, pungent, acrid gas of F2 molecules. Fluoride has a molecular weight of 19.0 g/mol and it is the most electronegative element and has the highest chemical reactivity of all elements in the Periodic Table. Due to its high reactivity, fluorine is not present naturally in its elemental state; rather, it exists either as inorganic fluoride (i.e., ionic fluoride, [F-], which is either free or matrix-bound in minerals or covalently bound in inorganic compounds such as hydrogen fluoride), or as organic fluoride (covalently bound in organic compounds). The assessment of whether inorganic fluorides are "toxic" is principally evaluated on the basis of hydrogen fluoride, calcium fluoride, sodium fluoride, and sulphur hexafluoride (CEPA 1993).

Inorganic and organic fluorides are present in all soils and water, as well as in the plants and animals consumed by humans for food. Except for industrial emissions, the largest environmental source of fluorides is fluoridated water supplies; fluorine is added deliberately with the aim of preventing dental caries. Fluoride is found in all natural waters at some concentration. In some parts of the world, deposits of rocks containing a high level of fluoride cause a large increase in the fluoride content of water or food and, consequently, the exposure to fluoride is sufficiently high (usually more than 6 mg/day) to cause endemic fluorosis, which is characterized by stiff joints, weight loss, brittle bones, anemia and weakness. Fluoride is also present in insecticides, rodenticides, floor polishes, in the petroleum and aluminium industries, glass etching and timber preservation and in dietary supplementation and toothpastes (up to 1 mg/g of toothpaste), and is added to water supplies (WHO 2000).

In relation to exposure, air is responsible for only a small fraction of total fluoride exposure. In addition vegetables and fruits normally have low levels of fluoride, however higher levels have been found in barley and rice and tea. In general fluoride levels are low in most food products including meat and fish products, however as fluoride accumulates in bone, products that include bones of fish such as salmon and sardines may contain higher levels of fluorine. Higher levels of exposure occur through the use of dental products (with child exposure from swallowing toothpaste estimated to be up to 0.75 mg per child per day). Intakes of fluoride by adults (from all sources including drinking water) has been estimated in Canada (CEPA 1993) to be approximately 2.2-4.1 mg/day (or 0.03-0.06 mg/kg/day), and for young children (aged 7 months to 4 years) approximately 0.6-2.1 mg/day (or 0.05-0.16 mg/kg/day). These intakes exceed the toxicity reference values (TRVs) identified for consideration in this assessment.

In fluoridated water supplies in Australia, the target fluoride levels are typically between 0.6 and 1 mg/L with the lower value typically adopted in hot climates, allowing for a higher intake of water (NHMRC 2011).

Health Effects

Fluoride has beneficial effects on teeth at low concentrations in drinking-water, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects. These range from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases.

Approximately 75–90% of ingested fluoride is absorbed. Once absorbed into the blood, fluoride readily distributes throughout the body, with approximately 99% of the body burden of fluoride retained in calcium rich areas such as bone and teeth (dentine and enamel) where it is incorporated into the crystal lattice. In infants about 80 to 90% of the absorbed fluoride is retained but in adults this level falls to about 60%. Fluoride crosses the placenta and is found in mother's milk at low levels essentially equal to those in blood.

A large number of mutagenicity and genotoxic studies have been conducted with inorganic fluoride ion. While the results of these studies have been mixed, in general fluoride is not considered mutagenic or genotoxic. In addition, although there is some evidence for the carcinogenicity of inorganic fluoride, available data are inconclusive (WHO 2006, CEPA 1993).

In humans, acute (oral) exposure to fluoride may produce effects that include nausea, vomiting, abdominal pain, diarrhoea, fatigue, drowsiness, coma, convulsions, cardiac arrest, and death.

Skeletal fluorosis (including dental fluorosis) is a pathological condition that may arise following long-term exposure (either by inhalation or ingestion) to elevated levels of fluoride, and is considered to be the most relevant (and sensitive) effects in assessing long-term exposure to inorganic fluorides (and establishing public health guidelines). Although the incorporation of fluoride into bone may increase the stability of the crystal lattice, and render the bone less soluble, bone mineralization is delayed or inhibited, and consequently the bones may become brittle and their tensile strength reduced. In the preclinical phase, the "fluorotic" patient may be relatively asymptomatic, with only a slight increase in bone mass (detected radiographically). Sporadic pain and stiffness of the joints, chronic joint pain, osteosclerosis of cancellous bone, and calcification of ligaments are associated with the first and second clinical stages of skeletal fluorosis. Crippling skeletal fluorosis (clinical phase III) may be associated with limited movement of the joints, skeletal deformities, intense calcification of ligaments, muscle wasting, and neurological effects. Osteomalacia may be observed in fluorotic individuals with a reduced or suboptimal intake of calcium; secondary hyperparathyroidism may also be observed in a subset of patients.

Other effects identified in relation to long-term exposures to fluoride include endocrine effects (pineal function, thyroid function and diabetes) and neurological effects (IQ).

People with kidney impairment have a lower margin of safety for fluoride intake. Limited data indicates that their fluoride retention may be up to three times normal.

Identification of Quantitative Toxicity Reference Values

For the quantification of risks associated with exposure to fluoride in the environment (soil and water) an appropriate toxicity reference value relevant to ingestion (in particular) needs to be identified. Based on the available information in relation to adverse health effects associated with exposures to fluorides (where fluoride has not been identified as a genotoxic carcinogen), it is appropriate that a threshold dose-response approach is adopted.

It is noted that a number of soil guidelines are currently available for fluoride in soil. Many of these are not derived on a risk-based approach, utilising a published peer reviewed toxicity reference value. Rather a number of the available guidelines are based on background concentrations in a particular area (region) and are not specifically relevant for this evaluation.

Table C3 presents a summary of the currently available toxicity reference values for fluoride, based on published peer-reviewed sources as outlined in enHealth 2012.

Table C3 Available Toxicity Reference Values for Fluoride

Source	Toxicity Reference Value / Guideline	Basis / Comments
NHMRC (NHMRC 2011)	Guideline value (maximum) of 1.5 mg/L in drinking water Equivalent to TDI = 0.04 mg/kg/day	Guideline value adopted is consistent with the WHO guideline as noted below. The guidelines note that there is a narrow margin between concentrations producing beneficial effects to teeth and those producing objectionable fluorosis. The minimum concentration required for a protective effect against detail caries is 0.5 mg/L.
NHMRC (NHMRC 2006)	Upper limit = 0.7 mg/day for infants 0-6 months, 1.3 mg/day for children 1-3 years and 10 mg/day for ages 9 years and older (including pregnant and lactating women).	Upper limit of intake set at a level associated with moderate tooth fluorosis, based on a LOAEL of 0.1 mg/kg/day from community studies for infants and children up to 8 years of age and an uncertainty factor of 1. For older children and adults the upper limit is based on a NOAEL of 10 mg/day based on the relationship between fluoride intake and fluorosis and an uncertainty factor of 1. No data exists that shows increased susceptibility for pregnant or lactating women.
RIVM (1991)	TDI = 0.07	Limited information is available in relation to the basis for the TDI derived, however it is understood to be based on

Table C3 Available Toxicity Reference Values for Fluoride

Source	Toxicity Reference Value / Guideline	Basis / Comments
	mg/kg/day	a human study.
WHO (WHO 2006)	1.5 mg/L in drinking water Equivalent to TDI = 0.04 mg/kg/day	Guideline derived on the basis of a level at which dental fluorosis (a mottling of the teeth that can occur occasionally) should be minimal. Concentrations of greater than 4 mg/L have been associated with skeletal fluorosis. The WHO guidance also notes that local conditions (diet, water consumption etc.) should also be taken into account and the guideline should not be considered to be a fixed value.
ATSDR (ATSDR 2003)	Chronic oral MRL = 0.05 mg/kg/day	MRL for fluorine (soluble fluoride) derived on the basis of a NOAEL of 1.5 mg/kg/day associated with musculoskeletal effects in a human study and application of a 3 fold uncertainty factor.
Health Canada (CEPA 1993)	Provisional TDI = 0.2 mg/kg/day	Provisional TDI based on a NOAEL of 0.2 mg/kg/day associated with skeletal effects in a number of human studies and an uncertainty factor of 1. It is noted that this provisional guideline has been recently reviewed by the Office of the Auditor General of Canada and found to be inadequately protective of potential adverse effects.
USEPA (USEPA)	RfD = 0.06 mg/kg/day	RfD (last review in 1987) for fluorine (soluble fluoride) based on a NOAEL of 0.06 mg/kg/day associated with dental fluorosis in a human study and application of an uncertainty factor of 1. This RfD has been adopted by the USEPA in the derivation of the tap water and soil Regional Screening Levels (RSLs). In addition the same RfD has been adopted in the derivation of the Italian soil guideline.

Based on **Table C3**, there is reasonable consistency between the TRV adopted by NHMRC, WHO, ATSDR and USEPA. These are all generally based on the protection of the most sensitive effects of dental/skeletal fluorosis and are based on human studies. The TRV derived from the NHMRC guideline value (maximum) has therefore been adopted in this assessment.

For the purpose of deriving a soil or recreational water quality guidelines the following has been considered:

An oral TRV = 0.04 mg/kg/day has been adopted. This is based on the maximum water quality guideline of 1.5 mg/L;

In Australia, drinking water supplies are fluoridated. Based on information presented by NHMRC (NHMRC 2011, NHMRC 2007), target levels of fluoride in drinking water in most states (excluding Queensland where drinking water is not fluoridated) range from 0.6 to 1 mg/L, which comprise up to 66% of the maximum concentration allowable. As drinking water in NSW is fluoridated these intakes need to be accounted for when considering guidelines for both soil and recreational water as these will be in addition to normal daily water intakes.

Intakes from sources other than drinking water (such as food and dental hygiene practices) are variable and less well evaluated. Based on the available information these intakes have been conservatively estimated to comprise approximately 20% of the adopted TRV.

Based on the above, 10% of the adopted TRV may be considered in the derivation of intakes from other sources that include soil and recreational water. This assumption is conservative as it is based on generic information regarding intakes of fluoride from drinking water in the area as well as other sources.

APPENDIX D
SENSITIVITY ANALYSIS

Human Health Risk Assessment Sensitivity Analysis

- *Site name*: Hydro Aluminium Smelter, Kurri Kurri
- *Site location*: Hart Road, Loxford, NSW, Australia.

Table 1 Sensitivity Analysis – On-Site Construction Worker										
Variable	**Range**			**Hazard Index**			**Increased Lifetime Cancer Risk**			**Sensivity level/ Comment**
	HHRA Value	**Min**	**Max**	**HHRA Value**	**Min**	**Max**	**HHRA Value**	**Min**	**Max**	
Soil ingestion (mg/day)	330	25	500	-	-	-	6.8E-07	5.2E-08	1.0E-06	Doubling the soil ingestion rates has the same effect on the risk estimates, however even if the reasonable maximum ingestion rates are applied, the risk estimates do not exceeded the acceptable risk levels adopted for this assessment.
Direct Contact with Soil										
Skin exposed (cm^2) – soil dermal contact	3800[a]	600[b]	15,310[d]	-	-	-	4.3E-07	6.7E-08	1.7E-06	The amount of skin exposed during working activities will vary depending on the person and the activity being undertaken. The risk estimates for this HHRA are low and acceptable even if a worker's arms, face and arms are exposed to surface soil which is unlikely given the site's strict health and safety procedures.
Exposure frequency (days/yr)	40	20	80	-	-	-	4.3E-07	2.1E-07	8.5E-07	Doubling the exposure frequency has the same effect on the risk estimates, however even if the reasonable maximum exposure frequency is applied, the risk estimates do not exceeded the acceptable risk levels adopted for this assessment.
Dermal Contact with Groundwater in the Capped Waste Stockpile										
Skin surface area (cm^2)	3800[a]	600[b]	15,310[d]	2.8	0.44	11.0	-	-	-	The amount of skin exposed during working activities will vary depending on the person and the activity being undertaken. Should a worker wear waterproof gloves during work at the CWS the health risks are low and acceptable. If the worker gets their hands and forearms wet during activities, the risks increase significantly.

Table 1 Sensitivity Analysis – On-Site Construction Worker										
Exposure time to groundwater (hrs/event)	2	0.5	8	2.8	0.69	11.1	-	-	-	It is unlikely that a worker will have contact with groundwater at the CWS for an eight (8) hour period during the working day; should this occur health risks would increase significantly.
Exposure frequency (events/year)	80 (4 months)	40 (2 months)	120 (6 months)	2.8	1.4	4.2	-	-	-	Remediation of the CWS is anticipated to take 4 months to complete. Even if this task was undertaken in half the time, the health risks associated with exposure to groundwater would not be acceptable.

Notes:

a) Includes skin surface area of hands and face (NEPM, 2013).
b) Includes skin surface area of face only (assumes worker is wearing water proof gloves). Value represents 50% of the 95th percentile surface area for the head (enHealth, 2012).
c) Includes skin surface area of hands, head and arms for an adult male aged ≥ 21 years of age; 95th percentile value (US EPA, 2011).
d) Includes skin surface area of hands, head, arms and legs for an adult male aged ≥ 21 years of age; 95th percentile value (US EPA, 2011).
e) Absorption factor for arsenic adopted by US EPA (2013) during derivation of the regional screening levels (RSLs) for industrial soil.