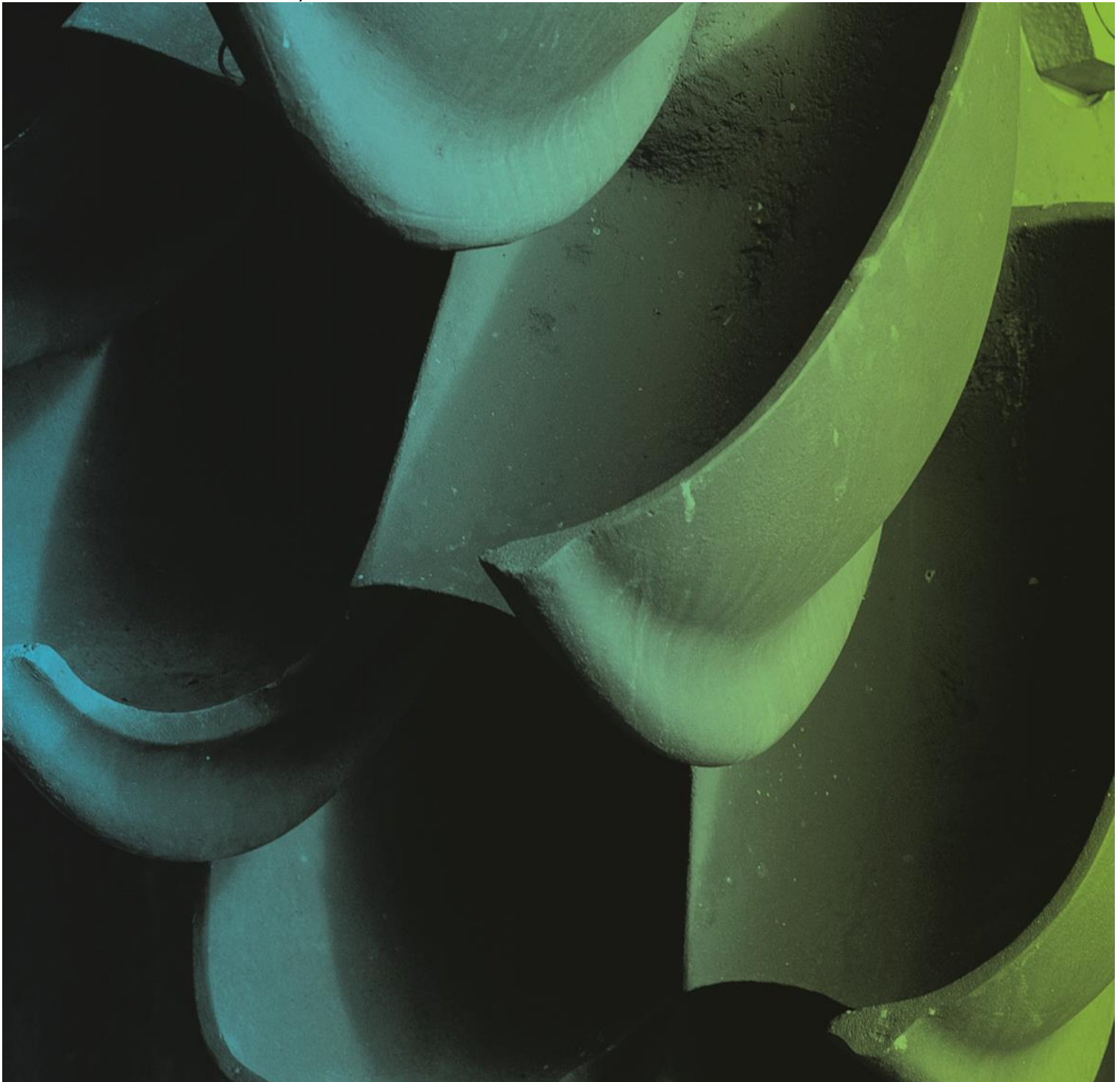


# Health Impact Assessment

Remediation Development Application, SSD 6617-2014, Barangaroo  
Hickson Road, EPA Declaration Area Number 21122



## Health Impact Assessment

Remediation Development Application, SSD 6617-2014, Barangaroo Hickson Road, EPA Declaration Area  
Number 21122

Client: Lend Lease (Millers Point) Pty Ltd

ABN: 15 127 727 502

Prepared by

**AECOM Australia Pty Ltd**

Level 21, 420 George Street, Sydney NSW 2000, PO Box Q410, QVB Post Office NSW 1230, Australia  
T +61 2 8934 0000 F +61 2 8934 0001 www.aecom.com

ABN 20 093 846 925

11-Mar-2015

60321826

AECOM in Australia and New Zealand is certified to the latest version of ISO9001, ISO14001, AS/NZS4801 and OHSAS18001.

This document was prepared by AECOM Australia Pty Ltd (AECOM) for the sole use of Lend Lease (Millers Point) Pty Ltd, the only intended beneficiary of our work. Any advice, opinions or recommendations contained in this document should be read and relied upon only in the context of the document as a whole and are considered current to the date of this document. Any other party should satisfy themselves that the scope of work conducted and reported herein meets their specific needs before relying on this document. AECOM cannot be held liable for any third party reliance on this document, as AECOM is not aware of the specific needs of the third party. No other party should rely on the document without the prior written consent of AECOM, and AECOM undertakes no duty to, nor accepts any responsibility to, any third party who may rely upon this document.

This document was prepared for the specific purpose described in our proposal dated 9 January 2012 and as agreed to by Lend Lease (Millers Point) Pty Ltd. From a technical perspective, the subsurface environment at any site may present substantial uncertainty. It is a heterogeneous, complex environment, in which small subsurface features or changes in geologic conditions can have substantial impacts on water and chemical movement. Uncertainties may also affect source characterisation assessment of chemical fate and transport in the environment, assessment of exposure risks and health effects, and remedial action performance.

AECOM's professional opinions are based upon its professional judgement, experience, and training. These opinions are also based upon data derived from the testing and analysis described in this document. It is possible that additional testing and analysis might produce different results and/or different opinions. AECOM has limited its investigation to the scope agreed upon with its client. AECOM believes that its opinions are reasonably supported by the testing and analysis that have been done, and that those opinions have been developed according to the professional standard of care for the environmental consulting profession in this area at the date of this document. That standard of care may change and new methods and practices of exploration, testing, analysis and remediation may develop in the future, which might produce different results. AECOM's professional opinions contained in this document are subject to modification if additional information is obtained, through further investigation, observations, or validation testing and analysis during remedial activities.

All rights reserved. No section or element of this document may be removed from this document, extracted, reproduced, electronically stored or transmitted in any form without the prior written permission of AECOM.

## Quality Information

Document Health Impact Assessment

Ref 60321826

Date 11-Mar-2015

Prepared by Holly Marlin

Reviewed by Amanda Lee

### Revision History

| Revision | Revision Date | Details                                       | Authorised                          |                                                                                       |
|----------|---------------|-----------------------------------------------|-------------------------------------|---------------------------------------------------------------------------------------|
|          |               |                                               | Name/Position                       | Signature                                                                             |
| A        | 9-Sep-2014    | Draft for internal review                     | Amanda Lee<br>Associate Director    |                                                                                       |
| B        | 16-Sep-2014   | Draft for client review                       | Amanda Lee<br>Associate Director    |                                                                                       |
| C        | 11-Nov-2014   | Final draft                                   | Michael Jones<br>Technical Director |                                                                                       |
| D        | 25-Feb-2015   | Final draft incorporating<br>client comments  | Andrew Rolfe<br>Principal Scientist |                                                                                       |
| E        | 5-Mar-2015    | Final report incorporating<br>client comments | Andrew Rolfe<br>Principal Scientist |                                                                                       |
| F        | 11-Mar-2015   | Final report                                  | Andrew Rolfe<br>Principal Scientist |  |

## Contents

|                                                              |    |
|--------------------------------------------------------------|----|
| Glossary of Terms                                            | i  |
| Executive Summary                                            | i  |
| 1.0 Introduction                                             | 1  |
| 1.1 Scope of Works                                           | 1  |
| 2.0 Site Description                                         | 2  |
| 2.1 Hickson Road and Adjoining Barangaroo Development        | 2  |
| 2.2 EPA Declaration Area (#21122)                            | 2  |
| 2.3 Summary of Site History and Key Contaminants             | 2  |
| 2.4 Definition of Site                                       | 3  |
| 2.5 Remedial Action Plan and Methodology                     | 3  |
| 2.6 Role of Lend Lease                                       | 3  |
| 2.7 Surrounding Land Use and Receptors                       | 3  |
| 3.0 Historical Investigations                                | 4  |
| 4.0 Project Description                                      | 6  |
| 4.1 Preferred Method – <i>In-situ</i> Remediation            | 6  |
| 4.1.1 Site Establishment                                     | 7  |
| 4.1.2 Well and Piping Installation – Hickson Road            | 7  |
| 4.1.3 Perimeter Retention Wall                               | 7  |
| 4.1.4 <i>In-situ</i> Remediation Compound Set-up             | 7  |
| 4.1.5 <i>In-situ</i> Remediation Operation                   | 8  |
| 4.1.6 Localised Excavation (if required)                     | 8  |
| 4.1.7 Hickson Road Validation                                | 8  |
| 4.1.8 Remediation Area Decommissioning                       | 8  |
| 4.2 Alternative Method - <i>Ex-situ</i> Remediation          | 8  |
| 4.2.1 Site Establishment                                     | 9  |
| 4.2.2 Services Diversion                                     | 9  |
| 4.2.3 Perimeter Retaining Walls                              | 10 |
| 4.2.4 Dewatering and Water Treatment                         | 10 |
| 4.2.5 Construction of Excavation Enclosures                  | 10 |
| 4.2.6 Excavation                                             | 10 |
| 4.2.7 Soil Treatment / Disposal                              | 10 |
| 4.2.8 Hickson Road Area Validation                           | 11 |
| 4.2.9 Backfilling and Decommissioning                        | 11 |
| 4.3 Haul Roads and Required Plant                            | 11 |
| 4.4 Environmental Controls                                   | 11 |
| 4.4.1 Sediment Controls                                      | 11 |
| 4.5 Temporary Excavation Enclosures ( <i>Ex-Situ</i> Method) | 12 |
| 4.6 Filtration Systems ( <i>Ex-Situ</i> Method)              | 12 |
| 4.7 Other Controls                                           | 12 |
| 4.8 Decontamination Area                                     | 12 |
| 4.8.1 Personnel                                              | 12 |
| 4.8.2 Plant                                                  | 13 |
| 4.9 Site Access                                              | 13 |
| 5.0 Pollutants                                               | 14 |
| 5.1 Screening of Pollutants                                  | 14 |
| 5.2 Chemicals of Potential Concern (COPC)                    | 14 |
| 5.3 Potential Health Effects of Identified COPC              | 15 |
| 5.3.1 BTEX                                                   | 16 |
| 5.3.2 Polycyclic Aromatic Hydrocarbons (PAHs)                | 16 |
| 5.3.3 Total Petroleum Hydrocarbons (TPH)                     | 17 |
| 5.3.4 Particulate Matter                                     | 17 |
| 5.3.5 Heavy Metals                                           | 17 |
| 5.3.6 Odour                                                  | 18 |
| 5.3.7 Asbestos                                               | 19 |
| 6.0 Expected Pollutant Sources                               | 20 |
| 7.0 Potential Sensitive Receptors                            | 21 |

|            |                                        |    |
|------------|----------------------------------------|----|
| 8.0        | Relevant Exposure Pathways             | 23 |
| 8.1        | Conceptual Site Model                  | 24 |
| 8.2        | Measures for Reducing Exposure         | 24 |
| 8.2.1      | Source Controls                        | 24 |
| 8.2.2      | Pathway Controls                       | 25 |
| 9.0        | Potential Health Impact Assessment     | 27 |
| 9.1        | Assessment of Risks to Local Receptors | 27 |
| 10.0       | Conclusions                            | 30 |
| 11.0       | Recommendations                        | 31 |
| 12.0       | References                             | 32 |
|            | Figures                                | 33 |
| Appendix A |                                        |    |
|            | Qualitative Risk Ranking Framework     | A  |

#### List of Tables

|         |                                                                         |    |
|---------|-------------------------------------------------------------------------|----|
| Table 1 | Previous Investigations                                                 | 4  |
| Table 2 | Sediment Control Options                                                | 11 |
| Table 3 | Chemicals of Potential Concern and Expected Distribution - Hickson Road | 15 |
| Table 4 | Significant Exposure Groups                                             | 21 |
| Table 5 | Exposure Pathway Analysis                                               | 23 |
| Table 6 | Conclusions Regarding Site-derived Risks to Local Receptors             | 28 |

#### List of Figures

|          |                                                                                  |    |
|----------|----------------------------------------------------------------------------------|----|
| Figure 1 | Site Location                                                                    | 34 |
| Figure 2 | Illustrated Conceptual Site Model for Exposure to Chemicals of Potential Concern | 35 |

## Glossary of Terms

| Term                                   | Description                                                                                                                                                                                                                                                                                                                         |
|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Block 4 Remediation Area               | Portion of the Declaration Area situated within Barangaroo South.                                                                                                                                                                                                                                                                   |
| Block 5 Remediation Area               | Portion of the Declaration Area located within Barangaroo Central (including remediation of some land adjacent to the Declaration Area on the west)                                                                                                                                                                                 |
| COPC                                   | Chemicals of Potential Concern                                                                                                                                                                                                                                                                                                      |
| CSM                                    | Conceptual Site Model                                                                                                                                                                                                                                                                                                               |
| EPA                                    | Environment Protection Authority                                                                                                                                                                                                                                                                                                    |
| EPA Declaration Area                   | Remediation Site Declaration 21122                                                                                                                                                                                                                                                                                                  |
| <i>Ex-situ</i> Remediation Methodology | Excavation of contamination and off-site disposal (with on-site pre-treatment, where required)                                                                                                                                                                                                                                      |
| <i>In-situ</i> Remediation Methodology | Remediation using in-sit chemical oxidation and/or extraction (product recovery). Process would be using SISCO (surfactant enhanced in-situ chemical oxidation)                                                                                                                                                                     |
| Hickson Road Remediation Area          | Portion of the Declaration Area situated within the Hickson Road reserve                                                                                                                                                                                                                                                            |
| LLMP                                   | Lend Lease (Millers Point)                                                                                                                                                                                                                                                                                                          |
| MSDS                                   | Material Safety Data Sheets                                                                                                                                                                                                                                                                                                         |
| PPE                                    | Personal Protective Equipment                                                                                                                                                                                                                                                                                                       |
| RAP                                    | Remedial Action Plan                                                                                                                                                                                                                                                                                                                |
| RWP                                    | Remediation Works Plan                                                                                                                                                                                                                                                                                                              |
| SEG                                    | Significant Exposure Group                                                                                                                                                                                                                                                                                                          |
| Site                                   | Area required for the purpose of the Hickson Road Remediation Development Application identified as: <ul style="list-style-type: none"> <li>- Hickson Road Remediation Area</li> <li>- Any other areas of Barangaroo or Hickson Road required for staging and undertaking the remediation and stormwater diversion works</li> </ul> |
| Site Remediation Area                  | The Hickson Road Remediation Area                                                                                                                                                                                                                                                                                                   |
| VMP                                    | Voluntary Management Proposal                                                                                                                                                                                                                                                                                                       |

## Executive Summary

AECOM Australia Pty Ltd (AECOM) was engaged by Lend Lease Millers Point Pty Ltd (Lend Lease) to prepare a Health Impact Assessment (HIA) report to accompany a Development Application for remediation of part of Hickson Road at Millers Point (SSD 6617) to be submitted to the Minister for Planning and Environment pursuant to Part 4 of the *Environmental Planning and Assessment Act, 1979*. The area of Hickson Road to be remediated is the subject of NSW EPA Remediation Site declaration 21122. The HIA was prepared to respond to the Secretary's Environmental Assessment Requirements (SEARs), which were issued for the project on 18 August 2014, specifically SEAR 6 as described below:

*Assess the impacts on health (including extraction of sediments, off-site transport and treatment as well as disposal of sediments), during and following remediation, including details of human exposure scenarios and demonstration that the project will not have unacceptable acute or chronic health effects.*

The objective of this HIA was to perform a qualitative assessment of potential risks to health arising from the remediation works. A desktop study was undertaken, which reviewed the results of historical investigations conducted at the site, developed a conceptual site model to outline potential exposure pathways of pollutants based on the proposed remediation methodologies, and included a preliminary qualitative assessment of potential health risks to site workers and surrounding receptors. The assessment was conducted in general accordance with national guidelines for human health risk assessments (enHealth, 2012).

Previous site investigations identified the presence of a number of contaminants within soil and groundwater. The proposed remediation works would include excavation and dewatering works and, as such, will potentially liberate contaminants such that site workers and other receptors may be exposed to contaminated dust, vapours and groundwater.

The preferred remediation method for Hickson Road is the use of *in-situ* chemical oxidation/product extraction, which would involve the installation of subsurface wells and piping in Hickson Road and a temporary staging compound in the road reserve to facilitate the controlled injection of chemical mixtures into the ground to treat required areas of gasworks contamination. The installation of well and piping infrastructure would be undertaken in two stages – first on the western half, and then on the eastern half of Hickson Road. Approximately 60 groundwater injection wells of 50 mm diameter and around 30 soil vapour points would be expected to be installed, with the final numbers subject to the design of the selected contractor. Vapours from the remediation process would be vented to atmosphere through a stack, which would be serviced by carbon filters. Emissions would be in accordance with the conditions of the Environment Protection Licence issued for the works. A limited amount of excavation might be required if this methodology is adopted; any such excavations would be undertaken in the same manner as those described below.

The alternative remediation method is through selective excavation of contaminated material, followed by off-site disposal (and treatment where required) of material at licensed facilities, backfilling and re-instatement of road/footpath. Approximately 16,000 m<sup>3</sup> of material would be excavated in two stages to allow traffic access along Hickson Road throughout the remediation works. The excavations would be undertaken within excavation enclosures, which would capture and contain emissions, and subsequently vent them to atmosphere via a filtered stack. This remediation methodology would result in greater potential exposure of workers to pollutants than the preferred remediation method.

The preliminary health risk assessment determined that potential risks to workers were high (possible with moderate consequences) but manageable. Risks to off-site receptors were considered to be low as the excavation activities would be undertaken utilising temporary excavation enclosures, where practicable, with emissions to air subjected to filtration.

A number of pollutant management measures were recommended to minimise potential health impacts from the proposed works. Provided that these measures are diligently implemented, the project is not expected to result in unacceptable health effects. Key recommendations included implementation of a vapour and dust monitoring program during the works and incorporation of the proposed management and monitoring measures into the Project Construction Environmental Management Plan.

Overall, reductions of site-derived dust and odour, with confirmation through air concentration monitoring that relevant odorous and non-odorous COPCs are not elevated above health exposure guidelines, are recommended as important goals of proactive site management, as are responses to meteorological and emission conditions such as still (particularly autumn) days where natural ambient air dispersal may be at a minimum.

## 1.0 Introduction

AECOM Australia Pty Ltd (AECOM) was engaged by Lend Lease Millers Point Pty Ltd (Lend Lease) to prepare a Health Impact Assessment (HIA) report to accompany a Development Application (DA) for remediation of part of Hickson Road at Millers Point (SSD 6617) to be submitted to the Minister for Planning and Environment pursuant to Part 4 of the *Environmental Planning and Assessment Act, 1979*. The area of Hickson Road to be remediated is the subject of NSW EPA Remediation Site declaration 21122. The location of the site is shown in **Figure 1**.

The HIA was prepared to respond to the Secretary's Environmental Assessment Requirements (SEARs), which were issued for the project on 18 August 2014, specifically SEAR 6 as described below:

*Assess the impacts on health (including extraction of sediments, off-site transport and treatment as well as disposal of sediments), during and following remediation, including details of human exposure scenarios and demonstration that the project will not have unacceptable acute or chronic health effects.*

The assessment was conducted in general accordance with national guidelines for human health risk assessments (enHealth, 2012).

### 1.1 Scope of Works

The aim of this assessment was to identify contaminant exposures associated with remediation works that may potentially affect health in order to describe workplace controls that may be implemented to prevent these potential risks. The HIA included development of a Conceptual Site Model (CSM) for chemicals of potential concern (COPC), identification and assessment of potential exposure pathways, analysis of the potential for health impacts with respect to COPC location and availability, and identification of proposed risk-mitigating workplace controls.

This HIA constitutes a qualitative assessment of potential health impacts associated with the proposed remediation works of the Site.

The objective of this HIA was to perform a qualitative assessment of potential risks to health arising from the remediation works. Specifically, this HIA is a desktop study conducted through the following procedure:

- Review of available historical investigations conducted at the subject site;
- Consideration of the results of the qualitative human health risk analysis undertaken for remediation worker and adjacent public exposure during the proposed remediation activities;
- Development of a conceptual site model outlining potential exposure pathways based on proposed remediation options;
- Desktop qualitative assessment of pollutant emissions to a hypothetical on-site worker or public person at the site boundary;
- Preliminary qualitative risk assessment of potential risks to health arising from the proposed remediation works (including cumulative impacts) including:
  - identification of potential hazard sources (both directly related to the works in the Hickson Road Remediation DA and other commensurate development);
  - identification of relevant receptors;
  - identification of potentially complete and significant exposure pathways; and
  - consideration and provision of commentary on resultant potential risk consequences.

## 2.0 Site Description

### 2.1 Hickson Road and Adjoining Barangaroo Development

Barangaroo is located on the north western edge of the Sydney Central Business District (CBD), bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east; and bounded to the south by a range of new development dominated by large CBD commercial tenants.

The 22 hectare (ha) Barangaroo site is roughly rectangular in shape and has frontage to the harbour foreshore of 1.4 km. Hickson Road is a public road that is adjacent to the eastern boundary of Barangaroo.

The Barangaroo Delivery Authority is the state government managing and delivering the development of Barangaroo.

### 2.2 EPA Declaration Area (#21122)

In May 2009, the EPA determined that a portion of land at Millers Point (part of the Barangaroo Site and an adjacent portion of Hickson Road) was contaminated in such a way as to present a significant risk of harm to human health and the environment. As a consequence, the EPA declared the area to be a remediation site (Declaration Number 21122; Area Number 3221) under the Contaminated Land Management Act 1997.

The Remediation Site Declaration 21122 indicates that the area of the declaration (Declaration Area) coincides with the known footprint of the former Millers Point gasworks facilities. This area is located on part of Barangaroo and part of Hickson Road adjacent to Barangaroo.

In accordance with Declaration Number 21122, the Declaration Area comprises:

- Part Lot 5 and Part Lot 3 DP 876514, Hickson Road, Millers Point, NSW 2000.
- Part of Hickson Road adjacent to:
  - 30 - 34 Hickson Road (Lot 11, DP1065410);
  - 36 Hickson Road (Lot 5, DP873158); and
  - 38 Hickson Road (SP72797) Millers Point.

The Barangaroo Delivery Authority has entered into a Voluntary Management Proposal (VMP) with the EPA associated with EPA Declaration Area (Approval No. 20101719). Phase 1 of this VMP involves investigative works and undertaking remedial design to determine and obtain agreement on a proposed remediation methodology. Phase 2 of the VMP will involve the implementation of the agreed remediation works. An independent, EPA-accredited Site Auditor has been appointed to undertake review of proposed remediation works and prepare statutory audit statements prior to and following completion of remediation.

For the purposes of planning and staging works, the EPA Declaration Area is divided into the following three areas:

- Block 4 Remediation Area - the part of the Declaration Area on Barangaroo South;
- Block 5 Remediation Area - the part of the Declaration Area on Barangaroo Central; and
- Hickson Road Remediation Area - the part of the Declaration Area located on Hickson Road.

This DA is for the Hickson Road Remediation Area only. Remediation for the Block 4 and Block 5 Remediation Areas were the subject of separate development applications.

### 2.3 Summary of Site History and Key Contaminants

The Millers Point gasworks operated on the Declaration Area between 1840 and 1921. The Site has subsequently been used for various activities, but predominantly a commercial port facility and public road.

When the EPA declared parts of Barangaroo and Hickson Road a "Remediation Site", it described the nature of contamination as gasworks waste with the following particular substances: polycyclic aromatic hydrocarbons (PAHs); benzene, toluene, ethylbenzene and total xylenes (BTEX); total petroleum hydrocarbons (TPH); ammonia and cyanide.

The *VMP/Block 4 Remedial Action Plan* (RAP) (AECOM 2013) provides more specific details regarding the type, magnitude and location of ground contamination of the site as identified in previous site investigations.

## 2.4 Definition of Site

For the purposes of the Hickson Road Remediation Development Application, the site includes the area of Hickson Road to be remediated (Site Remediation Area), plus any adjacent land used for the staging and undertaking of the proposed remediation. The Site Remediation Area comprises the part of Hickson Road within the Declaration Area that requires remediation, per the RAP.

## 2.5 Remedial Action Plan and Methodology

The proposed remediation of the Declaration Area is detailed in the *VMP/Block 4 RAP* (AECOM 2013). The *VMP/Block 4 RAP* (AECOM 2013) included two potential methodology options for Hickson Road:

- Preferred - *In-situ* remediation (chemical oxidation); or
- Alternate - *Ex-situ* remediation (excavate, off-site disposal and backfill).

The Development Application for Hickson Road Remediation includes undertaking either the preferred or the alternative method above, with the final method to be selected following agreement with the EPA.

## 2.6 Role of Lend Lease

Lend Lease was contracted by the Barangaroo Delivery Authority to undertake remediation of the Declaration Area, which includes the Hickson Road Remediation Area. Lend Lease was also appointed by the Barangaroo Delivery Authority as the Proponent to undertake the development for Barangaroo South.

## 2.7 Surrounding Land Use and Receptors

The site is bordered by Block 4 and Block 5 on the western side and by commercial and residential properties to the east. The closest receptors are located approximately 25 m to the east of the site boundary, and consist of residential and commercial properties. A number of finger wharves containing a mixture of residential and commercial developments are located directly opposite the site, the closest being approximately 250 m west of the site, while the residential suburb of Balmain East is located approximately 400 m to the west of the northern end of the site. Details of the sensitive receptors incorporated into the dispersion modelling undertaken for the *Air Quality Impact Assessment* (AQIA) (AECOM, 2015a) for the DA are provided in **Section 7.0**.

### 3.0 Historical Investigations

The Human Health and Ecological Risk Assessment (HHERA) prepared for the remediation activities of the EPA Declaration Area (AECOM, 2012b) provides a comprehensive summary of previous investigations undertaken at the Site. Relevant investigations are summarised in **Table 1**.

**Table 1 Previous Investigations**

| Date of Publication | Consultant                  | Report Title and Key Issues                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| June 2007           | ERM Australia Pty Ltd       | <i>Environmental and Geotechnical Site Assessment, East Darling Harbour, Sydney, NSW Final Report – Revision 1</i> – ESA intended to identify and report the environmental site conditions in preparation for the proposed development. Works included the completion of a Stage 1 Investigation and Stage 2 ESA comprising drilling and sampling of soils and groundwater at 150 locations (inclusive of Lots 1, 2, 4 and Northern portion of Lot 5). Chemicals of potential concern (COPC) were identified in groundwater in the vicinity of the former gas works.                                                                                                                                                                                             |
| May 2008            | Coffey Environments Pty Ltd | Preliminary environmental investigation at 30-38 Hickson Road, conducted for the City of Sydney Council. Included the drilling and sampling of 15 boreholes and the installation of 6 groundwater monitoring wells. Area of investigation included Hickson Road and the courtyard area between 30 and 38 Hickson Road.                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| June 2008           | ERM Australia Pty Ltd       | <i>Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW – Draft, Revision 1</i> – intended to address data gaps remaining following the Stage 2 ESA and included an additional 55 boreholes and construction of 13 monitoring wells across the site (inclusive of Lots 1, 2, 4 and Northern portion of Lot 5). The report identified the former gas works and reclaimed areas between the finger wharves as key areas of concern. Exceedences of assessment criteria for soil were identified for lead, TPH, PAH, BTEX and sulfate. The highest levels were identified in the vicinity of the former gas works and included the identification of phase separated hydrocarbons (PSH) in MW204D located within the gas works footprint. |
| August 2008         | ERM Australia Pty Ltd       | <i>Preliminary Sediment Screening Works at East Darling Harbour, Adjacent to Barangaroo, NSW, Draft, Rev 03</i> – preliminary sediment screening works were conducted at East Darling Harbour to identify potential offsite migration of contamination from the site to sediments in Darling Harbour. Sediments cores were collected from the Harbour adjacent to the site along 7 transects. Screening identified PAH, tributyl tin (TBT) and metals exceeding ANZECC (2000) and elevated levels of organochlorine pesticides (OCPs) and TPH C <sub>10</sub> -C <sub>36</sub> fractions.                                                                                                                                                                        |

| Date of Publication | Consultant | Report Title and Key Issues                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| September 2010      | AECOM      | <p>Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo Site and Hickson Road) Hickson Road, Millers Point NSW (AECOM, 2010a)</p> <p>The purpose of the DGI was to reduce uncertainties which exist in the current data set, confirm the characteristics of soil and groundwater underlying the Site, provide the additional data required if a quantitative HHERA is developed and facilitate the development of a RAP and Remediation Works Plan (RWP) which describe the remediation strategy to be implemented by Lend Lease as part of its proposed Stage 1 Development of the Barangaroo Precinct. The DGI identified elevated concentrations of chemicals of potential concern in soil and groundwater exceeding the adopted site investigation criteria. The reported results were considered to be primarily associated with the area's former land use as a gas manufacturing plant and with the importation of fill materials to level the site.</p>                                                                                                                                                                                                  |
| October 2010        | AECOM      | <p>Data Gap Investigation, Other Remediation Works (North) Area, Hickson Road, Millers Point NSW (AECOM, 2010b)</p> <p>The purpose of the DGI was to reduce uncertainties which exist in the current data set, confirm the characteristics of soil and groundwater underlying the site, provide the additional data required if a quantitative HHERA is developed and facilitate the development of a RAP and RWP which describe the remediation strategy to be implemented by Lend Lease as part of its proposed Stage 1 Development of the Barangaroo Precinct. The DGI identified elevated concentrations of contamination exceeding the adopted site investigation criteria. The reported results are considered to be primarily associated with contamination that has migrated from the former gasworks located on the eastern boundary of the Site (to the east) and to a lesser extent with the historic importation of fill materials during reclamation work. Since the DGI was prepared, the boundaries of the Remediation Areas have changed such that part of the Other Remediation Works (North) Area has been incorporated into the Site Remediation Area.</p> |
| March 2012          | AECOM      | <p>Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW. (AECOM, 2012a)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

## 4.0 Project Description

The following sections summarise the works proposed as part of the Hickson Road Remediation Development Application for the preferred and alternate remediation methods. Hickson Road is to remain open to traffic for both options, with required temporary road closures/diversion in place during remediation works.

### 4.1 Preferred Method – *In-situ* Remediation

The preferred remediation method for required Hickson Road areas is to use *in-situ* chemical oxidation/product extraction. The *in-situ* remediation method will be SISCO/SEPR (Surfactant Enhanced In-Situ Chemical Oxidation and Surfactant Enhanced Product Recovery) or a similar *in-situ* oxidation process.

The *in-situ* remediation process involves the installation of subsurface wells and piping in Hickson Road and a temporary staging compound in the road reserve, which will facilitate the controlled injection of chemical mixtures into the ground to treat required areas of gasworks contamination in-situ.

The works are summarised below:

- Localised pruning of street trees where required to facilitate works.
- Undertaking temporary lane/traffic diversion as required during works.
- Undertaking local service diversion or protection as required.
- Maintaining access to the driveways of 30 and 38 The Bond.
- Installation of remediation infrastructure (wells and piping) in Hickson Road.
- Installation of a temporary remediation compound/staging area in Hickson Road reserve.
- Installation of boundary groundwater control walls where required.
- Undertaking *in-situ* chemical oxidation remediation through controlled injection and extraction.
- Management of extracted fluids through limited storage/treatment within the Hickson Road site; transfer to a water treatment plant on the Barangaroo site; or tankering off-site.
- If required, undertaking localised excavation and off-site disposal with appropriate odour control measures. Excavation enclosures would be used for significant excavation works, with alternative suitable odour controls applied for minor excavation works. Alternative controls would include limiting exposed excavations, and use of foams, covers and odour suppressants. Some limited on-site pre-treatment may be undertaken to make the material transportable (e.g. use of additives/dry spoil to reduce moisture and make material spadeable).
- Undertaking detailed environmental monitoring (air, noise, water) for the duration of works.
- Validating the remediation per *VMP/Block 4 RAP* (AECOM, 2013), including groundwater monitoring where required.
- Decommissioning sub-surface well/piping infrastructure (capping and leaving in-situ).
- Re-surfacing required areas of road/pavement.

The installation of well and piping infrastructure would be undertaken in two stages – first on the western half, and then on the eastern half of Hickson Road. Approximately 40 groundwater injection wells of 50 - 100 mm diameter and around 30 soil vapour points would be expected to be installed, with the final numbers subject to the design of the selected contractor. The soil vapour extraction system would be serviced by carbon filters, and emissions would be in accordance with the conditions of the Environment Protection Licence issued for the works.

Some limited excavation of material may be required if the *in-situ* treatment method is implemented. The excavations would be undertaken in the same manner as planned for the *ex-situ* remediation method, with excavation enclosures used for significant excavation works, and alternative suitable odour controls applied for minor excavation works.

Further details regarding the proposed works are provided below.

#### 4.1.1 Site Establishment

- Temporary traffic diversion would be implemented as required (including temporary removal of street parking)
- Pedestrian diversions would be implemented where required.
- Local protection/pruning of Hickson Road trees would be undertaken where required for well installation.
- General environmental controls would be installed for works (e.g. bunding, sediment controls).

#### 4.1.2 Well and Piping Installation – Hickson Road

- Installation would generally be undertaken in two stages – west half and then east half of road. Localised traffic diversion and management on Hickson Road and footpath.
- Groundwater injection or monitoring wells – would be installed per *Preliminary ISCO Remediation Work Plan* (AECOM, 2014) and any modifications as required following the Pilot Trial. There are expected to be approximately 40 wells (50 - 100 mm diameter) – final quantity subject to selected contractor design.
- Soil Vapour Points would be installed per the *Preliminary ISCO Remediation Workplan* (AECOM 2014) and any modifications as required following the Pilot Trial. There are expected to be approximately 30 soil vapour points (final quantity subject to selected contractor design).
- Cutting of pavement and excavation of shallow trenches would be undertaken to install required piping to connect wells to central compound area in the Hickson Road reserve.
- Where required, wells and pavement would be re-instated, or road plates as applicable, to allow continued trafficking over. Some temporary traffic diversion may remain around some wells as required for access and monitoring during works.
- Spoil generated would be transferred off-site for treatment or disposal, following classification
- Excess water would be collected, sampled and transferred for treatment, as required, and disposed accordingly.

#### 4.1.3 Perimeter Retention Wall

- A groundwater control wall (e.g. secant piles) would be installed to gasworks structures at 36 Hickson Road boundary.
- Odour control would be implemented per the Preliminary Hickson Road PRW Odour Control Plan.

#### 4.1.4 In-situ Remediation Compound Set-up

- For each remediation stage – east half and then west half –temporary compounds would be set-up in road reserve.
- The temporary compound area within road reserve would be hoarded and fully secured to prevent unauthorised access.
- Appropriate traffic diversions would be in place per the Traffic Impact Assessment and any subsequent approved Traffic Control Plans.
- Vehicle and pedestrian access would be maintained to 38 Hickson Road and Sewer Pumping Station 1129.
- Establishment of plant/equipment and site accommodation, including after-hours deliveries for over-sized loads or to minimise peak hour traffic impact.
- Chemical storage, deliveries and use within compound area would be in accordance with the Preliminary ISCO Workplan, future detailed contractor design and Dangerous Goods Storage requirements.
- Chemical or extracted liquid storage would be fully bunded as required.
- The soil vapour extraction system would be set-up with carbon filters and emissions stack per Environment Protection License requirements.

#### 4.1.5 *In-situ* Remediation Operation

- Remediation would be undertaken in two stages:
  - 1st stage – east half of road/footpath (with traffic diverted to west)
  - 2nd stage – west half of road/footpath (with traffic diverted to east)
- Traffic diversions would be implemented to maintain vehicle and pedestrian movement along Hickson Road.
- Injection and extraction would be undertaken in required areas in accordance with the AECOM Remedial Action Plan, Preliminary ISCO Workplan, and future detailed contractor design.
- Chemical/materials would be delivered to site as required during works.
- Waste soil/material would be collected for classification, treatment & disposal off-site.
- Wastewater would be treated within the Hickson Road remediation compound area or transferred to a water treatment plant on the Barangaroo site (for subsequent disposal per the EPL); disposed off-site to a licensed liquid waste facility by licensed tanker trucks; or disposed of via sewer under a trade waste licence.
- Detailed monitoring would be undertaken for the duration of works.

#### 4.1.6 Localised Excavation (if required)

- If required, localised contamination excavation would be undertaken to supplement *in-situ* remediation process.
- Any excavation would subject to detailed odour control measures, which may include excavation enclosures or suitable alternate controls (e.g. odour suppressants, foams, covering). The extent of controls required will be assessed based on the amount of excavation proposed and agreed with the EPA prior to commencing.
- All excavated material would be loaded into sealed trucks and transported off-site to a licensed facility for treatment/disposal.

#### 4.1.7 Hickson Road Validation

- Remediation areas would be validated as per RAP, including detailed soil and groundwater sampling.

#### 4.1.8 Remediation Area Decommissioning

- All above ground infrastructure and plant would be removed.
- All below ground wells/piping would be capped and left *in-situ*.
- Temporary restoration of Hickson Road pavement and footpath would be undertaken where required around wells/piping.
- Traffic diversions would be removed and regular traffic restored.

### 4.2 Alternative Method - *Ex-situ* Remediation

If the preferred *in-situ* method is not undertaken, the alternative, *ex-situ*, remediation method would be used. For the *ex-situ* method, remediation would be undertaken through selective excavation of required Hickson Road areas (including footpath) followed by off-site disposal (and treatment, where required) of material at licensed facilities, backfilling and re-instatement of road/footpath. Approximately 16,000 m<sup>3</sup> of material would be excavated. The works are summarised below:

- Removal of street trees where required to facilitate excavation works.
- Undertaking temporary lane / traffic diversion as required during works.
- Undertaking local service diversion or protection as required.
- Maintaining access to the driveways of 30 and 38 The Bond.
- Undertaking remediation in two main stages (east and west):
  - Temporarily closing one half of Hickson Road and undertaking remediation while traffic is diverted to other half.

- Re-instatement of access to the remediated half of Hickson Road, and re-diverting traffic to complete remaining stage.
- Installation of boundary groundwater control walls and walls to facilitate staged excavation, where required.
- Installation of excavation enclosures over the excavation area (in stages as required).
- Excavation of gasworks contamination in stages, where required, from beneath road/footpath.
- Excavation of rock, if required, to facilitate access to deep contamination within the annulus trench.
- Transfer of excavation water to a water treatment plant on the Barangaroo site for treatment/disposal.
- Transfer of contaminated material directly off-site for disposal and/or treatment at a licensed facility as envisaged by Sections 13.3 and 14.1 of the *VMP/Block 4 RAP* (AECOM, 2013). The offsite treatment works would be subject to the facilities' environmental controls, such as the conditions of their Environment Protection Licences. Some limited on-site pre-treatment may be undertaken to make the material transportable (e.g. use of additives/dry spoil to reduce moisture and make material spadeable).
- Undertaking detailed environmental monitoring (e.g. air, noise) for the duration of works.
- Validation of the remediation per the *VMP/Block 4 RAP* (AECOM, 2013).
- Backfilling excavations with suitable imported fill or suitable excavated material.
- Decommissioning of odour tents.
- Re-surfacing of road / pavement.
- Planting of new street trees to replace those removed.
- Removal of temporary traffic diversions.

Regular cleaning/sweeping of the roads will be required as part of the remediation excavation activities to ensure silt build up does not occur. Lend Lease proposes to cover haulage trucks prior to exiting the temporary excavation enclosures and trucks would be decontaminated (where required) prior to moving to other areas of site or off-site.

Further details regarding the proposed works are provided below.

#### **4.2.1 Site Establishment**

- Traffic diversions would be implemented to establish temporary work zones where remediation and works staging is required. Through traffic would be maintained on Hickson Road at all times.
- Pedestrian diversions would be implemented as required.
- Remediation would be undertaken in two main stages (east and west):
  - 1<sup>st</sup> stage – One half of Hickson Road would be temporarily closed and traffic diverted to the other half of the road while remediation, backfilling and re-surfacing are undertaken.
  - 2<sup>nd</sup> stage – Traffic would then be rediverted to the other half of the road and the works completed.
- Site hoarding/exclusion zones and decontamination areas would be installed.
- Local protection, pruning or removal of site trees would be undertaken as required per the Arboricultural Impact Assessment
- General environmental controls would be installed for excavation works (e.g. bunding, sediment controls).
- Plant/equipment would be installed and site accommodation would be implemented, including after-hours deliveries for over-sized loads or to minimise peak hour traffic impact.

#### **4.2.2 Services Diversion**

- Temporary diversions or protection of existing services would be implemented as required.

#### 4.2.3 Perimeter Retaining Walls

- A groundwater control wall (e.g. secant piles) would be installed to gasworks structures at 36 Hickson Road boundary.
- Retention walls (e.g. secant piles) would be constructed within Hickson Road as required to facilitate excavation in controlled stages.
- Odour control would be implemented per the Preliminary Hickson Road PRW Odour Control Plan.
- Temporary ground anchors or associated support structures would be installed.

#### 4.2.4 Dewatering and Water Treatment

- Dewatering infrastructure and piping would be installed to transfer dewatered groundwater to a water treatment plant on Barangaroo. Works would include trenching across the road (and appropriately restored to allow continued trafficking over).
- Groundwater extraction, transfer of water to the water treatment plant, treatment of water and discharge would be undertaken per EPL requirements.
- Where required, highly contaminated liquid waste may be pumped by licensed liquid waste contractors (vacuum truck) and disposed off-site.

#### 4.2.5 Construction of Excavation Enclosures

- Temporary excavation enclosures would be installed over required excavation areas in stages. This may include installation of temporary ground structures (e.g. piles/capping beam) and/or perimeter weights as required to provide support.
- Structures would be installed to ensure all odours are contained. Structures would be serviced by an air exhaust system and associated emissions control, air filters/treatment and stack.
- Excavation enclosures may include retractable doors and an air lock system at the entrance/exit to minimise odour emissions.
- Final structures would be subject to future detailed design.

#### 4.2.6 Excavation

- Contaminated soil would be excavated from Hickson Road in accordance with the AECOM Remedial Action Plan - indicative excavation volume approximately 16,000 m<sup>3</sup>
- Excavation of east and west halves of Hickson Road would be undertaken in stages. All excavation would be undertaken beneath excavation enclosures.
- Rock would be excavated where required to facilitate contamination excavation from historic gasworks structures.
- Temporary excavation enclosures would be operated to manage and treat exhausted air.
- Water from excavations with no visible or olfactory signs of contamination (including surface water sheens or a smell or tar or petroleum) would be transferred to the onsite WTP for treatment and licensed discharge. Where required, highly contaminated liquid waste (i.e. that with a strong odour or high level of visible contamination) would be pumped by licensed liquid waste contractors (vacuum truck) and disposed of off-site.
- Vehicles/plant would be decontaminated in wheel wash/cleaning area prior to moving off-site.
- Detailed monitoring (air, noise, water) would be undertaken throughout the works.

#### 4.2.7 Soil Treatment / Disposal

- Excavated contaminated material would be transported directly off-site for treatment or disposal in accordance with NSW EPA requirements and waste guidelines. Temporary stockpiling may be required to classify or inspect material. Some limited on-site pre-treatment may be undertaken to make the material transportable (e.g. use of additives/dry spoil to reduce moisture and make the material spadeable).
- All excavated material would be transferred in sealed trucks (with odour suppressant foam or similar as required) to mitigate potential odours.

- Hazardous classified material would be transported off-site to a licensed treatment facility for treatment prior to landfill disposal in accordance with the *VMP/Block 4 RAP* (AECOM, 2013b).

#### 4.2.8 Hickson Road Area Validation

Remediation areas would be validated as per RAP, including detailed soil and groundwater sampling.

#### 4.2.9 Backfilling and Decommissioning

- Following each excavation stage, temporary excavation enclosures would be decommissioned.
- Excavations would be backfilled and compacted with suitable imported fill.
- Temporary restoration of road/pavements would be undertaken as required to match existing surfaces.
- Following works, new street trees would be planted to replace those removed (unless new landscaping requirements are approved generally for Hickson Road under separate DA/approvals).

### 4.3 Haul Roads and Required Plant

The site is currently covered in hardstand, which would be retained wherever practicable. As such, haul roads between the temporary excavation enclosures (under which the excavation works would be undertaken) and the site boundary would generally be paved. Regular cleaning/sweeping of the paved haul roads will be required as part of the remediation excavation activities to ensure silt build up does not occur.

Lend Lease proposes to cover haulage trucks prior to exiting the temporary excavation enclosures and trucks would be decontaminated (where required) prior to moving to other areas of site or off-site. Trucks transporting potentially odorous material would be covered with odour suppressant foam (or similar) prior to leaving the site, to mitigate odour emissions.

### 4.4 Environmental Controls

Due to the scale of the works and close proximity to sensitive receptors, the effectiveness of environmental controls and environmental management is critical to the overall success of the project. The EPA recommended that environmental management at Barangaroo should focus on source controls rather than end of pipe controls. Primary management was, therefore, the focus of proposed mitigation strategies; a number of secondary (end of pipe) controls are also recommended where necessary.

#### 4.4.1 Sediment Controls

In accordance with the EPA recommendations, the most effective sediment management measures will be based on source controls. As a contingency for the failure of source controls, a number of secondary controls should be constructed. A list of primary (source) controls and a number of secondary controls recommended in the *City of Sydney Guidelines to Erosion and Sediment Control on Building Sites* are provided in **Table 2**.

**Table 2 Sediment Control Options**

| Category           | Control Device                    | Location                                                                               |
|--------------------|-----------------------------------|----------------------------------------------------------------------------------------|
| Source controls    | Temporary excavation enclosures   | Remediation excavations                                                                |
|                    | Gutter                            | Temporary excavation enclosures /temporary buildings                                   |
|                    | Sediment sumps                    | Inside temporary excavation enclosures                                                 |
|                    | Runoff diversion                  | Perimeter of temporary excavation enclosures and stockpile areas                       |
|                    | Tarping/mulching/gravel armouring | External stockpiles (non-contaminated material only) and exposed soils, haulage trucks |
| Secondary controls | Wheel wash                        | Site exit                                                                              |
|                    | Shaker grids                      | Exits to temporary excavation enclosures                                               |
|                    | Sediment fence                    | Stormwater inlets, stockpile perimeters                                                |
|                    | Sediment sock                     | Stormwater inlets, stockpile perimeters                                                |

| Category | Control Device | Location                                |
|----------|----------------|-----------------------------------------|
|          | Straw bales    | Stormwater inlets, stockpile perimeters |

#### 4.5 Temporary Excavation Enclosures (*Ex-Situ* Method)

The purpose of the excavation enclosures is to minimise the release of malodorous and potentially harmful emissions during remediation excavation operations for the *ex-situ* method. The excavation enclosures would act as the predominant primary control of all environmental emissions at the site. Excavation enclosures would be established above excavation operations, essentially isolating these work areas from the external environment. The excavation enclosures would be constructed of impervious material, generally creating a seal between the internal and external atmosphere, and would include stormwater interception devices where practicable. Air quality monitoring will be conducted within the excavation enclosures to demonstrate that the atmosphere does not represent an unacceptable risk to workers.

Structure dimensions will be developed based on the following three primary goals:

- Cover and isolate potentially odorous works areas;
- Ensure adequate size to facilitate production rates sufficient to maintain the remediation works program; and
- Encapsulate a volume of air able to be reasonably ventilated and filtered.

#### 4.6 Filtration Systems (*Ex-Situ* Method)

The temporary excavation enclosures would be serviced by a number of filtration systems and fresh air fans. The filtration systems would be designed to reduce emissions to concentrations compliant with the relevant environmental standards and/or approved site emission criteria for Barangaroo South and would:

- Maintain fresh air circulation and an appropriate safe working environment inside excavation structures; and
- Reduce the concentration of potentially harmful gas and dust concentrations and malodorous emissions exiting structures.

The system is expected to be designed to achieve two to three complete air exchanges per hour within the structures, which will require the use of many filtration units. The systems would primarily consist of appropriately sized granular activated carbon (GAC) filters with particulate pre-filters. Multiple GAC filters (minimum of two) would be required to prevent fugitive emissions during filter exchanges. Filter saturation and changeover frequency would generally be guided by the environmental consultant based on stack emission monitoring. It is expected that filter changeover will be required approximately every two to three months.

The final design and detailing of Filtration Systems would be subject to further design development.

#### 4.7 Other Controls

The environmental control measures mentioned above would be regularly checked to ensure their ongoing integrity and operability. Any spillages would be appropriately managed in accordance with an Emergency Response and Contingency Plan to be prepared by Lend Lease as required by Section 13.1.3 of the *VMP/Block 4 RAP* (AECOM, 2013).

All excavated odorous material taken off site would be treated to minimise potential emissions of dust or odour. For example, odour suppressant foam (such as Rusmar AC-645 or equivalent) or similar materials would be used to seal the loads. As confirmed in the *Barangaroo Hickson Road Remediation DA (SSD 6617) – Preliminary Methodology for Off-site Transport and Treatment of Hazardous Waste* (AECOM, 2015b), the proposed off site transport is consistent with the *VMP/Block 4 RAP* (AECOM, 2013) and compliant with both the NSW EPA (2014) *Waste Classification Guidelines* and the amended *Protection of the Environment Operations (Waste) Regulation* (2014).

#### 4.8 Decontamination Area

##### 4.8.1 Personnel

For the *ex-situ* method, decontamination units would be established at the primary entrance/exit to each temporary excavation enclosures, and should include:

- Potable water supply;
- Running water and industrial hand wash;
- Waste bins;
- Supply of fresh personal protective equipment (PPE);
- Emergency shower (for inclusion based on risk assessment and Material Safety Data Sheets [MSDSs]); and
- Change area.

#### **4.8.2 Plant**

Decontamination would be required when earthmoving plant has been working with contaminated material and is due to be removed from site or transferred to a clean validated area. The plant decontamination area would consist of the following:

- A nominated hardstand area with adequate drainage (may be established inside odour and dust control structures);
- A drainage trap and pump system to allow all contaminated washout to be captured and pumped to water treatment plant on the Barangaroo site;
- Sediment controls around drains to intercept gross pollutants;
- Adequate water supply and high pressure cleaner;
- Waste bins; and
- Cleaning tools and detergent.

#### **4.9 Site Access**

Remediation works would be demarcated with temporary fencing and appropriate construction and traffic warning signage to restrict public access to the Site Remediation Area, as well as unauthorised access of general construction personnel to remediation areas and confined spaces. All confined spaces and other high risk areas of the Site Remediation Area would be identified and signposted/barricaded to restrict access and warn personnel of the risk. Confined spaces would be identified using the definition provided in AS2865-2009 and based on a risk assessment prior to the commencement of remediation works.

## 5.0 Pollutants

### 5.1 Screening of Pollutants

The distribution of soil and groundwater contamination in areas relevant to this HIA was assessed within the Data Gap Investigations (DGIs) (AECOM 2010a and 2010b) and the *VMP/Block 4 RAP* (AECOM, 2013). These investigations were not reproduced in this report in detail.

The DGIs identified that the primary potential for contamination at the site originates from:

- Potentially contaminated fill materials used in historical land reclamation within the site; and
- Potential migration of contamination from the former gasworks site located on the site.

Through the DGI study, soil and groundwater sampling results were compared with a multitude of generic regulatory assessment criteria in order to identify criteria contaminants. Concentrations of contaminants including heavy metals, TPH, benzene and xylenes (hereafter referred to within the category of benzene, toluene, ethylbenzene and xylenes [BTEX]), PAHs [including B(a)P] and sulfate were found to exceed the adopted site investigation criteria at various locations and depths.

### 5.2 Chemicals of Potential Concern (COPC)

For the purposes of this HIA, chemicals of potential concern (COPC) were defined as chemicals that have been detected on the site in concentrations greater than relevant human health screening criteria. The pollutants considered were restricted to those detected within the site boundaries as defined previously and were limited to those addressed in the *HHERA* (AECOM, 2012b).

The principal pollutants considered were:

- BTEX;
- PAHs;
- TPH (C<sub>6</sub>-C<sub>9</sub> and C<sub>10</sub>-C<sub>36</sub> fractions); and
- Heavy metals.
- Asbestos was not identified as a chemical of potential concern within the *Declaration Site HHERA* (AECOM, 2011a) based on the information available at the time of report preparation. Asbestos had been detected in only a limited number of sample locations and was not considered to be widespread. Subsequent earth works of the Other Remediation Works South (ORWS) Area, located south of and adjacent to the Declaration Site, identified asbestos contamination in that area. Based on review of the Sydney 1930 aerial photograph, however, demolition of the former gasworks infrastructure and the formation of Hickson Road occurred before 1930 and prior to the land reclamation works in the ORWS area (which occurred after 1951). *Broomhall* (2007) states that Hickson Road was formed in the mid-1920s. Consequently, asbestos impacts in the Hickson Road area are not expected to be similar to those observed during the ORWS bulk excavation works. The risk of inhaling asbestos fibres is most appropriately managed through implementation of appropriate management tools in the *VMP/Block 4 RAP* (AECOM, 2013) and through the preparation and implementation of an Asbestos Management Plan. Nevertheless, asbestos is included in the health impact assessment below as a basis for including its consideration throughout the remediation project.

The distributions of the COPC were detailed in the *DGI* (AECOM, 2010a). The details for the Hickson Road Remediation Area are summarised in **Table 3**.

Table 3 Chemicals of Potential Concern and Expected Distribution - Hickson Road

| COPC Category                                                      | Distribution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| BTEX (particularly benzene and xylenes)                            | <p><b>Soil:</b> Maximum concentrations of BTEX were generally in proximity to and down gradient of the former gasworks infrastructure. BTEX compounds exceeded the adopted site investigation criteria.</p> <p><b>Groundwater:</b> Significant concentrations reported in groundwater underlying the former footprint of the gasworks infrastructure.</p> <p><b>Air:</b> BTEX may vaporise from exposed soil or water, and also may be carried into the air whilst sorbed to small soil particles.</p>                                                                                                                                                                                                                                                                                                                  |
| PAHs [particularly benzo(α)pyrene or B(α)P]                        | <p><b>Soil:</b> B(a)P and total PAH assessment criteria exceedences were detected in shallow fill and at depth in natural soils.</p> <p><b>Groundwater:</b> Concentrations of naphthalene within the Hickson Road Remediation Area exceeded the site investigation criteria.</p> <p><b>Air:</b> PAHs may vaporise from exposed soil or water, and also may be carried into the air whilst sorbed to small soil particles.</p>                                                                                                                                                                                                                                                                                                                                                                                           |
| TPH                                                                | <p><b>Soil:</b> Exceedences of soil assessment criteria for C<sub>6</sub>-C<sub>9</sub> and C<sub>10</sub>-C<sub>36</sub> were found in a number of areas and a variety of depths.</p> <p><b>Groundwater:</b> Significant concentrations of TPH were reported in groundwater underlying the former footprint of the gasworks infrastructure.</p> <p><b>Air:</b> TPH comprises many chemical species, including BTEX and many PAHs, which may be considered representative of the volatile fractions of TPH (ATSDR 1999). Since TPH distribution was found to be consistent with PAH distribution in soil and groundwater, distribution in air is expected to be consistent with PAH distribution in air.</p>                                                                                                            |
| Suspended particulates (dust)                                      | <p><b>Air:</b> Suspended particulates would be generated during drilling and excavation activities. Suspended particles may carry small quantities of other COPC listed above.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Heavy metals (particularly lead, cadmium, copper, nickel and zinc) | <p><b>Soil:</b> Lead was the only heavy metal found to exceed soil assessment criteria. Exceedences found at shallow depths.</p> <p><b>Groundwater:</b> Heavy metals concentrations were reported above the assessment criteria adopted for the DGI in several groundwater samples. Exceedences were recorded for lead, cadmium, chromium (III &amp; VI), copper, nickel and zinc.</p> <p><b>Air:</b> Heavy metals are not volatile (with the exception of mercury, which may volatilise due to vapour pressure), so the presence of heavy metals in air is generally expected to be associated with suspended particles. Limited soil disturbance should minimise dust generation.</p>                                                                                                                                 |
| Odour                                                              | <p><b>Air:</b> The <i>Data Gap Investigation</i> (AECOM, 2010a) indicated that odours were commonly encountered in the soil and fill material and groundwater in the Declaration area, including tar-like odours from the former gas-works structures.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| Asbestos and asbestos materials                                    | <p><b>Soil:</b> Based on the observations during recent excavation of fill adjacent to the site, asbestos containing materials are considered to be likely within fill materials within the Declaration Area. The asbestos identified in the DGIs comprised either asbestos cement sheeting, friable asbestos fibre bundles or fibre board (AECOM 2013). ACM and asbestos fibres were rarely detected in soil above the adopted criteria in the Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites of Western Australia (WA Department of Health, 2009).</p> <p><b>Groundwater:</b> Asbestos is not considered a relevant hazard when wet.</p> <p><b>Air:</b> Asbestos is not volatile, but may be present in air as asbestos fibres or attached to suspended soil particles.</p> |

### 5.3 Potential Health Effects of Identified COPC

The potential effects of the COPC identified for this project are summarised in the following sections. Details were obtained from the National Pollutant Inventory (NPI, 2010) unless otherwise specified.

### 5.3.1 BTEX

BTEX are a category of volatile organic compounds (VOCs). VOCs are organic compounds with a vapour pressure at 20 °C exceeding 0.13 kPa. These compounds have been implicated as a precursor in the production of photochemical smog, which may cause atmospheric haze, eye irritation and respiratory effects. VOC emissions are typical for oil processing, petrochemical and chemical plants and include emissions from point sources (storage tanks and filling stations vents) and fugitive emissions from pipelines and process equipment leaks.

#### ***Benzene***

Benzene is an airborne substance that can be washed out of the air by rain, and evaporated into the air. It will decompose in soil or water when oxygen is present. Benzene exposure commonly occurs through inhalation of air containing the substance. It can also enter the body through the skin, although it is poorly absorbed this way. Low levels of benzene exposure may result from tobacco smoke and car exhaust.

Benzene is considered to be a toxic health hazard and a carcinogen. Human exposure to very high levels for even brief periods of time can potentially result in death. Lower level exposure can cause skin and eye irritation, drowsiness, dizziness, headaches and vomiting, and over longer periods damage to the immune system, leukaemia and birth defects.

#### ***Toluene***

Toluene (methylbenzene) is a highly volatile chemical that quickly evaporates to a gas if released as a liquid. After a few days, the substance breaks down in air into chemicals that are harmful to human health. Bacteria in soil and water also break down toluene. Due to relatively fast degradation, toluene emissions are typically confined to the local area in which it is emitted. Toluene is a component of petrol and paints, and is also found in tobacco smoke. Human exposure typically occurs through breathing contaminated air, but toluene can also be ingested or absorbed through the skin (in liquid form). Toluene usually leaves the body within twelve hours.

Short-term exposure to high levels of toluene can cause dizziness, sleepiness, unconsciousness and sometimes death. Long-term exposure can cause kidney damage and permanent brain damage that can lead to speech, vision and hearing problems, as well as loss of muscle and memory functions.

#### ***Ethylbenzene***

Ethylbenzene is a highly volatile substance, so is typically present in air. Ethylbenzene rapidly enters the body through the lungs and digestive tract. The substance has both acute and chronic toxic effects on animals and plants, including shortened lifespan, reproductive problems and behaviour changes. Exposure to high concentrations can cause dizziness, paralysis, breathing difficulties and death. Chronic health effects in humans can last for months or years. Ethylbenzene is present in petroleum, pesticides, cleaning products and solvents.

#### ***Xylenes***

Xylenes are flammable liquids that are moderately soluble in water. They are quickly degraded by sunlight when released to air, and rapidly evaporate when released to soil or water. They are used as solvents and in petrol and chemical manufacturing.

Xylenes can enter the body through inhalation or skin absorption (liquid form), and can cause irritation of the eyes and nose, stomach problems, memory and concentration problems, nausea and dizziness. Excessively high-level exposure can cause death.

### 5.3.2 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are another category of VOCs. They contain at least two fused benzene rings and are commonly formed by the incomplete combustion of fossil fuels and other organic materials. They travel through the atmosphere as a gas or attached to dust particles. Some PAHs readily evaporate into the air. The compounds can break down over days or weeks by reacting with sunlight and other chemicals in air, but do not dissolve easily in water. PAHs are moderately persistent in the environment and can bioaccumulate.

PAHs can be inhaled or ingested and can also be absorbed through the skin. Exposure can cause irritation of eyes and nose and other mucous membranes, headaches, nausea, damage to blood cells, liver and kidneys, and (in very high levels) may be life threatening. A number of PAHs are listed as probably or possibly carcinogenic to humans by the International Agency for Research on Cancer. They can have high acute and chronic toxicity effects on animals and aquatic life, with some also affecting agricultural and ornamental crops. Benzo[a]pyrene is one of the most toxic PAHs, and, as it typically found in the atmosphere with other PAHs, is often used as an indicator for the PAH group of pollutants. Naphthalene is another key PAH. Excessive non-life-threatening exposure may cause cataracts in the eyes, while ingestion can cause abdominal cramps, nausea, vomiting, diarrhoea in young infants. It is considered a possible carcinogenic to humans and carcinogenic in animals.

### 5.3.3 Total Petroleum Hydrocarbons (TPH)

TPH is a group of several hundred chemical compounds that originate from crude oil. Petroleum hydrocarbons are environmental contaminants, though they are not usually classified as hazardous wastes as many petroleum products are commonly used as fuel sources. Due to the variety of crude oil types and derivative products that form TPH, the assessment of health effects associated with these chemicals is problematic. Health effects are often assessed based on the presence of indicator compounds for separate fractions, which consist of petroleum hydrocarbons with similar physical and chemical properties. Common constituents of TPH known to cause severe health effects are PAHs and BTEX. As a worst-case assessment, exposure to TPH may be considered to cause similar health effects in humans as PAH and BTEX compounds (ATSDR 1999).

### 5.3.4 Particulate Matter

Suspended particulate matter may be emitted from site via combustion activities (i.e. vehicle and plant operations) and site preparation works.

Airborne particles are commonly differentiated according to size based on their equivalent aerodynamic diameter. Particles with a diameter of less than or equal to 50 micrometres ( $\mu\text{m}$ ) are collectively referred to as total suspended particulates (TSP). TSP primarily causes aesthetic impacts associated with settling on surfaces, which also causes soiling and discolouration. Uncontrolled emissions of these large particles, however, can cause some irritation of mucosal membranes and can increase health risks from ingestion if contaminated. Particles with diameters less than or equal to 10  $\mu\text{m}$  (known as  $\text{PM}_{10}$  or fine particles) tend to remain suspended in the air for longer periods than larger particles, and can penetrate into human lungs.

Exposure to particulate matter has been linked to a variety of health effects, including respiratory problems (such as coughing, aggravated asthma, chronic bronchitis) and non-fatal heart attacks. Furthermore, if the particles contain toxic materials (such as lead, cadmium, zinc) or live organisms (such as bacteria or fungi), toxic effects or infection can occur from the inhalation of the dust.

### 5.3.5 Heavy Metals

A variety of heavy metals were detected at the site. The metals detected at the site for which soil and groundwater assessment criteria were exceeded are discussed below.

#### **Cadmium**

Cadmium is a naturally-occurring element found in the earth's crust. The combustion of coal and other fossil fuels can result in airborne emissions of cadmium compounds, but are typically confined to the local area surrounding the emissions source, with a lifespan of 5 -15 days in particle form. Cadmium can be inhaled or ingested.

Cadmium is considered to be a probable carcinogen, with evidence suggesting it causes cancers of the kidney and prostate in humans, and lung and testicular cancer in animals. It is a known teratogen (i.e. at certain exposures can cause defects or malformations in developing embryos/foetuses) and may cause reproductive damage. Prolonged exposure to low concentrations of cadmium can cause permanent kidney damage, while high exposures can cause rapid respiratory damage resulting in shortness of breath, chest pain and fluid build-up in the lungs, as well as gastrointestinal symptoms such as nausea, vomiting, cramps and diarrhoea. Long-term exposure can result in symptoms such as anaemia, fatigue, and loss of the sense of smell. The general public is typically exposed to cadmium through food, since food material may take up and retain cadmium, and through smoking of tobacco. The toxicity of cadmium is affected by water hardness in freshwater, with greater toxicity associated with softer water.

#### **Chromium VI**

When chromium VI is released into the atmosphere as particulate matter from the manufacture/disposal of products or the combustion of fossil fuels, it is entrained in the air for up to ten days before settling in soil and water, adhering strongly to soil particles, where only small amounts dissolve.

While chromium III is an essential element, compounds of chromium VI are usually highly toxic. Inhalation of chromium VI can damage and cause adverse health symptoms of the respiratory and gastrointestinal systems, potentially leading to asthma and other allergic reactions. Long-term exposure to airborne chromium VI can adversely affect the immune system and cause cancer. Dermal contact can lead to skin ulcers, redness and swelling.

Chromium VI can have high to moderate acute toxic effects on plants, birds and land animals, resulting in low growth rates or death. Chromium VI is persistent and is thought to bioaccumulate in aquatic life.

## **Copper**

Copper is a naturally occurring substance that is an essential trace element for both animals and plants. Copper can be inhaled or ingested. Most copper released to air, water, sediment and soil strongly binds to other particles, which greatly reduces its toxicity.

Exposure to high levels of copper can, however, be harmful, and cause irritation to the nasal passages, mouth, eyes and throat, while ingestion of high concentrations can cause nausea, vomiting, liver and kidney damage and, possibly, death. Copper is classified as a hazardous substance by the office of the Australian Safety and Compensation Council.

## **Lead**

Lead is a naturally occurring substance that can enter the body by inhalation or ingestion, and primarily affects the nervous system. Excessive exposure to lead causes symptoms such as paralysis, anaemia, abdominal pain, brain and kidney damage and death. Lead can affect reproduction as well as the mental and physical development of children. Lead may be released as particles into the atmosphere, including through windblown dust and bush fires. Lead usually attaches to particles of organic matter, clay, soil or sand, and can accumulate in tissues.

## **Mercury**

Mercury is a naturally occurring element found in rocks and ores. Mercury chloride acts like a particle, while elemental mercury may be found as a gas in the atmosphere. It is naturally released into the atmosphere by evaporation from soils and water and volcanic eruptions. Significant anthropogenic sources of mercury are the burning of fossil fuels, municipal landfills, sewage, metal refining and chemical manufacturing.

Mercury can enter the body through inhalation, ingestion or dermal contact. The nervous system is very sensitive to all forms of mercury. Exposure can potentially causing permanent damage to the brain, eyes, kidneys and developing foetuses, and can cause fluid build-up in the lungs that can be fatal. Dermal contact can burns to the skin.

Mercury is highly toxic to aquatic life, with both acute and chronic effects. Mercury accumulates in body tissue; consumption of contaminated fish can poison humans and possibly birds and land animals. It is also highly persistent in water and the environment. It should be noted that mercury has not been frequently detected on site (AECOM, 2010b).

## **Nickel**

Nickel is an abundant, naturally-occurring element found in soil, water and food, typically found in combination with other elements such as arsenic, antimony and sulphur. Nickel is emitted to atmosphere from both natural and anthropogenic sources, such as combustion of fossil fuels, steel production, incineration and sewage treatment. Nickel can be transported as fine particulate matter, which is washed out of the air by rain into soil and water. Nickel is found in soils and sediments, and is kept soluble by organic matter.

Nickel and its compounds can be inhaled or ingested, with food and water being the primary sources of exposure for most people, as well as tobacco smoke. Inhalation of high concentrations of nickel can result in effects on the respiratory system, potentially causing sinus cancer, and nickel dust irritates the eyes, nose and throat.

## **Zinc**

Zinc is a naturally occurring element found in all foods as well as rocks, soil, air, water, plants, animals and humans. Trace amounts are essential for human health. It is found in a variety of compounds, the properties of which vary greatly. The metal has a strong tendency to form complexes with inorganic and organic compounds. Zinc is used in a range of manufacturing, industrial and applications such as fungicides, antiseptics, water-repellants, lubricants and concrete.

Zinc attaches to dust particles in the air and to soil and sediment particles, and can be inhaled or ingested. Excessive zinc ingestion can lead to nausea, vomiting, anaemia, and damage to the pancreas. Zinc dust irritates mucous membranes, while solid zinc compounds can irritate the skin and eyes.

### **5.3.6 Odour**

Odour is a sensory response to the inhalation of one or more chemicals in the air we breathe. A person's perception of an odour can vary significantly depending on the sensitivity of the person, the acuteness of the person's sense of smell and the connotations that the odour bestows on that person. Nuisance caused by odour

is dependent on a number of factors including quality, intensity, frequency, timing and duration of the odour. Odour may affect a person's quality of life and can have a large range of effects including stress and other physical symptoms.

It should be noted that the level of odour is not directly related to its health effects; some compounds can adversely affect health when present in concentrations that generate low levels of odour, while other compounds can have very strong odours without producing adverse health effects.

Odorous compounds detected at the site may include BTEX and PAHs, notably ethylbenzene, xylenes and naphthalene.

#### **5.3.7 Asbestos**

Asbestos poses a human health risk principally through the inhalation of its fibres from air. If deposited in the lungs, the fibres can initiate diseases that may take many years to produce major health effects. The effects include asbestosis, lung cancer and the normally rare cancer mesothelioma that affects certain chest membrane linings. Impacts tend to be the result of higher levels of exposure, most often occupational, but mesothelioma can also result from low level exposures. The human health risk from asbestos-contaminated soil varies depending on the form of asbestos, its quantity and its exposure situation (WA Department of Health, 2009).

## 6.0 Expected Pollutant Sources

Expected pollutant emission sources were determined based on conceptual understanding of the excavation and soil movement stages (informed by the Staging Plans prepared by ARUP), and on our previous experience with construction projects of a similar nature.

While there are no expected sources for the release of contaminated water, accidental contact with contaminated water is possible and was considered in this assessment. Formal discharge criteria will be agreed with the EPA. Treated water would be discharged to the harbour in accordance with the agreed discharge licence conditions.

The possible pollutant sources associated with the proposed in-situ treatment are limited to pollutants located within the Hickson Road Remediation Area and the treatment chemicals. Contamination pollutants will be sources during activities that expose the pollutants carried in the soil or groundwater, the release of which can also liberate the pollutants to air. The treatment chemicals will be sources during handling and use, as well as in the event of leaks.

The key management issues for *in-situ* treatment works are expected to be as follows:

- Soil vapours from volatilisation of contaminants in soils being treated *in-situ*, and from extracted soil and groundwater, may be released;
- Dust (particulate matter), which may include lead and chromium, may be generated from drilling and trenching within Hickson Road. Exhaust emissions, potentially containing particulate matter, oxides of sulfur and nitrogen, and carbon monoxide, may be released from delivery vehicles, fork-lifts and drilling equipment (due to the limited amount of plant involved in the operations, this source was not considered to be significant; as such, exhaust emissions were not addressed in this assessment); and
- Non-offensive odours may be detected from the treatment chemicals.

The limited nature of soil disturbance for the *in-situ* treatment is expected to limit airborne concentrations of pollutants. Larger scale excavations associated with the in-situ treatment option would be undertaken within excavation enclosures structures.

Exposure could potentially occur from other sources, such as leaks in pipes and/or emergency extraction procedures. Such exposure would not, however, occur during normal operating procedures. The Work Plan to be developed for the works would contain procedures designed to minimise the risk of such events, which would be of short duration and result in limited exposure to pollutants. As such, these exposure sources were not considered in this assessment.

For the *ex-situ* works, remediation excavation activities are proposed to be undertaken within temporary excavation enclosures structures as much as practicable. These structures would be fitted with filtration systems to remove contaminants from the exhaust stream. Typical contaminant removal rates are 85 % for gases and 98 % for dust, and emissions from the filtration units would be compliant with EPA emission standards. Actual emissions would be dependent on air pollutant concentrations within the temporary odour and dust control structures. Retaining wall works and piling would not be under an odour structure.

In addition to pollutant source controls, personnel within the enclosures would potentially be exposed to pollutants through contact with soil, dust, and vapours in the air. Exposure would be mitigated through the use of personal protective equipment (PPE).

The off-site transport and treatment of excavated material are also potential sources of emissions. As indicated in **Section 4.3**, trucks transporting potentially odorous material would be treated with odour suppressant foam prior to leaving the site. The off-site treatment of material would be undertaken at a licensed facility; any emissions associated with the treatment process would be managed in accordance with that site's Environment Protection Licence. The health risks associated with these activities are, therefore, expected to be low, so these potential emission sources were not considered further in this assessment.

It is also possible for odour emissions to arise due to drilling operations, as gasworks waste is inherently odorous material. Comparison of site data to theoretical odour-based soil concentrations near the gasworks source area, however, indicated minimal exceedences during small scale intrusive works (AECOM, 2010b).

## 7.0 Potential Sensitive Receptors

A sensitive receptor is identified by the EPA as someone who works or resides or may work or reside near a proposed activity, including people within residential areas, hospitals, hotels, shopping centres, play grounds, recreational centres, and the like. Barangaroo is surrounded by a number of residences, walkways and workplaces. In order to simplify this assessment, human receptors were considered in terms of Significant Exposure Groups (SEGs). SEGs are groups of receptors likely to:

- Experience similar concentrations and duration of exposure to COPC;
- Have similar tolerance to health impacts; and
- Have similar mitigation measures in place to prevent exposure to COPC.

Sensitive receptors relevant to operations at the Hickson Road Remediation Area were classified into the following SEGs:

- Site workers and visitors;
- Residents living to the east (particularly at 38 Hickson Road), south and north of the site, including the child care centre located at 37 High Street and including occupants of future residential buildings (R8 and R9) at Barangaroo South Stage 1a;
- Business patrons and staff (Bond Heritage Café, future commercial buildings at Barangaroo South Stage 1a and the King Street Wharf precinct) and office workers to the east and south of the site, including external and pedestrian receptors associated with King Street Wharf precinct, external dining and bar users, KPMG Tower and Macquarie Bank buildings, future commercial buildings T1, T2 and T3 at Barangaroo South, and employees and customers of open air buildings;
- Pedestrians; and
- Maintenance workers (utilities and adjacent properties).

These SEGs are described in **Table 4**. Mitigation measures are described in **Section 8.2**.

**Table 4 Significant Exposure Groups**

| SEG                       | Description                                                                                                                                                                   | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Site workers and visitors | Likely to be involved in the works that may potentially generate COPCs. Also likely to be temporarily housed (amenities and ablutions) in areas adjacent to remediation works | Likely to be closest to potential pollutant emissions, but use of engineering controls, personal protective equipment and safe work methods is expected to minimise exposure intensity and duration. Mitigation measures work practices and amenities protection are expected to minimise pollutant concentrations and exposure duration in amenities and ablutions areas. Air quality monitoring will be conducted to demonstrate the success of the mitigation measures and compliance with appropriate standards. |

| SEG         | Description                                                                                                                                                                  | Notes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Residents   | Located to the east, south and north of the site.                                                                                                                            | Exposure possible during and after working hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration; these include enclosure of excavations with emissions controls, as well as dust suppression practices and the covering of loads with odour suppressant foam (or similar). Children may be more susceptible to the health effects of certain contamination types. The child care facility at 37 High Street offers long day care services, and children may be residing within 38 Hickson Road, which is adjacent to the proposed works; as such, exposure may potentially occur during much of the operational hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration. Air quality monitoring will be conducted to demonstrate the success of the mitigation measures and compliance with appropriate standards. |
| Businesses  | Several commercial office blocks on Hickson Road, King Street Wharf, Moores Wharf and adjacent precincts, and future commercial buildings T1, T2 and T3 at Barangaroo South. | Exposure possible during working hours. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration. Existing air conditioning systems that are equipped with particle filters and/or intake areas located away from the proposed works will provide additional (but not essential) mitigation. Air quality monitoring will be conducted to demonstrate the success of the mitigation measures and compliance with appropriate standards.                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Pedestrians | Footpaths are located adjacent to Hickson Road Remediation Area.                                                                                                             | Individual exposure is likely to be of a short duration. Mitigation measures and work practices are expected to minimise pollutant concentrations and exposure duration. Air quality monitoring will be conducted to demonstrate the success of the mitigation measures and compliance with appropriate standards.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

## 8.0 Relevant Exposure Pathways

An exposure pathway describes the course a chemical or physical agent takes from its source to an exposed individual. In order for a human receptor to be exposed to a chemical contaminant from a site, a complete exposure pathway must exist, which generally includes the following elements (USEPA, 1989):

- A source and mechanism of chemical release;
- A retention or transport medium (or paths where chemicals are transferred between media);
- A point of potential human contact with the contaminated medium; and
- An exposure route (inhalation, ingestion or dermal contact) at the point of exposure.

In cases where one or more of the above elements is missing, the exposure pathway is considered to be incomplete. Such circumstances are not considered to pose a risk to receptors.

The potential exposure pathways of COPC to the receptors identified in **Section 7.0** are summarised in **Table 5**. On-site receptors are primarily personnel involved in the remediation trials. Off-site receptors include residents and visitors to the neighbouring areas, including those using Hickson Road.

**Table 5 Exposure Pathway Analysis**

| Exposure Pathway                                                                                                                   | Complete Pathway |          | Notes                                                                                                                                                                                                                                                                                                                                                                              |
|------------------------------------------------------------------------------------------------------------------------------------|------------------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                    | On-site          | Off-site |                                                                                                                                                                                                                                                                                                                                                                                    |
| Incidental ingestion of chemicals in soil                                                                                          | ✓                | (✓)      | Airborne soil generation possible during excavation and transport activities. Off-site receptor exposure will be minimised through undertaking excavation activities within enclosures, and where practicable and required, by covering truck loads and wetting down any external stockpiles. (N.B. all contaminated material will be stored within the odour control structures.) |
| Dermal absorption of chemicals from soil                                                                                           | ✓                | (✓)      |                                                                                                                                                                                                                                                                                                                                                                                    |
| Inhalation of chemicals in soil-derived airborne particulates                                                                      | ✓                | (✓)      |                                                                                                                                                                                                                                                                                                                                                                                    |
| Inhalation of soil-derived vapours                                                                                                 | ✓                | (✓)      | Filtration systems servicing excavation enclosures will remove the majority of odorous compounds from the exhaust stream. Exhaust from the filtration units will be monitored to maintain emissions at levels generally within acceptable concentrations.                                                                                                                          |
| Incidental ingestion of chemicals in groundwater (incidental contact)                                                              | ✓                | x        | Due to the shallow nature of and tidal influence on groundwater levels at the site, groundwater may seep into remediation trenches or other excavations; as a result, there is potential for on-site workers to come in contact with ground water                                                                                                                                  |
| Dermal absorption of chemicals in groundwater (incidental contact)                                                                 | ✓                | x        |                                                                                                                                                                                                                                                                                                                                                                                    |
| Inhalation of groundwater derived vapours                                                                                          | ✓                | ✓        | Vapour emissions may potentially travel outside site boundary                                                                                                                                                                                                                                                                                                                      |
| x Incomplete exposure pathway<br>(✓) Potentially complete pathway of minor significance<br>✓ Potentially complete exposure pathway |                  |          |                                                                                                                                                                                                                                                                                                                                                                                    |

## 8.1 Conceptual Site Model

A conceptual site model (CSM) was developed using the site activities, identified COPC, expected sources of COPC, and identified human receptors and exposure pathways to illustrate the full pathway of the migration of COPC from sources to receptors. **Figure 2** shows the possible exposure pathways; those unlikely to occur or to have minor health effects are denoted by an open circle, while those with the potential to result in noticeable health effects (and, as such, require further analysis) are denoted with a closed circle.

## 8.2 Measures for Reducing Exposure

A number of aspects of the proposed work at the Site Remediation Area will contribute to control of human health risk. These operations can be categorised as source and pathway controls and are discussed in the following sections.

### 8.2.1 Source Controls

It is widely accepted in the Risk Control Hierarchy (WorkCover, 2010) that if a hazard cannot be substituted for a lesser hazard, then isolating the hazard from people and using engineering means to reduce the hazard are the most effective means of risk control. In regards to isolation and engineering controls for the hazard of COPC within soil and groundwater on the site, the control measures for the Hickson Road Remediation Area are detailed below.

The existing air quality monitoring conducted for the project will be modified to consider emissions from the Hickson Road works. Should unacceptable levels of fugitive emissions be detected at the site boundaries or in the surrounding area during the works, an investigation will be conducted to determine the source of the emissions and to evaluate the appropriate measures to be implemented.

These measures may include the following:

- Alteration in the works program to minimise in the extent of disturbed open areas;
- Prompt removal and treatment of heavily contaminated materials that have been exposed and are identified to have caused the emissions;
- Use of fine mist sprays around the site;
- Delaying work until more favourable weather conditions occur;
- Use of alternate work practices to minimise the period of impact of the emissions;
- Use of additional features to control emissions from plant and equipment;
- Use of alternate work practices such as using modified equipment;
- Relocation of offending plant and equipment to less sensitive on-site areas;
- Reducing the number of plant and equipment items on-site; and
- Use of a deodorant within water sprays at locations on-site and at site boundaries provided the chemicals do not pose a contamination or OHS hazard.

### *In situ* Remediation

- During drilling and other soil movement activities, real-time visual observations will monitor whether dust is being generated and leaving the immediate work area. Measures including wetting down stockpiles, misting the area with water will be implemented to suppress dust.
- The extent of disturbance of contaminated materials will be minimised and minimal through work practices, which will include identifying areas requiring disturbance, staging of works to ensure the smallest practical amount of disturbance occurs, and ensuring that the contaminated materials are treated so as to reduce any potential emissions, such as through covering materials and use of odour suppressants and the like.
- Odours from volatilisation will be closely monitored at soil vapour monitoring points through the use of Summa canisters, a PID, multi-gas meter and CGI as required. A SVE system will treat odours that are determined to be potentially disruptive or harmful to individuals in the community or to occupants of buildings in the vicinity of the works.

**Ex-situ Remediation**

Particulate matter source control measures will include a combination of the following techniques:

- Dust suppression using hand held spraying, water sprays, chemical wetting agents, and/or hydromulch or a combination of techniques;
- Excavation of materials within temporary remediation odour and dust control structures;
- Managing groundwater removal and drawdown, where practicable, such that material excavated is retained in a moist state;
- Implementation and enforcement of site speed limits;
- Solid perimeter hoardings adjacent to sensitive receptors;
- Minimising haul road lengths;
- Minimising exposed/excavation areas where practicable;
- Covering surfaces where appropriate;
- Covering loads during transport;
- Watering and sweeping of exposed surfaces including haul roads;
- Undertaking remediation works in a staged and sequential manner;
- Surface stabilisation to minimise dust generation; and
- Clean up of soil load spillages as soon as practicable.

Source control of the emission of gaseous COPC from exposed contaminated soil and water include a combination of the following techniques:

- Enclosure (where practicable) of remediation excavation and other remediation activities and filtration of exhaust streams to manage COPC that may be produced/released during the soil excavation and remediation processes;
- Removal, covering and managing of heavily contaminated materials that have been exposed and are identified to have caused the emissions as soon as practicable;
- Preferential use of plant/equipment that meet international standards, and retrofitting of older equipment with diesel particulate filters or other exhaust-treatment devices if required;
- Location of offending plant or equipment to less sensitive on-site areas;
- Equipment, plant and machinery regularly tuned, modified or maintained; and
- Clean up of soil load spillages as soon as practicable.

Source control of contaminated water will include a combination of the following techniques:

- Installation of ground water control and retention walls as practicable around the excavation area to minimise the infiltration of groundwater from the Declaration Area into the less contaminated excavation area;
- Treatment of contaminated water to enable safe discharge in accordance with site regulatory requirements;
- Use of surface bunds and drainage diversions to divert clean water away from contaminated areas; and
- Silt fences to prevent potentially contaminated soil from being carried into undisturbed areas, and to prevent undisturbed soil entering disturbed areas.

**8.2.2 Pathway Controls**

Although controlling the release mechanism of COPC is the most effective strategy for minimising the potential for human exposure, additional post-release controls will also be used to further reduce the potential for health impacts. Key controls measures designed to interrupt the exposure pathways of COPC would include:

- Mandatory issue and use of appropriate PPE for all workers on and around the site to limit the potential for exposure to COPC in air, soil and water. This PPE would include hard hats, high visibility clothing, dust/face

masks, eye protection, safety gloves and safety boots for all staff, with respirators and overalls used where required.

- Use of fine mist sprays around the site to absorb soluble COPC vapours and to suppress wind-blown dust from exposed site areas. Note that the misting sprays are not expected to result in an additional exposure pathway from the site. The misting sprays will reduce the existing potential off-site dust exposure pathway. The only risk associated with misting sprays relates to the accumulation of moisture or liquids from the sprays. This liquid would be monitored and controlled as part of the site surface water management plan.
- The proposed fencing and security arrangements around the Hickson Road Remediation Area are considered adequate to prevent members of the public from entering the work area.
- It is considered that asbestos may be encountered as occasional ACM fragments, and possibly fill containing asbestos material, and that the potential for asbestos fibres exposure is best managed through the implementation of the management tools in the *VMP/Block 4 RAP* (AECOM, 2013) and through implementation of an Asbestos Management Plan for the works.

## 9.0 Potential Health Impact Assessment

### 9.1 Assessment of Risks to Local Receptors

Risk issues were assessed based on the application of site control measures using a simple risk ranking matrix, based on Australian Standard (AS4360-2004; Standards Australia, 2004), and consistent with risk management approaches recommended in updates to AS4360 (Standards Australia, 2009). The risk classifications for the works provided in **Table 6** were based on the likelihood and consequence risk analysis matrix used to assess the level of risk for each identified issue, which is provided in **Appendix A**.

Table 6 Conclusions Regarding Site-derived Risks to Local Receptors

| Sources of Chemicals of Potential Concern (COPC)                                                                                                                                      | Exposure Route                                       | Receptor Significant Exposure Groups | Conclusions                                                                                                                                                                                                                                                                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>COPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter</p> <p>Asbestos and asbestos materials.</p> <p>(Preferred and alternative remediation methods.)</p> | Inhalation of suspended particles (dust) and vapours | Workers on and adjacent to the site  | Risk considered to be high (possible with moderate consequences) but manageable through: Engineering controls and work practices; Filtration systems; Asbestos Management Plan; and Use of appropriate PPE.                                                                                                                                                                                                                         |
|                                                                                                                                                                                       |                                                      | Residences                           | Risk considered to be moderate (possible with minor consequences) due to use of temporary odour and dust control structures during excavation activities. Further protection will be achieved by source control including: Filtration systems; Asbestos Management Plan; On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces; and Vapour monitoring and extraction where required. |
|                                                                                                                                                                                       |                                                      | Businesses                           | Risk considered to be moderate (possible with minor consequences) due to use of temporary odour and dust control structures during excavation activities. Further protection will be achieved by source control including: Filtration systems; Asbestos Management Plan; On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces; and Vapour monitoring and extraction where required. |
|                                                                                                                                                                                       |                                                      | Pedestrians adjacent to the site     | Risk considered to be moderate (possible with minor consequences) due to use of temporary odour and dust control structures during excavation activities. Further protection will be achieved by source control including: Filtration systems; Asbestos Management Plan; On-site water-spraying of exposed soil areas for dust control and /or covering of spoil and surfaces; and Vapour monitoring and extraction where required. |
|                                                                                                                                                                                       | Ingestion                                            | Workers on and adjacent to the site  | Health risks considered moderate (unlikely with minor consequences) but manageable through: On-site dust control measures; Safe work practices; Use of appropriate PPE (mandated by works undertaken); and Effective hygiene procedures.                                                                                                                                                                                            |
|                                                                                                                                                                                       |                                                      | Other SEGs                           | Risks from wind dispersion of dust particles expected to be low (rare with minor consequences) as: Dust migration off-site site will be controlled; Further dilution occurs prior to reaching receptors; and Only a small fraction of dust and, therefore, contaminants, potentially ingested.                                                                                                                                      |
|                                                                                                                                                                                       | Dermal contact                                       | Workers on and adjacent to the site  | Health risks considered high (possible with moderate consequences) but manageable through: On-site dust control measures; Use of appropriate PPE (mandated by works undertaken); and Effective hygiene procedures such as hand washing.                                                                                                                                                                                             |

| Sources of Chemicals of Potential Concern (COPC)                                 | Exposure Route                                | Receptor Significant Exposure Groups | Conclusions                                                                                                                                                                                                                                                                                                                                                                                              |
|----------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                  |                                               | Other SEGs                           | Risks from wind dispersion of dust particles is expected to be low (rare with minor consequences) as:<br>Dust migration off-site will be controlled;<br>Further dilution occurs prior to reaching receptors; and<br>Only a small fraction of dust and, therefore, contaminants, potentially in dermal contact.                                                                                           |
| COPC within groundwater: BTEX, TPH and heavy metals<br><br>(Alternative method.) | Inhalation of vapours                         | Workers on and adjacent to the site  | Potential health risks are considered high (possible with moderate consequences) but manageable, minimised by:<br>Following appropriate safe work practices; and<br>Use of appropriate PPE (where mandated by works undertaken).                                                                                                                                                                         |
|                                                                                  |                                               | Other SEGs                           | Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).                                                                                                                                                                                                                                                                     |
|                                                                                  | Unintentional ingestion of contaminated water | Workers on and adjacent to the site  | While workers may potentially be exposed to contaminated groundwater, it is very unlikely that the water will come into contact with food and subsequently be ingested. Potential health risks are considered moderate (rare with moderate consequences) but manageable, minimised by:<br>Following appropriate safe work practices; and<br>Use of appropriate PPE (where mandated by works undertaken). |
|                                                                                  |                                               | Other SEGs                           | Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).                                                                                                                                                                                                                                                                     |
|                                                                                  | Dermal contact with contaminated water        | Workers on and adjacent to the site  | Workers involved the extraction works may be exposed to water containing COPC. Potential health effects are considered to be low (unlikely with minor consequences) but manageable by:<br>Following safe work methods; and<br>Use of appropriate PPE.                                                                                                                                                    |
|                                                                                  |                                               | Other SEGs                           | Off-site receptors are unlikely to be exposed to contaminated water. Health risks are considered low (rare with minor consequences).                                                                                                                                                                                                                                                                     |

## 10.0 Conclusions

Through detailed consideration of the scope of works contemplated for the proposed remediation operations, risks to workers were considered to be high (possible with moderate consequences) but manageable. Risks to off-site receptors were considered to be low as: the excavation activities would be undertaken using temporary excavation enclosures, where practicable, with emissions to air subjected to filtration; off-site transport of excavated material will be controlled through treatment of material with odour suppressant foam prior to leaving the site; and treatment will be undertaken at a licensed facility.

The main risk to human health is considered to be the inhalation of vapours originating from contaminated materials. Dermal contact and oral ingestion/inhalation of deposited dust are not considered likely to significantly affect health. The SEGs most likely to potentially encounter site-derived dust or vapours are workers on site and directly next to the site and local residents. Risks from exposure to asbestos and asbestos materials, should they be encountered, are considered directly manageable by minimising dust generation and by implementing specific source control and exposure measures described in an Asbestos Management Plan for the works.

To ensure that potential human health impacts on nearby sensitive receptors are minimised, the pollutant management measures listed in **Section 8.2** are considered necessary and appropriate. With diligent implementation of effective control measures, it is expected that the risk of exposure to harmful concentrations of COPC would be low and acceptable, consistent with the Secretary's Requirement that the project does not have unacceptable (acute or chronic) health effects.

It is noted that gasworks waste is inherently odorous material. While comparison of site data to theoretical odour-based soil concentrations near the gasworks source area indicated minimal exceedences during small scale intrusive works, large scale excavations or intrusive works may potentially result in odour issues (AECOM, 2011b). For odorous chemicals, the thresholds of odour detection are routinely well below toxicity thresholds. Odour is not, therefore, an indicator of health risk. Nevertheless, for work sites where COPC exposure concentrations do not exceed acute tolerance and guideline concentrations, exposure to low concentrations of some COPCs may lead to physical irritation and discomfort for some people.

To confirm that concentrations of COPC are acceptable, it is considered advisable to develop a monitoring program to assess the routine concentrations of COPC at locations representative of each SEG. The results of the monitoring program should be used to manage the intensity, location and duration of works being undertaken. This monitoring should be incorporated into the Air Quality Monitoring Plan included in the AQIA (AECOM, 2015a).

## 11.0 Recommendations

In order to confirm that actual concentrations of COPC within the site and at selected sensitive receptors beyond the site boundary are minimal, and that ongoing risks are low, it is recommended that a vapour and dust monitoring program be developed and implemented during the remediation and land forming work. Locations should be selected as a conservative representation of SEGs. Results from the monitoring program should be linked to corrective work actions in case of any exceedences of adopted assessment criteria, notably in areas identified as contaminated, including the modification of work patterns and procedures and the implementation of additional control measures.

It is recommended that the Project Construction Environmental Management Plan (CEMP) (Lend Lease, 2012, or as amended) should demonstrate and facilitate the implementation of all proposed control measures. The CEMP should, as a minimum, detail the statutory requirements of the project, key site roles, community consultation, complaints management, pollution control measures, monitoring requirements, corrective actions and a procedure for reviewing the effectiveness of the plan.

Overall, reductions of site-derived dust and odour, with confirmation through air concentration monitoring that relevant odorous and non-odorous COPCs are not elevated above health exposure guidelines, are recommended as important goals of proactive site management, as are responses to meteorological and emission conditions such as still (particularly autumn) days where natural ambient air dispersal may be at a minimum.

## 12.0 References

- AECOM. 2010a. Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Millers Point, NSW. 23 September, 2010. AECOM Australia Pty. Ltd.
- AECOM. 2010b. Data Gap Investigation, Other Remediation Works (North) Area. 20 October, 2010. AECOM Australia Pty. Ltd.
- AECOM. 2011b. Amended Remedial Action Plan, Barangaroo - ORWS Area. 7 July (Final).
- AECOM. 2012a. Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW. 9 March (Final).
- AECOM. 2012b. Human Health and Ecological Risk Assessment VMP Remediation Works Area (Addressing the NSW EPA Remediation Site Declaration 21122, Millers Point). 25 October 2012.
- AECOM. 2013. Remedial Action Plan - NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW.
- AECOM. 2014. Preliminary Work Plan for In situ Chemical Oxidation – Hickson Road Declaration Area, Barangaroo, NSW. 11 November.
- AECOM. 2015a. Air Quality Impact Assessment – Remediation Development Application, Barangaroo Hickson Road, EPA Declaration Area No. 21122, Millers Point, NSW.
- AECOM. 2015b. Barangaroo, Hickson Road Remediation DA (SSD 6617), Preliminary Methodology for Off-site Transport and Treatment of Hazardous Waste, Hickson Road, Millers Point.
- ANZECC. 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, October 2000
- ATSDR. 1999. Toxicological Profile for Total Petroleum Hydrocarbons (TPH), Agency for Toxic Substances and Disease Registry, September 1999.
- Broomhall, 2007. *Land at Millers Point, Ownership and Usage*. 1 June.
- enHealth. (2012). Environmental Health Risk Assessment – Guidelines for assessing human health risks from environmental hazards.
- ERM. 2008. Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney. September 2008
- ERM. 2007. Environmental and geotechnical Site Assessment, East Darling Harbour, Sydney, NSW Final Report – Revision 1.
- Lend Lease. 2012. Construction Framework Environmental Management Plan, Barangaroo Stage 1, Bulk Excavation and Basement Parking. Revision D. May 14.
- NPI. 2010. Substance fact sheets, <http://www.npi.gov.au/substances/factsheets.html> (accessed 2 June 2010), National Pollutant Inventory, 2010.
- Standards Australia. 2009. AS/NZS ISO 31000:2009. Risk management – Principles and guidelines. Standards Australia and New Zealand.
- Standards Australia, 2004 AS/NZS 4360:2004 (Superseded): Risk Management (replaced by AS/NZS ISO 31000:2009. Standard Australia and New Zealand.
- USEPA. 1989. Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual. United States Environmental Protection Agency. EPA/540/1-89/002 December 1989.
- WA Department of Health. 2009. Guidelines for the Assessment, Remediation and Management of Asbestos-Contaminated Sites in Western Australia, WA Department of Health, May 2009.
- WorkCover. 2010. <http://www.workcover.nsw.gov.au/healthsafety/makingyourworkplacesafer/Riskmanagement/Pages/Riskcontrol.aspx>, WorkCover NSW, 2010.

# Figures



G:\Projects\603 Projects\60323955 Barangaroo\FIGURES\Contam\60323955 F1 Barangaroo Site Location 01 09 2014 TO

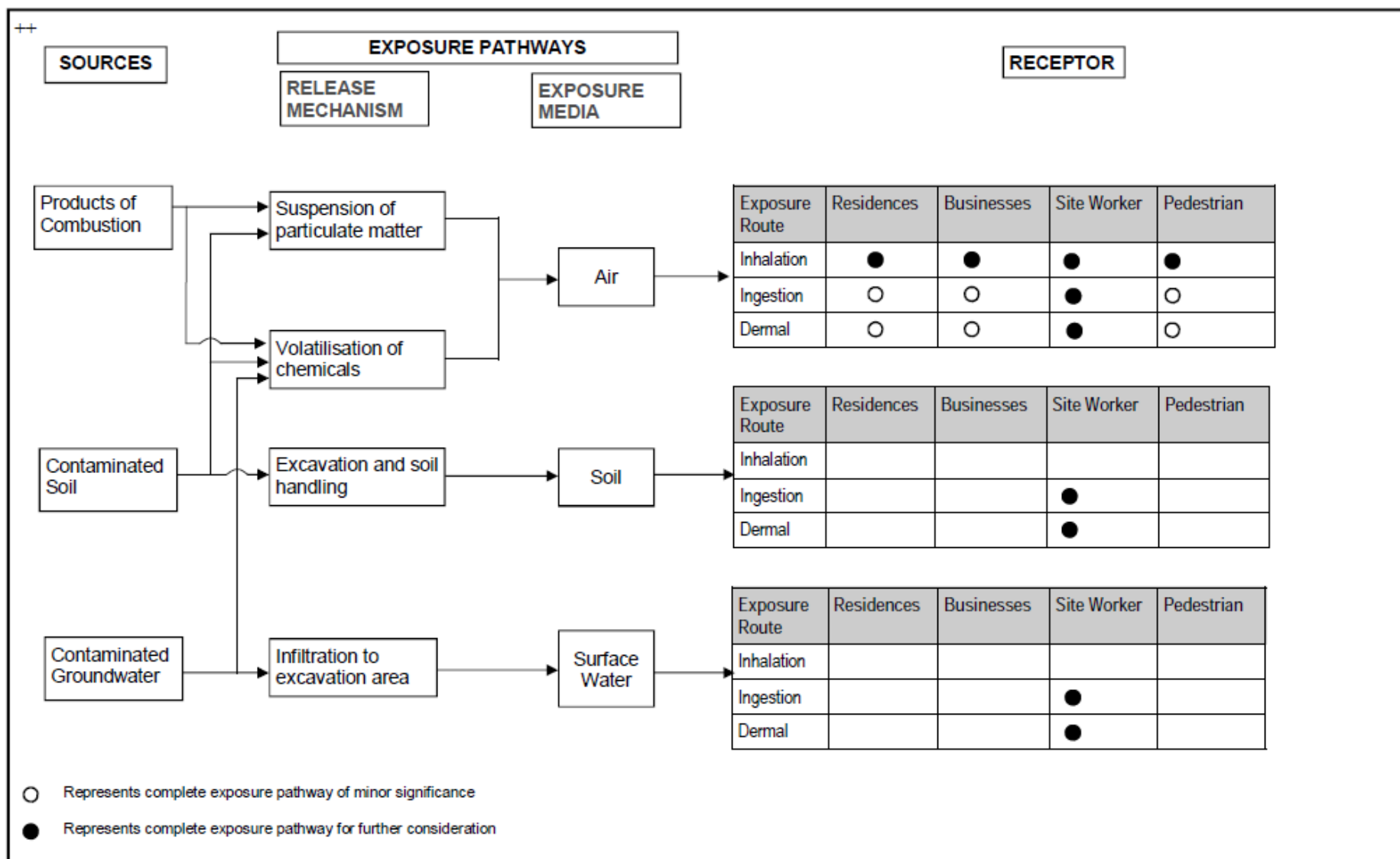


Figure 2 Illustrated Conceptual Site Model for Exposure to Chemicals of Potential Concern

## Appendix A

# Qualitative Risk Ranking Framework

## Appendix A Qualitative Risk Ranking Framework

Risk issues were assessed assuming implementation of the proposed control measures using a simple risk ranking matrix, which was based on Australian Standard (AS4360-2004; Standards Australia, 2004), and consistent with risk management approaches recommended in updates to AS4360 (Standards Australia, 2009). The likelihood and consequence classifications used in the table, and the risk analysis matrix used to assess the overall level of risk due to each identified risk issue, are provided in **Tables A1, A2 and A3**.

**Table A1: Qualitative Measures of Likelihood (after AS4360)**

| Level | Descriptor     | Description                                 |
|-------|----------------|---------------------------------------------|
| A     | Almost certain | Is expected to occur in most circumstances  |
| B     | Likely         | Will probably occur in most circumstances   |
| C     | Possible       | Might occur at some time                    |
| D     | Unlikely       | Could occur at some time                    |
| E     | Rare           | May occur only in exceptional circumstances |

**Table A2: Qualitative Measures of Consequence of Impact (after AS4360)**

| Level | Descriptor    | Description                                                                                                           |
|-------|---------------|-----------------------------------------------------------------------------------------------------------------------|
| 1     | Insignificant | No injuries, low financial loss                                                                                       |
| 2     | Minor         | First aid treatment, on-site release immediately contained, medium financial loss                                     |
| 3     | Moderate      | Medical treatment required, on-site release contained with outside assistance, high financial loss                    |
| 4     | Major         | Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss |
| 5     | Catastrophic  | Death, toxic release off-site with detrimental effect, huge financial loss                                            |

**Table A3: Qualitative Risk Analysis Matrix (after AS4360)**

| Likelihood     | Consequences  |       |          |       |              |
|----------------|---------------|-------|----------|-------|--------------|
|                | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost certain | H             | H     | E        | E     | E            |
| Likely         | M             | H     | H        | E     | E            |
| Possible       | L             | M     | H        | E     | E            |
| Unlikely       | L             | L     | M        | H     | E            |
| Rare           | L             | L     | M        | H     | H            |

**NOTES:**

E: Extreme risk; immediate action required

H: High risk; senior management attention needed

M: Moderate risk; management responsibility must be specified

L: Low risk; manage by routine procedures

The completed risk matrix for the identified SEGs is provided in **Table A4**.

Table A4: Completed Qualitative Risk Analysis Matrix for SEGs

| Sources of Pollutants of Potential Concern (POPC)                                                                      | Exposure Route                                       | Significant Exposure Groups         | Likelihood | Consequence | Risk     |
|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|-------------------------------------|------------|-------------|----------|
| POPC within contaminated soil: BTEX, PAHs, heavy metals and particulate matter<br><br>Asbestos and asbestos materials. | Inhalation of suspended particles (dust) and vapours | Workers on and adjacent to the site | Possible   | Moderate    | High     |
|                                                                                                                        |                                                      | Residences                          | Possible   | Minor       | Moderate |
|                                                                                                                        |                                                      | Businesses                          | Possible   | Minor       | Moderate |
|                                                                                                                        |                                                      | Pedestrians adjacent to the site    | Possible   | Minor       | Moderate |
|                                                                                                                        | Ingestion                                            | Workers on and adjacent to the site | Unlikely   | Minor       | Moderate |
|                                                                                                                        |                                                      | Other SEGs                          | Rare       | Minor       | Low      |
|                                                                                                                        | Dermal contact                                       | Workers on and adjacent to the site | Possible   | Moderate    | High     |
|                                                                                                                        |                                                      | Other SEGs                          | Rare       | Minor       | Low      |
| POPC within groundwater: BTEX, TPH and heavy metals.                                                                   | Inhalation of vapours                                | Workers on and adjacent to the site | Possible   | Moderate    | High     |
|                                                                                                                        |                                                      | Other SEGs                          | Rare       | Minor       | Low      |
|                                                                                                                        | Unintentional ingestion of contaminated water        | Workers on and adjacent to the site | Rare       | Moderate    | Moderate |
|                                                                                                                        |                                                      | Other SEGs                          | Rare       | Minor       | Low      |
|                                                                                                                        | Dermal contact with contaminated water               | Workers on and adjacent to the site | Unlikely   | Minor       | Low      |
|                                                                                                                        |                                                      | Other SEGs                          | Rare       | Minor       | Low      |