Site Audit Report
Remedial Action Plan, Crown Sydney Hotel Resort Development, Barangaroo

Prepared for:

Crown Sydney Property

Prepared by:
ENVIRON Australia Pty Ltd

Date:
January 2015

Project Number:
AS121686

Audit Number:
GN 439B-6

ENVIRON

20 January 2015 Our Ref: AS121686

Crown Sydney Property
Attn: Daniel Prince
Level 3, Crown Towers
8 Whiteman Street
Southbank, Victoria, 3006

Dear Daniel

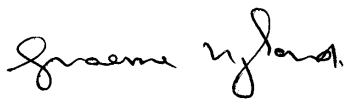
Re: Site Audit Report - Remedial Action Plan, Crown Sydney Hotel Resort Development, Barangaroo

I have pleasure in submitting the Site Audit Report for the subject site. The Site Audit Statement, produced in accordance with the NSW Contaminated Land Management Act 1997, follows this letter. The Audit was commissioned by Crown Sydney Property to assess the appropriateness of a plan of remediation.

Audit of the Barangaroo site (including the Crown Sydney Hotel Resort Development site) was previously notified to the EPA as a statutory audit based on the original Concept Plan Approval which required Detailed Remediation Action Works Plan(s) for relevant section(s) of the Barangaroo site, and that those plans be audited by an EPA accredited site auditor.

Thank you for giving me the opportunity to conduct this Audit. Please call me on 9954 8100 if you have any questions.

Yours faithfully,
ENVIRON Australia Pty Ltd



Graeme Nyland
EPA Accredited Site Auditor 9808

/ City of Sydney Council
/ NSW EPA

NSW Site Auditor Scheme
SITE AUDIT STATEMENT

A site audit statement summarises the findings of a site audit. For full details of the site auditor's findings, evaluations and conclusions, refer to the associated site audit report.

This form was approved under the* Contaminated Land Management Act 1997 *on 31st October 2012. For more information about completing this form, go to Part IV.

PART I: Site audit identification

Site audit statement no. GN 439B-6

This site audit is a **statutory audit/~~non-statutory audit~~*** within the meaning of the *Contaminated Land Management Act 1997*.

Site auditor details (as accredited under the *Contaminated Land Management Act 1997*)

Name:	Graeme Nyland	Company:	ENVIRON Australia Pty Ltd
Address:	Level 3, 100 Pacific Highway (PO Box 560)		
	North Sydney NSW	Postcode:	2060
Phone:	02 9954 8100	Fax:	02 9954 8150

Site details

Address: Hickson Road (Sussex Street),Barangaroo, NSW

Postcode: 2000

Property description *(attach a list if several properties are included in the site audit)*

Part Lot 5 and Part Lot 6 in DP 876514 (see attachment at end of Part I of this Statement)

Local Government Area: Sydney

Area of site (e.g. hectares): 10,242 m^2

Current zoning: Part zone B4 Mixed Use (eastern side) and part zone RE1 Public Recreation (western side).

To the best of my knowledge, the site **~~is~~/is not*** the subject of a declaration, order, agreement or notice under the *Contaminated Land Management Act 1997* or the *Environmentally Hazardous Chemicals Act 1985*.

Declaration/Order/Agreement/Proposal/Notice* no(s): NA

Strike out as appropriate

Site audit commissioned by

Name: Josef Seidler Company: Crown Sydney Property

Address: 8 Whiteman Street, Southbank, Victoria

Postcode: 3006

Phone: 03 9292 7065 Fax: NA

Name and phone number of contact person (if different from above)

Daniel Prince

Purpose of site audit

☐ ~~A. To determine land use suitability *(please specify intended use[s])*~~

……

~~**OR**~~

☑ B(i) To determine the nature and extent of contamination, and/~~or~~

☑ B(ii) To determine the appropriateness of an ~~**investigation/**~~**remedial action/~~**management** **plan***, and/~~or~~

☑ B(iii) To determine if the land can be made suitable for a particular use or uses by implementation of a specified **remedial action plan/~~management plan~~*** *(please specify intended use[s])*

Mixed commercial, high density residential and public open space

Information sources for site audit

Consultancy(ies) which conducted the site investigation(s) and/or remediation

- Jeffery and Katauskas Pty Ltd (J&K)
- Rosemary Broomham
- Environmental Resources Management Australia Pty Ltd (ERM)
- AECOM Australia Pty Ltd (AECOM)
- JBS Environmental Pty Ltd (JBS)

Title(s) of report(s) reviewed:

- 'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW' dated 21 August 2006, by J&K
- Report 'Land at Millers Point, Ownership and Usage' dated 1 June 2007, by Rosemary Broomham
- Final Report 'Environmental Site Assessment, East Darling Harbour, Sydney, NSW' dated 21 June 2007, by ERM
- Report 'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW' dated July 2008, by ERM
- Report 'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney' dated September 2008, by ERM

Strike out as appropriate

- Report 'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney', dated 1 June 2010 by ERM
- Draft Report 'Sampling, Analytical and Quality Plan, Other Remediation Works (North) Data Gap Investigation, Millers Point, NSW', 10 March 2010, AECOM
- Report 'Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo and Hickson Road) Millers Point NSW', 23 September 2010, AECOM
- Report 'Data Gap Investigation, Other Remediation Works North, Hickson Road, Barangaroo NSW', 20 October 2010, AECOM
- Report 'Groundwater Discharge Study, Stage 1 Barangaroo Development' dated 3 November 2010 (and drafts dated 16 June, 4 August and 20 October 2010), AECOM
- Report 'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area - Barangaroo', 9 June 2011, AECOM
- Report 'Human Health and Ecological Risk Assessment Addendum, Other Remediation Works (South) Area, Barangaroo', 4 July 2011, AECOM
- Report 'Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW', 9 March 2012, AECOM
- Report 'Data Gap Investigation', dated August 2012 (Rev C), JBS
- Report 'VMP Remediation Extent, VMP Remediation Works Area, (Parts of Barangaroo and Hickson Road), Millers Point NSW', 23 July 2013, AECOM
- Report 'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW', 24 July 2013, AECOM
- Report 'Human Health and Ecological Risk Assessment, Stage 1C Development (ORWN Area), Barangaroo South', 10 December 2014 (and draft dated 3 July 2014), AECOM
- Report 'Remedial Action Plan, Crown Hotel Development (Part of ORWN Area), Barangaroo South', 13 January 2015 (and drafts dated 11 August, 11 November and 19 December 2014), AECOM.

Other information reviewed (including previous site audit reports and statements relating to the site)

- EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009
- Site Audit Report - Overarching Remedial Action Plan, Barangaroo', and Site Audit Statement (SAS) GN 439A, dated 2 June 2010, by ENVIRON, prepared for Barangaroo Delivery Authority (BDA)
- DOP State Environmental Planning Policy (Major Projects) Amendment (Barangaroo), 2007, amendment dated 16 December 2010
- EPA 'Notice of Approval of Voluntary Management Proposal (Section 17 of the Contaminated Land Management Act 1997), Approval No.: 20101719, Approval Date: 23 July 2010, Area No.: 3221' Site Audit Report - Remedial Action Plan, Other Remedial Works (South), Barangaroo' and SAS GN 439B-1, dated 14 July 2011, by ENVIRON, prepared for Lend Lease
- Site Audit Report - Remedial Action Plan, Declaration Area and Block 4, Barangaroo' with two SAS dated 31 July 2013; GN 447A for the Declaration Area relating to revocation of the EPA declaration (and removal of the Voluntary Management Proposal (VMP), and GN439B-3 for Block 4, including part of the Declaration Area, relating to development of Block 4, by ENVIRON, prepared for Lend Lease

Strike out as appropriate

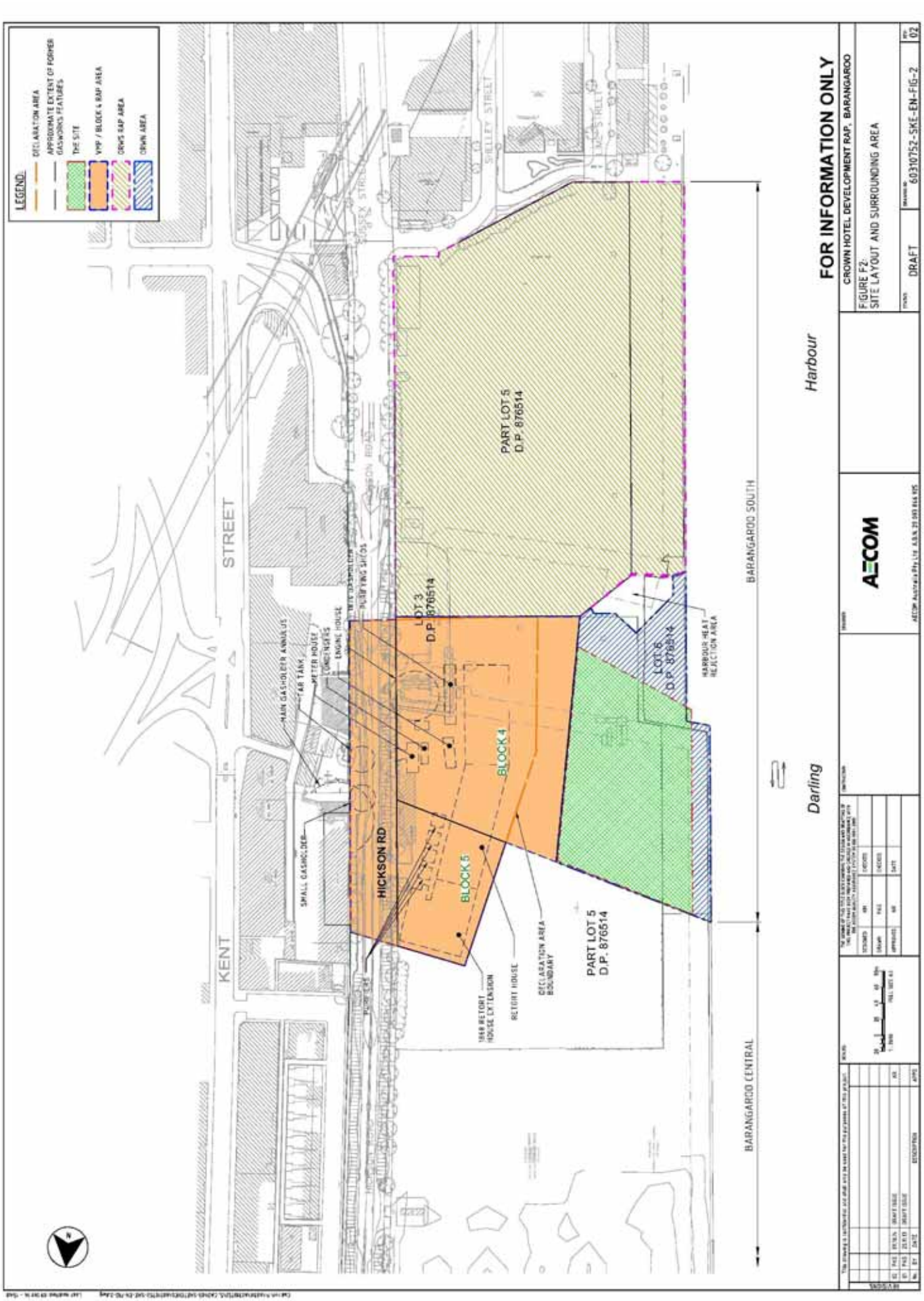
- Site Audit Report - Remedial Action Plan, Barangaroo Central' and SAS GN 439B-5, dated 31 July 2013, by ENVIRON, prepared for BDA
- DOP Director-General's Requirements, Barangaroo Concept Plan, MP06_0162 (MOD 8) dated 15 April 2014.

Site audit report

Title: Site Audit Report – Remedial Action Plan, Crown Sydney Hotel Resort Development, Barangaroo

Report no. GN 439B-6 (ENVIRON Ref: AS121686) Date: January 2015

Strike out as appropriate


LEGEND
DECLARATION AREA
APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
THE SITE
VMP / BLOCK 4 RAP AREA
ORWS RAP AREA
CROWN AREA
STREET
KENT
HICKSON RD
SHELLEY STREET
ESSEX STREET
MAIN GASHOLDER ANNULUS
GAS TANK
METER HOUSE
CONDENSERS
ENGINE HOUSE
PURIFYING SHEDS
SMALL GASHOLDER
LOT 3 D.P. 876514
PART LOT 5 D.P. 876514
LOT 6 D.P. 876514
BLOCK 4
BLOCK 5
HARBOUR HEAT REJECTION AREA
1888 RETORT HOUSE EXTENSION
RETORT HOUSE
DECLARATION AREA BOUNDARY
BARANGAROO CENTRAL
BARANGAROO SOUTH
Darling Harbour
FOR INFORMATION ONLY
CROWN HOTEL DEVELOPMENT RAP, BARANGAROO
FIGURE F2:
SITE LAYOUT AND SURROUNDING AREA
DRAFT
60310752-SKE-EN-FIG-2
AECOM

PART II: Auditor's findings

Please complete either Section A or Section B, **not** both. *(Strike out the irrelevant section.)*

Use Section A where site investigation and/or remediation has been completed and a conclusion can be drawn on the suitability of land use(s).

Use Section B where the audit is to determine the nature and extent of contamination and/or the appropriateness of an investigation or remedial action or management plan and/or whether the site can be made suitable for a specified land use or uses subject to the successful implementation of a remedial action or management plan.

~~Section A~~

❑ **I certify that, in my opinion, the site is SUITABLE for the following use(s)** *(tick all appropriate uses and strike out those not applicable)*:

- ❑ Residential, including substantial vegetable garden and poultry
- ❑ Residential, including substantial vegetable garden, excluding poultry
- ❑ Residential with accessible soil, including garden (minimal home-grown produce contributing less than 10% fruit and vegetable intake), excluding poultry
- ❑ Day care centre, preschool, primary school
- ❑ Residential with minimal opportunity for soil access, including units
- ❑ Secondary school
- ❑ Park, recreational open space, playing field
- ❑ Commercial/industrial
- ❑ Other *(please specify)* ……

subject to compliance with the following environmental management plan *(insert title, date and author of plan)* **in light of contamination remaining on the site:**

OR

❑ **I certify that, in my opinion, the site is NOT SUITABLE for any use due to the risk of harm from contamination.**

Overall comments:

Section B

Purpose of the plan[1] which is the subject of the audit is to remediate or manage the site to facilitate the future land-uses proposed as part of the Crown Sydney Hotel Resort Development.

I certify that, in my opinion:

☑ **the nature and extent of the contamination HAS~~/HAS NOT*~~ been appropriately determined**

AND~~/OR~~

☑ **the ~~investigation~~/remedial action plan/~~management plan~~* IS/~~IS NOT~~* appropriate for the purpose stated above**

AND~~/OR~~

☑ **the site CAN BE MADE SUITABLE for the following uses** *(tick all appropriate uses and strike out those not applicable)*:

- ☐ ~~Residential, including substantial vegetable garden and poultry~~
- ☐ ~~Residential, including substantial vegetable garden, excluding poultry~~
- ☐ ~~Residential with accessible soil, including garden (minimal home-grown produce contributing less than 10% fruit and vegetable intake), excluding poultry~~
- ☐ ~~Day care centre, preschool, primary school~~
- ☐ ~~Residential with minimal opportunity for soil access, including units~~
- ☐ ~~Secondary school~~
- ☐ ~~Park, recreational open space, playing field~~
- ☐ ~~Commercial/industrial~~
- ☑ Other *(please specify) …*development as described in the Remedial Action Plan including hotel, commercial/ retail, public open space and underground parking with minimum 1 m fill placed outside basement areas *……*

if the site is remediated/~~managed~~* in accordance with the following remedial action plan/~~management plan~~* *(insert title, date and author of plan)*

'Remedial Action Plan, Crown Hotel Development (Part of ORWN Area), Barangaroo South', 13 January 2015, AECOM Australia Pty Ltd

subject to compliance with the following condition(s):

…

[1] For simplicity, this statement uses the term 'plan' to refer to both plans and reports.

**** Strike out as appropriate***

Overall comments

The Crown Sydney Hotel Resort Development site comprises a portion of the site known as "Barangaroo", at Millers Point, NSW. The site is proposed to be developed for high density residential and commercial usage with recreational open space areas overlying a basement or existing ground with minimum 1 m fill.

Risk based remediation criteria have been developed based on the proposed site uses and development plans. Soil and groundwater investigations have been conducted, and the results compared to the criteria to determine the extent of remediation required.

In the Auditor's opinion, the proposed remediation and validation approach described in the Remedial Action Plan (RAP) is appropriate. The proposed remediation strategies are generally consistent with the Overarching RAP for Barangaroo.

Site Auditor review of a Validation Sampling, Analytical and Quality Plan (SAQP) is required prior to implementation of the RAP.

If significant changes are made to the development design, or if beneficial reuse of excavated material is contemplated, the RAP proposes to prepare Addendum documents, to be approved by the Site Auditor. This is considered an appropriate approach.

It is noted that the extent of remediation proposed with respect to protection of the environment relies upon implementation of remediation proposed in the VMP/ Block 4 RAP, which was reviewed in Site Audit Report GN 439B-3 and GN 447A, dated July 2013. The VMP/ Block 4 RAP defines remediation required at part of a former manufactured coal gasworks which has been declared by the NSW Environment Protection Authority (EPA) as a Remediation Site (No. 21122) and is located to the east of the Crown Sydney Hotel Resort Development site.

PART III: Auditor's declaration

I am accredited as a site auditor by the NSW Environment Protection Authority under the *Contaminated Land Management Act 1997* (Accreditation No. 9808).

I certify that:

- I have completed the site audit free of any conflicts of interest as defined in the *Contaminated Land Management Act 1997,* and
- with due regard to relevant laws and guidelines, I have examined and am familiar with the reports and information referred to in Part I of this site audit, and
- on the basis of inquiries I have made of those individuals immediately responsible for making those reports and obtaining the information referred to in this statement, those reports and that information are, to the best of my knowledge, true, accurate and complete, and
- this statement is, to the best of my knowledge, true, accurate and complete.

I am aware that there are penalties under the *Contaminated Land Management Act 1997* for wilfully making false or misleading statements.

Signed...  Date... 20/1/2015

PART IV: Explanatory notes

To be complete, a site audit statement form must be issued with all four parts.

How to complete this form

Part I identifies the auditor, the site, the purpose of the audit and the information used by the auditor in making the site audit findings.

Part II contains the auditor's opinion of the suitability of the site for specified uses or of the appropriateness of an investigation, or remedial action or management plan which may enable a particular use. It sets out succinct and definitive information to assist decision-making about the use(s) of the site or a plan or proposal to manage or remediate the site.

The auditor is to complete either Section A or Section B of Part II, **not** both.

In **Section A** the auditor may conclude that the land is *suitable* for a specified use(s) OR *not suitable* for any beneficial use due to the risk of harm from contamination.

By certifying that the site is *suitable*, an auditor declares that, at the time of completion of the site audit, no further remediation or investigation of the site was needed to render the site fit for the specified use(s). Any **condition** imposed should be limited to implementation of an environmental management plan to help ensure the site remains safe for the specified use(s). The plan should be legally enforceable: for example a requirement of a notice under the *Contaminated Land Management Act 1997* (CLM Act) or a development consent condition issued by a planning authority. There should also be appropriate public notification of the plan, e.g. on a certificate issued under s.149 of the *Environmental Planning and Assessment Act 1979*.

Auditors may also include **comments** which are key observations in light of the audit which are not directly related to the suitability of the site for the use(s). These observations may cover aspects relating to the broader environmental context to aid decision-making in relation to the site.

In **Section B** the auditor draws conclusions on the nature and extent of contamination, and/or suitability of plans relating to the investigation, remediation or management of the land, and/or whether land can be made suitable for a particular land use or uses upon implementation of a remedial action or management plan.

By certifying that a site *can be made suitable* for a use or uses if remediated or managed in accordance with a specified plan, the auditor declares that, at the time the audit was completed, there was sufficient information satisfying guidelines made or approved under the CLM Act to determine that implementation of the plan was feasible and would enable the specified use(s) of the site in the future.

For a site that *can be made suitable*, any **conditions** specified by the auditor in Section B should be limited to minor modifications or additions to the specified plan. However, if the auditor considers that further audits of the site (e.g. to validate remediation) are required, the auditor must note this as a condition in the site audit statement.

Auditors may also include **comments** which are observations in light of the audit which provide a more complete understanding of the environmental context to aid decision-making in relation to the site.

In **Part III** the auditor certifies his/her standing as an accredited auditor under the CLM Act and makes other relevant declarations.

Where to send completed forms

In addition to furnishing a copy of the audit statement to the person(s) who commissioned the site audit, statutory site audit statements must be sent to:

EPA (NSW)
Contaminated Sites Section
PO Box A290, SYDNEY SOUTH NSW 1232
nswauditors@epa.nsw.gov.au

AND

the **local council** for the land which is the subject of the audit.

Contents

List of Tables and Figures

List of Appendices

List of Abbreviations

AASS	Actual Acid Sulfate Soils
AC	Asbestos Cement
ACM	Asbestos Containing Material
AECOM	AECOM Australia Pty Ltd
AGL	Australian Gaslight Company
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ASET	Australian Safer Environment and Technology Pty Ltd. (Laboratory)
ASAC	Analyte Specific Acceptance Criteria
ASLP	Australian Standard Leaching Procedure
ASS	Acid Sulfate Soils
ANZECC	Australian and New Zealand Environment and Conservation Council
BaP	Benzo(a)pyrene
BDA	Barangaroo Delivery Authority
BGL	below ground level
BTEX	Benzene, Toluene, Ethylbenzene & Xylenes (Monocyclic Aromatic Hydrocarbons)
CIM	Confirmed Impacted Material
CLM Act	NSW *Contaminated Land Management Act 1997*
COC	Chain of Custody
COPC	Contaminants of Potential Concern
CPAH	carcinogenic PAHs and includes: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h) anthracene and indeno(1,2,3-cd)pyrene
Crown	Crown Sydney Property Pty Ltd
CRS	Chromium Reducing Sulfur
CSM	Conceptual Site Model
DAF	Dilution Attenuation Factor
DEC	NSW Department of Environment and Conservation (now OEH)
DECC	NSW Department of Environment and Climate Change (now OEH)
DGI	Data Gap Investigation Report
DGRs	Director-General's Requirements
DNAPL	Dense Non Aqueous Phase Liquid
DOP	Department of Planning (NSW)
DP	Deposited Plan
DQI	Data Quality Indicators
DQO	Data Quality Objectives
EMP	Environmental Management Plan
ENM	Excavated Natural Material
EnRiskS	Environmental Risk Sciences Pty Ltd
EPA	Environment Protection Authority (NSW)
EPL	Environment Protection License
ERM	Environmental Resources Management Australia Pty Ltd
ESA	Environmental Site Assessment report
ESD	Ecologically Sustainable Development
ha	Hectare
HHERA	Human Health and Ecological Risk Assessment
HHR	Harbour Heath Rejection
JBS	JBS Environmental Pty Ltd
J&K	Jeffery & Katauskas Pty Ltd
km	Kilometres
LCS	Laboratory Control Sample
LDPE	Low Density Polyethylene
Lend Lease	Lend Lease (Millers Point) Pty Ltd
m	Metres
MAH	Monocyclic Aromatic Hydrocarbons
Mercury	Inorganic mercury unless noted otherwise

Metals	As: Arsenic, Cd: Cadmium, Cr: Chromium, Cu: Copper, Fe: Iron, Ni: Nickel, Pb: Lead, Zn: Zinc, Hg: Mercury, Se: Selenium
mg/kg	Milligrams per Kilogram
mg/L	Milligrams per Litre
mBGL	Metres below ground level
MWQC	marine water quality criteria
µg/L	Micrograms per Litre
NAPL	Non Aqueous Phase Liquid
NATA	National Association of Testing Authorities
NC	Not Calculated
ND	Not Detected
ng/L	Nanograms per Litre
NEHF	National Environmental Health Forum
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
n	Number of Samples
OEH	Office of Environment and Heritage, NSW Department of Premier and Cabinet
OCPs	Organochlorine Pesticides
OH&S	Occupational Health & Safety
OPPs	Organophosphorus Pesticides
ORWN	Other Remediation Works (North) Area
ORWS	Other Remediation Works (South) Area
PAHs	Polycyclic Aromatic Hydrocarbons
PASS	Potential Acid Sulfate Soils
PCBs	Polychlorinated Biphenyls
PID	Photoionisation Detector
PIM	Potential Impacted Material
POEO Act	Protection of the Environment Operations Act 1997
PQL	Practical Quantitation Limit
pH	a measure of acidity, hydrogen ion activity
QA/QC	Quality Assurance/Quality Control
RAP	Remedial Action Plan
RPD	Relative Percent Difference
RWP	Remedial Work Plan
SAQP	Sampling, Analysis and Quality Plan
SAR	Site Audit Report
SAS	Site Audit Statement
SILs	Soil Investigation Levels
SMP	Site Management Plan
SPGWT	Separate Phase Gasworks Waste and Tar
SPT	Standard Penetration Test
SSESC	Site Specific Ecological Screening Criteria
SSTC	Site Specific Target Criteria
SVOCs	Semi Volatile Organic Compounds
TCLP	Toxicity Characteristics Leaching Procedure
TCM	Tar Containing Material
TPH	Total Petroleum Hydrocarbons
TSC	Terrestrial Soil Criteria
TTM	Total Toxicity of Mixtures
TV	Trigger Value
UCL	Upper Confidence Limit
VENM	Virgin Excavated Natural Material
VMP	Voluntary Management Proposal
VOCs	Volatile Organic Compounds
WAD	Weak Acid Dissociable (cyanide)
-	On tables is "not calculated", "no criteria" or "not applicable"

1 Introduction

1.1 Site Identification

A site contamination audit has been conducted in relation to a portion of the site known as 'Barangaroo', at Millers Point, NSW, on behalf of Crown Sydney Property Pty Ltd (Crown). Barangaroo is a large site being developed in stages for a variety of uses, with different portions subject to separate audits. The portion of Barangaroo that is the subject of this audit has been designated as the Crown Sydney Hotel Resort Development ('the site') and is part of the 'Other Remediation Works (North)' area (ORWN). The site location is shown on Attachment 1, Appendix A and the site layout is shown on Attachment 2, Appendix A. The portion of Barangaroo which previously contained part of a manufactured coal gasworks and which has been declared by the NSW Environment Protection Authority (EPA) (now part of Office of Environment and Heritage (OEH)) as a Remediation Site (No. 21122, 'the Declaration Area') is located to the east.

The Audit was conducted to provide an independent review by an NSW EPA Accredited Auditor of what remediation or management is necessary before the land is suitable for specified uses i.e. a "Site Audit" as defined in Section 4 (1) (b) (iv) of the *NSW Contaminated Land Management Act 1997* (the CLM Act). The primary document reviewed is a remedial action plan (RAP) prepared by AECOM Australia Pty Ltd (AECOM) which has been prepared to address remediation of the Crown Sydney Hotel Resort Development.

1.2 Background

Details of the audit are:

Requested by:	Josef Seidler on behalf of Crown Sydney Property
Request/Commencement Date:	9 December 2013
Auditor:	Graeme Nyland
Accreditation No.:	9808

A number of contamination investigations have been conducted at the larger Barangaroo site since 1996. As part of the audit, the Auditor has reviewed investigation results, risk-based remediation criteria and remediation planning documentation relevant to the site.

Separate RAPs are to be prepared for each development stage at Barangaroo. As it is envisaged that remediation in different portions of Barangaroo will be linked, for example by reuse of material from one part in another, an Overarching RAP has also been prepared (ERM, 2010) to identify strategies and remedial options for remediation of the whole site. Review of the Overarching RAP was conducted for Barangaroo Delivery Authority (BDA) by the Auditor and a Site Audit Report (SAR) prepared as follows:

- 'Site Audit Report - Overarching Remedial Action Plan, Barangaroo', and Site Audit Statement GN 439A, dated 2 June 2010.

RAPs for additional portions of Barangaroo surrounding the site have been reviewed by the Auditor on behalf of the BDA or Lend Lease (Millers Point) Pty Ltd (Lend Lease), and SARs prepared as follows:

- 'Site Audit Report, Remedial Action Plan, Other Remedial Works (South), Barangaroo' and Site Audit Statement (SAS) GN 439B-1, dated 14 July 2011. Located to south of site, prepared for Lend Lease *(the ORWS SAR)*.
- 'Site Audit Report, Remedial Action Plan, Declaration Area and Block 4, Barangaroo' with two SAS dated 31 July 2013; GN 447A for the Declaration Area relating to revocation of the EPA declaration (and removal of the Voluntary Management Proposal (VMP), and GN439B-3 for Block 4, including part of the Declaration Area, relating to development of Block 4. Adjoining the site to the east, prepared for Lend Lease *(the Declaration Site SAR)*.
- 'Site Audit Report, Remedial Action Plan, Barangaroo Central' and SAS GN 439B-5, dated 31 July 2013. Adjoining the site to the north, prepared for BDA *(the Central SAR)*.

1.3 Scope of Work

The scope of the audit included:

- Review of the following reports:
  - 'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW' dated 21 August 2006, by Jeffery and Katauskas Pty Ltd (J&K)
  - Report 'Land at Millers Point, Ownership and Usage' dated 1 June 2007, by Rosemary Broomham
  - Final Report 'Environmental Site Assessment, East Darling Harbour, Sydney, NSW' dated 21 June 2007, by Environmental Resources Management Australia Pty Ltd (ERM)
  - Report 'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW' dated July 2008, by ERM (2008a)
  - Report 'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney' dated September 2008, by ERM (2008b)
  - Report 'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney', dated 1 June 2010 by ERM *(the Overarching RAP)*
  - Draft Report 'Sampling, Analytical and Quality Plan, Other Remediation Works (North) Data Gap Investigation, Millers Point, NSW', 10 March 2010, AECOM (2010a)
  - Report 'Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo and Hickson Road) Millers Point NSW', 23 September 2010, AECOM (2010b)
  - Report 'Data Gap Investigation, Other Remediation Works North, Hickson Road, Barangaroo NSW', 20 October 2010, AECOM *(the ORWN DGI)* (2010c)

  - Report 'Groundwater Discharge Study, Stage 1 Barangaroo Development' dated 3 November 2010 (and drafts dated 16 June, 4 August and 20 October 2010), AECOM (*the Groundwater Discharge Study*) (2010d)
  - Report 'Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW', 9 March 2012, AECOM (2012)
  - Report 'Data Gap Investigation', dated August 2012 (Rev C), JBS Environmental Pty Ltd (JBS)
  - Report 'Human Health and Ecological Risk Assessment, Stage 1C Development (ORWN Area), Barangaroo South', 10 December 2014 (and draft dated 3 July 2014), AECOM *(the ORWN HHERA)* (2014)
  - Report 'Remedial Action Plan, Crown Hotel Development (Part of ORWN Area), Barangaroo South', 13 January 2015 (and drafts dated 11 August, 11 November and 19 December 2014), AECOM *(the RAP)* (2015)

- Review of the following OEH, EPA and Department of Planning (DOP) documents:
  - EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009
  - DOP State Environmental Planning Policy (Major Projects) Amendment (Barangaroo), 2007, amendment dated 16 December 2010
  - EPA 'Notice of Approval of Voluntary Management Proposal (Section 17 of the Contaminated Land Management Act 1997), Approval No.: 20101719, Approval Date: 23 July 2010, Area No.: 3221'
  - DOP Director-General's Requirements, Barangaroo Concept Plan, MP06_0162 (MOD 8) dated 15 April 2014
- Key documents considered in the Other Remediation Works (South) (ORWS) SAR (GN439B-1) and referred to herein are:
  - Report 'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area - Barangaroo', 9 June 2011, AECOM (*the Declaration Site HHERA*, AECOM 2011a)
  - Report 'Human Health and Ecological Risk Assessment Addendum, Other Remediation Works (South) Area, Barangaroo', 4 July 2011, AECOM (*the ORWS HHERA Addendum*, AECOM 2011b)
- Key documents considered in the Declaration Site SAR (GN439B-3 and GN 447A) and referred to herein are:
  - Report 'VMP Remediation Extent, VMP Remediation Works Area, (Parts of Barangaroo and Hickson Road), Millers Point NSW', 23 July 2013, AECOM (*the VMP Extent Report*, AECOM 2013a)

  - Report 'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW', 24 July 2013, AECOM (*the VMP/ Block 4 RAP*, AECOM 2013b)

- Site visits to Barangaroo by the Auditor or representative on 18 March 2010 and subsequently as part of audits of other parts of Barangaroo.
- Discussions with Crown, Lend Lease and BDA, and with AECOM, who undertook the recent works.

The ERM investigations were completed prior to the Auditor's engagement and no discussion with ERM was undertaken.

1.4 Audit Team

The Audit was completed by Graeme Nyland with the assistance of a site audit team.

Internal (ENVIRON) support was provided by the following staff:

- Rowena Salmon – overall audit support including analysis of field and laboratory data and review of proposed remediation
- Emma Struik – review of risk based remediation criteria
- Tom Onus – data analysis and review of laboratory data quality.

External support was provided by the following persons/ organisation for previous audits which were relied upon for this audit:

- Jackie Wright and Therese Manning, Environmental Risk Sciences Pty Ltd (EnRiskS) – review of HHERAs including a separate detailed report on the Declaration Site HHERA.

2 Site Details

2.1 Location

The site locality is shown on Attachment 1, Appendix A and the site boundary is illustrated on Attachment 2, Appendix A.

The site details are as follows:

Street address:	Hickson Road (Sussex Street), Barangaroo, NSW 2000
Identifier:	Part Lot 5 and Part Lot 6 in DP 876514
Local Government:	City of Sydney
Owner:	Barangaroo Delivery Authority
Site Area:	Approximately 10,242 m^2 (reported in AECOM (2015) based on CAD plans provided by Crown)

The boundaries of the site are currently not well defined in the field. A survey of the audit site boundary is not currently available.

2.2 Zoning

The current zoning of the site was identified in the RAP (AECOM, 2015) as part zone B4 Mixed Use (eastern side) and part zone RE1 Public Recreation (western side). This is the zoning identified under State Environmental Planning Policy (Major Development) Barangaroo, dated 16 December 2010.

2.3 Adjacent Uses

The site is located within an area of mixed uses (Attachment 2, Appendix A):

- North: part of Barangaroo Central, concrete/ hardstand area, currently being used by Lend Lease for staging of surrounding construction works.
- South: part of the ORWN area outside the site which includes the footprint of the proposed Southern Cove, followed by the Harbour Heat Rejection (HHR) inlet area and the Barangaroo South Stage 1A development, which is under construction for commercial, residential and open space land uses.
- East: Barangaroo South Stage 1B (Block 4) development area (including part of the Declaration Area) then Hickson Road and residential and commercial buildings beyond.
- West: part of the ORWN area outside the site, to be developed as a public foreshore walkway, followed by Darling Harbour.

Attachment 2, Appendix A, shows the location of the former gasworks facilities to the east of the site, located within the Declaration Area. The former gasworks facilities have potential to have caused contamination at ORWN.

Darling Harbour is a nearby environmental receptor.

2.4 Site Condition

The site is flat, at an elevation a few metres above Darling Harbour water level.

It is currently being used as a staging area for the adjacent Stage 1A (ORWS) construction site and for a water treatment plant.

2.5 Proposed Development

Based on current development plans described in the RAP (AECOM, 2015), the site is to be redeveloped for mixed uses including a hotel (incorporating high density residential with minimal access to soil), commercial/ retail, public open space and underground parking.

Key components of the site development are as follows (AECOM, 2015, refer Attachment 3, Appendix A):

- A tower containing hotel rooms, suites and residential apartments. The entire footprint of the tower will be above a basement.
- A podium containing hotel reception, retail and gaming facilities. The podium will be largely above a basement but with some limited areas constructed as slab on grade.
- An underground basement intended to provide car parking and loading facilities associated with the future intended Crown hotel development. The basement will be contained within a groundwater retention wall keyed into bedrock.
- Terrace areas containing restaurant and bar facilities. The elevated Terrace areas will be largely constructed as elevated slab on grade (these areas will be licensed by Crown from the BDA).
- Public open space, landscaping, roads, pedestrian ways and cycle paths, largely built on grade.

Development areas not located over basements (the podium and terrace areas) will be constructed at an elevation raised up to 1.6 m above the current ground level, therefore a minimum of 1 m of imported fill will be placed in these areas.

The general land use scenarios applicable to this audit are ‘commercial/industrial’, ‘high density residential’ and ‘parks, recreational, open space’.

The ORWN HHERA derives criteria for the following scenarios relevant to the site, as discussed in Section 10 of this SAR:

- Scenario 1 – lower-most basement car park level below water level
- Scenario 6 – short term ground-intrusive maintenance (with potential to contact groundwater)
- Scenario 9 – upper-most basement car park level
- Scenario 10 – unpaved recreation
- Scenario 11 – paved recreation
- Scenario 12 – intrusive maintenance work (without potential to contact groundwater)
- Scenario 13 – high density residential (overlying a basement)
- Scenario 14 – multistorey commercial elevated slab on grade (podium areas outside basement).

3 Site History

AECOM provided a site history summarised from information in previous reports prepared by ERM (2007 and 2008) and Broomham (2007). Information relevant to the site is summarised in Table 3.1 based on the DGIs (AECOM, 2010b and 2010c) and the Auditor's review of Broomham (2007).

Table 3.1: Site History

Date	Activity
Pre 1839	The original shoreline ran approximately along the western edge of Hickson Road.
1839-1920s	Land to east (declared area) occupied by Australian Gaslight Company (AGL). Included gasworks, retort house and gasholder. Gasworks demolished in mid 1920s, new finger wharves constructed crossing the Crown site area; former gasworks area subsequently used for various workshop facilities.
1800s	The site was occupied by finger wharves and was used for shipping and manufacturing.
1930s	MSB painted creosote on the wharf piles to protect them against insects.
1961-68	Finger wharves demolished. New sea walls and new longshore wharfs constructed. Filling undertaken behind (east of) sea walls. Site and remainder of Barangaroo filled with the exception of Southern Cove. Part of Southern Cove was located in the southern portion of the site, south of the caisson wall shown on Attachment 4, Appendix A.
By 1972	Large warehouse building (Warehouse 6) constructed on the north side of Southern Cove, straddling the site and Declaration Area to the east. Site covered by hard stand, used for various port related activities.
Late 1980s/ early 1990s	Southern Cove filled in (Broomham reports 1990-1993, AECOM report 1986-1988).
1995-2006	Longshore wharves leased to Patrick Stevedores. Port related activities.
2007, 2009	Declaration of Investigation Area then Remediation Site for Wharfs 5 and 7 and Hickson Road by NSW EPA (east of site).
2008-2011	Wharf at site vacated, buildings demolished.

The summary indicates that the site has been used for wharf/ port related activities since the 1800s. Original finger wharves were removed and the site was largely filled in 1968-1986 for the construction of longshore berthage, with additional filling in the south of the site (area of former Southern Cove) in the late 1980s or early 1990s.

In the Auditor's opinion, the site history provides an adequate indication of past activities, with the primary potential for contamination being in uncontrolled fill used in various stages of site reclamation. It does not appear that any part of the site was filled during the gasworks operation therefore the potential for significant quantities of gasworks wastes in fill would be expected to be low.

4 Contaminants Of Concern

The DGIs (AECOM, 2010b and 2010c) provided a list of the contaminants of concern and potentially contaminating activities. These have been tabulated in Table 4.1.

Table 4.1: Contaminants of Concern

Area	Activity	Potential Contaminants
Whole of site	Importation of fill materials to reclaim land	Unknown, could include HM, TPH, BTEX, PAHs, PCBs, OCPs, VOCs, SVOCs, asbestos
Whole of site	Demolition of former buildings potentially containing hazardous materials	Unknown, could include lead, PCBs, asbestos
Whole of site	Land reclamation	Acid sulfate soils
Offsite to the East	Former gasworks	Gasworks waste – could include HM, TPH, BTEX, PAHs, phenols, sulfate, cyanide, ammonia

HM heavy metals: arsenic, copper, chromium, cadmium, mercury, lead, nickel, zinc
TPH total petroleum hydrocarbons
BTEX benzene, toluene, ethylbenzene and xylenes
PAHs polycyclic aromatic hydrocarbons
PCBs polychlorinated biphenyls
OCPs organochlorine pesticides
VOCs volatile organic compounds
SVOCs semivolatile organic compounds
ASS Acid sulfate soils

The Auditor considers that the analyte lists used by ERM, JBS and AECOM in the investigations undertaken are generally appropriate for the site history and condition. Details of the soil and groundwater analyses performed are provided in Sections 8 and 9, respectively.

The majority of soil samples were analysed for the primary contaminants of concern, being heavy metals, TPH/ BTEX and PAH (over 80 samples analysed). Between 5 and 65 samples were also analysed for the extended suite of potential organic contaminants, including phenols, OCP, OPP, PCBs, other SVOCs and VOCs. This sampling density is considered acceptable since very few detections were made, and when they did occur, they were generally of low concentration and occurred in conjunction with other more significant concentrations of the primary contaminants. A lower sampling density was also completed for asbestos, with 9 samples analysed. Asbestos is discussed in Section 8.3.4.

Groundwater samples, from up to seven rounds of monitoring, were analysed for the primary contaminants of concern, being heavy metals, TPH/BTEX and PAH. Cyanide (either free or total), PCBs and SVOCs were also analysed in some wells in most rounds. These sampling densities are considered adequate.

The individual substances included in each suite of analytes are listed in Appendix D.

5 Stratigraphy and Hydrogeology

Following a review of the referenced reports, a summary of the site stratigraphy and hydrogeology was compiled as follows.

5.1 Stratigraphy

The 1:100,000 Geological Survey of NSW (Sydney) Sheet 9130 indicates the site to be underlain by Hawkesbury Sandstone and man-made fill, where man-made fill may consist of *"dredged estuarine sand and mud, demolition rubble, industrial and household waste"*. The sub-surface profile of the site based on investigations undertaken (refer Section 6) is summarised in Table 5.1. Investigation locations are shown on Attachment 4, Appendix A.

Table 5.1: Stratigraphy

Depth (mBGL)	Subsurface Profile
Surface	Hardstand, comprising asphalt or concrete pavement
Occurs below hardstand To between 12 and 25 m Thickness increases from east to west.	Fill, highly heterogeneous, comprises gravel, sand, silt and clay, with sandstone, bricks, concrete, timber, steel, slag and ash.
Occurs between fill and bedrock Thickness varies, 0 to over 15m	Alluvial sediments, sand, clayey sand, sandy clay and clayey silt, some shell fragments and organic matter
	Residual soils weathered from sandstone bedrock, clayey sand and sandy clay
Occurs below natural soil or directly below fill Highly variable, from between 19 and 32 m Apparent deeper troughs running east to west	Sandstone bedrock

Attachment 5, Appendix A, presents indicative bedrock and marine sediment contours prepared by AECOM. The difference between these contours can be used to determine the local thickness of natural soils (alluvial sediments and residual soil), which is generally thicker moving to the west, where bedrock is deeper.

Based on review of the site history (refer Section 3) the Auditor considers that there were three main stages representing the filling history:

- Original filling of the eastern portion for development, including construction of finger wharves, in 1800s.
- Demolition of finger wharves and filling of the majority of the western portion of the site in 1961-1968 for the construction of longshore berthage.

- Filling of southern cove (previously located in the south of the site) in late 1980s/ early 1990s, with the exception of the western portion which remains as a void below a suspended concrete slab (refer Attachment 3, Appendix A).

The filling of the majority of the site would have occurred during the second stage. AECOM (2015) reported that based on observations from the various investigations undertaken, distinct differences in fill type relative to the historical filling sequence of the site are difficult to identify.

5.2 Hydrogeology

Groundwater at the site is within 2-3 m below ground level (BGL), varying due to tidal fluctuation. The amplitude of fluctuation in groundwater due to tidal effect decreases with distance from the Darling Harbour (western) boundary, however, fluctuation is still noted as far east (inland) as Hickson Road (AECOM, 2010c). A caisson (sea) wall is present along the western boundary and crosses through the south of the site. This wall has been found to be highly permeable and does not prevent the tidal flow of groundwater (AECOM, 2010d).

Hydraulic conductivity of fill at the site was assessed by ERM (2008a) using tidal lag response equations based on site tidal fluctuation data, and by AECOM (2010b) using rising head permeability tests in three wells. AECOM (2010c) observed a range of permeabilities within the natural materials screened. Wells tested on the adjoining ORWS site were observed to recover almost instantaneously, reflecting the sand and gravel nature of the fill material tested. Testing conducted across the larger Barangaroo site indicated a wide range of hydraulic conductivity depending on the local fill type or natural material encountered. Further hydraulic testing was performed at the site as part of the Groundwater Discharge Study (AECOM, 2010d), discussed below.

Groundwater quality at the site is brackish to saline, approaching seawater composition (AECOM, 2010c).

A Groundwater Discharge Study (AECOM, 2010d) was conducted to investigate the interaction between site groundwater and Darling Harbour. Transects of multilevel piezometers were installed across the site and a range of hydraulic and analytical testing was performed. Key findings from this study were:

- Significant changes in water level in the unconfined fill aquifer (>1 m in some cases) suggested significant quantities of water are exchanged across the aquifer – harbour interface.
- Relative to the fill, groundwater discharge volumes and therefore contaminant mass flux from the marine sediments and basal sandstone was considered to be negligible.
- The proportion of groundwater to seawater discharging during the low tide cycle to Darling Harbour was derived from a connate water displacement model. The results suggest that much of the water discharged during ebb tides comprises seawater which infiltrated during the previous flood tide. The mixing analysis indicates that the groundwater component of any discharge is likely to be 10-20% of the total.
- Contaminant mass flux is difficult to estimate on a site wide basis due to the heterogeneity of the fill, but mass flux is likely to be strongly limited by dilution occurring up-gradient of the tidal exchange prism (the portion of fill adjacent to the harbour,

estimated at extending 10 m from the sea wall). A five-fold dilution factor was estimated for dissolved phase contamination migrating from an upgradient source zone into Darling Harbour.

The flux of contaminants in marine sediments was considered by AECOM in two further studies which were reviewed in the Declaration Site SAR. The studies concluded that there is negligible flux of contaminants from the natural soil and marine sediments underlying the site into Darling Harbour or into the overlying fill material.

Based on the Auditor's review, the hydrogeological conditions are reasonably well understood.

6 Evaluation of Quality Assurance and Quality Control

The Auditor has assessed the overall quality of the investigation data by review of the information presented in the referenced reports, supplemented by field observations. The initial investigations by ERM included parts of Barangaroo that are not included within the site. Only the information relevant to this site has been reviewed for this audit. The primary information reviewed comprised soil and groundwater well logs, and field and analytical methods and results for the following investigations within the site area and immediate surrounds ('offsite'):

- **ERM (2007):** environmental site assessment comprising approximately ten boreholes, installation of three groundwater wells (BH053/MW11, BH076/MW14, BH116/MW22) and sampling of three wells within the site. This investigation also included installation and sampling of one offsite well (BH129/MW24) located on the ORWN site, which were also considered as part of the scope for this review.
- **ERM (2008a):** additional investigations comprising two boreholes (BH191 and BH212) and installation of one groundwater well (MW212).
- Rock core logs for the above ERM investigations were reported in J&K (2006).
- **AECOM (2010b):** EPA Declaration Area DGI comprising one borehole offsite (BH48) and sampling of three onsite groundwater wells.
- **AECOM (2010c):** ORWN DGI comprising nine boreholes (BH39, BH40, BH46, BH47, BH56, BH57, BH60, BH72 and BH73), installation of three onsite groundwater wells (MW40, MW56, MW60), installation of one soil vapour well (SV08), and sampling of six wells and one soil vapour sampling point. Data from the soil vapour sampling is not relevant to the RAP and is therefore not included in this assessment.
- **AECOM (2012):** Supplementary Data Gap Investigation for the VMP Area comprising two boreholes (BH410 and BH411), which were converted into groundwater wells (IT04 and IT05) and sampled.
- **JBS (2012):** Central DGI comprising two wells located near the northern site boundary (MW544S/D and MW547S/D).

Comments specific to 'offsite' data are made by the Auditor where relevant, however, a detailed review for these investigations is not documented in this SAR. Data review was performed for adjacent site audits (including the ORWS, Declaration Site and Central SARs).

The AECOM investigations were performed following appointment of the Auditor, and were undertaken in general accordance with SAQP documents reviewed by the Auditor.

The Auditor's assessment of the data QA/QC follows in Tables 6.1 and 6.2.

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment

Sampling and Analysis Plan and Sampling Methodology	Auditor Comments
Sampling Pattern and Locations	**Soil:** The initial investigations by ERM (2007) comprised low density "strategic" sampling to support a design competition and identify any further work needed to complete the development approval, rather than full characterisation of the site. Investigation

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	locations were restricted by the presence of the large Wharf 8 terminal building and some smaller buildings on the eastern boundary, as well as operational constraints of the stevedoring business on the site. Additional investigations by ERM (2008a), AECOM (2010b, 2010c and 2012) and JBS (2012) aimed to fill data gaps from the preceding investigation, to support remediation planning. Key data gaps included: • Characterisation of deep fill • Delineation of previously identified impacts • Assessment of ASS. There were no localised sources of contamination identified onsite that were targeted by the soil investigation locations, however, the declared area to the east was recognised as a primary source of contamination. The resulting combined site coverage therefore comprises a higher density of sampling in the offsite areas to the east, with a lower density of sampling across the site. In the Auditor's opinion, the investigation locations performed adequately target the main areas of concern and provide reasonable coverage of the remainder of the site to allow for remediation planning. **Groundwater** monitoring wells are concentrated in the north western and mid-western portions of the site with one deep well located adjacent to the Declaration Area on the eastern boundary of the site. Given the proximity of the eastern portion of the site to the Declaration Area, the full range of groundwater conditions are not likely to have been assessed by the wells installed. In the Auditor's opinion, the groundwater well locations are considered adequate to allow for remediation planning given the style of basement development proposed.
Sampling Density	**Soil:** The combined sampling density of 26 soil investigation locations over approximately 1 ha exceeds the minimum recommended by EPA (1995) 'Sampling Design Guidelines' (51). If the locations were evenly spaced (not the case), this coverage would provide a 95% confidence of detecting a residual hot spot of approximately 23 m diameter. As noted above, there is a higher density of sampling in certain areas of the site. The density of investigation locations is considered adequate for remediation planning. The density of analysis for specific analytes was discussed in Section 4, and is generally considered appropriate. The low sampling density for asbestos is discussed in Section 8.3.4. **Groundwater:** A total of 22 groundwater wells were considered representative of groundwater conditions at the site. These wells were installed at 13 locations (multiple depths were targeted at some locations). Wells were sampled for the main contaminants of concern, one to two times each. The groundwater well locations

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	and analytical sampling density are considered adequate to allow for remediation planning.
Sample depths	Soil sampling focussed primarily on fill materials. Investigations have also assessed underlying natural sediments and the upper layers of weathered bedrock which could be penetrated by standard drilling methods. Deeper bedrock conditions (generally 3-4 m) were assessed by coring at around 11 locations from across the site (ERM, 2007), however, no samples were collected from bedrock for contamination testing. Therefore only a visual assessment of contamination could be performed. Photographic records of the cores were provided (J&K, 2006) to the Auditor for review. Generally 2-5 samples were analysed per location from the investigation stages. With the exception of the cored boreholes, these locations were advanced until refusal, generally in weathered sandstone and occasionally in fill. In the Auditor's opinion, this sampling strategy was appropriate and adequate to characterise the primary material types present on site, and to allow for remediation planning.
Well construction	Wells were constructed wells from 50mm uPVC casing with 0.4-0.5 mm machine slotted screen, graded sand filter pack and bentonite seal. The ERM (2007) wells screened the upper to middle sections of the fill. Screen lengths range from 3.5-7 m. The maximum well depth was 9 mBGL. The ERM (2008a) well (MW212) screened nearly the entire fill depth to 16.8 mBGL. The AECOM wells were generally constructed over discrete fill depths. Four nested wells of shallow, mid and deep screen intervals were installed on the site (IT01, IT02, IT04 and IT05). The screen intervals were 1 m long and targeted shallow fill, deep fill and natural sediment. Three wells (MW40, MW56, MW60) were generally screened across natural sediments at depths of between 14 and 22 mBGL. The JBS (2012) well (MW544) was installed as a nested shallow and deep pair. The shallow well was screened across shallow fill and the standing water level, from 3-5.5 mBGL. The deep well was screened across deep fill from 10-13 mBGL. Long well screen intervals are not ideal for the assessment of groundwater contamination. Long screen length results in dilution of samples, therefore, the sample results from these wells should be considered to potentially underestimate the discrete contaminant concentrations present. It is also noted that the top of the well screens are not all above the top of the groundwater table. This would not allow for identification of any floating separate phase product. Although the screened intervals were generally long and contaminant concentrations in discrete groundwater intervals may

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	be higher than reported, overall, the groundwater well construction is considered adequate to provide average groundwater concentrations. This is considered appropriate for remediation planning given the proposed basement construction discussed in Section 10.
Sample Collection Method	**Soil**: ERM and AECOM samples were obtained from push tube samplers and Standard Penetration Test (SPT) split spoons used in conjunction with push tube, auger, mud rotary and rotary casing advance techniques. Nearly all samples for laboratory analysis were semi undisturbed samples obtained from SPT or push tube. JBS samples were disturbed samples taken from solid stem auger flights. The Auditor notes that sampling from solid stem augers can result in cross contamination and loss of volatiles. ERM (2007) included locations coring through bedrock, generally for 3-4 m. **Groundwater**: ERM wells were developed using a submersible electric pump to remove a minimum of ten well volumes or until the well was dry. Wells were sampled after at least one week following development using low flow sampling techniques. AECOM wells were developed using both dedicated Teflon foot valves with low density polyethylene (LDPE) tubing and an electronic high volume submersible pump to remove at least ten well volumes or until the wells were purged dry. AECOM reportedly collected groundwater samples by low flow/ micropurge methods with purge volumes reported between 3-6 L. JBS purged and sampled wells using low flow methods. Samples collected for metals analysis were field filtered using a 0.45 µm filter. Overall the sample collection methods were acceptable.
Decontamination Procedures	ERM stated that downhole sampling equipment was decontaminated prior to the commencement of drilling and between drilling locations. AECOM (2010b, 2010c and 2012) reported decontamination of augers between each borehole location using a pressurised water cleaner. Reusable sampling equipment (spatula, push tube sampler, split tube sampler) was cleaned with detergent and rinsed with potable water between sampling events to prevent cross contamination and the equipment was then rinsed with deionised water. New gloves were reportedly used for each new sample. JBS did not discuss decontamination, but daily 'Field Equipment Calibration and Decontamination' forms state that new nitrile gloves were used for each sample and that augers were decontaminated after each location. ERM and AECOM did not report decontamination procedures for the non-disposable groundwater sampling equipment, although ERM did state that a "decontaminated" micropurge submersible pump was used. It is assumed that new sample tubing dedicated

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	to each well was used with the micropurge pump, but it was not stated how cleaning of the pump or other non-disposable equipment was performed. New gloves were reportedly used for each new sample. Overall the decontamination undertaken was found to be acceptable.
Sample handling and containers	Samples were placed into prepared and preserved sampling bottles provided by the laboratory and chilled during storage and subsequent transport to the labs. AECOM (2010b and 2010c) noted that a number of batches were received by the laboratory at temperatures greater than 4°C but noted that the ambient temperature at the time of sampling was high and that the laboratory received the samples within a few hours of sample collection. This indicates that the samples did not have sufficient time to cool and that sample handling was acceptable. Review of laboratory information indicated no material breaches of sample handling.
Chain of Custody	ERM, AECOM and JBS included completed chain of custody forms and reported that these were complete and acceptable. Occasionally instructions were provided by email from JBS to the laboratory. Forms were forwarded from the primary to the secondary laboratory. The auditor has undertaken a check of a selection of these and with the exception of the AECOM batches discussed above, found that they were signed and dated by the laboratories stating that samples were received in good order, chilled and were presented in adequate samples containers.
Detailed description of field screening protocols	ERM, AECOM and JBS reported that for each sample depth, additional soil was placed in a sealed plastic bag and subsequent Photoionisation Detector (PID) measurements were taken at ambient temperatures. ERM, AECOM and JBS reported that groundwater field parameters were measured during well sampling and development.
Calibration of field equipment	ERM stated that meters were calibrated prior to the start of each day. Calibration records for PID and groundwater meters were provided by ERM. AECOM reported that the PID was calibrated with isobutylene gas at 100 ppm at the commencement of each day of sampling and, if necessary, during the day in accordance with the procedure provided by the supplier. Calibration records were provided in the AECOM reports. AECOM included calibration records for the water quality meter for each day of groundwater sampling. JBS did not provide calibration records for groundwater meters and some results appeared incorrect, however these were used

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor Comments**
	only for stability in purging.
Sampling Logs	Soil logs are provided within the reports, indicating sample depth, PID readings and lithology. Logs recorded information regarding potential for contamination such as odours or staining. Rock logs by J&K (2006) provide detail of weathering and fracturing. Logs record indications of contamination such as odours and staining, where noted. The Auditor notes that logs were prepared by different people even within the same investigation stage, and there is some noticeable difference between logs and interpretations. There are noticeable differences when comparing logs by ERM, JBS and AECOM with logs prepared by JBS at locations shown as close to each other. The JBS logs were prepared from disturbed samples only and are less reliable. Groundwater field sampling records were provided and included observations regarding potential for contamination such as odours or sheens.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
Field quality control samples	Field quality control samples undertaken by ERM, JBS and AECOM included trip blanks, trip spikes, rinsate blanks, field intra-laboratory and inter-laboratory replicates.
Field quality control results	ERM reports include detailed data quality assessments. Minor QA/QC non-conformances were reported, with Relative Percentage Differences (RPDs) exceeding the acceptable limits in some samples, largely due to sample heterogeneity in the fill material, although in the context of the large dataset reported, these are not of significance. There were a few samples where holding times were exceeded, or where there was insufficient sample for moisture determination. AECOM reports included data quality assessment. Some RPD exceedances were reported for soil and groundwater field duplicates, mostly for metals in fill material. These were attributed to fill material heterogeneity and/or low concentrations. Rinsate blanks, trip blanks and trip spike results were generally acceptable. JBS included detailed QA/QC results. There were some exceedances of desirable RPDs in duplicates, attributed to results just above Practical Quantitation Limits (PQLs) and/or fill heterogeneity.
NATA registered laboratory and NATA endorsed methods	Laboratories used by ERM were Australian Laboratory Services (ALS) and LabMark. It is noted that the appendix containing laboratory certificates for ERM (2007) was not provided to the Auditor. Detailed laboratory quality control reports were

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	provided. Laboratories used by AECOM included ALS and MGT LabMark for soil and groundwater, SGS for soil vapour and Australian Safer Environment & Technology Pty Ltd (ASET) for asbestos. Laboratories used by JBS included Envirolab and SGS. Laboratory certificates inspected were NATA stamped.
Analytical methods	Analytical methods were included in the laboratory test certificates. Summary methods were presented in the AECOM reports. While, references to the USEPA methods for extraction and analysis were given for the certificates for TPH, VOCs and SVOCs, the exact methods used have not been detailed.
Holding times	Review of the Chain of Custody (COCs) and laboratory certificates indicate that the holding times had generally been met. ERM reported several minor breaches. JBS reported that all holding times were met. AECOM (2010b and 2010c): Review of the COCs and laboratory certificates indicate that the holding times had generally been met. Exceptions included: Batch numbers ES1003046 for free and complexed cyanide; ES1001619 for moisture; ES1002565 for soil pH. AECOM (2012): Review of the COCs and laboratory certificates indicate that the holding times had generally been met. Exceptions included: Batch numbers ES1103957, ES1103960 & ES1104964 for leach tests (organics). These were found to be 3-10 to days outside the holding times. In addition batch ES1104964 exceeded holding times for additional soil analyses (17 days outside holding times) on deeper soil samples from BH400-BH403 & BH409. These were required for additional information for the HHERA. Overall, in the context of the dataset reported and considering that the results from the investigations have been viewed in a multiple lines of evidence approach, the reported holding time exceedances are not significant to the outcome of the audit.
Practical Quantitation Limits	PQLs were less than the trigger values (TVs, see Section 7) for the contaminants of concern except for some groundwater analyses. Some PQLs were raised because of salinity or interference by other contaminants, but most PQLs were below the risk based remediation criteria (refer Section 10).
Laboratory quality control samples	ALS reports surrogates with organic results, and provide separate quality reports covering duplicates, laboratory control spikes, method blanks, matrix spikes and holding times. MGT LabMark reports laboratory control samples, method blanks, surrogates and spikes with the results, and also certified reference material results with metals. These did not include laboratory duplicates. Envirolab reports surrogates with organic results, and provide a

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor Comments**
	separate quality report with each batch including method blanks, control spikes and duplicates. SGS provided separate statements of QA/QC including surrogates, method blanks, duplicates, laboratory control samples, matrix spikes and matrix spike duplicates.
Laboratory quality control results	Laboratory certificates for ERM (2007) were not provided, though detailed laboratory quality control reports were. ERM provided a detailed quality review and concluded that data were acceptable. The results from nearly all laboratory quality control samples were within appropriate limits. Exceptions are listed below. – RPDs for some duplicate samples for some metal, TPH fractions and PAH analyses, for which the laboratory accepted the results because the soil was non homogenous. – Some samples where spike recovery could not be reported because of interference from high concentrations of analytes. – Minor detection of zinc in one rinsate blank. ERM (2008a) assessed the laboratory quality control data and concluded that the data were acceptable. Tables detailing the assessment were not included in the report supplied to the Auditor. AECOM (2010b and 2010c) assessed the laboratory quality control results and listed instances where results were outside acceptance limits as discussed below: – Poor laboratory duplicate results in a number of instances. AECOM consider that the poor duplicate results were due to results close to PQL or to sample heterogeneity. The Auditor does not consider this to affect the useability of the data. – Laboratory Control Sample (LCS) recoveries were outside the laboratory's Analyte Specific Acceptance Criteria (ASAC) or outside AECOM's acceptance criteria of 70–130% for different analytes on a small number of occasions. AECOM noted that most of the relevant compounds have not been historically detected on the site. The Auditor has observed that the only compound with a poor LCS result that has been historically detected at the site was a PAH indeno(1,2,3,cd)pyrene, and no PAHs were detected in the affected batch. The Auditor concludes that these minor breaches will not affect the useability of the data. All LCS water samples were within acceptance criteria. – Matrix spike sample recoveries outside acceptance criteria on a number of instances. AECOM noted that the corresponding LCS recoveries were within acceptance criteria except for some instances where poor recoveries were reported for nitrosamines and phenols. The Auditor considers that the poor results for these analytes for the

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control

Field and Lab QA/QC	Auditor Comments
	matrix spikes will not affect the useability of the data as historically there have not been detections of the affected compounds at the site. – Some poor recoveries for some acid-extractable and some base/neutral extractable surrogates in two reports, but review of the laboratory data indicates that in each instance there were several other surrogates with results within the acceptable ranges, and the results are not considered to affect the useability of the data. AECOM (2012) assessed the laboratory quality control results and listed instances where results were outside acceptance limits. These are discussed below: – poor laboratory duplicate results in 3 soil samples (Cd, Hg & Ni 80-97%) and one water sample (WAD cyanide 169% noting that this was very close to the limit of detection). AECOM noted that these were from the secondary laboratory. The Auditor does not consider that this will affect the useability of the data. – two samples out of the 134 water samples analysed reported LCS results (four analytes) that were either outside the laboratory's ASAC or outside AECOM's acceptance criteria of 70-130%. The Auditor has examined the laboratory data and found that the samples reported in the affected batches were not critically close to criteria, so the poor LCS results are not expected to have an impact on any conclusions that are made from the data set. – two soil samples out of the 76 matrix spike samples had analytes outside acceptance criteria. Although, with the exception of one cyanide result, the recorded exceedances were due to the LCS recovery not being determined due to matrix interference effects. The Auditor does not consider that these non-conformances will affect the useability of the data. JBS report that laboratory quality control results were within endorsed limits. SGS reported a few failures of QA/QC samples, attributed to "sample heterogeneity".
Data Quality Objectives and Data Evaluation (completeness, comparability, representativeness, precision, accuracy)	The ERM reports include data quality objectives (DQOs). They also include detailed review of data and conclude that the data comply with the ERM quality protocols. AECOM (2010b, 2010c and 2012) set data quality objectives for the report and outlined data quality indicators across the five category areas. In each report, AECOM concluded that the data quality indicators (DQIs) for the data were achieved and the data *"...to be reliable and representative of concentrations of the compounds analysed at the locations sampled".* JBS included data quality objectives in their Sampling, Analysis and Quality (SAQP) for the DGI. The DGI included a review of data and concluded that the analytical results were reliable and representative.

In considering the data as a whole the Auditor is able to conclude that:

- Limited groundwater wells have been installed in the eastern portion of the site, downgradient of the Declaration Area. Groundwater contaminant concentrations in this portion of the site could therefore be greater than the concentrations reported in the existing monitoring wells. Overall however, given the depth of the most significant groundwater contamination and the proposed basement design, the investigations undertaken are considered adequate for definition of the remediation extent.
- Investigation locations and sample depths are likely to be representative of the overall site conditions. Although conditions may vary locally within non-homogenous fill and due to preferential contaminant migration pathways within marine sediment, it is considered that analytical results should be representative of the overall soil and groundwater conditions.
- Due to the investigation methodology employed, observations of fill material were limited and may underestimate the occurrence of asbestos and other anthropogenic material. The results are sufficient to confirm the conceptual site model of contamination determined for the site (refer Section 10) and the likely extent of contamination for remediation planning purposes noting additional sampling is proposed.
- The laboratories provided sufficient information to conclude that data is of sufficient precision, and field and laboratory quality control measures were sufficient to be confident that most of the data is likely to be accurate.
- The data is considered complete and usable. The data set is large enough that the minor departures from data quality objectives noted above would not greatly impact the conclusions from the assessments.
- Although different consultants, different staff and different laboratories were used, data appears to be sufficiently comparable for each sampling and analytical event.

The Auditor therefore concludes that the data is suitable as a basis for preparation of a RAP.

7 Environmental Quality Criteria

A conservative set of environmental quality screening criteria were developed by the Auditor for use in performing an initial review of the soil and groundwater analytical data for key contaminants, discussed in the following sections. The screening criteria were used to gauge the general degree of contamination impact, for use in identifying trends in contaminant occurrence. The findings are discussed in Sections 8 and 9 of this SAR.

Risk-based remediation criteria have been developed by AECOM to determine the extent of remediation required at the site as discussed in Section 10 of this SAR.

7.1 Soil Screening Criteria

Table 7.1 presents a summary of the soil screening criteria used.

Table 7.1: Summary of Auditor's Screening Criteria for Key Soil Contaminants

Analyte	Screening Criteria (mg/kg)	Source
Lead	300	Soil Investigation Levels for Urban Redevelopment Sites in NSW in DEC (2006) 'Guidelines for the NSW Site Auditor Scheme, 2nd Edition'. Lower of • SIL Column 1 – 'residential with gardens and accessible soil' • SIL Column 5 – 'provisional phytotoxicity-based investigation levels'
Arsenic	20	
Copper	100	
Zinc	200	
Total PAH	20	SIL Column 1 – 'residential with gardens and accessible soil'
TPH C_{10}-C_{36}	1000	EPA (1994) 'Guidelines for Assessing Service Station Sites'

Further details of the sources adopted are provided in Appendix B.

7.1.1 Asbestos

Criteria for asbestos are provided in the National Environment Protection Council (NEPC) National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013) (NEPM (1999)[2013]). Areas of the site outside the proposed basement have an intended commercial and recreational land use therefore criteria considered by the Auditor are as follows:

- Less than 0.05% asbestos as asbestos containing material (ACM) (commercial)
- Less than 0.02% asbestos as ACM (recreational)
- Less than 0.001% asbestos as asbestos fines (AF) or fibrous asbestos (FA)
- No visible asbestos on the surface

7.1.2 Acid Sulfate Soils

AECOM considered the NSW Acid Sulfate Soil manual (ASSMAC, 1998) for the assessment and management of ASS.

7.2 Groundwater Screening Criteria

The Auditor has assessed the groundwater data in reference to ANZECC (2000) 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality' for marine waters. TVs provided are concentrations that, if exceeded, indicate a potential environmental problem and 'trigger' further investigation. The 95% level of protection has been adopted for the current review, with reference to Low Reliability criteria where necessary and 99% protection level to account for the potential for bio-accumulation or acute toxicity to particular species. These criteria are the basis of the Marine Water Quality Criteria (MWQC) considered by AECOM in the HHERA and RAP.

The referenced criteria are listed in Appendix B.

8 Evaluation of Soil Results Against Screening Criteria

8.1 Introduction

Soil conditions have been investigated by over 25 boreholes as outlined in Section 6. Soil sampling locations are shown on Attachment 4, Appendix A.

Soil data summary tables are provided in the RAP in area and depth groupings. Data from all investigations is tabulated together. Data from offsite locations was included where this was considered likely to be representative of conditions on site.

The following sections discuss the field and laboratory results for fill, natural soil and bedrock investigations.

8.2 Field Observations

8.2.1 Definitions of Contaminated Material

A range of definitions for contaminated material have been adopted for the site. The primary definition used is Separate Phase Gasworks Waste and Tar (SPGWT). This definition was proposed by AECOM and adopted by Lend Lease and BDA particularly in the context of material that is unsuitable for beneficial reuse.

SPGWT includes dense non aqueous phase liquid (DNAPL) and tar containing material (TCM). TCM has been defined as greater than 10% visible coal tar or analytical results exceeding concentrations of 2,000 mg/kg for total PAH and 150 mg/kg for benzo(a)pyrene.

These definitions represent significant contamination impact; however, in assessing the site, it is also appropriate to consider other indications that are representative of gasworks impact, albeit less significant impact. These include odour and visual evidence less than 10% coal tar, as well as lower concentration contaminant impacts. AECOM considered gasworks-related impacts in determining the extent of offsite remediation required to allow revocation of the declaration (SAS GN447A) which considered potential gasworks impacts on the Crown development site, being downgradient (and offsite) of the Declaration Area.

Field observations of contamination are discussed in the following sections.

8.2.2 Soil (Fill and Natural)

Visual and olfactory indications of contamination were observed throughout the fill material during all stages of investigation, including SPGWT, sheen, odours, black staining, furnace waste and slag. Odours were variably described as hydrogen sulfide, tar, gaseous, chemical, naphthalene and hydrocarbon (AECOM, 2015).

The distribution of SPGWT and sheen on the site and offsite is presented in Attachment 6, Appendix A. SPGWT was identified in the site vicinity as follows:

- In MW60, described as “*black staining*”, “*tar mottles*” and “*strong tar odour*” at depths ranging between 16 and 17.5 mBGL within the natural marine sediments. It is noted that soil samples collected from the discussed depths reported benzo(a)pyrene and PAH concentrations which are less than the TCM criteria.

- In MW48 (offsite to the east), described as "*crude tar (shiny, black vesicular), strong tar odour and black staining*" at a depth of 14.5 mBGL at the top of sandstone bedrock. Black staining was also observed in sandstone at a depth of 17 mBGL.

- In BH406 (offsite to the east), described as *"band of tar"* at a depth of 14.3-14.5 mBGL in silty clay fill above natural marine sediment, and *"tar observed throughout the matrix"* (20-30%) in marine sediment at a depth of 15-16.8 mBGL (limit of investigation).

SPGWT was identified within marine sediment or bedrock within the central northern portion of the site and offsite to the east (upgradient). SPGWT occurred with greater frequency in locations to the east of the site within and immediately downgradient of the Declaration Area. The extent suggests the migration of SPGWT within marine sediment downgradient from the Declaration Area has been reasonably limited. However, the presence of SPGWT in marine sediment at BH/MW60, located around 85 m downgradient of the Declaration Area, suggests that migration of gasworks waste may have occurred through narrow pathways given the constraints of the field investigations undertaken (limited spatial coverage and limited potential for detailed visual observation). In the Auditor's opinion, there is potential for an undetected continuous pathway of gasworks impact to be present from the Declaration Area towards location BH/MW60 and possibly elsewhere.

Alternately, the occurrence of SPGWT in marine sediment at BH/MW60 may be an isolated location, potentially derived from the filling process, but this is not consistent with the generally accepted conceptual site model (CSM) of contamination at the site.

The distribution of other gasworks impacts (odour and visual evidence, as well as analytical results for naphthalene and TPH C_{10}-C_{14} at elevated concentrations) is shown on Attachments 7a and 7b, Appendix A, for fill and marine sediment, respectively. AECOM (2013a) considers that the results are *"sporadic and not indicative of continuous migration of gasworks related impacts from the Site… likely to be the result of historic landfilling of impacted fill materials…"*.

Tar was generally absent from overlying fill material within the site area, however was identified in shallow fill material in some offsite boreholes to the north and east and there is potential that similar conditions may be present within parts of the site area not subject to investigations. In the Auditor's opinion, the shallow occurrence of tar (offsite) is probably due to filling while the impact within deep fill/ marine sediments (including onsite) is likely due to subsurface migration down the sloping bedrock.

Field observations with respect to asbestos are discussed in Section 8.3.4, below.

8.2.3 Bedrock

ERM (2007 and 2008a) investigations cored sandstone bedrock to reach the desired investigation depth. Borehole logs included photographs of cores (J&K, 2006). The AECOM investigations (AECOM, 2010b, 2010c and 2012) did not include cored investigations into bedrock, however, some observations were made in the upper weathered layers which were penetrated by standard drilling methods.

Olfactory indications of contamination were not observed in the top of sandstone in onsite locations, however were identified in approximately twelve offsite locations to the east and northeast. Odours generally extended less than 1 m into bedrock, however the vertical extent of odours was often not delineated due to limitations of the drilling technique employed by AECOM.

The VMP Extent Report (AECOM, 2013a) reported "...*the overall site dataset does not support the presence of significant gasworks related contamination within the bedrock underlying the site*". Based on experience remediating a portion of the former gasworks located offsite to the east (30-34 Hickson Road), AECOM (2013a) concluded that "...*the movement of gasworks related contaminants into the surrounding bedrock was limited both vertically and horizontally due to the relatively impermeable nature of the natural sandstone and the limited presence of bedrock fracture zones*".

Based on the Auditor's review of the borehole logs, significant contamination of bedrock does not appear to be present, although the extent of impact in fractured bedrock has not been determined. Some staining, odours and potentially SPGWT may be present in the upper weathered layers of sandstone bedrock and fractures, particularly in the east of the site, near the Declaration Area.

8.3 Soil Analytical Results

Soil samples were analysed for a variety of contaminants including petroleum hydrocarbons, PAHs, phenols, pesticides, PCB, cyanide, asbestos, sulfate and heavy metals. More specialised analyses were also performed to determine ASS and leaching potential. The following Table 8.1 summarises the analytical program undertaken for the combined stages of work, summarised from the RAP (AECOM, 2015). Table 8.1 excludes duplicate analyses.

Table 8.1: Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
Lead	118	104	764
Arsenic	118	22	38
Barium	65	53	300
Beryllium	65	0	<PQL
Cadmium	118	0	<PQL
Total Chromium	118	117	210
Chromium VI	18	1	1.4
Cobalt	65	28	39
Copper	118	81	281
Manganese	65	46	819
Mercury	118	33	6.2
Nickel	118	81	164
Vanadium	65	57	139

Table 8.1: Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
Zinc	118	94	1,020
Phenols	65	13	97.6
Total PAHs	100	60	1,353
Benzo(a)pyrene	100	53	62
Naphthalene	100	40	517
OCP/ OPP	6	0	<PQL
PCB	5	0	<PQL
Other SVOCs [1]	9	3	49.4
TPH (C_6-C_9)	83	7	84
TPH (C_{10}-C_{36})	89	30	6,400
Benzene	84	14	8.9
Toluene	84	11	20.8
Ethylbenzene	84	5	1.6
Total Xylene	84	10	27.1
Other VOCs [2]	14	4	9.1
WAD Cyanide	12	0	<PQL
Free cyanide	5	0	<PQL
Total cyanide	11	0	<PQL
SPOCAS	2	0	-
Asbestos	7	3 [3]	-
Sulfate	6	6	2,660

- not applicable

PQL practical quantitation limit

1 Other SVOCs detected comprised 3,3-dichlorobenzidine, carbazole and dibenzofuran

2 Other VOCs detected comprised trimethylbenzenes and styrene. A duplicate contained n-propylbenzene and p-isopropyltoluene

3 Amosite asbestos detected in one sample, unidentified mineral fibre identified in three samples.

The analytical results have been assessed against screening criteria (Table 7.1) to identify trends in contaminant occurrence. The results have also been assessed against risk based remediation criteria, discussed in Section 11. The following sections present a discussion of the results according to contaminant type.

8.3.1 Heavy End TPH and PAH

The primary contaminants detected at the site were heavy end TPH in the C_{15}-C_{36} range and a suite of PAH associated with coal tars and other gasworks wastes.

35% of samples analysed contained TPH in the C_{15}-C_{36} range. 17% of samples exceeded the Auditor's screening criterion of 1,000 mg/kg. The maximum concentration detected was 6,400 mg/kg.

PAH detections were associated with the heavy end TPH detections. PAH detections were more common than TPH detections (primarily due to the lower PQL for PAH analyses). 25% of samples analysed reported a total PAH concentration exceeding the Auditor's screening criterion of 20 mg/kg. Of these, 63% exceeded 100 mg/kg (equivalent to 15% of the total samples), and the maximum total PAH concentration detected was 1,353 mg/kg.

The major contributors to total PAH depended on the source of contamination. Where SPGWT was the source, naphthalene was a major contributor (discussed in the following section). Where SPGWT was not present, approximately 40-50% of the total PAH concentration was contributed to by pyrene, fluoranthene and phenanthrene. Significant contributions from five more PAH were also made, with individual concentrations of between 5 and 10% of the total PAH concentration (benz(a)anthracene, benzo(b)fluoranthene, chrysene, benzo(a)pyrene (BaP) and anthracene). These are carcinogens except for anthracene.

The proportion of the total PAH concentration contributed to by BaP was generally between 5 and 10%, with a maximum BaP concentration detected at the site of 62 mg/kg.

The distribution of significantly elevated heavy end TPH and PAH concentrations were generally located where SPGWT was identified (MW60 and BH48), although the concentrations detected did not exceed the nominated TCM criteria (Section 8.2.1). Significantly elevated concentrations were also found in fill material from a range of depths. At such locations, intervening samples were commonly found to be free of PAH. The results indicate a high degree of both lateral and vertical variability within the fill material.

8.3.2 Light End TPH, BTEX and Naphthalene

Concentrations of BTEX and light end TPH in the C_6-C_9 range exceeded the Auditor's screening criteria in a limited number of samples. Where light end detections occurred, observations of SPGWT and higher concentrations of TPH C_{10}-C_{36} and PAHs were also commonly present.

Naphthalene contributed approximately 30% to 47% of total PAHs where SPGWT was the primary source of contamination. Where PAHs are related to fill material, naphthalene contributed approximately 2-5% of total PAHs.

8.3.3 Heavy Metals

Soil samples were analysed for a suite of between 8 and 14 heavy metals (refer Table 8.1). Heavy metals observed to occasionally exceed screening criteria included arsenic, lead, copper, mercury, nickel and zinc. The occasional exceedances did not significantly exceed the screening criteria and appear to be associated with fill material and not related to gasworks impact.

8.3.4 Asbestos

Limited asbestos analyses were performed during the investigations (ERM, 2008a and AECOM, 2010b and 2010c) on the basis that no visual evidence of ACM was observed. Seven samples of fill were analysed for asbestos, and detections were made in three samples. Sampled material typically contained waste materials, however no ACM was observed.

In the Auditor's opinion, the investigation method used (borehole drilling) does not allow for adequate observation of the bulk filling to identify ACM fragments. The extent of characterisation for asbestos is not considered adequate given the variability of fill materials, the depth of filling and the limited vertical coverage of the asbestos analyses performed. In the Auditor's opinion, there is a high potential for undetected asbestos to be present in the fill, most likely associated with ACM fragments that may not have been observed during the drilling investigations.

AECOM documented further information with respect to asbestos in the RAP, which identified widespread ACM within material excavated from the basement excavation of the adjacent ORWS Area. AECOM (2015) therefore assumed that "…*there is significant potential for bonded ACM to be present within fill material within the site*".

The Auditor agrees with this finding and notes the need for management of asbestos during the site remediation and development, discussed further in Section 12.

8.3.5 Other Analyses

Specialised analyses performed and results were as follows:

- Two samples were analysed for Suspension Peroxide Oxidation Combined Acidity & Sulfur (sPOCAS) during the DGI (AECOM, 2010c). Samples were selected for analysis based on field testing to identify potential ASS (PASS). The results indicated that ASS were not present. Testing on other areas of Barangaroo has identified PASS.
- Six samples were analysed for sulfate, with a maximum concentration of 2,660 mg/kg. Detections at this concentration are not of concern for human health or the environment however may be corrosive towards building materials.
- Toxicity Characteristics Leaching Procedure (TCLP) was performed on nine samples for selected heavy metals and BaP, including high concentration samples. The maximum leachable lead was 0.6 mg/L and leachable BaP was all less than the PQL. The TCLP were undertaken for preliminary waste classification purposes.
- Australian Standard Leaching Procedure (ASLP) deionised water leachability tests were performed on nine samples for selected heavy metals and PAH, including high concentration samples. Several heavy metals (mostly barium and zinc) and PAH (excluding BaP) were detected in the leachates. AECOM (2010c) inferred that the soil and fill material at the site had the potential to leach under deionised water leach conditions.

8.4 Conclusion

The soil analytical results indicate fill materials are impacted by heavy end TPH, PAH and some heavy metals. Contamination from gasworks wastes was present in underlying natural

materials at depth supporting the migration of contamination from the up gradient former gasworks on the natural ground surface, at the base of fill. Tar was absent from overlying fill material. Bedrock from the site has not been sampled extensively; however, visual observations have indicated limited contaminant impacts.

Fill from the site has not been well characterised for the potential for asbestos contamination.

The need for remediation of detected soil contamination has been considered by AECOM (2015) based on risk based remediation criteria, and is discussed in Section 11.

9 Evaluation of Groundwater Results Against Screening Criteria

9.1 Introduction

Groundwater conditions at the site have been assessed in multiple stages of investigation by ERM, JBS and AECOM, with locations shown on Attachment 4, Appendix A.

Monitoring wells installed on and in close proximity to the site include:

- ERM (2006-2008): EBH53/MW11, EBH76/MW14, EBH116/MW22, EBH129/MW24, EBH212/MW212
- JBS (2012): JMW544S, JMW544D
- AECOM (2010-2012): IT01 (Shallow, Mid, Deep), IT02 (Shallow, Mid, Deep), IT04 (Shallow, Mid, Deep), IT05 (Shallow, Mid, Deep), MW40, MW56, MW60

The ERM wells have been sampled over two to five rounds (July 2006, August 2006, August 2007, May 2008 and March 2010) depending on the well location. The JBS wells have been sampled once (2012) and the AECOM wells have generally been sampled once (2010 or 2011).

9.2 Overview of Groundwater Monitoring

Table 9.1 provides a summary of the wells installed in the vicinity of the site and a summary of the key analytical results from each well. Also included are field indications of contamination noted in soils during installation of the wells (log indicators), observations of the groundwater during sampling (sampling observations) and the coverage of fill materials provided by the well screening (screened fill interval).

Due to the duplication of well numbers, the Auditor has prefaced the well numbers with ‘E’, ‘A’ or ‘J’ based on which company they were installed by (ERM, AECOM or JBS, respectively). Shading indicates wells screened in natural materials.

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Screened Fill Interval	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
Barangaroo Central							
JMW544S	2012	2.5-5.5	Upper fill (base of fill at 15.5 m)	None	1	Strong organic odour	No organic detections TPH not analysed
JMW544D	2012	10-13	Mid to lower fill (base of fill at 15.5 m)	None	1	None	No organic detections TPH not analysed
EBH129/ MW24	2007	2.3–6.9	Full extent of fill	none	3	*	Minor naphthalene

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Screened Fill Interval	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
Crown Development Site							
EBH53 / MW11	2006	3.0-9.0	Full extent of fill	Faint H_2S odour at 3 m.	2	*	Very minor TPH and naphthalene. No BTEX.
EBH76 / MW14	2006	3.0-9.0	Full extent of fill	None	4	*	No organic detections
EBH116 / MW22	2006	3.0-9.0	Full extent of fill	None	3	H_2S odour	Very minor TPH in 2006/2008. No organic detections 2010.
EBH212 / MW212	2008	1.3-16.8	Full extent of fill (fill logged to 17.5 m)	Black staining and slight hydrocarbon odour 1.5-6.0 m.	2	None	No organic detections
ABH40 / MW40	2010	14.3-20.3	Gravelly clayey sand (below fill)	Chemical odour from 16 m. Veins of tar noted at 16.5 m with sheen and strong odour.	1	H_2S odour	Minor BTEX, naphthalene and ammonia. No TPH results.
ABH56 / MW56	2010	18-21	Sand (below fill)	Moderate tar odour	1	H_2S odour	Minor TPH/BTEX. No PAHs/ naphthalene.
ABH60 / MW60	2010	14-22	Sandy clay and clayey sand (below fill)	Strong tar odour	1	Mild tar odour	TPH/BTEX and naphthalene
IT01 (shallow)	2010	1.7-2.7	Upper fill	None	1	No odour or sheen	No organic detections
IT01 (mid)	2010	8-9	Mid fill	Slight tar odour and coke fragments	1	H_2S odour	TPH, minor PAH/ naphthalene and ammonia
IT01 (deep)	2010	16.6-17.6	Silty clay (no fill)	None	1	Slight odour	Minor naphthalene TPH and BTEX
IT02 (shallow)	2010	2.3-3.3	Upper fill	Slight HC odour	1	Tar odour	Minor naphthalene TPH and BTEX
IT02 (mid)	2010	7.7-8.7	Mid fill	None	1	Tar odour	Ammonia, minor naphthalene and TPH

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Screened Fill Interval	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
IT02 (deep)	2010	16.7-17.5	Silty sandy clay	None	1	Tar odour, very slight sheen	Minor naphthalene TPH and BTEX
ABH410 / IT04 (shallow)	2011	2-3	Upper fill unit	None	1	No odour or sheen	Minor detections of PAHs.
ABH410 / IT04 (mid)	2011	16.5-17.5	Silty Clay	None	1	HC odour, no sheen	Ammonia. Minor detections PAHs.
ABH410 / IT04 (deep)	2011	31.2-32.2	Clayey sand	Hydrocarbon Odour and minor black staining at 17 m at start of natural material	1	Very slight HC odour, no sheen	Ammonia, minor phenol, benzene, ethylbenzene and naphthalene.
ABH411 / IT05 (shallow)	2011	2-3	Upper fill unit	None	1	No odour or sheen	No organic detections. Some metals
ABH411 / IT05 (mid)	2011	13.5-14.5	Mid to lower fill unit	None	1	No odour or sheen	No organic detections.
ABH411 / IT05 (deep)	2011	26-27	Clayey sand (no fill)	None	1	Slight HC odour, no sheen	Ammonia, naphthalene, minor BTEX some phenols.

Shading indicates wells screened within natural materials

n number samples

* information not included since sampling records not located by the Auditor during review

H_2S hydrogen sulphide

HC hydrocarbon

Observations of impact to soil by hydrocarbons were made during installation of wells in the central (IT01, IT02 and MW56) and north western (MW60, IT04) parts of the site, particularly in the deeper wells at these locations. Impact was also noted in MW40 installed along the boundary with Block 4 (around 20 m from the boundary of the Declaration Area). Groundwater from these wells displayed some strong indicators of contamination, including odour and sheen, particularly in the deeper wells. Mild/ transient observations of potential contamination impact were noted in most other wells, not always evidenced in the laboratory analytical results. The most significant (persistent) field observations of contamination impact to groundwater were at MW60, located in the northwest of the site.

9.3 Groundwater Analytical Results

The groundwater analytical results are summarised following in Tables 9.2 and 9.3 which relate to results from wells screened within the fill (13 wells) and wells screened within the underlying natural material (8 wells) respectively. The summary excludes results for heavy

metals since soil results indicated only minor impacts by heavy metals, occurring variably in fill material and not associated with gasworks impacts.

Table 9.2: Groundwater Analytical Results Summary - Wells Screened within Fill Material (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Ammonia	18	9	**9,260**	5	MW11, MW14, MW22, IT2(M) with maximum in IT2(M)
Cyanide (Free)	17	1	**45**	1	IT01 (M)
Cyanide (Total)	9	4	**14**	4	MW11, MW14, MW22, MW24 with max in MW22
TPH (C_6-C_9)	25	4	40	NA	Maximum in IT2(S)
TPH (C_{10}-C_{36})	25	8	4,110	NA	Maximum in IT2(M)
Benzene	28	4	5	0	Maximum in MW22
Toluene	28	2	20	0	Maximum in IT2(S)
Ethylbenzene	28	2	3	0	Maximum in IT5(M)
Total Xylene	28	1	2	0	Maximum in MW22
Benzo(a)pyrene	28	3	**5.3**	3	Detection limit generally exceeded screening criteria. Detected exceedances in MW24, IT4(S), IT1(M) with maximum in IT1(M)
Naphthalene	28	8	41	0	Maximum in IT2(M)
Total PAH	28	10	131	NA	Maximum in IT1(M)
Phenol	21	4	2	0	Maximum in IT2(M)
2,4-dimethylphenol	21	3	**10**	1	IT2(M)
2-methylphenol	21	2	5	0	Maximum in IT2(M)
3&4 methylphenol	21	1	9	0	Maximum in IT2(M)
3-Methylphenol	6	0	NA	0	None detected
SVOC	14	0	NA	NA	None detected
VOC	13	0	NA	NA	None detected

S – Shallow
M- Medium
D – Deep
Bold indicates ANZECC (2000) Marine Water Quality Guidelines exceeded
Note TPH C_6-C_9 is not minus BTEX

Table 9.3: Groundwater Analytical Results Summary - Wells Screened within Natural Material (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Ammonia	6	6	**9,700**	6	IT4(M), IT4(D), IT5(D), IT1(D), IT2(D), MW40. Maximum in MW40
Cyanide (Free)	10	1	**53**	1	IT1(D)
Cyanide (Total)	0	NA	NA	NA	Total cyanide not analysed for wells screened in natural
TPH (C_6-C_9)	10	6	4,360	NA	Maximum in MW60
TPH (C_{10}-C_{36})	10	5	21,250	NA	Maximum in MW60
Benzene	11	9	**1,380**	1	MW60
Toluene	11	6	**969**	2	MW56, MW60. Maximum in MW60
Ethylbenzene	11	7	34	0	None
Total Xylene	11	7	**461**	2	MW56 and MW60Maximum in MW60
Benzo(a)pyrene	11	1	**17**	1	Maximum in IT1(D) Detection limit elevated above screening criteria in IT2(D), MW40, MW56, MW60
Naphthalene	11	9	**1,500**	5	IT5(D), IT1(D), IT2(D), MW4, MW60. Maximum in MW60
Total PAH	11	9	1,558	NA	Maximum in MW60
Phenol	11	7	29	0	Maximum in MW60
2,4-dimethylphenol	11	8	**2,260**	8	IT4(D), IT5(D), IT1(D), IT2(D), MW40, MW60. Maximum in MW60
2-methylphenol	11	8	390	8	IT4(D), IT5(D), IT1(D), IT2(D), MW40, MW60. Maximum in MW60
3&4-methylphenol	5	3	305	3	IT2(D), MW40, MW60. Maximum in MW60 Detection limit above screening criteria in IT1(D)
3-Methylphenol	4	2	1.6	0	Maximum in IT4(D)
SVOC	5	1	4	NA	Aniline detected at 4 µg/L in IT2(D)
Styrene	8	4	**160**	1	MW60
1,2,4-Trimethylbenzene	5	3	37	NA	Maximum in MW60
1,3,5-Trimethylbenzene	5	2	11	NA	Maximum in MW56

Bold indicates ANZECC (2000) Marine Water Quality Guidelines exceeded
Note TPH C_6-C_9 is not minus BTEX

9.3.1 Contaminant Distribution

No separate phase (or tar) was observed during the groundwater sampling although H_2S, tar and hydrocarbon odours were observed at a number of locations.

Consistent with the results of the AECOM Groundwater Discharge Study (2010d), a review of the groundwater analytical results from the shallow (screened in fill) and deep (screened in underlying natural material) groundwater monitoring wells indicate that the most significant groundwater contamination was identified in groundwater found in the natural material consistent with field observations, particularly in the north western corner of the site in the vicinity of deep well MW60.

Some elevated concentrations of ammonia, cyanide, benzo(a)pyrene and 2,4-dimethylphenol in excess of the screening criteria were however also detected in groundwater from wells screened in the fill including in particular IT1(M) and MW14, IT2(M) and MW11 and MW22 which are located in the central portion of the Crown site along the western boundary of the proposed basement footprint. The other area where some contaminated groundwater (total cyanide and benzo(a)pyrene) was detected in the fill was in the north western corner of the site, just outside the basement foot print in shallow wells MW24 and IT04(S).

The Auditor notes that although the most significant deep groundwater contamination has been detected in MW60, the deep groundwater (within the natural material) from all sampled locations is generally contaminated to some extent with the main chemicals of concern (cyanide, ammonia, BTEX and PAHs). The Auditor also notes that there are no wells screened within the fill material in the eastern portion of the site or approaching the boundary with the Declaration Area. It is therefore not possible to assess the shallow groundwater conditions in this portion of the site which may be more highly contaminated than the western portion of the site due to the proximity to the Declaration Area.

Elevated heavy metal impacts are detected across the site and do not follow any particular patterns (summary data not included in Table 9.2 or 9.3). It is likely that metal concentrations are influenced by the fill quality and local groundwater conditions (e.g. pH) that may affect leaching of metals from soil.

9.3.2 Natural Attenuation

The RAP does not attempt to demonstrate the degree to which natural attenuation is occurring and natural attenuation is not relied upon in determining the required remediation extent for the site.

9.4 Conclusion

The results indicate some significant impact to groundwater by TPH, BTEX, PAH, ammonia, cyanide and heavy metals, particularly in the deeper groundwater within the natural soils in the north western portion of the site. Some impact to the shallow groundwater located within the fill has also been identified although is generally less elevated than that detected in the deeper groundwater zone. There is limited information on the groundwater quality in the eastern portion of the site (both shallow and deep), which has the potential to be more highly contaminated due to the proximity to the Declaration Area.

The need for remediation of detected groundwater contamination has been considered by AECOM (2015) based on risk based remediation criteria, and is discussed in Section 11. The groundwater results are considered adequate for determining groundwater remediation requirements for the site.

10 Assessment of Risk and Development of Risk Based Remediation Criteria

10.1 Overview

Site specific assessment criteria were originally developed to address a range of potential generic development scenarios for the Barangaroo site in the Declaration Site HHERA (AECOM, 2011a) and ORWS HHERA Addendum (AECOM 2011b). Criteria were derived for the protection of:

- human health – site specific target criteria (SSTC); and
- environment – site specific ecological screening criteria (SSESC).

These criteria were applied as remediation criteria in the RAP for the ORWS area and for the VMP/ Block 4 area. A detailed review of these criteria was undertaken by the Auditor and expert support team (EnRiskS) as documented in the ORWS SAR (GN439B-1). OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South approved the Declaration Site HHERA (AECOM, 2011a) and ORWS HHERA Addendum (AECOM, 2011b) subject to Conditions of Approval which incorporate the design, construction and operational assumptions made in their derivation.

In addition to the above body of work, AECOM undertook an assessment of risks specific to the Crown Sydney Hotel Resort Development in the ORWN HHERA (AECOM, 2014), the objectives of which were to:

- Develop human health SSTC for soil and groundwater for use in defining the remediation end-point for the site, where the remediation end-point is defined as that required to render the site suitable for use following redevelopment; and
- Assess the risk to ecological receptors that the site will represent based on the assumption that the remediation works described by the VMP/ Block 4 RAP (AECOM, 2013b) are undertaken.

The RAP has defined three areas within the site that are based on land uses and material depth. These areas are referenced in some parts of the HHERA and the following sections of this SAR and are relevant to the criteria that have been derived. The areas are defined by AECOM as the following (Attachment 8, Appendix A):

- Area A – material to remain in situ outside the Crown Basement retention wall system and potentially in hydraulic connection with the Harbour (unsaturated and saturated materials are considered separately). Area A comprises the podium and terrace areas which are to have limited or no excavation.
- Area B – material to be removed as part of basement excavation works.
- Area C – material to remain in situ below the proposed Crown Basement and without hydraulic connection to the Harbour. Land uses above Area C comprise hotel, commercial and high density residential with basements.

AECOM's consideration of risk to human health and the environment, including derivation of risk based remediation criteria for the protection of human health, are discussed in the following sections, followed by consideration of other risk issues such as aesthetics.

10.2 Risk to Human Health

10.2.1 Design Assumptions

AECOM developed SSTC that are specific to the proposed Crown Sydney Hotel Resort Development and as such the application of the criteria derived and to be implemented within the RAP are tied to some fundamental aspects of the proposed design. If these aspects are not adhered to, then the objectives of the HHERA will not be met as there will be the potential for unacceptable risks to human health, and the SSTCs will not be relevant.

The fundamental assumptions and design specifications of the proposed development that have been incorporated in the derived SSTCs are as follows:

- Tar will be removed from the immediate vicinity of outer basement walls to the extent practicable and basement design and engineering controls will ensure that tar seepage into basements does not occur.
- Future car-parking basements, if present, will include engineering controls to ensure that contaminated groundwater does not accumulate in the publically accessible car park areas.
- Specific basement design assumptions include:
  - Basements are to extend over a footprint equal to or greater than the footprint of the proposed hotel tower.
  - Basements will extent to a depth below the groundwater table (that is will be constructed within both the saturated and unsaturated soil).
  - Basements will be constructed with a groundwater retention wall system that will extend around the perimeter of that part of the Site that will be occupied by the basement and will be designed to prevent groundwater from migrating from within the basement footprint.
  - Outer basement walls are anticipated to comprise 800 mm to 1200 mm thick reinforced concrete diaphragm walls.
  - Basement walls and floor construction to be at least 150 mm thick.
  - The concrete walls are of sufficient strength/density to prevent tar seepage into the concrete.
  - A physical barrier will be constructed inside the basement to prevent dermal contact with any groundwater seepage water within the basement in the unlikely event that groundwater seepage occurs.
  - A drainage system will be provided that prevents the accumulation of groundwater seepage that may occur through the basement wall by draining water away from the wall.
  - The lowermost basement floor will be in contact with groundwater, but the basement will have water collection devices and engineering controls, such as

damp proof barriers to minimise the potential of groundwater wetting the lower basement floor or walls.

- The smallest occupiable basement dimension that will be independently ventilated and accessible to general building users is an area of 2,500 m^2 based on a dimension of (50 m x 50 m).
- Where basement walls are exposed to groundwater, it is assumed that groundwater will seep through an area equivalent to half of (2 out of the total 4) basement walls. In the lower basement, it is assumed that in addition to the walls, groundwater will also seep through half of the basement floor footprint.
- The basement will be mechanically vented in accordance with *Australian Standard AS 1668.2* (Standards Australia, 2002).
- In accordance with *Australian Standard AS1668.2* (Standards Australia, 2002), the basement levels will be maintained at a negative pressure when compared to the overlying occupied areas.
- The air exchange rate within the basement car park has been assumed to be an average of 3.5 air changes per hour. This air exchange rate is based on the proposed approach to the basement car park ventilation for the Crown basement. It is understood that it is consistent with the Australian Standard AS 1668.2 and accounts for periods of decreased ventilation when vehicle movement in the basement is minimal.
- The hydraulic conductivity of the basement walls has been calculated based on the Crown performance specification for the Crown Basement which requires that groundwater ingress not exceed 0.75 L/min across the entire basement wall area.
- For Scenario 14 (Crown Commercial with advection), the air exchange rate will be at least 5 air changes per hour, which is greater than that typically assumed for a generic commercial building (2 air changes per hour) and is based on the proposed approach to ventilation for the Crown hotel podium.

- For unpaved areas, it has been assumed that ‘Suitable Fill’ will be present at the surface at these locations. In particular, a 1 m thick layer of Suitable Fill has been assumed for Scenario 10. For the purpose of this definition ‘Suitable Fill’ is defined as:
  - Virgin excavated natural material (VENM); or
  - Soil which contains contaminant concentrations below the Terrestrial Soil Criteria (TSC) (developed for the maintenance of plant health and human health); and
  - Soil which contains contaminant concentrations below the relevant SSTC; and
  - Soil which is visually free of bonded ACM.
- For paved open space (Scenario 11) it has been assumed that at least 1 m of Suitable Fill will be placed directly underneath paved areas. For the purpose of this definition, ‘Suitable Fill’ is defined as for unpaved areas.

10.2.2 Derivation of Human Health SSTCs

SSTCs have been derived for eight land use scenarios (referred to as Scenarios 1, 6, 9-14 in the RAP). Scenarios 1 and 6 were consistent with two of the generic land use scenarios developed for ORWN (and based on the ORWS basement design) which were considered by AECOM to be relevant for the Crown development, while the remaining six scenarios (Scenarios 9-14) were based on information specific to the proposed Crown Sydney Hotel Resort Development. The land use scenarios are summarised in Table 10.1 following.

Table 10.1: SSTC Land Use Scenarios

Scenario Number	Description	Exposures Assessed	Review Comments
1 (ORWN Generic)	**Lower Basement** Lower level basement car park in multi-storey building assuming groundwater seepage occurs through walls and floor	Adult worker Child resident exposed during incidental use of the basement for access to vehicles. Only pathway of exposure assessed is vapour inhalation.	Direct contact assumed not relevant as there will be a physical barrier constructed inside the basement to prevent direct contact with any groundwater seepage. Adult resident not considered and therefore lifetime risks for non-threshold chemicals can not be calculated. Some model assumption changes from previous generic criteria.
6 (ORWN Generic)	**Intrusive Maintenance** Maintenance of subsurface services	Adult workers who may come in direct contact with soil and groundwater during these works. Exposure pathways assessed include: • Incidental ingestion of soil and groundwater • Dermal contact with soil and groundwater • Inhalation of vapours from soil and groundwater • Inhalation of dust	Exposures parameters for the intrusive maintenance worker scenario have been adjusted for consistency with the approach adopted in the Friebel and Nadebaum (2011). Some model assumption changes from previous generic criteria.
9 (Crown Specific)	**Upper Basement** Upper basement car park in multi-storey building assuming partially above the water table. May be used for loading / unloading or have a full time car park attendant	The most significant exposures occur by adult workers within a car park. Only pathway of exposure assessed is vapour inhalation	Exposures by a worker in the car park will be more significant than incidental exposure by users of the car park hence it is appropriate that the calculations are based on these exposures. Note that the scenario is relevant for workers in the basement as ventilated and used as a car park only. No other changes in design/use have been assessed. In addition the scenario relies on only the upper 3 m of walls being in contact with soil directly adjacent to 2 of the 4 walls and groundwater seepage occurs through the lower 2 m of 2 of the 4 walls. Direct contact assumed not relevant as there will be a physical barrier constructed inside the basement to prevent direct contact with any groundwater seepage.
10 (Crown Specific)	**Unpaved recreation** Relevant to the public	Recreational exposures by adults and children.	The scenario is reliant on 1 m of clean fill being placed across the area such that direct contact

Table 10.1: SSTC Land Use Scenarios

Scenario Number	Description	Exposures Assessed	Review Comments
	domain areas with no concrete/hardstand paving but 1 m of clean fill at the surface	Only pathway of exposure assessed is vapour inhalation.	with underlying soil does not occur.
11 (Crown Specific)	**Paved recreation** Relevant to the public domain areas that are covered with concrete or paving. It has been assumed that paved recreation areas will also be covered in a 1 m thick layer of clean fill.	Recreational exposures by adults and children. Only pathway of exposure assessed is vapour inhalation.	The scenario is reliant on the concrete cover remaining in place and intact such that underlying soil is not at the surface of the ground. In addition the scenario considers 1 m of clean filling underneath new paving in the event that areas may become unpaved in the future.
12 (Crown Specific)	**Intrusive maintenance worker** Maintenance of subsurface services but assumes no direct contact with groundwater	Adult workers who may come in direct contact with contaminated soil only. Exposure pathways assessed include: • Incidental ingestion of soil • Dermal contact with soil • Inhalation of vapours from soil • Inhalation of dust	Assumes depth of trench is limited to 2 m bgl and therefore will not intercept groundwater based on the finished ground level being 1 m above the existing ground level.
13 (Crown Specific)	**High Density Residential over a basement car park**	Adults and children living on the ground floor of a multi-story building, overlying basement levels. Only pathway of exposure assessed is vapour inhalation.	The assessment has been conducted on the assumption that vapours from the basement levels migrate into the ground floor living areas. Vapours on the ground floor are assumed to be 10 times lower than modelling in the upper basement (basement used as a car park only).
14 (Crown Specific)	**Commercial slab on grade multi-storey** Multi-storey slab on grade construction.	Adult workers within building. Only pathway of exposure assessed is vapour inhalation.	Assumes a typical multi-storey commercial construction. Assumes 5 air changes per hour which is greater than the default for commercial buildings. Assumes at least 1 m of suitable fill overlying contaminated soil.

Note: Inconsistency exists between the RAP and HHERA with respect to the required depth of Suitable Fill (1 m versus 0.5 m). The Auditor has assumed 1 m is correct based on the RAP.

SSTCs have been derived for chemicals of potential concern (COPC) identified in soil and groundwater.

The derived human health criteria have addressed mixtures of key groups of COPC including BTEX (benzene, toluene, ethylbenzene and xylenes), TPH, CPAHs (carcinogenic PAHs that include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene and indeno(1,2,3-cd)pyrene and are assessed based on a toxicity equivalent factor approach), and non-carcinogenic PAHs.

In addition to health based SSTCs, odour-based SSTCs ($SSTC_{odour}$) were also derived by AECOM in the ORWN HHERA to provide an indication of the chemicals likely to create odours in indoor and outdoor spaces following remediation. While the approach adopted for the assessment of odour issues is uncertain, the outcome of the assessment is generally considered reasonable.

The HHERA is based on no TCM being present in the vicinity of the basement walls and floor, however the HHERA does recognise that while such material may be removed to the extent practical some TCM may remain and will require management in accordance with the RAP to ensure that no TCM seeps into the basement levels.

10.2.3 Review of SSTCs Presented in Crown RAP

Detailed review of all SSTCs derived for the land use scenarios outlined in Table 10.1 has not been conducted as part of this audit since previously derived SSTCs had already been approved for similar generic land use scenarios. The Auditor has however completed a more detailed review of the Crown SSTCs for analytes which were found to occur at concentrations exceeding the lowest of the previously approved generic SSTCs. This occurred for groundwater detections only. Minor modifications to account for changes in the updated NEPM (1999)[2013] and Crown specific design requirements (as listed above in Section 10.2.1 for the basement and capping layer) were made by AECOM in derivation of the Crown SSTCs and these have been considered by the Auditor.

Table 10.2 summarises the SSTCs presented in the Crown RAP compared to the lowest of the previously approved generic SSTCs as well as the maximum groundwater concentrations reported for the Crown site. Only chemicals of concern with concentrations exceeding the lowest of the previously approved SSTC have been included.

Table 10.2: Crown SSTCs compared to previously approved generic SSTCs

Chemical of Concern	Maximum Groundwater Concentration on Crown Site (mg/L)	Lowest of Previously Approved Generic SSTC (mg/L)	New Crown Specific SSTCs	Auditor Comment
Benzene	**1.38**	0.41	2.0	*Assess whether revised SSTC appropriate*
Naphthalene	**1.5**	0.92	1.3	*Review risk (Section 11)*
TPH C_6-C_{10} (minus BTEX)	1.5 (note that AECOM report max TPH C_6-C_9 as 4.4 as they do not subtract BTEX)	1.6	9	No action *
TPH > C_{10}-C_{16}**	**18.5**	6.3	12	*Review risk (Section 11)*

18.5 indicates concentration above both old and new SSTC
1.38 indicates concentration above old SSTC but below new Crown SSTC
* No action required as maximum concentration on the Crown site is less than both the lowest of the previously approved SSTCs
** Unclear whether SSTCs for TPH C_{10}-C_{16} include Naphthalene

On the basis of the data presented in Table 10.2, the Auditor has completed a detailed review of the Crown specific SSTC for benzene (the lowest criteria for which was derived for the Crown Scenario 14 – Multistorey Commercial Slab on Ground) compared to the lowest of the previously approved SSTC for benzene (derived for generic Scenario 8 – Multistorey Commercial Slab on Ground) as presented in Table 10.3.

Table 10.3: Comparison of Assumptions for Crown Scenario 14 Compared to Previously Approved Generic Scenario 8

Assumption	Crown Scenario 14 – Multistorey Commercial slab-on-ground	Previously Approved Scenario 8 - Multistorey Commercial slab-on-ground	Auditor Comment
Exposure Time (hours/day)	8	8	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Exposure Frequency (days/year)	240	240	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Exposure Duration (years)	30	30	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Depth to groundwater contamination (m)	3	2	Acceptable as although the depth to groundwater is 2 m below the current ground level, the final level of the podium area (the slab on ground portion of the development) is to be raised 1 m above the current ground level making the depth to groundwater approximately 3 m in this area.
Vadose zone thickness (m)	2.83	1.83	Acceptable as per above
Capillary Fringe Thickness (cm)	17	17	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Air Filled Porosity in Vadose Zone	0.321	0.321	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Water Filled Porosity in Vadose Zone	0.054	0.054	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Air Filled Porosity in Capillary Fringe	0.122	0.122	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Water Filled Porosity in	0.253	0.253	Acceptable as consistent with value used in derivation of generic SSTCs for

Table 10.3: Comparison of Assumptions for Crown Scenario 14 Compared to Previously Approved Generic Scenario 8

Assumption	Crown Scenario 14 – Multistorey Commercial slab-on-ground	Previously Approved Scenario 8 - Multistorey Commercial slab-on-ground	Auditor Comment
Capillary Fringe			the same scenario
Internal Building Height (m)	3	3	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Foundation Thickness (cm)	15	15	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Air Exchange Rate (per second)	1.38×10^{-3} (5/hour)	5.6×10^{-4} (2/hour)	5 changes/hour is significantly more than typical default (1-2 changes/hour) assumed for commercial buildings. This value was adopted based on the "assumed approach to ventilation for the Crown hotel development podium"
Fraction Cracks	0.00038	0.00038	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Air Filled Porosity in Cracks	0.321	0.321	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Water Filled porosity in Cracks	0.054	0.054	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario
Rate of Advection (cm^3/sec)	83	83	Acceptable as consistent with value used in derivation of generic SSTCs for the same scenario

Based on the details in Table 10.3, it is appears as if the difference between the Crown specific SSTCs and the original generic SSTCs (for benzene) for a multistorey commercial slab on grade development are the result of the increased depth to groundwater (due to importation of 1 m fill material in the vicinity of the Crown slab on grade podium) from 2 m to 3 m and to the increase in the indoor air exchange rate (from 2 changes/ hour to 5 changes/ hour). The Auditor notes that validation of this increased exchange rate will be required upon construction.

Based on the assumptions identified in Table 10.3 and independent modelling completed for the Auditor, it is considered that the Crown specific SSTC for benzene is reasonable for use in determining the remediation extent given the design specifications presented in the RAP for the Crown hotel podium area including the proposed raising of ground levels by 1 m.

10.2.4 Asbestos

Asbestos detected at other parts of Barangaroo, including during the extensive excavations performed at the ORWS site, is predominately bonded ACM and therefore the potential for AF generation is considered to be minimal. AECOM has assumed that asbestos which may be present within the ORWN area is likely to be similar – that is predominantly bonded ACM. The asbestos SSTCs proposed by AECOM are summarised in the following table along with Auditor comments. The asbestos SSTCs are to be applied in addition to other applicable SSTCs and TSC, in the case of Suitable Fill, that have also been developed in the ORWN HHERA (AECOM, 2014).

Table 10.4: Asbestos SSTCs and Auditor Comments

Exposure Scenario	Intrusive Maintenance Worker	Suitable Fill
Asbestos SSTC	0.05% w/w	No visible asbestos
Exposure Assumptions	Asbestos quantification in accordance with NEPM (1999)[2013] The intrusive maintenance worker exposure scenario is applicable to soil in areas used for paved and unpaved recreation land use at depths: a) below the 1 m thick Suitable Fill; b) up to approximately 3 m below the final development level (which will be at least 1 m above the current ground surface); and c) above the groundwater table.	Suitable (imported) fill will be placed to 1 m depth in open space areas.
Applicability	Areas outside the basement where an intrusive maintenance worker may be exposed to bonded ACM in soil as part of future maintenance works associated with the completed development (i.e. the Area A unsaturated soil)	Areas outside the basement where a recreational user of the completed development may be exposed to bonded ACM in surface soils (specifically Suitable Fill placed in the top 1 mBGL) in areas used for unpaved recreation.
Auditor Comments	2 mBGL is considered an adequate validation depth considering additional 1 m fill to be placed. Exclusion of criteria for AF is considered acceptable given bonded nature of ACM at site. 0.05% is consistent with commercial/ industrial criteria in NEPM (1999)[2013] (0.05% w/w). Characterisation of Area A unsaturated soils against these criteria is proposed in the RAP.	1 m of fill is considered an adequate validation depth, being an adequate thickness of material to protect paved and unpaved recreational users. “No visible asbestos” is considered an acceptable criteria when considering material will be imported ENM/ VENM.

The Driscoll report on use of asbestos-contaminated soils on Barangaroo does not relate specifically to the ORWN site since reuse of materials originating from this site is not proposed at Headland Park, however, AECOM has considered this report for the protection of workers during remediation.

10.2.5 Overall Applicability of the SSTCs and Determination of Remediation Goals

Based on the findings of the ORWN HHERA (AECOM, 2014), the primary remediation goal for the protection of human health has been identified in the RAP as removal/ remediation of SPGWT to the extent practical. SPGWT is significant since DEC (2007) 'Guidelines for the Assessment and Management of Groundwater Contamination' requires that where non-aqueous phase liquid (NAPL) is present in the subsurface, it must be removed or treated as much as practicable. DNAPL is included within the definition of SPGWT.

The secondary remediation goal identified in the RAP includes removal/ remediation of Confirmed Impacted Material (CIM) to the extent practical, where CIM is determined by comparison of soil and groundwater data with the relevant risk-based remediation criteria (SSTC) and is defined as:

- Unsaturated soil concentrations exceeding the soil SSTCs; and
- Unsaturated and saturated soil concentrations that are considered to be the source of groundwater concentrations exceeding the groundwater SSTCs.

Saturated soil concentrations are not applicable in determining the remedial extent for the protection of human health (and therefore there are no saturated soil SSTC) because there is no complete exposure pathway as follows:

- Area A – saturated material to remain in situ outside the Crown Basement will occur below 3 mBGL and therefore will not be accessed by site users or maintenance workers. The risk from volatile components in soil is considered via groundwater SSTC.
- Area B – material is to be removed as part of basement excavation works.
- Area C – the proposed Crown basement will extend below the groundwater table therefore all material to remain in situ below the proposed Crown Basement will be saturated and the risk from volatile components in soil is considered via groundwater SSTC.

The Auditor considers this to be acceptable, although notes that consideration of potential SPGWT within saturated soil materials is still required.

The derived criteria have been applied by AECOM (2015) to the site data as follows:

- Area A (podium and terrace area outside Crown basement, remaining in hydraulic connection with Darling Harbour):
  - Unsaturated soil SSTCs (termed SSTC-A) for Scenarios 6, 9, 10, 11, 12, 13 and 14. The most sensitive scenarios (with the lowest SSTC) were found to be Scenarios 12 and 14, Crown-specific scenarios for intrusive maintenance worker and multistorey commercial elevated slab on grade.

  - Groundwater SSTCs (termed SSTC-A) for Scenarios 1, 6, 9, 10, 11, 12, 13 and 14. The most sensitive scenarios were found to be Scenarios 6, 12 and 14, generic and Crown-specific scenarios for intrusive maintenance worker and Crown-specific scenario for multistorey commercial elevated slab on grade.

- Area C (remaining soil beneath the Crown basement excavation):
  - Groundwater SSTCs (termed SSTC-C) for Scenarios 1, 9 and 13. The most sensitive scenario was found to be Scenario 1, lower basement.

Data from Area B were compared to the DECC (2014) 'Waste Classification Guidelines' since all material removed from the proposed Crown basement is proposed to be disposed offsite. However, AECOM also determined criteria appropriate to be used as SSTC-B in the event that some of the excavated material is considered suitable for reuse (which would require an Addendum to the RAP) and for application to material to be imported to the site (and placed below the 1 m of Suitable Fill). The derived criteria considered relevant to Area B are:

- Unsaturated soil SSTCs (termed SSTC-B) for Scenarios 6, 9, 10, 11, 12, 13 and 14. These are equivalent to the SSTC-A.

Based on the proposed development and controls, the Auditor considers that the above scenarios are reasonable for the areas defined. The Auditor has considered the previously approved generic SSTCs in conjunction with SSTCs derived specific to the ORWN and Crown hotel developments in reviewing the site contamination status and considering the required remediation extent (refer Section 11). The criteria are reproduced in Appendix E.

10.3 Risk to the Environment

10.3.1 From Current Conditions

The Declaration Site SAR found that if the VMP/Block 4 RAP (AECOM, 2013b) is implemented, residual gasworks related contamination remaining in situ down hydraulic gradient of the Declaration Area (including the site) would not represent an unacceptable risk to the environment. Only non-gasworks related contamination was therefore considered by AECOM from an ecological risk perspective. Gasworks related contaminants are considered to be those chemicals specified in the NSW EPA Declaration specifically: BTEX, PAHs, phenol, TPH, ammonia and cyanide.

As the site and surrounding terrestrial area have been extensively developed, contain minimal natural vegetation and do not contain threatened or vulnerable terrestrial species, populations, communities or significant habitats (DOP, 2007), AECOM (2014) considered that an assessment of the potential for site related contamination to impact the current limited terrestrial environment in not warranted. The ecological assessment therefore focused on potential risks to Darling Harbour (the closest aquatic ecological receptor) from non-gasworks related contamination.

For assessment of ecological risk, the ORWN HHERA (AECOM, 2014) included a review of the groundwater data compared to the marine water quality criteria (MWQC) which were defined and approved for previous stages of work at Barangaroo (refer ORWS SAR). Chemicals detected above the MWQCs in the marine sediments were not considered COPCs from an ecological risk perspective as there was assumed to be no significant flux of

contamination from the marine sediments to either the fill or Darling Harbour. On this basis, the ORWN HHERA (AECOM, 2014) identified the non-gasworks related COPC as copper, zinc, cobalt and cadmium.

The ORWN HHERA (AECOM, 2014) found that the identified non-gasworks related COPCs (copper, zinc, cobalt and cadmium) would not present an unacceptable risk to the environment based on the following considerations:

- The proposed remedial strategy presented within the VMP Extent Report (AECOM, 2013a) and VMP/ Block 4 RAP (AECOM, 2013b) includes: (a) historical infrastructure source removal; and, (b) removal of secondary sources of contamination, such as SPGWT, which are both up-gradient sources of contamination at the site.
- The groundwater retention wall system to be constructed as part of the proposed Block 4 Development Works will effectively cut off groundwater movement from up-gradient sources to the site. AECOM considered that the up-gradient sources are a significant contributor to the groundwater quality within those wells screened within the fill materials.
- The proposed Crown development will incorporate a basement, similar to that proposed as part of the Block 4 Development Works, contained within a groundwater retention wall system which will be keyed into bedrock. The groundwater retention wall system will reduce groundwater migration and potential contaminant flux from that area of the site in which the basement is constructed.
- Results of the Groundwater Discharge Study (AECOM, 2010d), which concludes that there is a fivefold mixing and dilution of groundwater within the unconfined aquifer prior to discharge through the tidal prism to Darling Harbour. The Ecological Risk Assessment (refer to Section 7.0 of the ORWN HHERA (AECOM, 2014)) has not adjusted the groundwater concentrations to reflect dilution, and therefore it is considered that concentrations reported within groundwater at the site will undergo additional dilution prior to discharge to the nearest environmental receptor, Darling Harbour.
- Additional remediation works (as might be required to achieve a greater degree of environment protection), would be impracticable, cost prohibitive and inconsistent with the principles of Ecologically Sustainable Development (ESD). That is, the net cost to the environment of undertaking the additional works would be greater than the environment benefit realised from the additional work at the site (AECOM, 2013a).

Based on the above multiple lines of evidence, the ORWN HHERA (AECOM, 2014) concluded that residual metals contamination reported within groundwater wells screened within the fill materials will not pose a risk to the environment and that the quality of groundwater in fill within the site will improve over time following the proposed remedial works in the Declaration Area and Block 4. AECOM therefore considered that the risks to identified environmental receptors at the site are low and acceptable. Based on these conclusions, risk to the environment was not considered any further in the RAP and the focus of any required remediation works was the appropriate protection of human health.

Based on the consideration of gasworks contamination documented in the Declaration Site SAR and the discussion presented by AECOM regarding other contaminants, the Auditor

considers the findings of the assessment to be appropriate and agrees that remediation is not required based on the identified ecological risk provided the remedial works described by the VMP/ Block 4 RAP are completed. The Auditor notes that given the relatively low density of sampling across the site area there is potential for undetected higher concentrations. However, considering the results from adjacent sites, the data set presented is considered adequately representative of the range of contaminant concentrations likely present within the fill.

10.3.2 From Imported Material

Any fill materials considered “suitable” for placement in the top 1 m of the site, where plants are expected to be grown, are required to meet TSC. The TSC (Appendix E) are based on the protection of plant/soil health and human health under the proposed land use (unpaved recreation), are adopted from published sources (not derived) and are appropriate for the top 1 m.

The TSC were developed in the Declaration Site HHERA (AECOM, 2011a) and were approved by the Auditor in the ORWS SAR. Although some source documents for derivation of the TSC have been updated since their approval (e.g. NEPM (1999)[2013]), the TSC are considered adequately conservative for the protection of future plantings.

Section 10.3.1 considered the risk from leachate discharging to groundwater and potentially Darling Harbour due to current soils. The ORWN HHERA (2014) noted the requirement that, in addition to meeting the above criteria, imported material to be placed in the unsaturated zone (to a depth of 2 m) must also demonstrate neutral leachate conditions which are below the MWQC. AECOM (2014) concluded and the Auditor agrees that application of the TSC for Suitable Fill is considered to be suitably protective of the closest down gradient ecological receptor.

10.4 Other Risk Issues

Following implementation of the RAP, there is potential for odorous soils or AC fragments to be encountered at depth during any future disturbance of fill soils to be retained within Area C and to a lesser extent Area A (which is to be subject to further testing). There is also potential for more significant contamination in the form of SPGWT or TCM to be encountered at depth, particularly in natural materials (marine sediment). The potential for these issues should be considered in any future redevelopment of the site, and should be noted in the final Site Audit Statement (SAS), following completion of remediation.

All surface soils at the site (to minimum 1 mBGL) must contain ‘no visible asbestos’ and will be free of visual amenity impacts as required to meet the imported fill requirements and Suitable Fill criteria.

11 Determination of Remediation Extent

11.1 Introduction

The RAP proposes removal of SPGWT and CIM. SPGWT was identified based on field and laboratory results, while the presence of CIM was determined by comparison of unsaturated soil and groundwater data with the relevant risk based remediation criteria (SSTC), discussed in Section 10. Consideration was also given to the presence of asbestos in soil.

The relevant criteria are included in Appendix E. Attachment 6, Appendix A shows the occurrence of SPGWT.

The design and construction of the basement walls (including the groundwater retention walls) and base requires that tar will be removed from the immediate vicinity of outer basement walls and base to the extent practicable (discussed in Section 10). However, the construction methodology to be employed does not allow for inspection of excavation walls or removal of tar. AECOM has therefore considered existing data and proposes to consider results of future sampling for in situ waste classification to assess the potential for tar to be present in the immediate vicinity of outer basement walls.

The Auditor has reviewed the data and analysis presented by AECOM (2015). The results are summarised in the following sections according to the different site areas/ material types, being Areas A to C (refer Section 10). Samples from above 2 mBGL were considered unsaturated. Data from Area B (material to be removed during basement excavation) were considered by AECOM with reference to DECC (2014) 'Waste Classification Guidelines' to determine a preliminary waste classification.

11.2 Area A – Materials to Remain *In Situ* Outside Basement

AECOM determined the extent of remediation required in Area A based on the following considerations.

11.2.1 SPGWT

SPGWT was not identified in Area A.

11.2.2 Soil

The SSTC-A were compared to unsaturated soil data (less than 2 mBGL) tabulated in the RAP for Area A and adjacent locations. As discussed in Section 10, saturated soil criteria are not applicable to the Area A remediation requirements.

No soil samples were analysed for asbestos. AECOM (2015) has assumed there is significant potential for bonded ACM to be present within fill materials within Area A, as discussed in Section 8.3.4 of this SAR.

All other COPC concentrations were reported to be less than the relevant soil SSTC-A for unsaturated soil, with many reported below the laboratory limit of reporting. The Auditor notes however that limited data were available. Between 1 and 17 samples were analysed for each of the 12 COPC for which SSTC-A are identified in the RAP. AECOM noted this deficiency in the RAP and proposed additional validation of unsaturated soil as part of remediation/ validation.

11.2.3 Groundwater

The following groundwater wells were considered to represent the groundwater quality within Area A: IT01, MW410/IT04, MW411/IT05, MW212, MW24, MW544 and MW40.

All COPC concentrations were reported to be less than the relevant groundwater SSTC-A, although only seven wells were located in this area.

It is noted that concentrations of TPH C_{10}-C_{14} and naphthalene exceed SSTC-A in a well located within Area C (MW60). The well is located in the northwest of Area C and contamination could migrate onto Area A. It is considered unlikely that the contamination detected in groundwater at location MW60 poses an unacceptable risk to human health given:

- These exceedances are only marginally above the SSTCs.
- Concentrations above SSTC-A were only detected in one (MW60) of the 22 monitoring wells considered to be representative of the range of groundwater conditions at the site.
- MW60 was screened across the base of the fill and marine sediment interface. As discussed in Section 5.2, there was considered to be negligible flux from marine sediment into overlying fill.
- Widespread contamination at these concentrations seems unlikely given elevated concentrations (above the Crown SSTCs) were not detected in monitoring wells MW40 and MW56 located in closer proximity to the Declaration Area.
- A downgradient well in Area A (IT04) had contaminant concentrations less than SSTC-A, and the groundwater retention wall will stop future migration of contamination from Area C onto Area A.

11.2.4 Auditor's Opinion

Only limited investigation of unsaturated soil from Area A has been undertaken to date. No TCM was identified in Area A and analytical results were below the SSTC-A. The results to date indicate that soil remediation at Area A is not likely to be required, however, further investigations (in situ validation) are proposed in this area to ensure adequate characterisation of the fill material and to confirm this finding. The proposed investigations are discussed as a validation item in Section 12.

The Auditor is satisfied that active remediation of groundwater in Area A is not required.

11.3 Area B – Materials to be Removed for Crown Basement Excavation

Since Area B material is proposed to be excavated as part of the site development, AECOM compared the Area B data to DECC (2014) 'Waste Classification Guidelines' to provide an indication of the potential classification of materials to be disposed of to landfill. Data from locations within the proposed basement up to a depth of 12 mBGL was considered and AECOM found that:

- The detection of asbestos in one sample and the common occurrence of asbestos in fill from the Stage 1A (ORWS) basement indicates it is probable that the majority of Area B material would be classified as Special Waste (containing asbestos).

- Based on total COPC concentrations and excluding asbestos, it is likely that the majority of Area B material would be classified as General Solid Waste.
- Material in the vicinity of BH191 (3.7 m depth) and any SPGWT encountered would likely be classified as Restricted Solid Waste (or higher).

AECOM notes that additional sample analysis will be required to fully characterise the Area B material to be excavated as part of the Crown basement for landfill disposal. The RAP does not consider waste classification works any further other than to state that in situ waste classification is likely to occur and that the methodology would be agreed with NSW EPA prior to implementation. The Auditor has not reviewed in detail the preliminary waste classification performed.

11.4 Area C – Materials to Remain *In Situ* Below Crown Basement

AECOM determined the extent of remediation required in Area C based on the following considerations.

11.4.1 SPGWT

SPGWT was observed in marine sediment at MW60 (16-17.5 mBGL) in the northwest of Area C as discussed in Section 8.2. AECOM considered that field observations and soil analytical results for nearby sampling locations (BH72 and BH191) indicate that the SPGWT observed at MW60 is relatively localised. SPGWT was also identified offsite to the east in fill material and underlying marine sediment. As discussed in Section 8.2, the Auditor considers that there is potential for further unidentified SPGWT, particularly in the east of the site near the Declaration Area boundary.

Derivation of the SSTCs assumes that tar will not be present in the immediate vicinity of the outer basement walls and base. The RAP reports that the proposed basement will extend to approximately 11.65 mBGL (RL-9.45 mAHD). The depth of the SPGWT identified in MW60 is approximately 4 m below the proposed depth of the basement, and is therefore not likely to be in the vicinity of the base. However, the density of sampling was low and there is potential for unidentified SPGWT. This will be accounted for by inspection of the base of the excavation for evidence of SPGWT, as discussed in Section 12 of this SAR. However, inspection of the basement excavation walls is not possible due to the construction method proposed. AECOM (2015) considered that unidentified SPGWT within marine clays, even if in contact with the groundwater retention wall system, *"…is not considered to represent an unacceptable risk to site users … because the SPGWT would be several metres below the basement and not be in direct contact with the outer basement walls or floor"*.

Notwithstanding the above, to further account for this uncertainty, AECOM propose further consideration of the potential for SPGWT to be present in proximity to basement walls and floor by consideration of:

- Field and laboratory data from proposed Area B in situ waste classification works; and
- Assessment of spoil generated from construction of the groundwater retention wall.

11.4.2 Soil

Soil data for greater than 12 mBGL was tabulated in the RAP as representative of the soil to remain below the Crown basement in Area C and adjacent locations. As discussed in Section 10, saturated soil criteria are not applicable to the Area C remediation requirements.

One soil sample analysed for asbestos did not detect asbestos fibres. AECOM (2015) reported that there was significant potential for ACM in fill material at the site given its widespread occurrence in fill material in the ORWS area. The Auditor notes that while there is significant potential for bonded ACM to be present within fill materials within Area C (refer Section 8.3.4) there is no pathway for human exposure.

11.4.3 Groundwater

The chemicals of potential concern detected in groundwater at the site were less than the SSTC-C. It is noted that concentrations of naphthalene and TPH C_{10}-C_{14} in MW60 exceeded the SSTC-A, as discussed in Section 11.2.3 of this SAR. Whilst the density of sampling is low, it is likely that any unidentified high concentration groundwater impacts within Area C would be associated with marine sediments which are likely to occur below the basement. As noted in Section 11.2.3, MW60 was screened across the base of the fill and marine sediment interface and there is negligible flux from marine sediment into overlying fill, therefore elevated groundwater concentrations at depth are unlikely to present a risk to site users.

11.4.4 Auditor's Opinion

Based on review of the analytical data against the site specific remediation criteria, and in considering the justification presented by AECOM (2015), the Auditor is satisfied that remediation to address identified SPGWT at MW60 and active remediation of groundwater in Area C is not required. Further consideration of the potential for SPGWT in the vicinity of the basement walls and floor will be undertaken following in situ waste classification, wall construction and basement excavation.

11.5 Conclusion

AECOM have not identified any soil contamination requiring remediation, although: the potential for asbestos contamination is acknowledged; further investigations (in situ validation) are proposed in Area A; and further consideration of the potential for SPGWT to be in contact with the basement walls and floor is proposed. In the Auditor's opinion, the extent of soil remediation, the proposed additional testing and the approach to management of asbestos in soil defined in the RAP (AECOM, 2015) are considered appropriate.

Active remediation of groundwater is not proposed by AECOM (2015). Groundwater contamination is essentially proposed to be addressed by containment. In the Auditor's opinion, the approach to management of groundwater contamination defined in the RAP (AECOM, 2015) is considered appropriate.

Discussion of the proposed remediation, validation and future management issues is provided in Section 12.

12 Evaluation of Proposed Remediation

12.1 Remediation Strategy and Methodology Overview

The RAP adopted remediation criteria developed in the ORWN HHERA (AECOM, 2014) (refer Section 10) to determine CIM that requires remediation due to potential risks to human health or the environment (refer Section 11). No CIM has been identified on the site requiring remediation.

Since the site development will require extensive excavation for a basement, soil falling within the proposed basement area is required to be excavated from the site regardless of contamination status (Area B). Excavated material will be treated (if required) and disposed offsite. Beneficial reuse of excavated material is not proposed, and would require an addendum to the RAP. Excavations will be regularly inspected to identify SPGWT and/or CIM not identified during previous site investigations.

No CIM outside the proposed basement excavation areas has been determined to require excavation (refer Section 11). Some material within Areas A and C is acceptable to remain on site managed via *in situ* containment that prevents exposure pathways, as follows:

- Between the existing caisson wall and the basement groundwater retention system, and below existing concrete hardstand (Area A).
- Within the basement groundwater retention system (Area C).

In summary, the overall remediation approach for the site involves retention of some materials on site and excavation of soil from basement areas, followed by offsite disposal to a licensed landfill, with treatment if required.

Ex situ treatment may be required for offsite disposal (with appropriate approvals). The treatment may utilise the facility set up for the Block 4 remediation.

The RAP does not propose groundwater monitoring during and post-remediation.

12.2 Excavation Process

12.2.1 Overview

The RAP describes the steps to be taken in the excavation and disposal process, including *in situ* waste classification, physical separation of recyclable and oversize material, *ex situ* treatment (if required) and validation. AECOM (2015) state that "*Excavations will be regularly inspected by a suitably experienced environmental engineer or scientist to confirm that the visual and olfactory characteristics of the excavated materials are consistent with expectations. These regular inspections will also serve to identify hotspots of SPGWT and/or CIM that may not otherwise have been identified by the previous site investigations / additional validation sampling*".

Materials in Area B will be classified *in situ* in accordance with the DECC (2014) 'Waste Classification Guidelines'. Further details on the waste classification process were not provided in the RAP.

Excavated material will be sorted to remove recyclable material (e.g., steel, concrete, brick, rock and timber) and transferred directly to landfill in accordance with the appropriate waste tracking requirements. Stockpiling of excavated material on site will be minimised by *in situ* waste classification and direct transfer offsite.

12.2.2 Remedial Work Plan

AECOM (2015) report that a Remedial Work Plan (RWP) will be prepared to provide detailed excavation plans, including the anticipated classification of materials.

The RWP will not provide further information regarding the contamination status of the site, and therefore it is not required for review in order to complete the current audit.

12.2.3 Retention Walls

A groundwater and excavation retention wall will be installed to facilitate the remediation and development works. The retention wall system will effectively prevent groundwater migration to/from the site.

The proposed alignment of the basement retention wall system is shown in Attachment 3, Appendix A. The wall will comprise a diaphragm wall keyed into bedrock and have a minimum thickness of 800 mm.

The RAP notes that the basement and retention wall system is subject to further refinement during the design process. The RAP considers the implications of changes to the depth of the basement (increase or reduction) and/or the alignment of the retention wall.

Changes that affect the assumptions of the ORWN HHERA (AECOM, 2014) or RAP (AECOM, 2015) would require an Addendum to the RAP to be prepared for Auditor consideration.

12.2.4 Materials Tracking

The RAP (AECOM, 2015) describes a materials tracking process to allow verification of the correct movement and handling of materials handled during the remediation works. Standard forms will be prepared as part of a Materials Tracking Procedure. The process includes registered survey of stockpiles to reduce the risk of cross contamination and a series of forms including:

- Off-site Transport/Disposal Form.
- Imported Fill Form.
- Material Excavation Form.
- Material Treatment Form.
- Material Stockpiling Form.
- Material Placement Form.

12.3 Evaluation of Remedial Action Plan

The Auditor has reviewed the RAP (AECOM, 2015) by comparison with the checklist included in EPA (1997) ‘Guidelines for Consultants Reporting on Contaminated Sites’. The

RAP was found to adequately address the required information for all items, as detailed in Table 12.1, below.

Table 12.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
Remedial Goal RAP s1.1	The key objective of the remediation is *"to facilitate the currently permissible and future intended land-uses proposed as part of the Crown hotel development. Specific objectives of the remediation works are:* • *To ensure the remediated site is protective of human health in the context of the:* - *Currently permissible land uses - including a groundwater retention wall and underground car park; and* - *Intended future land uses proposed as part of the Crown hotel development - including the future intended basement car park and hotel.* • *To ensure the remediated site is protective of the environment (specifically groundwater and the adjacent Darling Harbour), to the extent practicable, by minimising the risk of ongoing contamination; and* • *Comply with applicable legislative and policy requirements including the appropriate requirements of the NSW EPA and NSW Department of Planning and Environment (DoPE)."*	The identified remedial objectives (remedial goal) are considered appropriate.
Discussion of the extent of remediation required RAP s8	The remediation extent was determined based on: • The standard of remediation that can be practically achieved by the adopted remediation technologies. • Consideration of the proposed basement designs and land uses and the location of the associated basement groundwater retention wall system. • Consideration of regulatory policy requirements including the principles of ESD. The remediation extent was discussed in Section 11 of this SAR. No CIM requiring remediation was identified on the site, however management of identified contamination during development is proposed. The extent of the management strategies was defined as follows: **Area A:** A minimum of 1 m of imported VENM will be placed over the existing concrete slab, with services installed in the imported material. Validation sampling of unsaturated material to be retained in Area A is also proposed (Table 12.2).	The defined extent of management strategies is considered appropriate as discussed in Section 11 of this SAR. The extent of any remediation required in Area A will be determined following validation sampling.

Table 12.1: Evaluation of Amended Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
	Area B: Material to be excavated for basement and disposed offsite. The proposed excavation depth is 11.65 mBGL (-9.45 mAHD). The lateral extent is presented in Attachment 3, Appendix A. Treatment is not proposed, however may be required prior to offsite disposal. **Area C:** The area is below the basement and within the retention wall, which will prevent groundwater migration from the area.	
Remedial Options RAP s9	The RAP does not include a remedial technology assessment as previous investigations have not identified CIM requiring remediation. Contingencies are provided should CIM be identified in Area A or Area C (during validation of the basement excavation). Remedial options considered are based on the Remedial Technology Assessment in the VMP/ Block 4 RAP (reviewed in the Declaration Site SAR).	The absence of a remedial technology assessment is considered appropriate. Reference to the VMP/ Block 4 RAP is considered appropriate for contingency remediation.
Selected Preferred Option RAP s10 S16.4.2.1	The RAP notes that remediation is not required to make the site suitable for the proposed use. Development of the site will incorporate the following management strategy for each area: • Excavation for proposed basements (Area B) and offsite disposal of material to licensed landfill (including treatment if required). • Retention of material in situ, either: - Between the existing caisson wall and the basement groundwater retention wall, and below existing concrete hardstand and a minimum of 1 m of Suitable Fill (Area A), or - Within the basement groundwater retention wall system (Area C). Contingency remediation measures, comprising excavation and offsite disposal, are proposed in the event that SPGWT or CIM are identified during additional sampling of Area A, or during inspection of the excavation base in Area C. If SPGWT is confirmed in the base of the completed basement excavation, the vertical extent of excavations will be increased in the vicinity of the impact to the following depths: • 2 m from the underside of the basement floor slab if permeable fill will be used to backfill the over excavation area; or • 1 m from the underside of the basement floor slab if clay will be used to backfill the over excavation area. Contingency remediation in the unlikely event that	The selected preferred management options are considered appropriate.

Table 12.1: Evaluation of Amended Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
	the excavation is founded in rock and SPGWT is present.	
Rationale RAP s10	The selected management strategies were justified for each area based on feasibility and sustainability considerations.	The rationale presented is considered appropriate.
Proposed Validation Criteria RAP s7	The proposed validation criteria are the remediation criteria (SSTCs) discussed in Section 10 of this SAR.	The defined remediation/ validation criteria are considered appropriate as discussed in Section 10 of this SAR.
RAP s16.2	Statistical validation is proposed. For soil, the 95% UCL will be used to assess the mean concentrations of chemicals of potential concern (where appropriate). Data sets will be defined for different areas. The statistical criteria outlined in NEPM (1999)[2013] are proposed.	The statistical validation proposed is considered acceptable provided data sets are representative of different areas and strata.
Proposed Validation Testing RAP s16	The RAP incorporates the following validation approach: • Preparation of a validation SAQP. • A suitably qualified consultant will undertake the supervision and validation of the remedial works. • Use of systematic sampling patterns, although locations will be biased towards material identified to be the most impacted. • Excavations will be assessed for visual and olfactory evidence of potential contamination, and field screening of samples for volatile organic compounds will be undertaken using a PID.	General validation approach is considered appropriate.
RAP s16.4	**Soil:** Soil validation sampling is proposed at various stages of the remediation works. The proposed soil sampling is summarised in Table 12.2, below.	The approach to validation sampling is considered reasonable. While the various sampling densities (e.g. 1 per 100 m^2) appear adequate, confirmation of their adequacy will depend on the results obtained and their consistency.
RAP s16.6, 16.7	**Sampling Methodology:** The RAP details the proposed soil sampling methods. A discussion of DQOs, QA/QC samples and control limits for DQIs is also provided.	The proposed sampling methods are considered appropriate. The QA/QC information outlined is considered acceptable.
RAP s16.3	**HHERA Assumptions:** The RAP describes a	The proposed approach to

Table 12.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
	validation process to confirm that key assumptions regarding the proposed development and on which the ORWN HHERA was based have been or will be implemented. Review of "issued for construction" or "as constructed" drawings is proposed to achieve this, supplemented by inspections as appropriate. A survey of the site layout including the groundwater retention wall system is also proposed. A review is also proposed to assess the implications of any changes to the design of the depth of basements and/or the final alignment of the basement groundwater retention wall system. In order to manage the impact of potential changes to the development design, AECOM prepared contingencies. If design changes affect the assumptions of the RAP and the ORWN HHERA, an Addendum to the RAP would be prepared.	validation of key risk assessment and remedial design assumptions is considered appropriate.
Interim Site Management Plan (before remediation)	None proposed.	Not required since the site is currently secure
Site Management Plan (operation phase) including stormwater, soil, noise, dust, odour and OH&S RAP s12, 13, 14, 17, 18	The RAP outlines environmental protection measures proposed to be implemented in relation to materials management, water management and other aspects such as odours, dust, noise and vibration. In particular, an Emissions Control System is proposed for the basement excavation if required to manage air quality. Minimum standard occupational health and safety (OH&S) measures are also outlined in the RAP. A site-specific Environmental Management Plan (EMP) and OH&S Plan are to be developed prior to commencement of the works. Assessment of air quality is also proposed. An assessment of noise and vibration impacts has been completed by Wilkinson Murray, which AECOM (2015) report concluded that no exceedance of noise management levels is expected.	The outline measures are considered appropriate. The level of detail provided is considered appropriate for the RAP.
Contingency Plans to Respond to Site Incidents. RAP s20	The RAP identifies a number of potential operational contingency issues and outlines proposed responses. Issues identified include: • Flooding of the site • Control of dust • Fugitive emissions and odours • Noise and vibration • Spills and leaks An emergency response plan will be prepared prior	Contingency measures are considered appropriate.

Table 12.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
	to the commencement of the works.	
Contingency Plan if Selected Remedial Strategy Fails RAP s20	The RAP identifies a number of potential contingency issues relating to the success of the remediation, and outlines the proposed approach to these. Issues identified include: • Changes to the development strategy • Variation of contaminant characteristics • Validation of basement excavation founded in bedrock • Identification of SPGWT/CIM requiring remediation • Treatment required to facilitate disposal to landfill • Failure of the preferred treatment approach • Insufficient storage capacity for stockpiling • Changes to the Stage 1C basement and groundwater retention wall system designs (including changes to basement depth and wall alignment)	The issues identified and proposed responses are considered reasonable.
Remediation Schedule and Hours of Operation RAP s11.2, s12.4.2	The RAP outlines the task-wise project schedule however the project duration is not specified. The detailed work program is proposed to be prepared prior to site establishment. Hours of operation were anticipated to be 7am to 6pm Monday to Friday, and 7am to 5pm Saturdays. No works were anticipated on Sundays and Public Holidays.	The identified tasks appear appropriate. The level of detail provided is considered appropriate for the RAP.
Licence and Approvals RAP s2	The RAP outlines the relevant legislation and planning approvals required for the remediation works. The RAP (AECOM, 2015) reports that *"Remediation works as described by this RAP will be subject to assessment and determination by the Minister for Planning as State Significant Development under Part 4 of the EP&A Act. As such, an application(s) will be made to the NSW Department of Planning and Environment (DP&E) for, potentially among other things, remediation works within the site. An Environmental Impact Statement(s) (EIS) will be prepared to address these assessment requirements, in support of the application and to seek planning approval."* The proposed remediation is not expected to comprise soil treatment of a volume greater than 30,000 m^3 within the larger Barangaroo site area (therefore "onsite"), as described in Schedule 1 of the NSW 'Protection of the Environment Operations	The identified approvals and waste classification process appear appropriate.

Table 12.1: Evaluation of Amended Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
	Act 1997' (POEO Act). Notwithstanding, AECOM considers that variation to the existing Environment Protection License (EPL) may be required under the POEO Act depending on the quantity and area of material treated or disturbed in association with other parts of the Barangaroo site. Discharge of treated stormwater to Sydney Harbour is undertaken under an existing EPL (13336). Variation to the EPL may be required for emissions from odour control structures (if required) and for treatment of material (if required). The RAP outlines the requirements of SEPP 55 with respect to the definition of Category 1 remediation, which requires development consent. The RAP reports that remediation is not required at the site, therefore categorisation of the proposed works in accordance with SEPP 55 is not required. In the event that contamination requiring remediation is identified during development, it would be categorised as Category 1 Remediation Works. A Trade Waste License from Sydney Water will be required for disposal to sewer (if required). Materials to be disposed offsite will be assessed in accordance with the DECC (2014) 'Waste Classification Guidelines Part 1: Classifying Waste'. Material requiring stabilisation prior to offsite disposal will be treated and tested in accordance with an immobilisation approval from NSW EPA (approval # 2005/14 or site specific). Offsite disposal will require consent from a licensed landfill to receive waste generated from the remediation works. Imported fill is required to be VENM or ENM as defined in the NSW 'Protection of the Environment Operations (Waste) Regulation 2005'. ACM encountered will be collected and disposed of by a licensed Asbestos Removal Contractor in accordance with the requirements of the NSW WorkCover, the NSW 'Work Health and Safety Act 2011', the NSW 'Work Health and Safety Regulation 2011' and the requirements of Safe Work Australia.	
Contacts/ Community Relations RAP s19	The RAP provides a summary of the Remediation Community Engagement Sub Plan to be developed and implemented for delivery of the remediation works at the site.	The level of detail provided in the RAP is considered appropriate.
Staged Progress	The RAP does not discuss staged reporting of the remediation and validation of the site. Validation	Considered acceptable.

Table 12.1: Evaluation of Amended Remedial Action Plan

RAP Element	Details	Auditor Comments
Reporting RAP s16.8	reporting is proposed in accordance with the EPA (2011) 'Guidelines for Consultants Reporting on Contaminated Sites'.	
Long term site management plan RAP s17.5	The RAP states that *"On the basis that both the key assumptions and requirements of this RAP and the Draft ORWN HHERA … are successfully delivered and implemented during the execution of the works, and validated accordingly upon completion, no Long Term Management Plan is envisaged as a requirement of this RAP".*	The Auditor agrees that no Long Term Management Plan should be required if the RAP is implemented and validated successfully, provided that adequate ongoing management of ventilation and seepage control systems can be demonstrated. Depending on the results of proposed sampling and possible remediation of Area A soils, there may also be a requirement for ongoing management in relating to maintenance of services below hardstand in Area A.
	The RAP notes further that *"Should future land owners propose to re-develop the Site for a land use that is different to those included as part of the proposed Crown Hotel Development Works, the associated development application would be required to consider the requirement (or otherwise) for a Long Term Environmental Management Plan or further remediation to facilitate the proposed re-developed land use. Such considerations are beyond the scope of this RAP".*	This is considered appropriate. Issues for consideration in future developments at the site will be noted by the Auditor in the final SAS addressing site suitability. The SAS will be referenced in the Section 149 certificate for the site which is maintained by Council and is required to be considered in any future development consent.

Table 12.2: Summary of Proposed Soil Validation

Area	Item	Proposed Validation Method	Analytes	Soil Criteria
A	Retained fill	Additional sampling to achieve a 20 m grid, with samples collected at depths of 0.5 and 1.5 mBGL.	SSTC-A COPC including bulk asbestos	SSTC-A
	Excavation of any SPGWT/ CIM identified during additional validation sampling	1/10 m wall samples 1/10 m or 10 m grid base samples Sample locations to be selected based on field indicators/ PID	SSTC-A COPC	SSTC-A

Table 12.2: Summary of Proposed Soil Validation

Area	Item	Proposed Validation Method	Analytes	Soil Criteria
B	Untreated soil for offsite disposal	Waste classification details not provided in the RAP. In situ classification likely, methodology to be agreed with NSW EPA prior to implementation.	Not provided	Waste Classification Guidelines (DECC, 2014)
	Treated soil for offsite disposal	In accordance with General Immobilisation Approval or specific approval, where required 1/500 m^3 Visual inspection free of ACM and SPGWT	Untreated materials: heavy metals, PAH, phenols, TPH, BTEX, cyanide, asbestos Treated materials: TCLP – heavy metals, PAH, phenols, cyanide	In accordance with approval/ Waste Classification Guidelines (DECC, 2014)
C	Fill adjacent to the retention wall	Potential for SPGWT to be present in proximity to basement walls and floor to be considered by: • Field and laboratory data from proposed Area B in situ waste classification works • Assessment of spoil generated from construction of the groundwater retention wall	-	TCM criteria
	Bedrock exposed in the base of the basement excavation	Visual inspection free of SPGWT Removal of any SPGWT and validation of excavation base visually	-	-
	Fill exposed in the base of the basement excavation	Visual inspection free of ACM and SPGWT Sampling of excavation base at 1/20 m grid within footprint of potential SPGWT Visual validation of removal of SPGWT	PAH	TCM criteria
Treatment and stockpiling areas	Hardstand	Visual inspection for any contamination relating to treatment operations	-	-
	Soil beneath hardstand if contamination of hardstand present	20 m grid samples 0-0.15 m depth	SSTC COPC	Relevant criteria not specified Assumed to be relevant Area SSTC

Table 12.2: Summary of Proposed Soil Validation				
Area	**Item**	**Proposed Validation Method**	**Analytes**	**Soil Criteria**
Entire site	Imported material – VENM/ quarry product	VENM certificate demonstrating physical and chemical quality, including supporting test data Inspection at importation to confirm consistent and no evidence of contamination	-	VENM criteria.
	Imported material – non quarry product (including landscaping products such as mulch)	Inspection of source site Sample at 1/100 m^3 or minimum 3 samples per source Inspection at importation to confirm consistent and no evidence of contamination	HM, PAH, phenols, TPH, BTEX, OPP, OCP, PCB, asbestos	ENM criteria, TSC and SSTC-B.
	Groundwater	None required, adequately characterised/ validated	-	-

In the Auditor's opinion, the remediation and validation approach recommended by AECOM are appropriate. The proposed remediation strategies for the site are generally consistent with the Overarching RAP.

12.4 Additional Remediation Documentation

AECOM (2015) identify the following supporting documentation that will be prepared prior to commencement of the remediation works:

- OH&S Plan
- Community Consultation Plan
- Environmental Management Plan
- Project Management Plan
- Quality Management Plan
- Asbestos Management Plan
- Emergency Response and Contingency Plan
- Remedial Work Plan
- Validation SAQP

Other remediation documentation or further studies referenced throughout the RAP (AECOM, 2015) include:

- operation and maintenance management systems for the Remediation Enclosure and Emissions Control System, to be developed on completion of the final design of the system
- an Air Quality Impact Assessment

- a noise and vibration assessment (prepared by Wilkinson Murray, April 2014)

With the exception of the validation SAQP, review of these studies and other documentation relating to the site operations is not required by the Site Auditor since these issues are not related to site suitability and are outside the Site Auditor's area of expertise. Specialist peer review or review by the regulator may be warranted.

The RAP (AECOM, 2015) notes that *"If the final development design is changed in a way which affects the assumptions of the ORWN HHERA and this RAP, an Addendum will be prepared, as required, and submitted to the NSW EPA Accredited Site Auditor for approval"* and further that *"If the reuse of Area B material is required, it will be described in an Addendum to this RAP and submitted to the NSW EPA Accredited Site Auditor for approval"*. This is considered an appropriate means to manage potential changes to the development design or the proposed reuse of material onsite.

12.5 Conclusion

In the Auditor's opinion, the proposed remediation and validation approach described in the RAP (AECOM, 2015) is appropriate. The proposed remediation strategies are consistent with the Overarching RAP.

Preparation of a validation SAQP is proposed and requires review by the Site Auditor prior to remediation.

A RWP is proposed to be prepared to detail the excavation plans. The RWP will not provide further information regarding the contamination status of the site, and therefore it is not required for review in order to complete the current audit.

If significant changes are made to the development design, or if beneficial reuse of excavated material is proposed, AECOM (2015) proposes to prepare an Addendum to the RAP for approval by the Site Auditor. This is considered an appropriate approach to management of significant changes to the development design and the potential for beneficial use of excavated material.

13 Contamination Migration Potential

The potential for offsite migration of contamination from the site relates to the leaching potential of contaminants from soils and the movement of groundwater from the site to Darling Harbour. These factors have been addressed in the Groundwater Discharge Study (AECOM, 2010d, discussed in Section 5.2), by the VMP Extent report (AECOM, 2013a, reviewed in the Declaration Site SAR) and the considerations discussed in Section 10.3 of this SAR.

In the Auditor's opinion, completion of the remediation works as described in Section 12 will minimise the potential for future offsite migration of contamination from the site, provided the remedial works described by the VMP/ Block 4 RAP are also completed. Post-remediation monitoring of groundwater is not proposed and is not considered necessary.

14 Ongoing Site Management

AECOM (2015) states that "*On the basis that both the key assumptions and requirements of this RAP and the Draft ORWN HHERA … are successfully delivered and implemented during the execution of the works, and validated accordingly upon completion, no Long Term Management Plan is envisaged as a requirement of this RAP*". Maintenance of ventilation and seepage control systems will be required in order to ensure that the key assumptions and requirements of the RAP are maintained into the future. Adequate ongoing management may be able to be demonstrated through the validation process. If not, some ongoing maintenance may require a Site Management Plan (SMP) which may be made a condition of the Site Audit. This will depend on the validation performed following remediation.

15 Compliance with Regulatory Guidelines And Directions

Guidelines currently approved by the EPA under section 105 of the NSW *Contaminated Land Management Act 1997* are listed in Appendix C. The Auditor has used these guidelines.

The investigations were generally conducted in accordance with SEPP 55 Planning Guidelines and reported in accordance with the EPA (1997) 'Guidelines for Consultants Reporting on Contaminated Sites'. A checklist based on that document was used in reviewing the reports. The EPA's 'Checklist for Site Auditors using the EPA Guidelines for the NSW Site Auditor Scheme' has also been referred to.

DOP Director-General's Requirements (DGRs) for the original Barangaroo Concept Plan approval included that Remedial Action Works Plans be prepared for relevant sections of Barangaroo, and clearly demonstrate that the site will be remediated to a standard commensurate with the site use. Those plans were required to be audited by an EPA accredited site auditor. This Site Audit Report and attached Site Audit Statement have been prepared to fulfil this requirement.

On the basis of the above, audit of the Barangaroo site (including the Crown Sydney Hotel Resort Development site) was previously notified to the EPA as a statutory audit (SAN GN 439 dated 19 May 2010). The current DGRs for the Barangaroo Concept Plan (MP06_0162 (MOD 8) dated 15 April 2014) require preparation of a RAP however do not require a site audit. It is excepted that future development approvals for the site will require a site audit prior to occupation confirming the site is suitable for the intended uses.

Regulatory approvals and licenses required for the proposed remediation works are discussed in Table 12.1.

16 Conclusions and Recommendations

AECOM (2015) concluded in the RAP:

> *"It is concluded that the preferred management strategy described in the RAP will, upon successful implementation as evidenced by the prescribed validation program, ensure that the Site is suitable for both the currently permissible and future intended land uses, specifically a mixed use including hotel (incorporating high density residential with minimal access to soil), commercial/retail (with minimal access to soil), public open space and underground parking or any combination of the above."*

Based on the information presented in the reports reviewed, the Auditor concludes that the site can be made suitable for the proposed development described in Section 2.5 of this Site Audit Report (including hotel, commercial/ retail, public open space and underground parking with minimum 1 m fill placed outside basement areas) if the site is remediated, developed and managed in accordance with the following remedial action plan:

- 'Remedial Action Plan, Crown Hotel Development (Part of ORWN Area), Barangaroo South' dated 13 January 2015, by AECOM Australia Pty Ltd.

The general land use scenarios applicable to this audit are 'commercial/industrial', 'high density residential' and 'parks, recreational, open space'.

It is noted that the extent of remediation proposed with respect to protection of the environment relies upon implementation of remediation proposed in the VMP/ Block 4 RAP.

17 Other Relevant Information

This Audit was conducted on the behalf of Crown Sydney Property Pty Ltd to provide an independent review by an NSW Environment Protection Authority (EPA) Accredited Auditor of what remediation or management is necessary before the land is suitable for specified uses i.e. a “Site Audit” as defined in Section 4 (1) (b) (iv) of the *NSW Contaminated Land Management Act 1997*.

This summary report may not be suitable for other uses. ERM, AECOM and JBS included limitations in their reports. The audit must also be subject to those limitations. The Auditor has prepared this document in good faith, but is unable to provide certification outside of areas over which he had some control or is reasonably able to check.

The Auditor has relied on the documents referenced in Section 1 of the Site Audit Report in preparing his opinion. If the Auditor is unable to rely on any of those documents, the conclusions of the audit could change.

It is not possible in a Site Audit Report to present all data which could be of interest to all readers of this report. Readers are referred to the referenced reports for further data. Users of this document should satisfy themselves concerning its application to, and where necessary seek expert advice in respect to, their situation.

Appendix A: Attachments

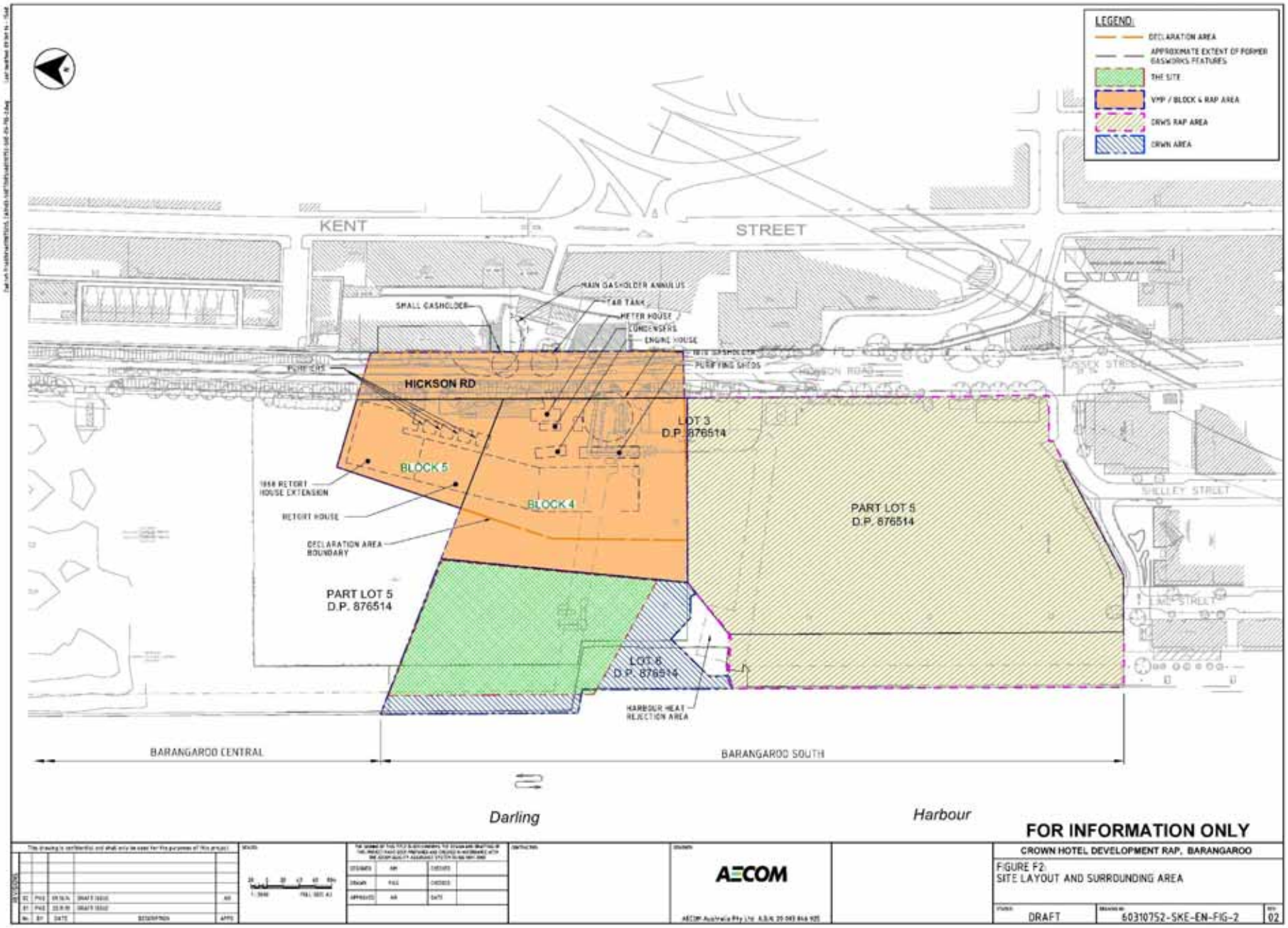
Attachment 1: Site Location
Attachment 2: Site Layout and Surrounds
Attachment 3: Proposed Land Use
Attachment 4: Investigation Locations
Attachment 5: Indicative Bedrock and Marine Sediment Contours
Attachment 6: Location of Separate Phase Gasworks Wastes and Tar
Attachment 7a: Gasworks Related Impacts in Fill Material
Attachment 7b: Gasworks Related Impacts in Marine Sediment
Attachment 8: Schematic Cross Section

Attachment 1: Site Location

AECOM

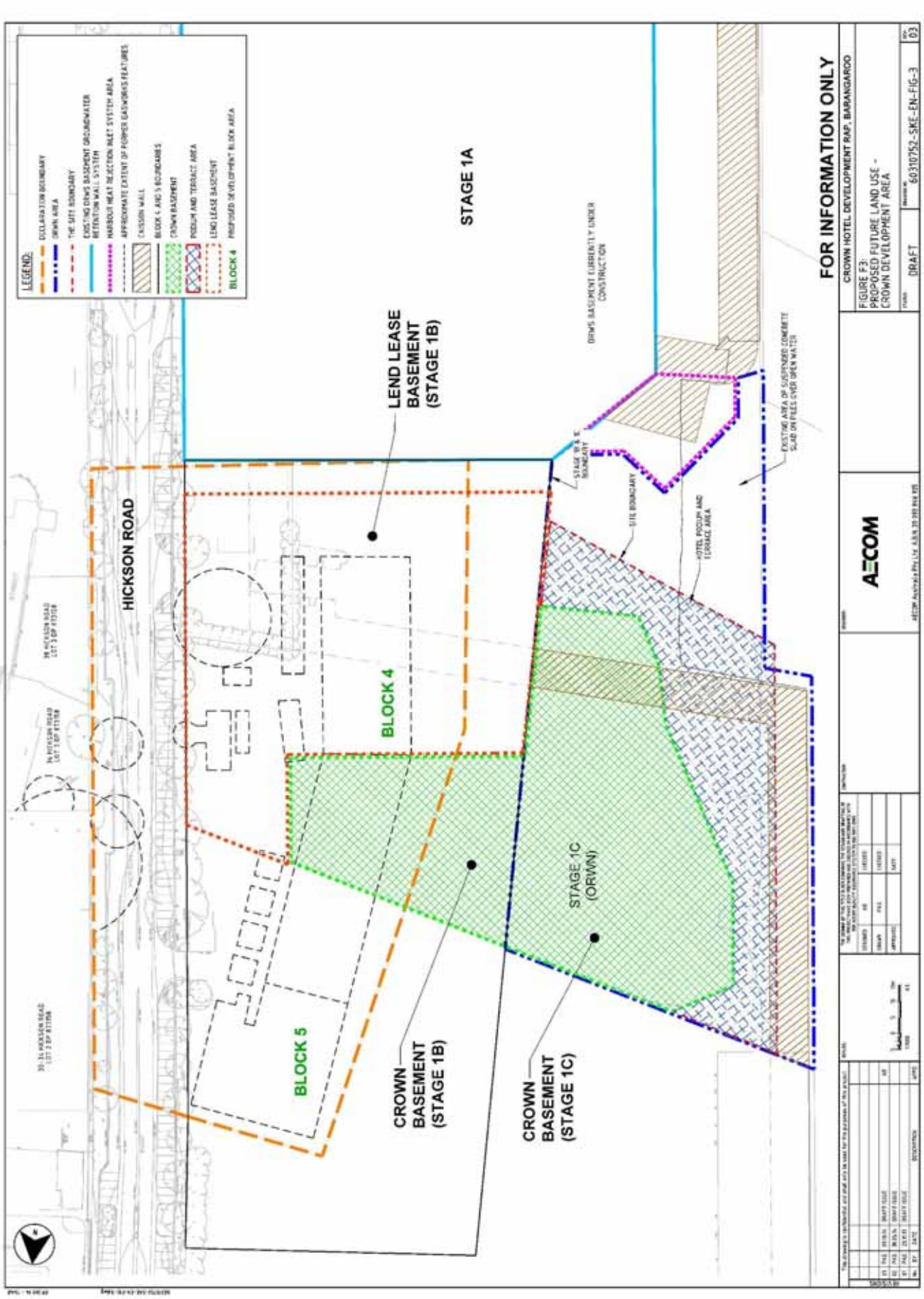
SITE LOCATION
Crown Hotel Development RAP
Barangaroo
Crown Resorts Limited

FIGURE F1

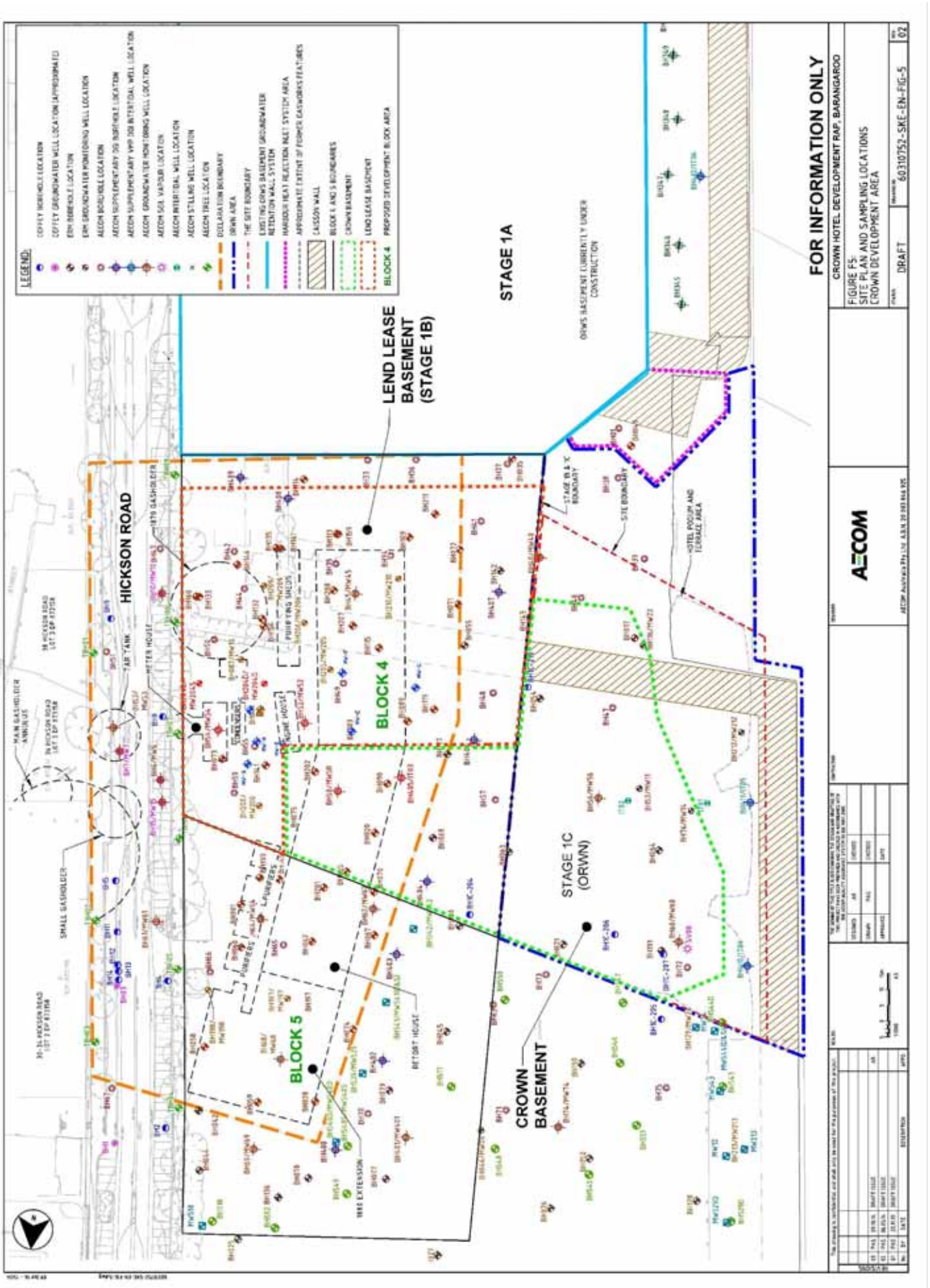


Attachment 2: Site Layout and Surrounds

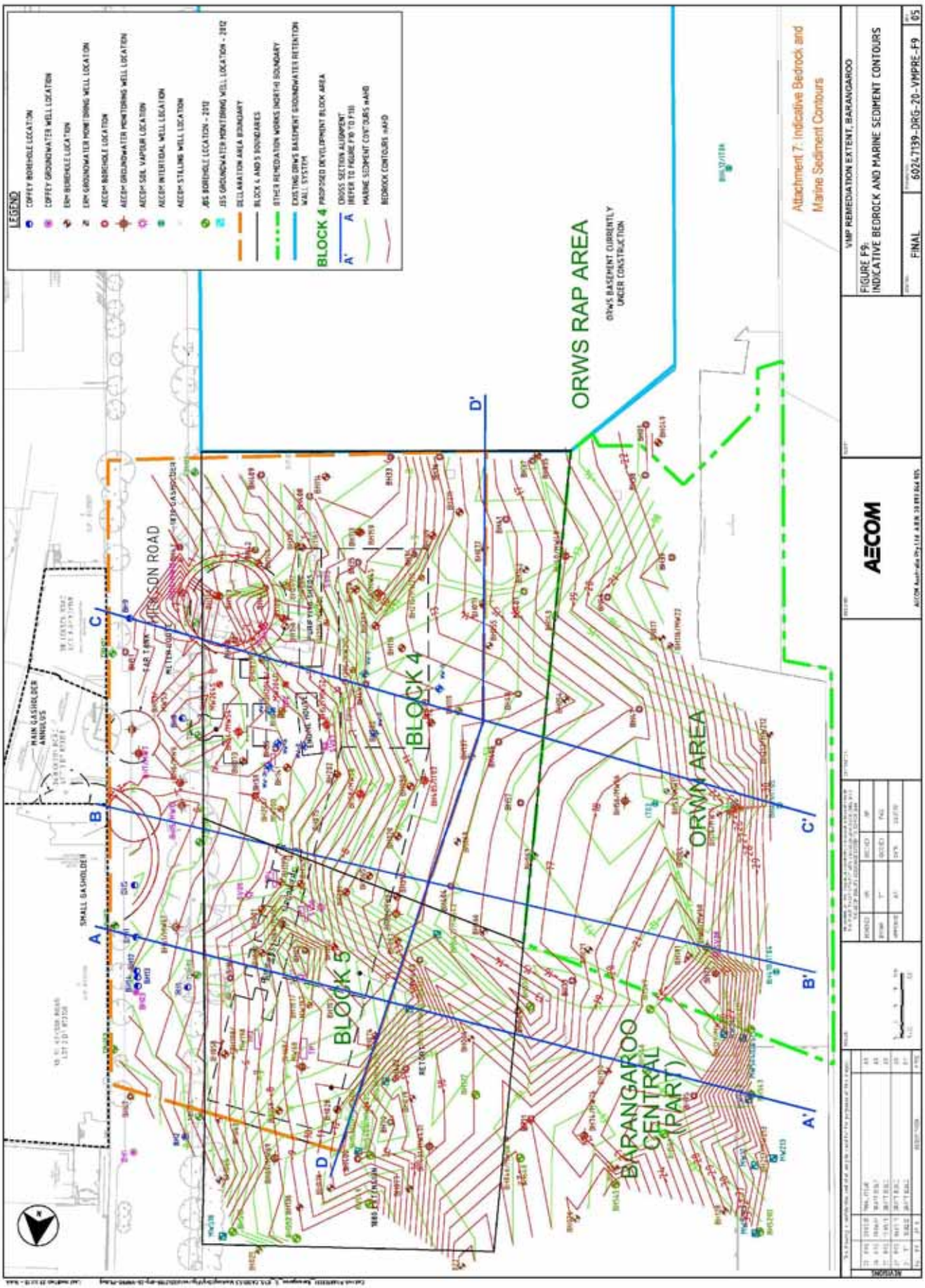
Attachment 3: Proposed Land Use



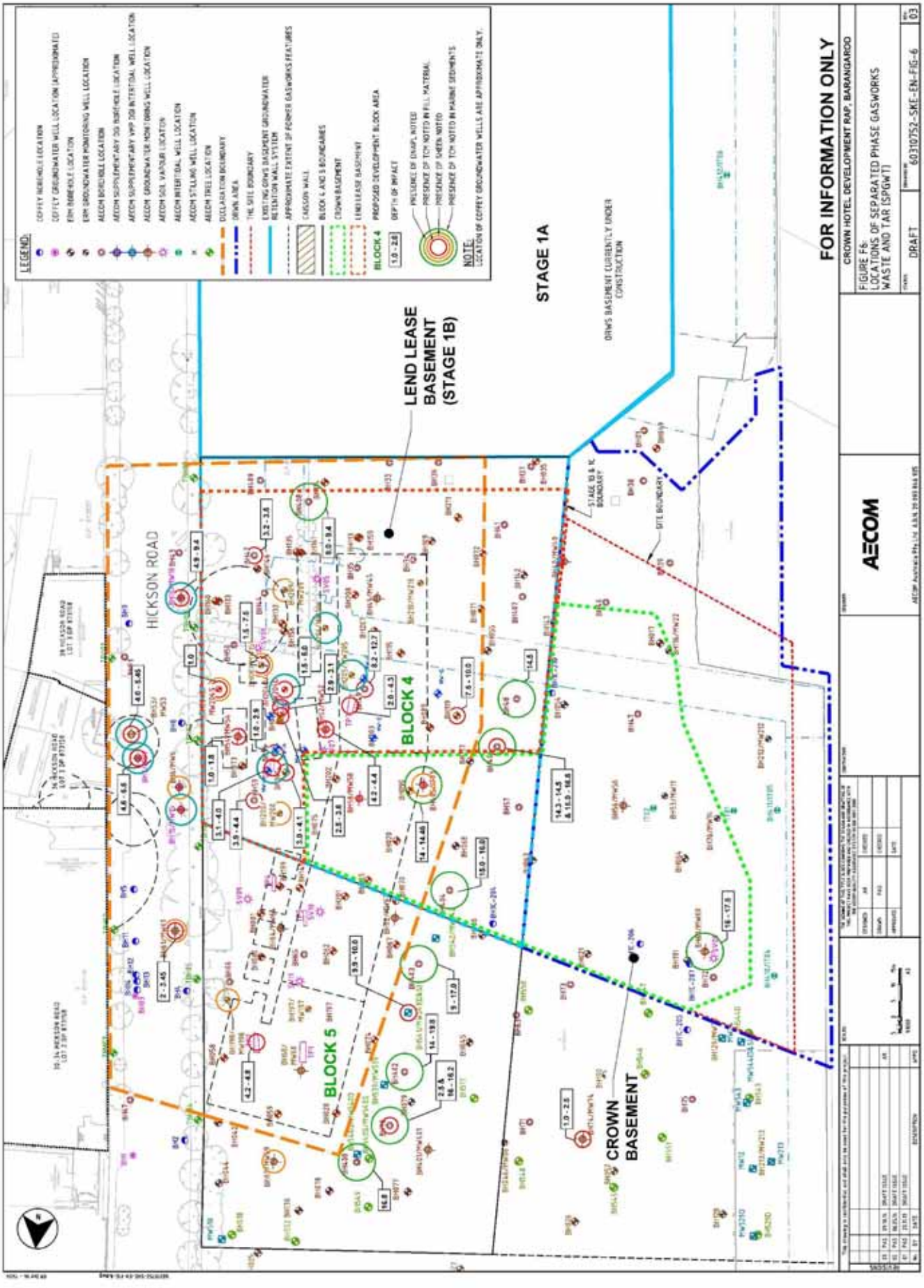
Attachment 4: Investigation Locations



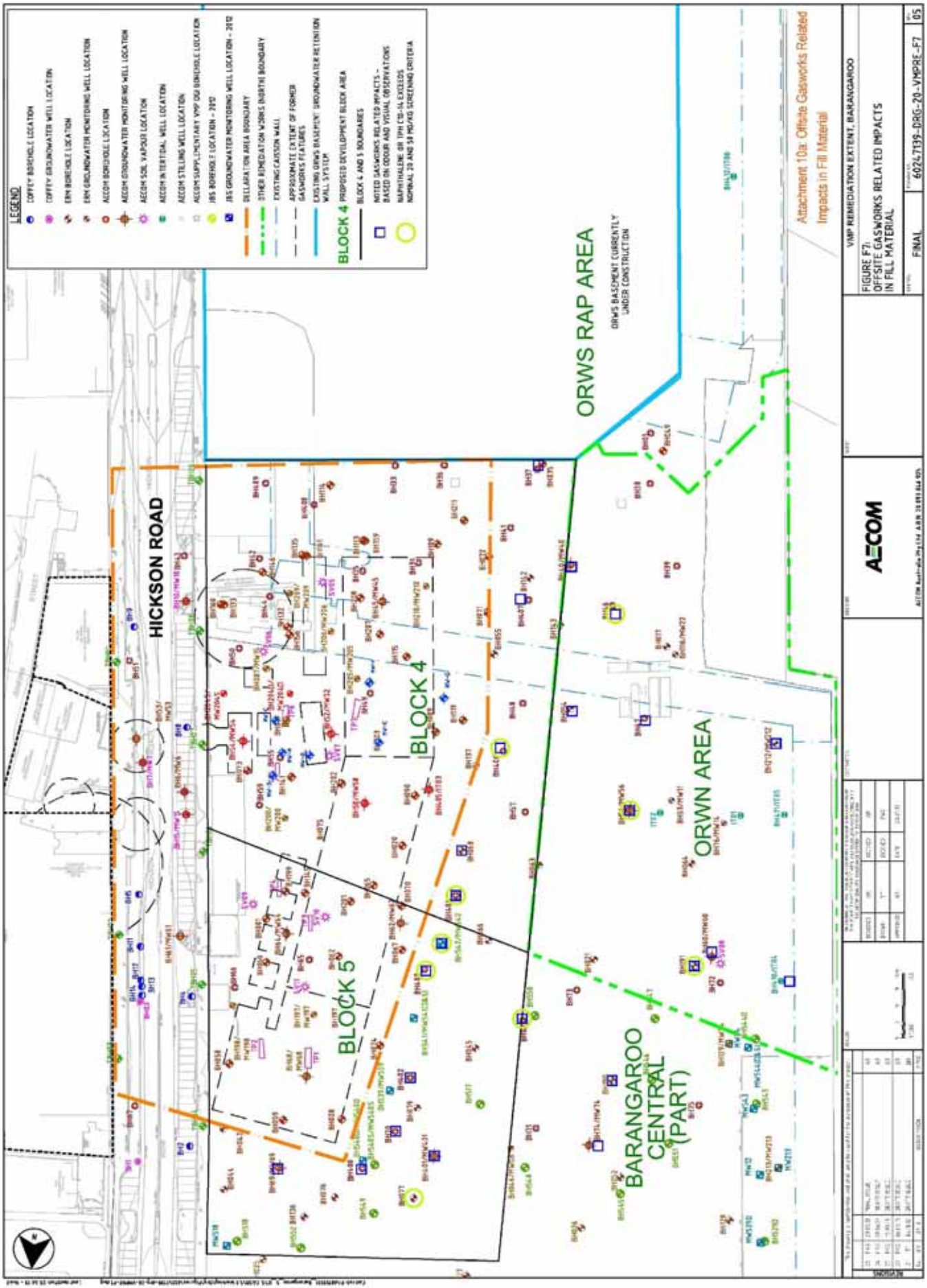
Attachment 5: Indicative Bedrock and Marine Sediment Contours

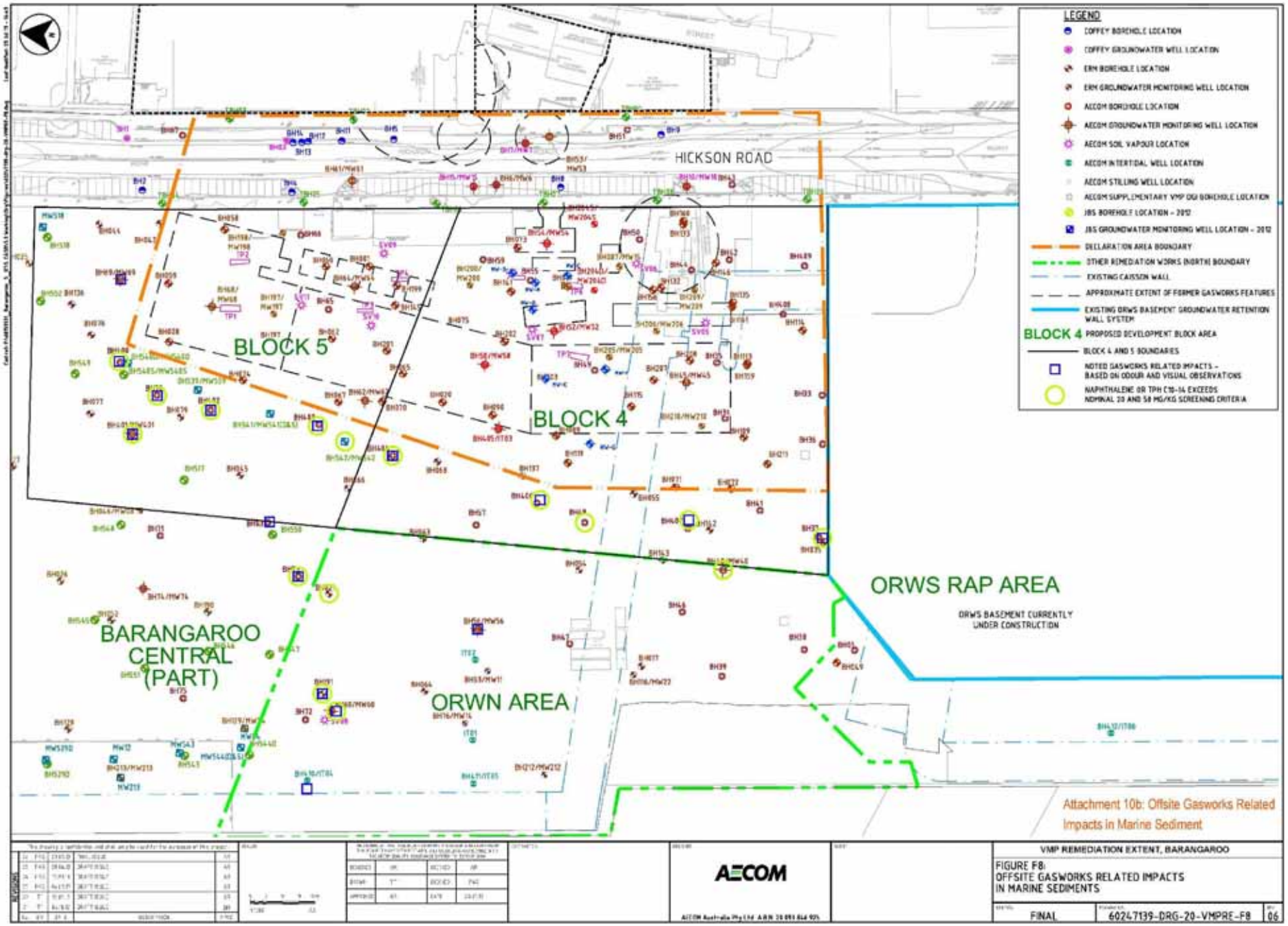


Attachment 6: Location of Separate Phase Gasworks Wastes and Tar



Attachment 7a: Gasworks Related Impacts in Fill Material

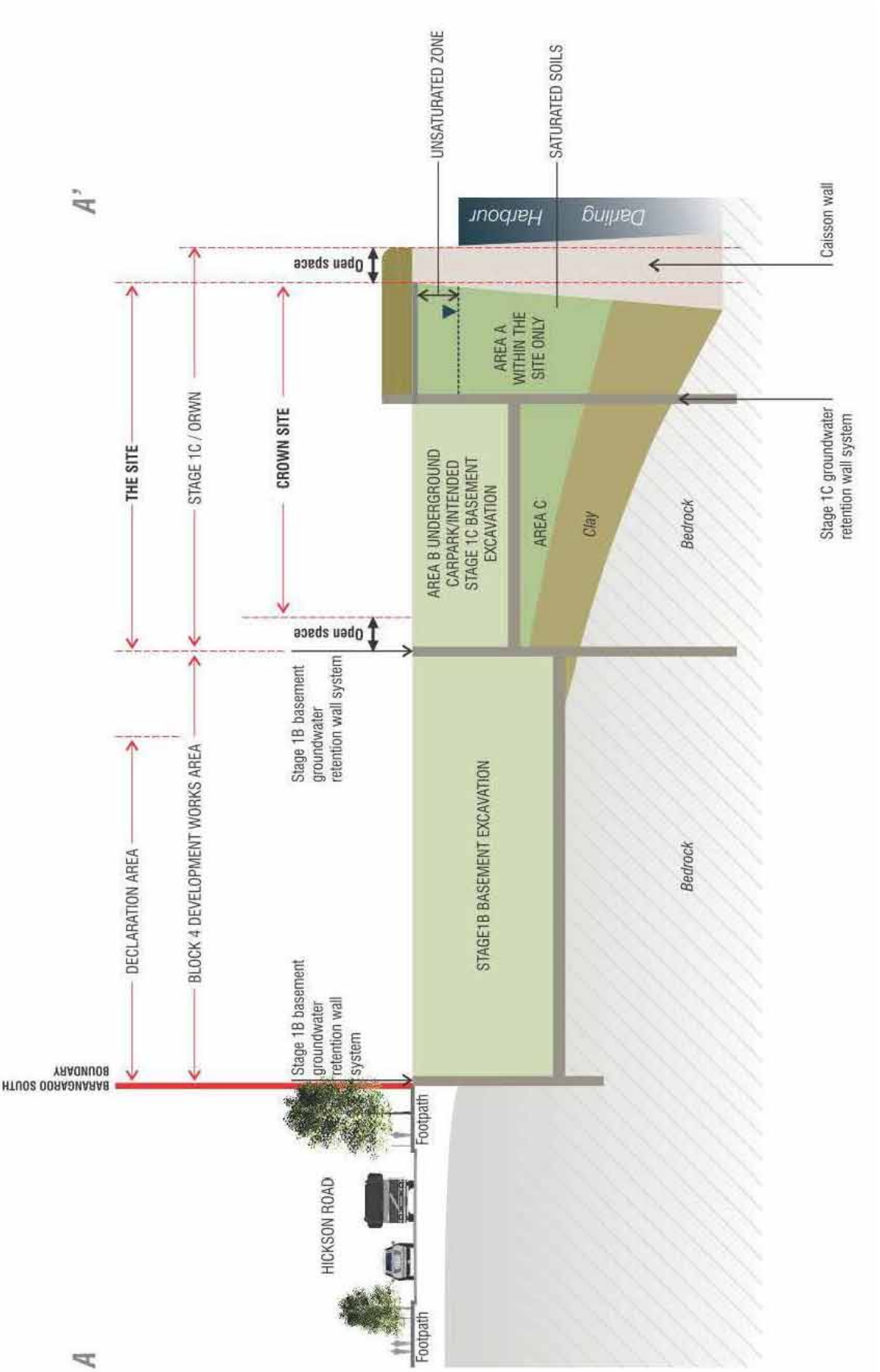




Attachment 7b: Gasworks Related Impacts in Marine Sediments

Attachment 8: Schematic Cross Section

Figure 1 Schematic Cross Section A-A' (not to scale)



Appendix B:
Soil and Groundwater Screening Criteria

Soil investigation levels for urban development sites
Department of Environment and Conservation NSW (April 2006)

Substance	Health-based investigation levels[1] (mg/kg)				Provisional phytotoxicity-based investigation levels[2] (mg/kg)
	Residential with gardens and accessible soil (home-grown produce contributing < 10% fruit and vegetable intake; no poultry), including children's day-care centres, preschools, primary schools, townhouses, villas (NEHF A)[3]	Residential with minimal access to soil including high-rise apartments and flats (NEHF D)	Parks, recreational open space, playing fields including secondary schools (NEHF E)	Commercial or industrial (NEHF F)	
	Column 1	Column 2	Column 3	Column 4	Column 5
Metals and metaloids					
Arsenic (total)	100	400	200	500	20
Beryllium	20	80	40	100	–
Cadmium	20	80	40	100	3
Chromium (III)[4]	12%	48%	24%	60%	400
Chromium (VI)	100	400	200	500	1
Cobalt	100	400	200	500	–
Copper	1,000	4,000	2,000	5,000	100
Lead	300	1,200	600	1,500	600
Manganese	1,500	6,000	3,000	7,500	500
Methyl mercury	10	40	20	50	–
Mercury (inorganic)	15	60	30	75	1[5]
Nickel	600	2,400	600	3,000	60
Zinc	7,000	28,000	14,000	35,000	200
Organics					
Aldrin + dieldrin	10	40	20	50	–
Chlordane	50	200	100	250	–
DDT + DDD + DDE	200	800	400	1,000	–
Heptachlor	10	40	20	50	–
PAHs (total)	20	80	40	100	–
Benzo(a)pyrene	1	4	2	5	–
Phenol[6]	8,500	34,000	17,000	42,500	–
PCBs (total)	10	40	20	50	–
Petroleum hydrocarbon components[7]					
>C16–C35 (aromatics)	90	360	180	450	–
>C16–C35	5,600	22,400	11,200	28,000	–
>C35 (aliphatics)	56,000	224,000	112,000	280,000	–
Other					
Boron	3,000	12,000	6,000	15,000	–[8]
Cyanides (complex)	500	2,000	1,000	2,500	–
Cyanides (free)	250	1,000	500	1,250	–

1 The limitations of health-based soil investigation levels are discussed in Schedule B(1) Guidelines on the Investigation Levels for Soil and Groundwater and Schedule B(7a) Guidelines on Health-based Investigation Levels, *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999)

2 The provisional phytotoxicity-based investigation levels proposed in this document are single number criteria. Their use has significant limitations because phytotoxicity depends on soil and species parameters in ways that are not fully understood. They are intended for use as a screening guide and may be assumed to apply to sandy loam soils or soils of a closely similar texture for pH 6–8.

3 National Environmental Health Forum (NEHF) is now known as enHealth.

4 Soil discolouration may occur at these concentrations.

5 Total mercury

6 Odours may occur at these concentrations.

7 The carbon number is an 'equivalent carbon number' based on a method that standardises according to boiling point. It is a method used by some analytical laboratories to report carbon numbers for chemicals evaluated on a boiling point GC column.

8 Boron is phytotoxic at low concentrations. A provisional phytotoxicity-based investigation level is not yet available.

Notes:

This table is adapted from Table 5-A in Schedule B(1): Guidelines on Investigation Levels for Soil and Groundwater to the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC 1999).

Soil investigation levels (SILs) may not be appropriate for the protection of ground water and surface water. They also do not apply to land being, or proposed to be, used for agricultural purposes. (Consult NSW Agriculture and NSW Health for the appropriate criteria for agricultural land.)

SILs do not take into account all environmental concerns (for example, the potential effects on wildlife). Where relevant, these would require further consideration.

Impacts of contaminants on building structures should also be considered.

For assessment of hydrocarbon contamination for residential land use, refer to the Guidelines for Assessing Service Station Sites (EPA 1994).

Threshold Concentration for Sensitive Land Use – Soils Guidelines for Assessing Service Station Site (NSW EPA 1994)	
Contaminant	**Threshold Concentration (mg/kg)**
TPH (C_6-C_9)	65
TPH (C_{10}-C_{36})	1,000
Benzene	1
Toluene	1.4
Ethylbenzene	3.1
Xylenes (total)	14

Trigger Values (TV) for Screening Marine Water Quality Data (µg/L) for Slightly to Moderately Disturbed Ecosystems (ANZECC 2000)		
Contaminant	**Threshold Concentration (µg/L)**	**Guideline Source**
Metals and Metalloids		
Arsenic – As (III/V)	2.3/4.5	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Cadmium – Cd	0.7	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Mercury – Hg	0.1	
Nickel – Ni	7	ANZECC (2000) 99% protection level due to potential for toxicity to particular species.
Manganese	80	Low reliability trigger values (derived from the mollusc figure) from Volume 2 of ANZECC (2000)
Chromium – Cr (III/VI)	27.4/4.4	ANZECC (2000) 95% protection levels.
Copper – Cu	1.3	
Cobalt	1	
Lead – Pb	4.4	
Zinc – Zn	15	
Aromatic Hydrocarbons		
Benzene	500	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Toluene	180	
Ethylbenzene	5	
o-xylene	350	
m-xylene	75	
p-xylene	200	
Polycyclic Aromatic Hydrocarbons		
Naphthalene	50	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Anthracene	0.01	Low reliability trigger values from Volume 2 of ANZECC (2000)
Phenanthrene	0.6	
Fluroanthene	1	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Benzo (a) pyrene	0.1	
Chlorinated Alkanes		
Tetrachloroethene - PCE	70	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
1,1,2 Trichlorothene- TCE	330	
1,1,2 Trichlorothene- 1,1,2-TCE	330	
Vinyl chloride (chloroethene)	100	
1,1,1 Trichloroethane – 1,1,1-TCA (111-TCE)	270	
1,1 Dichloroethene	700	
1,1 Dichloroethane	250	
1,2 Dichloroethane	1900	
1,1,2 - Trichloroethane	1900	Moderate reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Chloroform	370	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Non-Metallic Inorganics		
Ammonia Total – NH_3 (at pH of 8)	910	ANZECC (2000) 95% protection levels.
Cyanide (Free or unionised HCN)	4	

While the low reliability figures should not be used as default guidelines they will be useful for indicating the quality of groundwater migrating off-site.

Appendix C:
EPA Approved Guidelines

Guidelines made or approved by the EPA under section 105 of the *Contaminated Land Management Act 1997*

(*as of 16 April 2014)*

Section 105 of the Contaminated Land Management Act 1997 (CLM Act) allows the Environment Protection Authority (EPA) to make or approve guidelines for purposes connected with the objects of the Act. These guidelines must be taken into consideration by the EPA whenever they are relevant and by accredited site auditors when conducting a site audit. They are also used by contaminated land consultants in undertaking investigation, remediation, validation and reporting on contaminated sites.

A current list of guidelines made or approved by the EPA under the CLM Act appears below. To obtain hard copies of the guidelines, contact Environment Line on 131 555.

Guidelines made by the EPA

- Guidelines for the Vertical Mixing of Soil on Former Broad-acre Agricultural Land (2003028VerticalMixGuidelines.pdf, 148KB) (January 1995)
- Sampling Design Guidelines (9559sampgdlne.pdf, 2MB) (September 1995)
- Guidelines for Assessing Banana Plantation Sites (bananaplantsite.pdf; 586KB) (October 1997)
- Guidelines for Consultants Reporting on Contaminated Sites (20110650consultantsglines.pdf; 428KB) (reprinted August 2011)
- Guidelines for Assessing Former Orchards and Market Gardens (orchardgdlne.pdf; 172KB) (June 2005)
- Guidelines for the NSW Site Auditor Scheme, 2nd edition (auditorglines06121.pdf; 510KB) (April 2006)
- Guidelines for the Assessment and Management of Groundwater Contamination (groundwaterguidelines07144.pdf; 604KB) (March 2007)
- Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997 (09438gldutycontclma.pdf; 1MB) (June 2009)

Note: All references in the EPA's contaminated sites guidelines to:

- the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, November 1992) are replaced as of 6 September 2001 by references to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, October 2000)
- the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPC 1999) are replaced as of 16 May 2013 by references to the National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013)

subject to the same terms.

Guidelines approved by the EPA

ANZECC publications

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality, published by ANZECC and the Agriculture and Resource Management Council of Australia and New Zealand, Paper No. 4 (October 2000)

EnHealth publications (formerly National Environmental Health Forum monographs)

- Composite Sampling, Lock, W. H., National Environmental Health Forum Monographs, Soil Series No.3, 1996, SA Health Commission, Adelaide
- Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards, Department of Health and Ageing and EnHealth Council, Commonwealth of Australia (2012)

National Environment Protection Council publications

- National Environment Protection (Assessment of Site Contamination) Measure 1999 (April 2013)

The NEPM consists of a policy framework for the assessment of site contamination, Schedule A (Recommended General Process for the Assessment of Site Contamination) and Schedule B (Guidelines).

Schedule B guidelines include:

Guideline on Investigation Levels for Soil and Groundwater
Guideline on Site Characterisation
Guideline on Laboratory Analysis of Potentially Contaminated Soils
Guideline on Site-specific Health Risk Assessment Methodology
Guideline on Ecological Risk Assessment
Guideline on Methodology to Derive Ecological Investigation Levels in Contaminated Soils
Guideline on Ecological Investigation Levels for Arsenic, Chromium(III), Copper, DDT, Lead, Naphthalene, Nickel and Zinc
Guideline on the Framework for Risk-based Assessment of Groundwater Contamination
Guideline on Derivation of Health-based Investigation Levels
Guideline on Community Engagement and Risk Communication
Guideline on Competencies and Acceptance of Environmental Auditors and Related Professionals

More details on the amended NEPM and the transitional arrangements for its implementation

Other documents

- Guidelines for the Assessment and Clean Up of Cattle Tick Dip Sites for Residential Purposes, NSW Agriculture and CMPS&F Environmental (February 1996)
- Australian Drinking Water Guidelines, NHMRC and Natural Resource Management Ministerial Council of Australia and New Zealand (2011)
- Further guidance webpage

Appendix D:
Analytical Lists and Methods

MGT LABMARK ANALYTICAL LISTS AND METHODS

Target Compounds	MGT LabMark Method	Methodology Summary
Heavy Metals		
Arsenic	LM-LTM-MET-3100	0.5 g digested in nitric/hydrochloric acid. Analysis b ICP-MS
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	LM-LTM-MET-3100	0.5 g digested in nitric/hydrochloric acid. Analysis by CV-ICP-MS or FIMS.
Polycyclic Aromatic Hydrocarbons (PAHs)		
Naphthalene	E007.2	8-10 g soil extracted with 20 mL DCM /Acetone/ Hexane (10:45:45). Analysis by GC-MS.
Fluorene		
Phenanthrene		
Anthracene		
Acenaphthylene		
Acenaphthene		
Fluoranthene		
Pyrene		
Benz(a)anthracene		
Chrysene		
Benzo(b) & (k)fluoranthene		
Benzo(a)pyrene		
Indeno(1.2.4-cd)pyrene		
Dibenzo(a.h)anthracene		
Benzo(g.h.l)perylene		
BTEX Compounds		
Benzene	E029.2/E016.2	8-10g soil extracted with 20ml methanol. Analysis by P&T/GC/MSD or by P&T/GC/FID/MSD.
Toluene		
Chlorobenzene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
Total Petroleum Hydrocarbons		
C6-C9 Fraction	E029.2/E016.2	8-10g soil extracted with 20ml methanol. Analysis by P&T/GC/MSD or by P&T/GC/FID/MSD.
C10-C14 Fraction	E006.2	8 – 10 g soil extracted with 20 mL DCM /Acetone /Hexane (10:45:45). Analysis by GC/FID.
C15-C28 Fraction		
C29-C36 Fraction		
Organochlorine Pesticides (OCP)		
alpha-BHC	E013.2	8-10g soil extracted with 20 mL hexane/acetone (1:1). Analysis by GC/dual ECD.
HCB		
beta-BHC & gamma-BHC		
delta-BHC		
Heptachlor		
Aldrin		
Heptachlor epoxide		
Endosulfan 1		

Target Compounds	MGT LabMark Method	Methodology Summary
Trans-Chlordane		
Cis-Chlordane		
methoxychlor		
4.4'-DDE		
Dieldrin		
Endrin		
Endosulfan 11		
4.4'-DDD		
Endosulfan sulfate		
4.4'-DDT		
Organophosphorus Pesticides (OPP)		
Dichlorvos	E014.2	8-10 g soil extracted with 20mL hexane/acetone (1:1). Analysis by GC/MSD.
Mevinphos		
Demeton		
Ethoprop		
Monocrotophos		
Phorate		
Dimethoate		
Diazinon		
Disulfoton		
Methyl parathion		
Ronnel		
Fenitrothion		
Malathion		
Chlorpyrifos		
Fenitrothion		
Fenthion		
Parathion		
Stirofos		
Azinophos methyl		
Coumaphos		
Inorganic Analytes		
Weak Acid Dissociable Cyanide	E040.2/E054.2	Caustic soil extraction, Acetate distillate collected in sodium hydroxide. Analysis by colour.
Ammonia	E036.1/E050.1	The water sample is filtered and ammonia by colourimetry using the indophenol method (ref APHA 21st Edition 2006)
Cyanide	E040.1/E054.1	Strong acid distrillate collected in sodium hydroxide. Analysis by colour.
Sulphate	E042.2/E045.2	1:5 water extraction. Determination by colour and/or ion chromatography.
Polychlorinated Biphenyls (PCB)		
Arochlor 1016	E013.2	8-10g soil extracted with 20mL DCM/Acetone/Hexane. Analysis by GC/dual ECD.
Arochlor 1232		
Arochlor 1242		
Arochlor 1248		
Arochlor 1254		
Arochlor 1260		

ALS ANALYTICAL LISTS AND METHODS

Target Compounds	ALS Method	Methodology Summary
Heavy Metals		
Arsenic Cadmium Chromium Copper Nickel Lead Zinc	EG005T/ EG020A-F	Solid matrix: APHA 21st ed., 3120; USEPA SW 846 - 6010) (ICPAES Appropriate acid digestion of the soil is followed by analysis by ICPAES. Water matrix: (APHA 21st ed., 3125; USEPA SW846 - 6020, ALS QWI-EN/EG020): Samples are 0.45 um filtered prior to analysis followed by ICPMS.
Mercury	EG035T/ EG035F	Solid matrix: 3550, APHA 21st ed., 3112 Hg - B (Flow-injection (SnCl2)(Cold Vapour generation) AAS) Appropriate acid digestion followed by reduction of ionic mercury to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve. Water matrix: 3550, APHA 21st ed. 3112 Hg – B. Samples are .45 um filtered prior to oxidation of any organic mercury with a bromated/bromide reagent. Then reduction of ionic mercury to atomic mercury vapour by SnCl2 which is then purged into a heated quartz cell. Quantification is by comparing absorbance against a calibration curve
Polycyclic Aromatic Hydrocarbons (PAHs)		
Naphthalene Fluorene Phenanthrene Anthracene Acenaphthylene Acenaphthene Fluoranthene Pyrene Benz(a)anthracene Chrysene Benzo(b) & (k)fluoranthene Benzo(a)pyrene Indeno(1.2.4-cd)pyrene Dibenzo(a.h)anthracene Benzo(g.h.l)perylene	EP075(SIM)	Soil Matrix: In-house, Mechanical agitation (tumbler). 10g of sample, Na2SO4 and surrogate are extracted with 20mL 1:1 DCM/Acetone by end over end tumble. The solvent is transferred directly to a GC vial for analysis. Water Matrix: USEPA SW 846 - 3510B) 500 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract. The resultant extracts are combined, dehydrated and concentrated for (USEPA SW 846 - 8270B) Extracts are analysed by Capillary GC/MS in Selective Ion Mode (SIM) and quantification is by comparison against an established 5 point calibration curve.
Monocyclic Aromatic Hydrocarbons		
Benzene Toluene Ethylbenzene Meta- & para-Xylene Ortho-Xylene Styrene Isopropylbenzene n-propylbenzene 1,3,5-trimethylbenzene Sec-Butylbenzene	EP074A	Extraction of Solids: (USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS. USEPA SW 846 - 8260B) Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve.

Target Compounds	ALS Method	Methodology Summary
1,2,4-Trimethylbenzene		
Tert-Butylbenzene		
p-isopropyltoluene		
n-Butylbenzene		
Total Petroleum Hydrocarbons (TPH)		
C6-C9 Fraction	EP080	USEPA SW 846 - 8260B. Extracts are analysed by Purge and Trap, Capillary GC/MS. Quantification is by comparison against an established 5 point calibration curve. Extraction of Solids: (USEPA SW 846 - 5030A) 5g of solid is shaken with surrogate and 10mL methanol prior to analysis by Purge and Trap - GC/MS.
C10-C14 Fraction	EP071	USEPA SW 846 - 8015A. Sample extracts are analysed by Capillary GC/FID and quantified against alkane standards over the range C10 - C36. Solid matrix extraction: In-house, Mechanical agitation (tumbler). 10g of sample, Na2SO4 and surrogate are extracted with 20mL 1:1 DCM/Acetone by end over end tumble. The solvent is transferred directly to a GC vial for analysis. Water matrix extraction: USEPA SW 846 - 3510B 500 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract.
C15-C28 Fraction		
C29-C36 Fraction		
Other Analytes		
Cyanide	EK026G	Sample are distilled with a weak organic acid, converting selected CN species to HCN. The distillates are analysed for CN by Discrete Analyser.
Suspension Peroxide Oxidation-Combined Acidity and Sulphate	EA029	Ahern et al 2004 - a suspension peroxide oxidation method following the 'sulfur trail' by determining the level of 1M KCL extractable sulfur and the sulfur level after oxidation of soil sulphides. The 'acidity trail' is followed by measurement of TAA, TPA and TSA. Liming Rate is based on results for samples as submitted and incorporates a minimum safety factor of 1.5.
Asbestos	EA200 ASB-SOL	AS 4964 - 2004 Method for the qualitative identification of asbestos in bulk samples
Ammonia	EK055G	APHA 21st ed., 4500 NH3+-G. Ammonia is determined by direct colourimetry by Seal Discrete Analyser.
Sulphate	ED040T	In-house. Total Sulphate is determined off a HCl digestion by ICPAES as S, and reported as SO4
Phenol		
Phenol	EP075(SIM)	Soil Matrix: In-house, Mechanical agitation (tumbler). 20g of sample, Na2SO4 and surrogate are extracted with 150mL 1:1 DCM/Acetone by end over end tumble. The solvent is decanted, dehydrated and
2-Chlorophenol		
2-Methylphenol		
3-&4-Methylphenol		
2-Nitrophenol		

Target Compounds	ALS Method	Methodology Summary
2,4-Dimethylphenol		concentrated (by KD) to the desired volume for analysis. Water Matrix: USEPA SW 846 - 3510B) 500 mL to 1L of sample is transferred to a separatory funnel and serially extracted three times using 60mL DCM for each extract. The resultant extracts are combined, dehydrated and concentrated for analysis. (USEPA SW 846 - 8270B) Extracts are analysed by Capillary GC/MS in Selective Ion Mode (SIM) and quantification is by comparison against an established 5 point calibration
2,4-Dichlorophenol		
2,6-Dichlorophenol		
4-Chloro3-methylphenol		
2,4,6-Trichlorophenol		
2,4,5-Trichlorophenol		
Pentachlorophenol		
Organochlorine Pesticides (OCP)		
alpha-BHC	EP075I	USEPA SW846 – 8270B. extracts are analysed by Capillary GC/MS and quantification is by comparison against an established 5 point calibration curve.
HCB		
beta-BHC & gamma-BHC		
delta-BHC		
Heptachlor		
Aldrin		
Heptachlor epoxide		
Endosulfan 1		
Trans-Chlordane		
Cis-Chlordane		
methoxychlor		
4.4'-DDE		
Dieldrin		
Endrin		
Endosulfan 11		
4.4'-DDD		
Endosulfan sulfate		
4.4'-DDT		
Organophosphorus Pesticides (OPP)		
Dichlorvos	EP075J	USEPA SW846 – 8270B. extracts are analysed by Capillary GC/MS and quantification is by comparison against an established 5 point calibration curve.
Dimethoate		
Diazinon		
Chlorpyrifos-methyl		
Malathion		
Fenthion		
Chlorpyrifos		
Pirimphos-ethyl		
Chlorofenvinphos		
Ethion		
Polychlorinated Biphenyls (PCB)		
Arochlor 1016		
Arochlor 1232		
Arochlor 1242		
Arochlor 1248		
Arochlor 1254		
Arochlor 1260		
Chlorinated Hydrocarbons		
1,3-Dichlorobenzene	EP075G	USEPA SW846 – 8260B. Extracts are analysed by purge and trap, capillary GC/MS. Quantification is by comparison against a
1,4-Dichlorobenzene		
1,2-Dichlorobenzene		

Target Compounds	ALS Method	Methodology Summary
Hexachloroethane		calibration curve.
1,2,4-Trichlorobenzene		
Hexachloropropylene		
Hexachlorobutadiene		
Hexachlorocyclopentadiene		
Pentachlorobenzene		
Hexachlorobenzene		
Volatile Organic Compounds (VOCs)		
Vinyl Acetate	EP074	USEPA SW846 – 8260B. Extracts are analysed by purge and trap, capillary GC/MS. Quantification is by comparison against a calibration curve.
2-Butanone (MEK)		
4-Methyl-2-pentanone (MIBK)		
2-Hexanone (MBK)		
Carbon disulfide		
2.2-Dichloropropane		
1.2-Dichloropropane		
cis-1.3-Dichloropropylene		
trans-1.3-Dichloropropylene		
Dichlorodifluoromethane		
Chloromethane		
Vinyl chloride		
Bromomethane		
Chloroethane		
Trichlorofluoromethane		
1.1-Dichloroethene		
Iodomethane		
trans-1.2-Dichloroethene		
1.1-Dichloroethane		
cis-1.2-Dichloroethene		
1.1.1-Trichloroethane		
1.1-Dichloropropylene		
Carbon Tetrachloride		
1.2-Dichloroethane		
Trichloroethene		
Dibromomethane		
1.1.2-Trichloroethane		
1.3-Dichloropropane		
Tetrachloroethene		
1.1.1.2-Tetrachloroethane		
trans-1.4-Dichloro-2-butene		
cis-1.4-Dichloro-2-butene		
1.1.2.2-Tetrachloroethane		
1.2.3-Trichloropropane		
Pentachloroethane		
1.2-Dibromo-3-chloropropane		
Chlorobenzene		
Bromobenzene		
2-Chlorotoluene		
4-Chlorotoluene		
1.2.3-Trichlorobenzene		
Chloroform		
Bromodichloromethane		
Dibromochloromethane		
Bromoform		

Target Compounds	ALS Method	Methodology Summary
Semi-Volatile Organic Compounds (SVOCs)		
Dimethyl phthalate	EP075	USEPA SW846 – 8270B. Extracts are analysed by capillary GC/MS. Quantification is by comparison against a calibration curve.
Diethyl phthalate		
Di-n-butyl phthalate		
Butyl benzyl phthalate		
bis(2-ethylhexyl) phthalate		
Di-n-octylphthalate		
N-Nitrosomethylethylamine		
N-Nitrosodiethylamine		
N-Nitrosopyrrolidine		
N-Nitrosomorpholine		
N-Nitrosodi-n-propylamine		
N-Nitrosopiperidine		
N-Nitrosodibutylamine		
N-Nitrosodiphenyl & Diphenylamine		
Methapyrilene		
2-Picoline		
Acetophenone		
Nitrobenzene		
Isophorone		
2.6-Dinitrotoluene		
2.4-Dinitrotoluene		
1-Naphthylamine		
4-Nitroquinoline-N-oxide		
5-Nitro-o-toluidine		
Azobenzene		
1.3.5-Trinitrobenzene		
Phenacetin		
4-Aminobiphenyl		
Pentachloronitrobenzene		
Pronamide		
Dimethylaminoazobenzene		
Chlorobenzilate		
Bis(2-chloroethyl) ether		
Bis(2-chloroethoxy) methane		
4-Chlorophenyl phenyl ether		
4-Bromophenyl phenyl ether		
Aniline		
4-Chloroaniline		
2-Nitroaniline		
3-Nitroaniline		
Dibenzofuran		
4-Nitroaniline		
Carbazole		
3.3`-Dichlorobenzidine		

SGS ANALYTICAL LISTS AND METHODS

Target Compounds	SGS Method	Methodology Summary
Heavy Metals		
Arsenic	AN318 / SEP-015	Water sample is digested with nitric acid at 105 degrees C for total metals analysed by ICPMS. Determination of elements at trace levels in waters by ICP-MS.
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	SEM-005	Determination of elements at trace levels in waters by ICP-MS.
Polycyclic Aromatic Hydrocarbons (PAHs)		
Naphthalene	SEO-030	Determination by GC/MS following extraction with DCM or DCM/acetone.
Fluorene		
Phenanthrene		
Anthracene		
Acenaphthylene		
Acenaphthene		
Fluoranthene		
Pyrene		
Benz(a)anthracene		
Chrysene		
Benzo(b) & (k)fluoranthene		
Benzo(a)pyrene		
Indeno(1.2.4-cd)pyrene		
Dibenzo(a.h)anthracene		
Benzo(g.h.l)perylene		
BTEX Compounds		
Benzene	SEO-018	Determination by purge and trap/ GC with MS detection.
Toluene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
Total Petroleum Hydrocarbons (TPH)		
C6-C9 Fraction	SEO-017	Determination by purge and trap GC with FID and PID.
C10-C14 Fraction	SEO-020	Determination by GC following extraction with DCM/acetone for solids and DCM for liquids.
C15-C28 Fraction		
C29-C36 Fraction		
Other Analytes		
Ammonia	SEI-037	Determined by colourimetric method using discrete analyser
Phenol		
Phenol	SEI-066	Determined by colourimetric method using discrete analyser, following steam distillation.
2-Chlorophenol		
2-Methylphenol		
3-&4-Methylphenol		
2-Nitrophenol		
4-Nitrophenol		
2,4-Dimethylphenol		
2,4-Dichlorophenol		

Target Compounds	SGS Method	Methodology Summary
2,6-Dichlorophenol		
4-Chloro3-methylphenol		
2,4,6-Trichlorophenol		
2,4,5-Trichlorophenol		
Pentachlorophenol		
2,3,4,5-Tetrachlorophenol		
2,4-Dinitrophenol		

ENVIROLAB ANALYTICAL LISTS AND METHODS

Target Compounds	ENVIROLAB Method	Methodology Summary
Heavy Metals		
Arsenic	Metals.20 ICP-AES	Determination of various metals by ICP-AES.
Cadmium		
Chromium		
Copper		
Nickel		
Lead		
Zinc		
Mercury	Metals.21 CV-AAS	Determination of Mercury by Cold Vapour AAS.
Polynuclear Aromatic Hydrocarbons (PAHs)		
Naphthalene	GC.12 subset	Soil samples are extracted with Dichloromethane/ Acetone and waters with Dichloromethane and analysed by GC-MS.
Fluorene		
Phenanthrene		
Anthracene		
Acenaphthylene		
Acenaphthene		
Fluoranthene		
Pyrene		
Benz(a)anthracene		
Chrysene		
Benzo(b) & (k)fluoranthene		
Benzo(a)pyrene		
Indeno(1.2.4-cd)pyrene		
Dibenzo(a.h)anthracene		
Benzo(g.h.l)perylene		
BTEX Compounds		
Benzene	GC.16	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS.
Toluene		
Chlorobenzene		
Ethylbenzene		
Meta- & para-Xylene		
Ortho-Xylene		
VOC Compounds		
See attached list	GC.13	Water samples are analysed directly by purge and trap GC-MS.
Total Petroleum Hydrocarbons		
C6-C9 Fraction	GC.16	Soil samples are extracted with methanol and spiked into water prior to analysing by purge and trap GC-MS. Water samples are analysed directly by purge and trap GC-MS.
C10-C14 Fraction	GC.3	Soil samples are extracted with Dichloromethane/ acetone and waters with Dichloromethane and analysed by GC-FID.
C15-C28 Fraction		
C29-C36 Fraction		
Other Analytes		
Ammonia as N	LAB.57	Determined colourimetrically based on EPA350.1, soils are analysed following a

Target Compounds	ENVIROLAB Method	Methodology Summary
		water extraction.
Asbestos	ASB.1	Qualitative identification of asbestos type fibres in bulk samples using Polarised Light Microscopyand Dispersion Staining Techniques.

Appendix E:
Risk Based Remediation Criteria

	SOIL REMEDIATION CRITERIA			
	Soil SSTC-A		Soil SSTC-B	
Chemicals of Potential Concern		**Land Use Scenario**		**Land Use Scenario**
Relevant Land Use Scenarios	**mg/kg**	**Area A - unsaturated soil**	**mg/kg**	**Area B (if required)**
Benzene	2.0	Scenario 14	2.0	Scenario 14
Cresols (Total)	250	Scenario 14	250	Scenario 14
Dimethylphenol, 2,4-	36,000	Scenario 12	36,000	Scenario 12
Ethylbenzene	50	Scenario 14	50	Scenario 14
Methylnaphthalene, 2	100	Scenario 14	100	Scenario 14
Naphthalene	4.0	Scenario 14	4.0	Scenario 14
Lead	11,000	Scenario 12	11,000	Scenario 12
Toluene	480	Scenario 14	480	Scenario 14
TPH C_6-C_9	260	Scenario 14	260	Scenario 14
TPH C_{10}-C_{16}	1,100	Scenario 14	1,100	Scenario 14
Trimethylbenzene, 1,2,4-	1.0	Scenario 14	1.0	Scenario 14
Xylenes (total)	-	-	-	-
CPAH**	130	Scenario 12	130	Scenario 12
Asbestos [1]	0.05% w/w	Scenario 12	0.05% w/w	Scenario 12

Notes:
All soil criteria in mg/kg
SSTC - Site Specific Target Criteria
TPH - Total Petroleum Hydrocarbons
CPAH= Sum of 8 carcinogenic PAH Compounds (Benz(a)anthracene Benzo(a) pyrene; Benzo(b)fluoranthene; Benzo(g,h,i)perylene; Benzo(k)fluoranthene; Chrysene; Dibenz(a,h)anthracene; Indeno(1,2,3-c,d)pyrene)

[1] Asbestos analysis to be conducted as per Schedule B2 of the NEPM (NEPC, 1999, as amended 2013)

Land Use Scenarios:
Scenario 12: Crown Intrusive Maintenance Worker
Scenario 14: Crown Commercial with Advection

	GROUNDWATER REMEDIATION CRITERIA			
		Groundwater SSTC-A		Groundwater SSTC-C
Chemicals of Potential Concern		**Land Use Scenario**		**Land Use Scenario**
Relevant Land Use Scenarios	**mg/L**	**Area A**	**mg/L**	**Area C**
Acenaphthylene	33	Scenario 6	-	-
Acenaphthene	35	Scenario 6	-	-
Ammonia	150	Scenario 6	920	Scenario 1
Aniline	680	Scenario 6	67,000	Scenario 1
Arsenic	140	Scenario 6		
Barium	830	Scenario 6		
Benzene	2.0	Scenario 14	49	Scenario 1
Cadmium	110	Scenario 6	-	-
Cobalt	250	Scenario 6	-	-
Cresols (Total)	2.7	Scenario 6	22	Scenario 1
Dimethylphenol, 2,4-	430	Scenario 6	-	-
Ethylbenzene	100	Scenario 6	-	-
Lead and compounds	630	Scenario 6	-	-
Manganese	27,000	Scenario 6	-	-
Methylnaphthalene, 2-	22	Scenario 6	150	Scenario 1
Naphthalene	1.3	Scenario 6	7.8	Scenario 1
Nickel	1,300	Scenario 6	-	-
Phenol	340	Scenario 6 + 12	4,800	Scenario 1
Styrene	47	Scenario 6	-	-
Toluene	370	Scenario 6	-	-
TPH C_6-C_{10}	9	Scenario 14	19,000	Scenario 1
TPH >C_{10}-C_{16}	12	Scenario 6	1,800	Scenario 1
TPH >C_{16}-C_{34}	-	-	-	-
TPH >C_{34}-C_{40}	-	-	-	-
Trimethylbenzene, 1,2,4-	4.0	Scenario 14	91	Scenario 1
Trimethylbenzene, 1,3,5-	15	Scenario 14	460	Scenario 1

Notes:
All groundwater criteria in mg/L
SSTC - Site Specific Target Criteria
TPH - Total Petroleum Hydrocarbons
CPAH= Sum of 8 carcinogenic PAH Compounds (Benz(a)anthracene Benzo(a) pyrene; Benzo(b)fluoranthene; Benzo(g,h,i)perylene; Benzo(k)fluoranthene; Chrysene; Dibenz(a,h)anthracene; Indeno(1,2,3-c,d)pyrene)

= an SSTC has not been determined for remediation purposes as the derived level is at least 10 times greater than saturation/ solubility limits

Land Use Scenarios:
Scenario 1: Lower Basement
Scenario 6: Intrusive Maintenance Worker
Scenario 12: Crown Intrusive Maintenance Worker
Scenario 14: Crown Commercial with Advection

Analyte	Criteria (µg/L)	Source
Metals and Inorganics		
Arsenic	2.3	ANZECC (2000) 95% Marine Water Environmental Concern Level
Cadmium	0.7	ANZECC (2000) 99% Marine Water Trigger Value
Chromium (hexavalent)	4.4	ANZECC (2000) 95% Marine Water Trigger Value
Chromium III	27.4	ANZECC (2000) 95% Marine Water Trigger Value
Cobalt	1	ANZECC (2000) 95% Marine Water Trigger Value
Copper	1.3	ANZECC (2000) 95% Marine Water Trigger Value
Lead	4.4	ANZECC (2000) 95% Marine Water Trigger Value
Mercury	0.1	ANZECC (2000) 99% Marine Water Trigger Value
Nickel	70	ANZECC (2000) 95% Marine Water Trigger Value
Vanadium	100	ANZECC (2000) 95% Marine Water Trigger Value
Zinc	15	ANZECC (2000) 95% Marine Water Trigger Value
Ammonia	910	ANZECC (2000) 95% Marine Water Trigger Value
Cyanide	4	ANZECC (2000) 95% Marine Water Trigger Value
Low MW PAHs		
Acenaphthene	5.8	CCME (1999) Freshwater Guideline
Acenaphthylene	5.8	Adopted criteria for Acenaphthene as surrogate
Anthracene	0.01 [a]	ANZECC (2000) 99% Marine Water Trigger Value
Fluorene	3	CCME (1999) Freshwater Guideline
Naphthalene	70	ANZECC (2000) 95% Marine Water Trigger Value, moderate reliability
Phenanthrene	0.6 [a]	ANZECC (2000) 99% Marine Water Trigger Value
2-methylnaphthalene	2.1	Oakridge Secondary Chronic Value (1996) for 1-methylnaphthalene
High MW PAHs		
Benz(a)anthracene	0.1 [a,b]	Value for high molecular weight PAHs is based off the ANZECC (2000) 99% Marine Water Trigger Values for benzo(a)pyrene. A TEF approach is presented below in accordance with NEPC (2013), CCME (2010) and the *Declaration Site HHERA* (AECOM, 2011a) *Appendix K*, toxicity profile for PAHs:
		- Benzo(a)anthracene (0.1)
Benzo(a)pyrene		- Benzo(a)pyrene (1)
Benzo(b)fluoranthene		- Benzo(b)fluoranthene (0.1)
Benzo(g,h,i)perylene		- Benzo(g,h,i)perylene (0.01)
Benzo(k)fluoranthene		- Benzo(k)fluoranthene (0.1)
Chrysene		- Chrysene (0.01)
Dibenz(a,h)anthracene		- Dibenzo (a,h) anthracene (1)
Indeno(1,2,3-c,d)pyrene		- Indeno (1,2,3-cd)pyrene (0.1)
Fluoranthene	1	ANZECC (2000) 99% Marine Water Trigger Value
Pyrene	0.025 [a]	CCME (1999) Freshwater Guideline
Other Organics		
2,4-dimethylphenol	2	ANZECC (2000) 95% Marine Water Trigger Value, low reliability
2-methylphenol	13	Oakridge Secondary Chronic Value (1996)
3-&4-methylphenol	13	Adopted value for 2-methylphenol as surrogate
Dibenzofuran	3.7	Oakridge Secondary Chronic Value (1996)
Pentachlorophenol	22	ANZECC (2000) 95% Marine Water Trigger Value
Phenol	400	ANZECC (2000) 95% Marine Water Trigger Value
2,4 dinitrophenol	45	ANZECC (2000) 95% Fresh Water Trigger Value
Styrene	72	CCME (1999) Freshwater Guideline

Petroleum Hydrocarbons		
Benzene	700	ANZECC (2000) 95% Marine Water Trigger Value, moderate reliability
Ethylbenzene	80	ANZECC (2000) 95% Fresh Water Trigger Value
Toluene	180	ANZECC (2000) 95% Marine Water Trigger Value, low reliability
Xylene (m & p)	75	ANZECC (2000) 95% Marine Water Trigger Value, low reliability for m-xylene.
Xylene (o)	350	ANZECC (2000) 95% Marine Water Trigger Value, low reliability for o-xylene.
TPH C_6 - C_9	110	CCME (2008 Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil – Table B-9 values for TPH C_6 to C_8 and $>C_8$ to C_{10}. Criteria calculated from a weighted average assuming a Coal Tar composition of 25% aliphatic and 75% aromatic components
TPH C_{10} - C_{14}	40	CCME (2008) Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil – Table B-9 values for TPH $>C_{10}$ to C_{12} and $>C_{12}$ to C_{16}. Criteria calculated from a weighted average assuming a Coal Tar composition of 25% aliphatic and 75% aromatic components
TPH C_{15} - C_{28}	-	No guidelines values available
TPH C_{29} - C_{36}	-	No guidelines values available

Notes:

Taken from the ORNW HHERA (AECOM, 2013)

All criteria in ug/L

(a) It is noted that these MWQC are less than the laboratory standard LOR. The laboratory standard LOR will be adopted in place of the MWQC where: (i) analysis of these chemicals is required; or, (ii) where the MWQC are considered in derivation of risk based criteria. This approach is consistent with Section 3.4.3.2 and Section 8.3.5.4 of ANZECC (2000) and has been agreed with the Auditor and the NSW EPA. It is noted that it is not practical to use the laboratory ultra-trace LOR because: (i) the high salinity present in the water (particularly in areas close to the harbour) will cause interferences in the reporting of some analytes and therefore an increased LOR; (ii) the presence of other contaminants (matrix interference) will raise the LOR; and (iii) groundwater turbidity can lead to raised LOR.

(b) In the case of high molecular weight PAHs the standard limit of reporting is greater than the adopted MWQC above which is based on B(a)P (99% Marine Water Guideline). Therefore it is considered appropriate to adopt the standard laboratory limit of reporting for these compounds in applying the TEF approach outlined in CCME, 2010 (Appendix I PAH Toxicity Profile).

TABLE T1
SUMMARY OF SSTCS & SSESCS
AMENDED RAP
BARANGAROO ORWS AREA
LEND LEASE

	SOIL SSTCS AND SSESCS													
CoPC	**SSTC-A**	**Land Use Scenario**	**SSESC-A^{Unsat}**	**Daf**	**SSESC-A^{Sat}**	**Daf**	**SSTC-B**	**Land Use Scenario**	**SSESC-B**	**Daf**	**SSTC-C**	**Land Use Scenario**	**SSTC-D**	**Land Use Scenario**
Site Area	**Area A**						**Area B**				**Area C**		**Area D**	
Relevant land use Scenario	**Scenario 2, 4, 5, 6 & 7**		**Unsaturated soils**		**Saturated soils**		**Scenario 3 to 6**		**Unsaturated soils**		**NA**		**Scenario 2, 3, 4, 5, 6, 7 & 8**	
	mg/kg		**mg/kg**		**mg/kg**		**mg/kg**		**mg/kg**		**mg/kg**		**mg/kg**	
Arsenic, Inorganic	-	-	20	DAF x 4	5	DAF x 1	-	-	20	DAF x 4	-	NA	-	-
Acenapthene	-	-	-	-	-	-	-	-	8	DAF x 4	-	NA	-	-
Acenapthylene	-	-	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Anthracene	-	-	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Benz(a)anthracene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Benzene	15	Scenario 2	-	-	-	-	81	Scenario 5	-	-	-	NA	0.25	Scenario 8
Benzo(a)pyrene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Benzo(b)fluoranthene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Benzo(k)fluoranthene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Benzo(g,h,i)perylene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Cadmium	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Chromium(III), Insoluble Salts	180,000	Scenario 6	-	-	-	-	180,000	Scenario 6	-	-	-	NA	180,000	Scenario 6
Chromium(VI)	950	Scenario 6	-	-	-	-	950	Scenario 6	-	-	-	NA	950	Scenario 6
Chrysene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Cobalt	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Copper	-	-	170	DAF x 20	42	DAF x 5	-	-	170	DAF x 20	-	NA	-	-
Dibenz(a,h)anthracene	**	Scenario 6	-	-	-	-	**	Scenario 6	-	-	-	NA	**	Scenario 6
Ethylbenzene	600	Scenario 2	-	-	-	-	-	-	-	-	-	NA	64	Scenario 8
Fluoranthene	-	-	-	-	-	-	-	-	8	DAF x 4	-	NA	-	-
Fluorene	-	-	-	-	-	-	-	-	5	DAF x 4	-	NA	-	-
Indeno(1,2,3-cd)pyrene	**	Scenario 6	-	-	-	-	**	Scenario 6			-	NA	**	Scenario 6
Lead	15,000	Scenario 6	1800	DAF x 40	440	DAF x 10	15,000	Scenario 6	1,700	DAF x 40	-	NA	15,000	Scenario 6
Manganese	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Mercury	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Methylnaphthalene, 2-	1,100	Scenario 2	-	-	-	-	-	-	-	-	-	NA	18	Scenario 8
Methylphenol, 3&4	5,400	Scenario 6	-	-	-	-	5,400	Scenario 6			-	NA	140	Scenario 8
Naphthalene	41	Scenario 2	-	-	-	-	320	Scenario 5	21	DAF x 4	-	NA	0.67	Scenario 8
Nickel	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Phenanthrene	-	-	-	-	-	-	-	-	4	DAF x 4	-	NA	-	-
Toluene	-	-	-	-	-	-	-	-	-	-	-	NA	160	Scenario 8
TPH C06-C09 aliphatic	3,400	Scenario 6	40	DAF x 4	10	DAF x 1	-	-	39	DAF x 4	-	NA	55	Scenario 8
TPH C10-C14 aliphatic	13,000	Scenario 6	50	DAF x 4	50	DAF x 1	61,000	Scenario 5	50	DAF x 4	-	NA	210	Scenario 8
TPH C10-C14 aromatic														
TPH C15-C28 aliphatic	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
TPH C15-C28 aromatic														
TPH C29-C36 aliphatic	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
TPH C29-C36 aromatic														
TPH C10-C36 (Sum of Total)	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Total PAHs	-	-	-	-	-	-	-	-	-	-	-	NA	-	-
Trimethylbenzene, 1,2,4-	14	Scenario 2	-	-	-	-	110	Scenario 5	-	-	-	NA	0.23	Scenario 8
Vanadium	22,000	Scenario 6	-	-	-	-	22,000	Scenario 6	-	-	-	NA	-	-
Xylenes (total)	-	-	-	-	-	-	-	-	-	-	-	NA	14	Scenario 8
Zinc	-	-	220	DAF x 20	55	DAF x 5	-	-	220	DAF x 20	-	NA	-	-
CPAH**	67	Scenario 6	-	-	-	-	67	Scenario 6	-	-	-	NA	67	Scenario 6

Notes:
** CPAH = carcinogenic PAHs in top 2m of soil profile and includes: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h) anthracene and indeno (1,2,3-cd)pyrene.
NA = Not Applicable

Land Use Scenarios:
Scenario 2: Upper-most basement car park level (above water table);
Scenario 3: Unpaved Recreation, Public Domain (South) with no concrete/hardstand paving;
Scenario 4: Paved Recreation, Public Domain (South) with concrete/hardstand paving;
Scenario 5: Typical commercial slab on ground construction;
Scenario 6: Short term ground-intrusive maintenance;
Scenario 7: High density residential (above a car park basement); and
Scenario 8: Commercial slab on ground (with advection).

TABLE T2
SUMMARY OF GROUNDWATER SSTCS AND SSESCS
AMENDED RAP
BARANGAROO ORWS AREA
LEND LEASE

	GROUNDWATER SSTCS AND SSESCS									
CoPC	**SSTC-A**	**Land Use Scenario**	**SSESC-A**	**Land Use Scenario**	**NA**	**Land Use Scenario**	**SSTC-C**	**Land Use Scenario**	**SSTC-D**	**Land Use Scenario**
Site Area	**Area A**				**Area B**		**Area C**		**Area D**	
Relevant land use Scenario	**Scenario 1, 2, 4, 5, 6 & 7**				**Scenario 3, 4, 5 & 6**		**Scenario 1**		**Scenario 1, 3, 4, 5, 6, 7 & 8**	
	ug/L		**ug/L**		**ug/L**		**ug/L**		**ug/L**	
Acenaphthene	-	-	-	-	-	NA	-	-	-	-
Acenaphthylene	57,000	Scenario 6	-	-	-	NA	-	-	-	-
Ammonia	2,400,000	Scenario 1	-	-	-	NA	2,400,000	Scenario 1	1,500,000	Scenario 8
Aniline	980,000	Scenario 6	-	-	-	NA	-	-	-	-
Anthracene	-	-	1	Tidal Prism	-	NA	-	-	-	-
Arsenic, Inorganic	380,000	Scenario 6	2.3	Tidal Prism	-	NA	-	-	-	-
Barium	570,000	Scenario 6	-	-	-	NA	-	-	-	-
Benz(a)anthracene	-	-	-	-	-	NA	-	-	-	-
Benzene	3,400	Scenario 6	-	-	-	NA	21,000	Scenario 1	410	Scenario 8
Benzo(a)pyrene	-	-	-	-	-	NA	-	-	-	-
Benzo(b)fluoranthene	-	-	-	-	-	NA	-	-	-	-
Benzo(g,h,i)perylene	-	-	-	-	-	NA	-	-	-	-
Benzo(k)fluoranthene	-	-	-	-	-	NA	-	-	-	-
Cadmium	15,000	Scenario 6	-	-	-	NA	-	-	-	-
Chromium(III)	8,400,000	Scenario 6	-	-	-	NA	-	-	-	-
Chromium(VI)	7,600	Scenario 6	-	-	-	NA	-	-	-	-
Chrysene	-	-	-	-	-	NA	-	-	-	-
Cobalt	260,000	Scenario 6	-	-	-	NA	-	-	-	-
Copper	-	-	6.5	Tidal Prism	-	NA	-	-	-	-
Cyanide (WAD)	-	-	-	-	-	NA	-	-	-	-
Dibenz(a,h)anthracene	-	-	-	-	-	NA	-	-	-	-
Dibenzofuran	-	-	-	-	-	NA	-	-	-	-
Dimethylphenol, 2,4-	720,000	Scenario 6	-	-	-	NA	-	-	-	-
Ethylbenzene	210,000	Scenario 6	-	-	-	NA	-	-	49,000	Scenario 8
Fluoranthene	-	-	-	-	-	NA	-	-	-	-
Fluorene	-	-	-	-	-	NA	-	-	-	-
Indeno(1,2,3-cd)pyrene	-	-	-	-	-	NA	-	-	-	-
Lead	1,100,000	Scenario 6	44	Tidal Prism	-	NA	-	-	-	-
Manganese	2,400,000	Scenario 6	-	-	-	NA	-	-	-	-
Mercury	-	-	-	-	-	NA	-	-	-	-
Methylnaphthalene, 2-	38,000	Scenario 1/6	-	-	-	NA	38,000	Scenario 1	32,000	Scenario 8
Methylphenol, 2	4,900,000	Scenario 6	-	-	-	NA	-	-		
Methylphenol, 3&4	270,000	Scenario 6	-	-	-	NA	1,000,000	Scenario 1	660,000	Scenario 8
Naphthalene	920	Scenario 1	-	-	-	NA	920	Scenario 1	1,700	Scenario 8
Nickel	350,000	Scenario 6	-	-	-	NA	-	-		
Phenanthrene	-	-	1	Tidal Prism	-	NA	-	-		
Phenol	23,000,000	Scenario 6	-	-	-	NA	310,000,000	Scenario 1	190,000,000	Scenario 8
Styrene	88,000	Scenario 6	-	-	-	NA	-	-	110,000	Scenario 8
Toluene	760,000	Scenario 6	-	-	-	NA	-	-	200,000	Scenario 8
TPH C06-C09 aliphatic	86,000	Scenario 5	110	Tidal Prism	-	NA	28,000,000	Scenario 1	1,600	Scenario 8
TPH C10-C14 aliphatic	7,700	Scenario 1	40	Tidal Prism	-	NA	7,700	Scenario 1	6,300	Scenario 8
TPH C10-C14 aromatic					-	NA			-	-
TPH C15-C28 aliphatic	220,000	Scenario 6	-	-	-	NA	-	-	-	-
TPH C15-C28 aromatic			-	-	-	NA	-	-	-	-
TPH C29-C36 aliphatic	250,000	Scenario 6	-	-	-	NA	-	-	-	-
TPH C29-C36 aromatic			-	-	-	NA	-	-	-	-
Trimethylbenzene, 1,2,4-	86,000	Scenario 5	-	-	-	NA	87,000	Scenario 1	1,500	Scenario 8
Vanadium	960,000	Scenario 6	-	-	-	NA	-	-	-	-
Xylenes (total)	-	-	-	-	-	NA	-	-	10,000	Scenario 8
Zinc	-	-	75	Tidal Prism	-	NA	-	-	-	-
CPAH	-	-	-	-	-	NA	-	-	-	-

Notes:
MWQC = Marine Water Quality Criteria
** CPAH = Carcinogenic PAHs as BaP TEF (benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno (1,2,3-cd)pyrene (see main body report for details)
DAF = Dilution Attenuation Factors based on the MWQC values.
NA = Not Applicable
WAD - Weak Acid Dissociable

Key Chemical	Criteria for Protection of Plants and Soil (mg/kg)	Grouped Criteria (mg/kg)	Data Sources/Notes
Metals and inorganics			
Arsenic[1]	20		NEPM (1999) - Interim Urban
Cadmium	3		NEPM (1999) - Interim Urban
Chromium	190		NEPM (draft, 2010) EILs - Public open space - aged
Copper[1]	60		NEPM (draft, 2010) EILs - Public open space - aged
Lead[1]	1100		NEPM (draft, 2010) EILs - Public open space - aged
Mercury	1		NEPM (1999) - Interim Urban
Nickel	30		NEPM (draft, 2010) EILs - Public open space - aged
Zinca	200		NEPM (1999) - Interim Urban
Cyanide (if free)	8		CCME (1999a) coarse soil
Ammonia			Calculate based on irrigation guideline of 5 mg/L as N (based on protection of plants)
Petroleum Hydrocarbons			
TPH C6 - C9a	210		CCME (2008b) coarse soil
TPH C10 - C14a	150		CCME (2008b) coarse soil
TPH C15 - C28	-	300	CCME (2008b) coarse soil
TPH C29 - C36	-		
Benzene	1		NSW EPA (1994)
Toluene	1.4		NSW EPA (1994)
Ethylbenzene	3.1		NSW EPA (1994)
Xylenes	14		NSW EPA (1994)
Low MWT PAHs			
Acenaphthene[1]		sum - 50b	a: CCME (1999b)
Acenaphthylene[1]			b: Total PAHs (excluding carcinogenic PAHs), from USEPA Eco SSLs of 48mg/kg rounded to 50mg/kg
Anthracene			
Fluorene[1]			
Phenanthrene			
Naphthalene[1]	22a		
High MWT PAHs			
Benzo[a]anthracene	40 c		c: Criteria derived from 4 for benzo(a)pyrene and applied using the following TEFs from CCME (2008a):
Benzo[a]pyrene	4 c		- benzo[a]anthracene, 0.1
Benzo[b]fluoranthene	40 c		- benzo[a]pyrene, 1
Benzo[k]fluoranthene	40 c		- benzo[b]fluoranthene, 0.1
Benzo[ghi]perylene	400 c		- benzo[k]fluoranthene, 0.1
Chrysene	400 c		- benzo[ghi]perylene, 0.01
Dibenz[ah]anthracene	4 c		- chrysene, 0.01
Fluoranthenea	- c		- dibenz[ah]anthracene, 1
Indeno[123cd]pyrene	40 c		- indeno[123cd]pyrene, 0.1
Pyrene	- c		TEFs for fluoranthene and pyrene not used by CCME (2008b)
Phenols			
Phenol	3.8		CCME (1999c) coarse soil
2,4dimethylphenol	3.8		CCME (1999c) coarse soil
2-methylphenol	3.8		CCME (1999c) coarse soil
3&4-methylphenol	3.8		CCME (1999c) coarse soil

Note:
[1] Where the TSC are greater than the derived leachability based soil SSESC (refer to Section 5.7.3.3, ORWS HHERA Addendum) the relevant soil SSESC will be adopted.