Site Audit Report
Remedial Action Plan, Declaration Area and Block 4, Barangaroo

Prepared for:

Lend Lease (Millers Point) Pty Ltd

Prepared by:
ENVIRON Australia Pty Ltd

Date:
July 2013

Project Number:
AS121111B/AS121111C

Audit Number:
GN 439B-3
GN 447A

ENVIRON

31 July 2013 Our Ref: AS121111

Lend Lease (Millers Point) Pty Ltd
Attn: Mark Burns
Level 4, 30 The Bond
Hickson Road
Millers Point NSW 2000

Dear Mark

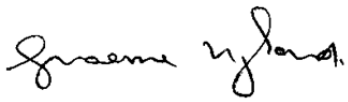
Re: Site Audit Report - Remedial Action Plan, Declaration Area and Block 4, Barangaroo

I have pleasure in submitting the Site Audit Report for the subject site. Two Site Audit Statements relating to the site, produced in accordance with the NSW Contaminated Land Management Act 1997, follow this letter. The Audit was commissioned by Lend Lease (Millers Point) Pty Ltd to assess the appropriateness of a plan of remediation.

This Site Audit is a requirement of an EPA-approved Voluntary Management Proposal by Barangaroo Delivery Authority, Approval No. 20101719, dated 23 July 2010, and is therefore statutory.

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 447A

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 3 and part Lot 5 in DP 876514; and part of Hickson Road adjacent to 30-34, 36 and 38 Hickson Road (See Attachment at end of Part 1of this Statement)

Local Government Area: Sydney

Area of site (e.g. hectares): 2.123 ha

Current zoning: Part zone B4 Mixed Use and Public Recreation RE1

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):

- EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009.
- 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'.

****Strike out as appropriate***

Site audit commissioned by

Name: Warwick Bowyer Company: Lend Lease (Millers Point) Pty Ltd

Address: 30 The Bond, 30 Hickson Road, Millers Point NSW

Postcode: 2000

Phone: 0417 697 834 Fax: 9383 8259

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

Mark Burns (Lend Lease) Phone: 9277 2724

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])~~

Remediation to standard to allow removal of EPA Declaration

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)
- Coffey Environments Pty Ltd (Coffey)
- AECOM Australia Pty Ltd (AECOM)
- VeruTEK Technologies Inc. (VeruTEK)
- JBS Environmental Pty Ltd (JBS)

Title(s) of report(s) reviewed:

Title	Date	Author
'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW'	21 August 2006	Jeffery and Katauskas Pty Ltd (J&K)

Strike out as appropriate

Title	Date	Author
'Land at Millers Point, Ownership and Usage'	1 June 2007	Rosemary Broomham
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DRAFT 'Preliminary Environmental Investigation, 30-38 Hickson Road, Millers Point, NSW, 2000'	12 May 2008 (final report dated 29 June 2009 publicly available)	Coffey Environments Pty Ltd (Coffey)
'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW'	July 2008	ERM
'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney'	September 2008	ERM
'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney'	1 June 2010	ERM
'Sampling, Analytical and Quality Plan [SAQP] Declaration Area – Issue 2 VMP and PDA Works, NSW EPA Declaration Area 21122, former Millers Point Gasworks'	6 July 2010 (and draft dated 2 March 2010)	AECOM Australia Pty Ltd (AECOM)
'Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Hickson Road, Millers Point, NSW'	23 September 2010 (and drafts dated 16 April 2010 and 30 July 2010)	AECOM
'Treatability Study Recommendations for the Implementation of an In Situ Remedy, Barangaroo – Block 5 and Hickson Rd Site, Lend Lead (LL), Sydney, Australia'	23 September 2010 (and draft dated 16 June 2010)	VeruTEK Technologies Inc. (VeruTEK)
'Work Plan, Surfactant Enhanced In Situ Chemical Oxidation, Surfactant Enhanced Product Recovery, Block 5 and Hickson Road, Pilot Trial'	7 October 2010 (and drafts dated June 2010, 27 August 2010 and 28 September 2010)	VeruTEK
'Data Gap Investigation, Other Remediation Works North, Hickson Road, Millers Point, NSW'	20 October 2010 (and draft dated 3 June 2010)	AECOM
'Groundwater Discharge Study, Stage 1 Barangaroo Development'	3 November 2010 (and draft dated 4 August 2010)	AECOM
'Revised Work Plan and Trial Management Plan, Surfactant Enhanced in Situ Oxidation (S-ISCO®) & Surfactant Enhanced Product Recovery (SEPR™), Block 5 and Hickson Road Pilot Trial'	May 2011 (and drafts dated 27 August 2010 and 7 October 2010)	VeruTEK

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MEMO: 'Contaminant Flux and Discharge Estimates for Natural Residual Soil and Marine Sediments, EPA Declaration Area 21122 and adjacent areas of Barangaroo South and Barangaroo Central'	14 March 2012	AECOM
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MEMO: 'Additional Groundwater Modelling to Supplement Contaminant Flux and Discharge Estimates for Natural Soils and Marine Sediments for EPA Declaration Area 21122'	12 Mach 2013 (and draft dated 21 January 2013)	AECOM

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Title	Date	Author
'VMP Remediation Extent, VMP Remediation Works Area, (Parts of Barangaroo and Hickson Road), Millers Point NSW (Privileged & Confidential)'	23 July 2013 (and drafts dated 3 September 2012, 12 October 2012, 13 March and 11 July 2013)	AECOM
'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW'	24 July 2013 (and drafts dated 6 November 2012, 21 March and 12 July 2013)	AECOM

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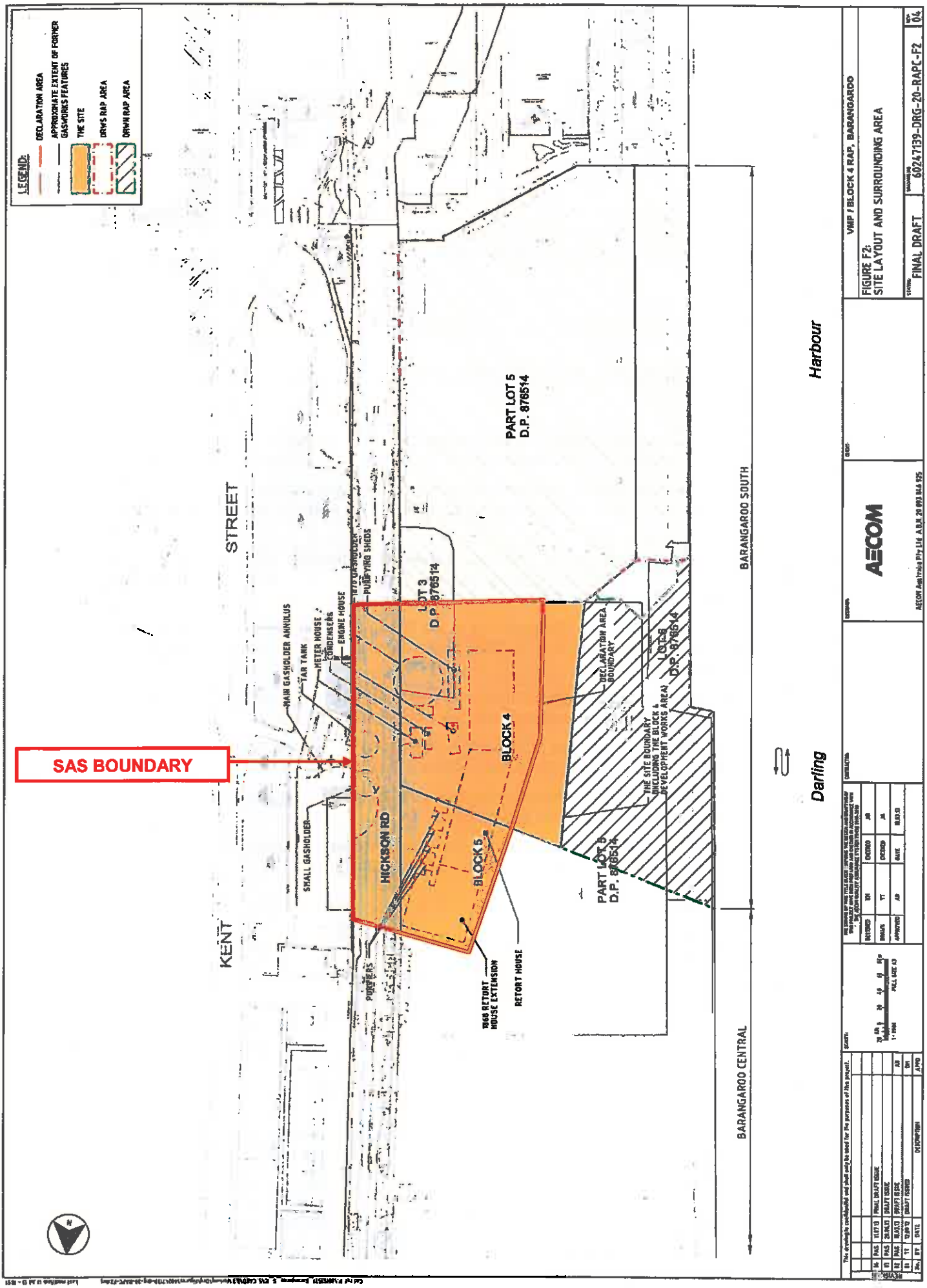
- EPA 'Notice of Approval of Voluntary Management Proposal (Section 17 of the Contaminated Land Management Act 1997), Approval No.: 20101719, Approval Date: 23 July 2010, Area No.: 3221'.
- DOP 'Project Approval (Section 75J of the Environmental Planning and Assessment Act 1979)', Application No.: 10_0087 dated 3 March 2011, for SISCO and SEPR remediation pilot trial.
- OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South (Ref DOC11/30893) re human health and environmental risk assessments.
- EPA Letter dated 23 May 2012 to BDA (Ref DOC12/20618) re 'Barangaroo VMP Draft HHERA for area of EPA Declaration Number 21122'.
- "Site Audit Report - Overarching Remedial Action Plan, Barangaroo", and Site Audit Statement GN 439A, dated 2 June 2010.
- "Site Audit Report, Remedial Action Plan, Other Remedial Works (South), Barangaroo" and Site Audit Statement GN 439B-1, dated 14 July 2011.

Site audit report

Title:... Site Audit Report – Remedial Action Plan, Declaration Area and Block 4, Barangaroo

Report no. GN 447A (ENVIRON Ref: AS121111B/AS121111C) Date: July 2013


LEGEND:
DECLARATION AREA
APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
THE SITE
DRWS RAP AREA
DRWN RAP AREA
SAS BOUNDARY
KENT STREET
HICKSON RD
BARANGAROO SOUTH
BARANGAROO CENTRAL
Darling Harbour
PART LOT 5 D.P. 876514
LOT 3 D.P. 876514
LOT 6 D.P. 876514
PART LOT 6 D.P. 876514
BLOCK 4
BLOCK 5
DECLARATION AREA BOUNDARY
THE SITE BOUNDARY INCLUDING THE BLOCK 4 DEVELOPMENT WORKS AREA
MAIN GASHOLDER ANNULUS
TAR TANK
METER HOUSE
CONDENSERS
ENGINE HOUSE
PURIFYING SHEDS
SMALL GASHOLDER
POTTERS
1868 RETORT HOUSE EXTENSION
RETORT HOUSE
AECOM
VMP / BLOCK 4 RAP, BARANGAROO
FIGURE F2:
SITE LAYOUT AND SURROUNDING AREA
FINAL DRAFT
60247139-DRG-20-RAPC-F2
04

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: *To enable the NSW EPA's declaration of the Declaration Area as a Remediation Site (Declaration Number 21122; Area Number 3221) to be revoked.*

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) ...~~

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, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW', dated 24 July 2013 by 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 site comprises a former gasworks located within the site known as "Barangaroo", at Millers Point, NSW. The site area includes part of proposed development Blocks 4 and 5 and part of Hickson Road. The site was declared by NSW EPA as a Remediation Site in 2009 (Declaration Number 21122; Area Number 3221). The site is subject to a Voluntary Management Proposal (VMP), EPA Approval No. 20101719, dated 23 July 2010.

Risk based remediation goals and remediation criteria have been developed based on protection of human health and the environment under the current site uses. 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 to allow remediation of the site to a standard that:

- reduces the risk currently posed to human health and the environment under the existing land use;
- meets the objectives of the VMP; and
- will allow removal of the NSW EPA declaration.

It is noted that some tasks, principally completion of remediation technology trials and then preparation of a remedial work plan, need to be completed to fulfil the Stage 1 VMP objectives.

Site Auditor review of a number of additional remediation planning documents is required, prior to commencement of remediation, including validation Sampling, Analysis and Quality Plans (SAQPs), Groundwater Monitoring Programs (GMPs) and a Detailed Work Plan for proposed in situ remediation techniques. These documents are to be prepared based on the results of remediation trials and the project requirements. This approach is considered appropriate.

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... 31/7/2013

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.

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-3**

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 3 and part Lot **5** in DP 876514 (See Attachment at end of Part 1of this Statement)

Local Government Area**:** Sydney

Area of site (e.g. hectar**es**)**:** 1.421 ha

Current zoning: Part zone B4 Mixed Use and Public Recreation RE1

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):

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Strike out as appropriate

Site audit commissioned by

Name: Warwick Bowyer Company: Lend Lease (Millers Point) Pty Ltd

Address: 30 The Bond, 30 Hickson Road, Millers Point NSW

Postcode: 2000

Phone: 0417 697 834 Fax: 9383 8259

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

Mark Burns (Lend Lease) Phone: 9277 2724

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])*

Commercial/residential with recreational open space over basement

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)
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Title(s) of report(s) reviewed:

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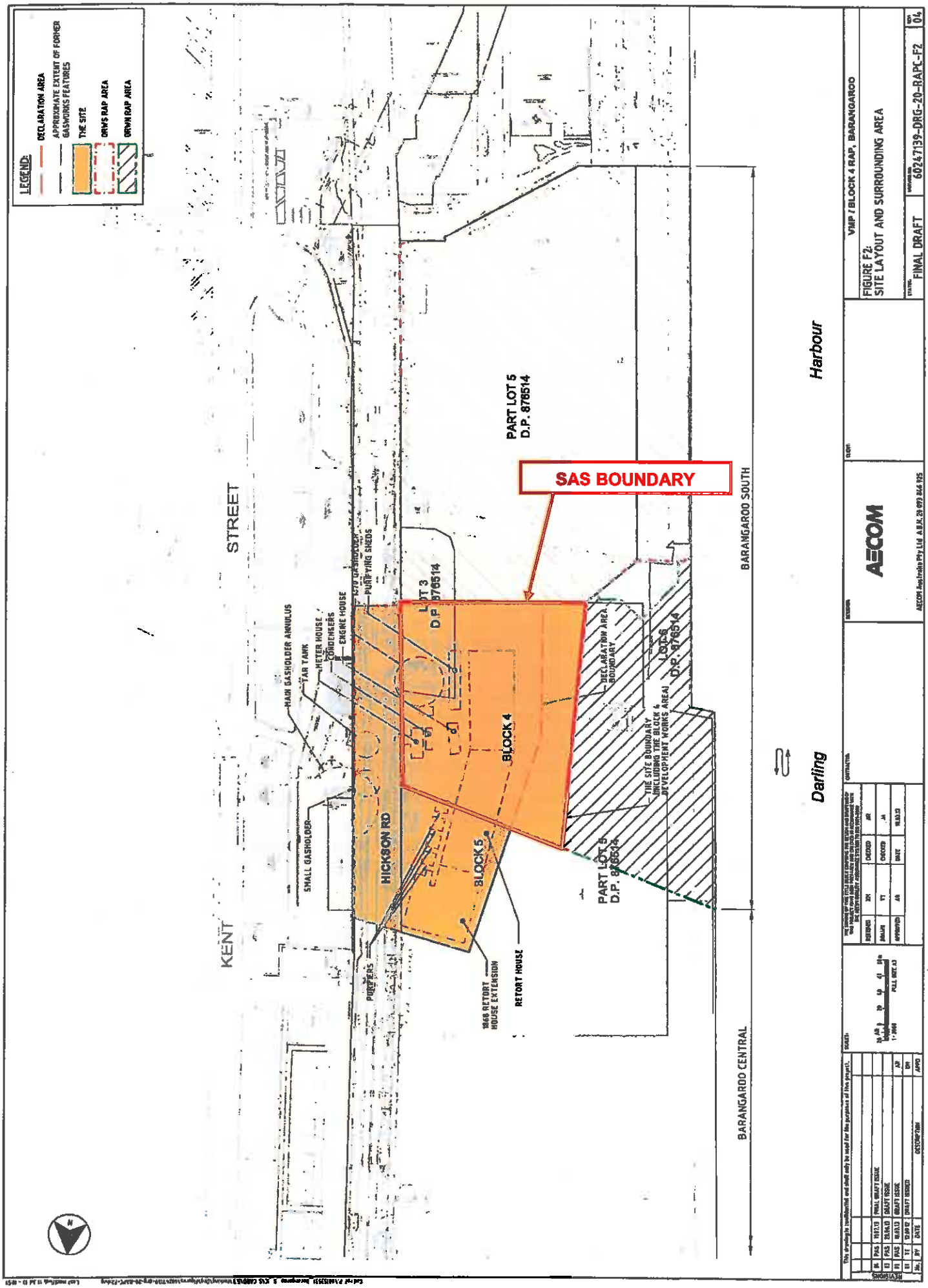
- DOP 'Barangaroo Concept Plan' (Concept plan 06_0162) as approved on 9 February 2007 and modified on 25 September 2007, 16 February 2009 and 16 December 2010.
- EPA 'Declaration of Remediation Site (Section 21 of the Contaminated Land Management Act 1997), Declaration Number 21122; Area Number 3221' dated 6 May 2009.
- 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 'Project Approval (Section 75J of the Environmental Planning and Assessment Act 1979)', Application No.: 10_0087 dated 3 March 2011, for SISCO and SEPR remediation pilot trial.
- OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South (Ref DOC11/30893) re human health and environmental risk assessments.
- EPA Letter dated 23 May 2012 to BDA (Ref DOC12/20618) re 'Barangaroo VMP Draft HHERA for area of EPA Declaration Number 21122'.
- "Site Audit Report - Overarching Remedial Action Plan, Barangaroo", and Site Audit Statement GN 439A, dated 2 June 2010.
- "Site Audit Report, Remedial Action Plan, Other Remedial Works (South), Barangaroo" and Site Audit Statement GN 439B-1, dated 14 July 2011.

Site audit report

Title:... Site Audit Report – Remedial Action Plan, Declaration Area and Block 4, Barangaroo

Report no. GN 439B-3 (ENVIRON Ref: AS121111B/AS121111C) Date: July 2013


LEGEND:
DECLARATION AREA
APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
THE SITE
DRWS RAP AREA
DRWN RAP AREA
SAS BOUNDARY
PART LOT 5 D.P. 878514
LOT 3 D.P. 876514
LOT 6 D.P. 876514
BLOCK 4
BLOCK 5
HICKSON RD
KENT STREET
BARANGAROO SOUTH
BARANGARDO CENTRAL
Darling Harbour
MAIN GASHOLDER ANNULUS
TAR TANK
METER HOUSE
CONDENSERS
ENGINE HOUSE
PURIFYING SHEDS
SMALL GASHOLDER
PUMPS
1868 RETORT HOUSE EXTENSION
RETORT HOUSE
DECLARATION AREA BOUNDARY
THE SITE BOUNDARY INCLUDING THE BLOCK 4 DEVELOPMENT WORKS AREA
AECOM
VMP / BLOCK 4 RAP, BARANGAROO
FIGURE F2:
SITE LAYOUT AND SURROUNDING AREA
FINAL DRAFT
60247139-DRG-20-RAPC-F2
04

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: *To ensure that Block 4 is remediated to a standard suitable for the proposed 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) ...recreational open space located over basement....

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, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW', dated 24 July 2013 by 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

Block 4 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. Part of Block 4 was previously the location of a former gasworks which has been declared by NSW EPA as a Remediation Site (Declaration Number 21122; Area Number 3221). Removal of the declaration is required prior to development and is addressed by Site Audit Statement GN 447A.

Risk based remediation goals and 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 for Block 4 are generally consistent with the Overarching RAP for Barangaroo.

Site Auditor review of a number of additional remediation planning documents is required, including validation Sampling, Analysis and Quality Plans (SAQPs) and Groundwater Monitoring Programs (GMPs). These documents are to be prepared prior to commencement of remediation based on the project requirements and final design of the basement groundwater retention wall system. Review of a Site Management Plan (SMP) for future land owners is also required after remediation.

If significant changes are made to the development design, the RAP proposes to prepare Addendum documents, to be approved by the Site Auditor: This is considered an appropriate approach to management of significant changes to the development design.

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... 31/7/2013

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 Sulphate Soils
AC	asbestos cement
ACM	asbestos containing material
AECOM	AECOM Australia Pty Ltd
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 sulphate soils
ANZECC	Australian and New Zealand Environment and Conservation Council
BACM	Bonded asbestos containing material
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*
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
CRS	Chromium Reducing Sulfur
CUTEP	clean-up to the extent practicable
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
DNAPL	dense non aqueous phase liquid
DOP	Department of Planning (NSW)
DP	Deposited Plan
DQI	Data Quality Indicators
DQO	Data Quality Objectives
ENM	excavated natural material
EnRisks	Environmental Risk Services Pty Ltd
EPA	Environment Protection Authority (NSW)
EPL	Environment Protection License
ESA	Environmental Site Assessment report
ESD	ecologically sustainable development
ERM	Environmental Resources Management Australia Pty Ltd
GDS	Groundwater Discharge Study
ha	Hectare
HHERA	Human Health and Ecological Risk Assessment
J&K	Jeffery & Katauskas Pty Ltd
km	Kilometres
LCS	Laboratory Control Sample
LLMP	Lend Lease (Millers Point) Pty Ltd
LOR	Limit of Reporting
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
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 Sulphate Soils
PCBs	Polychlorinated Biphenyls
PID	Photoionisation Detector
PIM	Potential impacted material
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
SAR	Site Audit Report
SEPR	surfactant enhanced product removal
S-ESCO	surfactant-enhanced ex situ chemical oxidation
S-ISCO	surfactant-enhanced in situ chemical oxidation
SILs	Soil Investigation Levels
SMP	site management plan
SPGWT	Separate Phase Gasworks Waste and Tar
SSESCs	site specific ecological screening criteria
SST	sandstone
SSTCs	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 Introduction and Objective

A site contamination audit has been conducted in relation to part of the site known as "Barangaroo", at Millers Point, NSW, on behalf of Lend Lease (Millers Point) Pty Ltd (LLMP). Barangaroo is a large site to be developed in stages and 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 "the declaration area" and "Block 4" areas. The declaration area consists of a portion of Barangaroo which previously contained a manufactured coal gasworks and which has been declared by the Environment Protection Authority (NSW) (EPA) as a Remediation Site (No. 21122). The declaration area includes a portion of Hickson Road and a portion of Blocks 4 and 5 of the Barangaroo development. The remainder of Block 4 which includes additional land to the west of the declaration area is also the subject of this audit. The site location is shown on Attachment 1, Appendix A and the boundary of the declaration area and historical gasworks infrastructure locations is shown on Attachment 2, Appendix A.

For the purpose of this audit, the site has been considered in two portions, with two different objectives (refer Attachment 3, Appendix A), as follows:

- Declaration area – including portions of Hickson Road, Block 4 and Block 5, objective is to allow the EPA declaration to be revoked (Voluntary Management Proposal (VMP) removal).
- Block 4 – including part of the declaration area, objective is to allow development of Block 4.

The Audit was conducted to provide an independent review by an EPA Accredited Auditor of the suitability and appropriateness of a plan of management, long-term management plan or a voluntary management proposal i.e. a "Site Audit" as defined in Section 4 (1) (b) (v) of the *NSW Contaminated Land Management Act 1997* (the CLM Act). The relevant plan is a remedial action plan (RAP) prepared by AECOM Australia Pty Ltd (AECOM) which has been prepared to address the two different areas and two different objectives, above. Two separate site audit statements (SAS) have been prepared to accompany this site audit report (SAR).

1.2 Background

Details of the audit are:

Requested by:	Warwick Bowyer on behalf of Lend Lease (Millers Point) Pty Ltd
Request/Commencement Date:	30 October 2009
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 declaration area and Block 4.

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 re-use of material from one part in another, an Overarching RAP was prepared by Environmental Resources Management Australia Pty Ltd (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 SAR prepared as follows:

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

The RAP for the portion of Barangaroo adjoining the declaration area to the south, the Other Remediation Works South (ORWS) area, was reviewed by the Auditor on behalf of Lend Lease and a SAR prepared as follows:

- "Site Audit Report, Remedial Action Plan, Other Remedial Works (South), Barangaroo" and Site Audit Statement GN 439B-1, dated 14 July 2011.

During the course of the current audit, the Auditor has prepared a letter reviewing the pilot trial methodology for possible in-situ remediation technologies for the declaration area which include Surfactant-enhanced In Situ Chemical Oxidation (S-ISCO) and Surfactant Enhanced Product Recovery (SEPR). Tasks relating to S-ISCO and SEPR are included in the VMP for the declaration area, which is discussed in the following section. The review was documented in the following letter, which is included as Appendix G of this SAR:

- "Re: Review of Block 5 and Hickson Road Pilot Test, S-ISCO and SEPR, Barangaroo" dated 13 October 2010.

1.3 Voluntary Management Proposal

BDA has entered into a VMP with the EPA, Approval No. 20101719, dated 23 July 2010, which addresses those works required to remove the declaration. The contaminants identified in the VMP comprise TPH, BTEX, PAHs, ammonia, phenol and cyanide. The VMP is proposed in two stages, as follows:

(a) "Stage 1: VMP in which:

(1) investigative works would be undertaken with the objective of identifying, and obtaining the Site Auditor's and the EPA's approval of a preferred remedial strategy to address the groundwater contamination on the Site;

(2) presenting the detailed design of the remedial strategy in a Remedial Action Plan ("RAP") and a Remedial Work Plan ("RWP"); and

(3) obtaining the Site Auditor's endorsement of or confirmation that he has no objection to the RAP, and obtaining the EPA's approval of the RAP.

(b) Stage 2: VMP in which the remedial measures set out in the RAP would be implemented".

Objectives identified for stage 1 of the VMP are as follows:

"O1. Conduct a Data Gap Investigation for the Site in order to adequately characterise the nature and extent of the Site contamination.

O2. Prepare a Human Health and Ecological Risk Assessment ("HHERA") which would identify the Site specific soil and groundwater acceptance criteria for the Site and for the remediation works.

O3. Conduct remediation technology trials to determine applicability and selection of proposed remediation technologies for the Site.

O4. Prepare and submit a RAP (which outlines the agreed detailed design and specifications of the remedial measures and how these will be implemented, and is conditional upon a strategy to confirm the preferred remediation technologies (subject to completion of remediation technology trials)) to the Site Auditor and the EPA; obtain the Site Auditor's endorsement of the RAP or confirmation that he has no objection to the RAP; and obtain the EPA's approval of the RAP.

O5. Based on the RAP, prepare and submit a RWP (which sets out the technical specifications of the remediation works on the Site) to the Site Auditor and the EPA; obtain the Site Auditor's endorsement of the RWP or confirmation that he has no objection to the RWP; and obtain the EPA's approval of the RWP".

The status of the VMP stage 1 objectives are discussed in Section 17. The VMP states that *"The objectives of stage 2 will be defined in a separate voluntary management proposal upon completion of stage 1…".*

1.4 Scope of Work

The scope of the audit included:

- Review of the documents listed in Table 1.1, below.

Table 1.1: Documents Reviewed

Document Type	Title	Date	Author	Relevance	Reference
Report	'Report to Sydney Harbour Foreshore Authority on Geotechnical Investigation for Proposed Redevelopment of Wharves 3-8 at Hickson Road, Darling Harbour East, NSW'	21 August 2006	Jeffery and Katauskas Pty Ltd (J&K)	Investigation data, whole of Barangaroo	J&K, 2006
Report	'Land at Millers Point, Ownership and Usage'	1 June 2007	Rosemary Broomham	Site history	Broomham, 2007
Report	'Environmental Site Assessment, East Darling Harbour, Sydney, NSW'	21 June 2007	Environmental Resources Management Australia Pty Ltd (ERM)	Investigation data, whole of Barangaroo	ERM, 2007
Draft Report	'Preliminary Environmental Investigation, 30-38	12 May 2008 (final	Coffey Environments	Investigation data, Hickson	Coffey, 2008

Table 1.1: Documents Reviewed

Document Type	Title	Date	Author	Relevance	Reference
	Hickson Road, Millers Point, NSW, 2000'	report dated 29 June 2009 publicly available)	Pty Ltd (Coffey)	Road	
Report	'Additional Investigation Works at Barangaroo, Hickson Road, Millers Point, NSW'	July 2008	ERM	Investigation data, whole of Barangaroo	ERM, 2008a
Report	'Draft Stage 2 Remedial Action Plan for Barangaroo, Hickson Road, Sydney'	September 2008	ERM	Draft overarching remediation of whole of Barangaroo	ERM, 2008b
Report	'Overarching Remedial Action Plan for the Barangaroo Project Site, Sydney'	1 June 2010	ERM	Overarching remediation of whole of Barangaroo	ERM, 2010 *(the Overarching RAP)*
Report	'Sampling, Analytical and Quality Plan [SAQP] Declaration Area – Issue 2 VMP and PDA Works, NSW EPA Declaration Area 21122, former Millers Point Gasworks'	6 July 2010 (and draft dated 2 March 2010)	AECOM Australia Pty Ltd (AECOM)	SAQP for declaration area	AECOM, 2010a
Report	'Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Hickson Road, Millers Point, NSW'	23 September 2010 (and drafts dated 16 April 2010 and 30 July 2010)	AECOM	Investigation data, declaration area	AECOM, 2010b (*the DGI*)
Report	'Treatability Study Recommendations for the Implementation of an In Situ Remedy, Barangaroo – Block 5 and Hickson Rd Site, Lend Lead (LL), Sydney, Australia'	23 September 2010 (and draft dated 16 June 2010)	VeruTEK Technologies Inc. (VeruTEK)	Laboratory treatability study of proposed treatment technologies	VeruTEK, 2010a
Report	'Work Plan, Surfactant Enhanced In Situ Chemical Oxidation, Surfactant Enhanced Product Recovery, Block 5 and Hickson Road, Pilot Trial'	7 October 2010 (and drafts dated June 2010, 27	VeruTEK	Describes the proposed pilot trial of in situ remediation technologies	VeruTEK, 2010b

Table 1.1: Documents Reviewed

Document Type	Title	Date	Author	Relevance	Reference
		August 2010 and 28 September 2010)			
Report	'Data Gap Investigation, Other Remediation Works North, Hickson Road, Millers Point, NSW'	20 October 2010 (and draft dated 3 June 2010)	AECOM	Investigation data, ORWN to the west	AECOM, 2010c (*the ORWN DGI*)
Report	'Groundwater Discharge Study, Stage 1 Barangaroo Development'	3 November 2010 (and draft dated 4 August 2010)	AECOM	Groundwater investigation onsite and down gradient	AECOM, 2010d
Report	'Revised Work Plan and Trial Management Plan, Surfactant Enhanced in Situ Oxidation (S-ISCO®) & Surfactant Enhanced Product Recovery (SEPR™), Block 5 and Hickson Road Pilot Trial'	May 2011 (and drafts dated 27 August 2010 and 7 October 2010)	VeruTEK	Update of proposed pilot trial of in situ remediation technologies, not reviewed in detail by Auditor	VeruTEK, 2011
Report	'Human Health and Ecological Risk Assessment, Declaration Site (Development Works) Remediation Works Area - Barangaroo'	9 June 2011 (and drafts dated 30 July 2010, 31 January 2011, 12 April 2011 and 6 May 2011)	AECOM	Development of site specific target criteria (SSTC) and site specific ecological screening criteria (SSESC) for redevelopment of declaration area	AECOM, 2011 (*the Declaration Site HHERA*)
Report	'Supplementary Data Gap Investigation, VMP Area, Hickson Road, Millers Point, NSW'	9 March 2012	AECOM	Investigation data, onsite and offsite	AECOM, 2012a (*the Supplementary DGI*)
Memorandum	'Contaminant Flux and Discharge Estimates for Natural Residual Soil and	14 March 2012	AECOM	Analysis of contaminant flux for	AECOM, 2012b

Table 1.1: Documents Reviewed

Document Type	Title	Date	Author	Relevance	Reference
	Marine Sediments, EPA Declaration Area 21122 and adjacent areas of Barangaroo South and Barangaroo Central'			determining required remediation extent	
Report	'S-ISCO & SEPR Pilot Trial Proving Phase, Addendum to Revised Work Plan and Trial Management Plan'	July 2012	VeruTEK	Describes the proving phase trial of in situ remediation technologies	VeruTEK, 2012
Letter	'Re: Human Health and Ecological Risk Assessment - Declaration Site, Barangaroo. Assessment of the Implications of the Revised Basement Design'	3 July 2012	AECOM	Amended risk assessment to reflect changes to proposed building basement design and use	AECOM, 2012c *(the Declaration Site HHERA Letter)*
Report	'Data Gap Investigation, Barangaroo Central, Hickson Road, Sydney, NSW'	21 August 2012 (and draft dated 17 July 2012)	JBS Environmental Pty Ltd (JBS)	Investigation data, offsite and down gradient	JBS, 2012 *(the Central DGI)*
Report	'Human Health and Ecological Risk Assessment, VMP Remediation Works Area (Addressing the NSW EPA Remediation Site Declaration 21122, Millers Point)'	25 October 2012 (and drafts dated 21 March 2012, 16 August 2012, 9 October 2012)	AECOM	Development of SSTC for removal of NSW EPA Declaration	AECOM, 2012d (*the VMP HHERA*)
Report	'Tree Root Mass Investigation, Hickson Road, Millers Point, NSW'	23 November 2012	AECOM	Investigation data, tree roots along Hickson Road	AECOM, 2012e
Report	'The Use of Asbestos-Contaminated Soils on Barangaroo'	March 2013	Associate Professor Tim Driscoll, Sydney School of Public Health, Sydney Medical	Reviewed for relevance – not applicable	Driscoll, 2013

Table 1.1: Documents Reviewed

Document Type	Title	Date	Author	Relevance	Reference
			School, University of Sydney		
Memorandum	'Additional Groundwater Modelling to Supplement Contaminant Flux and Discharge Estimates for Natural Soils and Marine Sediments for EPA Declaration Area 21122'	12 Mach 2013 (and draft dated 21 January 2013)	AECOM	Further analysis of contaminant flux for determining required remediation extent	AECOM, 2013a
Report	'VMP Remediation Extent, VMP Remediation Works Area, (Parts of Barangaroo and Hickson Road), Millers Point NSW (Privileged & Confidential)'	23 July 2013 (and drafts dated 3 September 2012, 12 October 2012, 13 March and 11 July 2013)	AECOM	Defines the extent of remediation required to remove the NSW EPA Declaration	AECOM, 2013b *(the VMP Extent Report)*
Report	'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW'	24 July 2013 (and drafts dated 6 November 2012, 21 March and 12 July 2013)	AECOM	Proposed remediation of declaration area and Block 4	AECOM, 2013c *(the RAP)*

- Review of the following Office of Environment and Heritage (OEH), EPA and Department of Planning (DOP) documents:
  - DOP 'Barangaroo Concept Plan' (Concept plan 06_0162) as approved on 9 February 2007 and modified on 25 September 2007, 16 February 2009 and 16 December 2010.
  - EPA 'Declaration of Remediation Site (Section 21 of the *Contaminated Land Management Act 1997*), Declaration Number 21122; Area Number 3221' dated 6 May 2009 *(the declaration).*
  - 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' *(the VMP).*

  - DOP 'Project Approval (Section 75J of the *Environmental Planning and Assessment Act 1979*)', Application No.: 10_0087 dated 3 March 2011, for SISCO and SEPR remediation pilot trial.
  - OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South (Ref DOC11/30893) re human health and environmental risk assessments.
  - EPA Letter dated 23 May 2012 to BDA (Ref DOC12/20618) re 'Barangaroo VMP Draft HHERA for area of EPA Declaration Number 21122'.

- Site visits by the Auditor on 18 March 2010 and subsequently.
- Discussions with LLMP, BDA, and with AECOM, who undertook the recent works (since 2010). The ERM and Coffey investigations were completed prior to the Auditor's engagement and no discussion with ERM was undertaken.

1.5 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 – analysis of field and laboratory data and review of proposed remediation
- Emma Struik – review of risk based remediation criteria
- Tom Onus – review of laboratory data quality.

External support was provided by the following person/organisation:

- Therese Manning and Jackie Wright, Environmental Risk Services Pty Ltd (EnRisks)– review of human health and environmental risk assessments (HHERAs) and contributed to preparation of Section 10 of this SAR. Ms Wright has also prepared a separate detailed report supporting the summary provided in Section 10 with respect to the Declaration Site HHERA (for development).

2 Site Details

2.1 Location

The site locality is shown on Attachment 1, Appendix A.

The site details are as follows:

Street address:	Hickson Road (Sussex Street), Barangaroo, NSW 2000
Identifier:	Part Lot 3 and part Lot 5 in DP 876514 and part of Hickson Road adjacent to 30-34, 36 and 38 Hickson Road. (refer Attachment 2, Appendix A)
Local Government:	City of Sydney
Owner:	Barangaroo Delivery Authority
Site Area:	2.476 ha

The site boundary is defined to the east by the eastern side of Hickson Road (refer Attachment 3, Appendix A). The northern, southern and western boundaries are not readily identifiable as they are proposed development boundaries, and not based on current site features or usage.

A site survey from 2010 showing the extent of the declaration area is included as Attachment 4, Appendix A.

The site area comprises ‘Area 1’, ‘Area 3’ and a small portion of ‘Area 2’ (Attachment 5, Appendix A) as referenced in previous investigations and the Overarching RAP (ERM, 2010).

2.2 Zoning

The current zoning of the site was identified in the RAP (AECOM, 2013c) as ‘part zone B4 Mixed Use and Public Recreation RE1’ within Barangaroo and ‘Maritime and Transport Zone’ within Hickson Road.

2.3 Adjacent Uses

The site is located within an area of mixed uses (Attachment 3, Appendix A):

- North: Barangaroo (Central), currently open space concrete/hardstand.
- South: Barangaroo (ORWS), currently being developed for commercial, residential and open space use.
- East: Commercial and residential buildings.
- West: Barangaroo (ORWS and Central), currently open space concrete/hardstand, then Darling Harbour.

Occupants of commercial and residential premises along Hickson Road and the general public using Hickson Road are potential receptors from any contamination migrating from the site. Site Audit Statements have been prepared for the properties at 30-34, 36 and 38

Hickson Road (dated 10 March 2003, 16 March 2004 and 30 June 2003, respectively), and state that these sites are suitable for their current land use, variously subject to conditions.

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. AECOM noted the following site features in their DGI report (AECOM, 2010b):

- A two story 'amenities' building in the east of the site
- A portion of the 'former maintenance building' was located within the south of the site
- Sewerage pumping station SP1129
- Majority of site was covered by a hardstand including concrete and bitumen
- Mature trees along the eastern and western side of Hickson Road.

Based on the Auditor's most recent inspections, and as reported by AECOM in the RAP (2013c), the sewerage pumping station is the only permanent building remaining onsite. Temporary/ demountable site sheds are present and hardstand remains at the site. The trees along Hickson Road remain.

2.5 Proposed Development

2.5.1 Block 4

Based on current development plans described in the RAP (AECOM, 2013c), Block 4 is to be redeveloped for mixed commercial and high density residential usage overlying a basement, with associated public open space area (incorporating community and related land uses). The car park basement will cover the entirety of Block 4 to a depth of 8 m below ground level (BGL), equivalent to a relative level of -5.6m Australian Height Datum (AHD) . The basement excavation will be supported by a basement groundwater retention wall system around the perimeter, to be keyed into bedrock. Attachment 6, Appendix A, illustrates a cross section of the proposed Block 4 development. It can be seen that the basement will be excavated into bedrock in the eastern portion while fill material and natural soils will be retained below the western portion of the basement and behind (to the east of) the groundwater retention wall system.

The RAP (AECOM, 2013c) describes the potential for the final details and configuration of land uses within the site to be revised from time to time by LLMP as part of the continued development design. The Declaration Site HHERA (AECOM, 2011) and Declaration Site HHERA Letter (AECOM, 2012c) assume a number of development concepts and controls in developing risk-based acceptance criteria. These are required to be implemented at the site for the risk-based criteria to remain valid. AECOM (2013c) state that *"… the proposed land uses … will remain generally consistent with that described within this RAP"*. AECOM (2013c) notes that *"If the final development design is changed in a way which affects the assumptions of the Declaration Site HHERA … and Declaration Site HHERA Letter … and this RAP, an Addendum will be prepared…"*. This is discussed further in Section 13.5 of this SAR.

The general land use scenarios applicable to the audit of Block 4 are 'residential with minimal access to soil' and 'commercial/ industrial'. The general land use scenario for recreational usage is not relevant since the entire area will be underlain by a basement. The Declaration Site HHERA (AECOM, 2011) derived criteria for the following scenarios, representing the range of potential development land uses for the larger declaration area (not specifically Block 4) as discussed in Section 10 of this SAR:

- Scenario 1 – lower-most basement car park level below water.
- Scenario 2 – upper-most basement car park level partially above water.
- Scenario 3 – unpaved public domain / open space.
- Scenario 4 – paved public domain / open space.
- Scenario 5 – commercial slab on ground.
- Scenario 6 – short term ground-intrusive maintenance.
- Scenario 7 – residential above basement construction.

2.5.2 Declaration Area

Development of the declaration area outside Block 4 is not currently proposed and is not contemplated in the RAP. The land use considered for removal of the declaration from the declaration area is the existing land use – being use of Hickson Road and the site area, in its current state, by the public. The general land use scenario applicable to removal of the declaration is 'parks, recreational, open space'. The VMP HHERA (AECOM, 2012d) derived criteria for the following scenarios, as discussed in Section 10 of this SAR:

- Scenario 1 – paved public domain / open space.
- Scenario 2 – short term ground-intrusive maintenance.

The RAP notes that if the proposed Block 4 development works do not occur, the VMP remediation works will still be undertaken.

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 DGI (AECOM, 2010b) 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	Gasworks operated by The Australian Gas Light Company on the site, including what is now Hickson Road and offsite on the eastern side of Hickson Road. The remainder of Barangaroo was used for commercial and wharf use during this period. The original gasworks was located in the south of the declaration area. Significant expansions occurred as follows: • 1882: AGL acquired additional land to the north of former gasworks, constructed retort house and replaced smaller gas holders. Installed tramway system and hydraulic lift for transport of coke. • 1897: Gasworks waterfront extended 40 feet to north by acquisition of additional land. • 1899: Construction of building to house carburetted water gas plant. Gasworks demolished in mid 1920s, new finger wharves constructed; area subsequently used for various workshop facilities.
1925	Part of site became Hickson Road.
1930s	Maritime Services Board (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. Southern Cove was in the south of the site and Other Remediation Works North (ORWN) area to west, and was previously located between the Wharf 6 and 7 buildings.
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.
1999	Overseas passenger terminal constructed at Wharf 8 (offsite to south), requiring demolition of two previous buildings.
2007, 2009	Declaration of Investigation Area then Remediation Site for Wharfs 5 and 7 and Hickson Road by NSW EPA.
2008-2011	Wharf vacated, buildings demolished.

The summary indicates that the site was operated as a gasworks until the 1920s and was used for wharf/ port related activities after that time. Original finger wharves were removed and the site was largely filled in 1961-1968 for the construction of longshore berthage, with some additional filling in the south of the site (area of former Southern Cove) in the late 1980s or early 1990s.

The former AGL (now Jemena) gasworks historically occupied the eastern portions of Block 4 and Block 5 and extended to the area now occupied by Hickson Road and properties to the east (Attachment 2, Appendix A). The gasworks comprised the following infrastructure:

- Retort house
- Meter house
- Tar tank
- Engine house
- Gasholders (cut into bedrock up to 10 mBGL)
- Purifying sheds
- Purifier beds.

Previous investigations and remediation works undertaken at 30-34 Hickson Road (Attachment 3, Appendix A) identified gasworks infrastructure extending across Hickson Road, including part of the annulus of the former main gasholder, a smaller secondary gas holder and part of a tar tank (Coffey, 2008). Portions of these features remain within 36 Hickson Road, and the basement of a building at 38 Hickson Road is known to have experienced inflow of gasworks-contaminated groundwater.

In the Auditor's opinion, the site history provides an adequate indication of past activities, with the primary potential for contamination being the operation of the former gasworks, disposal of gasworks waste and uncontrolled fill used in various stages of site reclamation.

4 Contaminants Of Concern

The DGI (AECOM, 2010b) 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	Former gasworks	Gasworks waste – could include HM, TPH, BTEX, PAHs, phenols, sulphate, cyanide, ammonia
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 buildings	Unknown, could include lead, PCBs, asbestos
Whole of site	Land reclamation	Acid sulphate soils (ASS)

HM heavy metals: arsenic, copper, chromium, cadmium, lead, mercury, 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

The contaminants identified in the VMP comprise TPH, BTEX, PAHs, ammonia, phenol and cyanide.

The Auditor considers that the analyte lists used by ERM, Coffey 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 Section 8 and 9, respectively.

The majority of soil samples were analysed for the primary contaminants of concern, being TPH, BTEX and PAH (over 200 samples analysed), phenol and cyanide (over 100 samples analysed). Between 16 and 60 samples were also analysed for the extended suite of potential organic contaminants, including phenols, OCP, OPP, PCBs and other 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 and ammonia. Asbestos is discussed in Section 8.3.6. Potential contamination by ammonia has been considered primarily through the assessment of groundwater.

Groundwater samples from between one to five rounds of monitoring (depending on location of monitoring well) were analysed for the primary contaminants of concern - heavy metals, TPH/BTEX and PAH. Cyanide (either total, free or weak acid dissociable (WAD)) was also analysed in each round. Selected samples were also analysed for phenols. Additional

analytes included during the earlier monitoring rounds undertaken by ERM and Coffey included chlorinated hydrocarbons and PCBs. 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 is summarised in Table 5.1.

Table 5.1: Stratigraphy

Depth (mBGL)	Subsurface Profile
Surface	Hardstand, comprising asphalt or concrete pavement
Occurs below hardstand To between 3 and 19 m Thickness increases from east to west.	Fill, highly heterogeneous, comprises gravel, sand, silt and clay, with sandstone, bricks, concrete, timber, steel, slag, ash and tar.
Occurs between fill and bedrock Thickness varies from 0 to 10 m	Alluvial sediments, clayey sand, sandy clay, clayey silt and clay, some shell fragments and organic matter
	Residual soils weathered from sandstone bedrock, clayey sand and sand
Occurs below natural soil or directly below fill From between 3 and >27.5 m	Sandstone bedrock with shale bands.

Attachment 7, 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.

The filling of the majority of the site would have occurred during the second stage. AECOM (2013c) 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 mBGL, 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, 2010b). A caisson (sea) wall is present along the western boundary of Barangaroo. 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 four wells (two onsite and two downgradient). AECOM (2010b) reported that testing indicated a wide range of hydraulic conductivity depending on the local fill type. Further hydraulic testing was performed as part of the Groundwater Discharge Study (AECOM, 2010d), discussed below.

Groundwater quality at the site is saline, approaching seawater composition (AECOM, 2010b). A few exceptions were wells located in the east of the site which had fresh to brackish conditions.

A Groundwater Discharge Study (AECOM, 2010d) was conducted to investigate the interaction between site groundwater and Darling Harbour. Transects of multilevel piezometers were installed to the west (downgradient) of 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 10m 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 (2012b and 2013a). 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. These studies are discussed further in Section 11.5.

Based on the Auditor's review, the hydrogeological conditions at the site 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. Information relevant to the declaration area and Block 4 was reviewed for this audit. In addition to the site specific data, information relating to the downgradient (western) areas adjacent to the site was considered in defining the remediation extent required to address the VMP (refer Section 11). Investigation locations are shown on Attachment 8, Appendix A. The primary information reviewed comprised soil and groundwater well logs, and field and analytical methods and results for the following investigations:

- **ERM (2007):** environmental site assessment comprising approximately thirty nine boreholes, installation of one groundwater well (BH087/EMW15) and sampling of one well within the site. This investigation also included installation and sampling of five offsite wells (BH046/MW08, BH129/MW24, BH53/MW11, BH76/MW14 & BH116/MW22) located on the Barangaroo Central and ORWN sites, which were also considered as part of the scope for this review.
- **ERM (2008a):** additional investigations comprising fifteen boreholes and eight groundwater wells (MW198, MW200, MW204S/D, MW205, MW206, MW209, MW210). This investigation also included installation of three offsite wells (BH213/MW213, BH057/MW12 & BH212/MW212) located on the Barangaroo Central and ORWN sites, which were also considered as part of the scope for this review.
- Rock core logs for the above ERM investigations were reported in J&K (2006).
- **Coffey (2008):** environmental site assessment in Hickson Road comprising fifteen boreholes, installation and sampling of five onsite wells (BH3/MW3, BH6/MW6, BH7/MW7, BH10/MW10 & MW15) (an additional well BH2/MW2 was installed to the north [outside the current audit area and this was not considered as part of the scope for the current audit]).
- **AECOM (2010b):** Declaration Area DGI comprising twenty five boreholes, installation of nine onsite groundwater wells (MW45, MW52, MW53, MW54, MW58, MW61, MW62, MW64, MW68), installation of seven soil vapour wells, and sampling of twenty wells and seven soil vapour sampling points. Data from the soil vapour sampling is not relevant to the RAP and is therefore not included in this assessment. This investigation also included seven offsite wells (MW40, MW56, MW60, MW69, MW74, IT01 and IT02) located on the Barangaroo Central and ORWN sites, which were also considered as part of the scope for this review.
- **AECOM (2012a):** Supplementary DGI comprising fourteen boreholes, installation of six groundwater wells, of which four offsite wells (MW401, IT03, IT04 and IT05) were considered to be relevant to the current audit area.
- **AECOM (2012e):** investigation of root mass zone of trees along Hickson Road comprising nine boreholes and three inspection pits.
- **JBS (2012):** Central DGI comprising ten offsite wells located on part Block 5 (MW518, MW539, MW540D, MW541S/D, MW542) and Barangaroo Central (MW529D, MW543, MW544S/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.

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's Summary and 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 locations were restricted by the presence of buildings as well as operational constraints of the stevedoring business on the site. Additional investigations by ERM (2008a) and AECOM (2010b, 2012a and 2012e) 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 acid sulphate soils (ASS). Localised sources of contamination associated with the former gasworks were targeted by the soil investigation locations. 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:** Within the declaration area, monitoring wells are concentrated in the Hickson Road and Block 4 areas, with additional wells located in Block 5. A series of wells is located immediately downgradient of the Block 5 (northern) portion of the declaration area. Although there are no wells immediately downgradient of the Block 4 (southern) portion of the declaration area, downgradient wells are located further to the west in the ORWN RAP area. There is also a well (BH40/MW40) located downgradient of and adjacent to the Block 4 boundary. Given the variability of the fill encountered, the full range of groundwater conditions are not likely to have been assessed by the wells installed. However, wells have been placed in proximity to the highest soil contaminant detections, therefore, they should be reasonably representative of the upper range of potential contamination. Groundwater wells are not placed in a regular fashion and well coverage is limited in Block 5, the west of Block 4 and immediately downgradient of Block 4. However, comparison of groundwater results with field observations from boreholes (which have more regular coverage than groundwater wells) indicates a strong correlation between field indicators of gasworks impact and

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor's Summary and Comments**
	contamination in groundwater. Therefore the Auditor has used field observations of significant gasworks impact to delineate potential groundwater impacts and to assess the adequacy of the proposed remediation extent with respect to groundwater contamination. In the Auditor's opinion, the groundwater well locations are adequate to demonstrate the likely range of contamination within groundwater at the site and are considered adequate to allow for remediation planning in consideration of other lines of evidence.
Sampling Density	**Soil:** The combined sampling density of 113 soil investigation locations over approximately 2.476ha exceeds the minimum recommended by EPA (1995) "Sampling Design Guidelines" (35). If the locations were evenly spaced (not the case), this coverage would provide a 95% confidence of detecting a residual hot spot of approximately 17.5m diameter. As noted above, there is a higher density of sampling in the souther portion of the site, within the declared area. 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 8.3.7. **Groundwater:** A total of 26 onsite and 34 relevant offsite groundwater wells have been installed. Wells were sampled for all potential contaminants of concern, between one and five times. The groundwater well locations and analytical sampling density are considered adequate to allow for remediation planning.
Sample depths	Soil sampling focussed primarily on fill materials within the declaration area. 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 3-4m) were assessed by coring however, no samples were collected, 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 between 2-5 samples were analysed per location from the first three investigation stages (ERM 2007 and 2008a and AECOM 2010b). During the AECOM (2012a) investigations soil samples were analysed at a rate of between 3-7 samples per borehole. With the exception of the cored boreholes, the 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	All wells were constructed from 50mm uPVC casing with 0.4-0.5mm machine slotted screen, graded sand filter pack and bentonite seal. The screened intervals for each well is summarised in Table 9.1 (see Section 9). Most of the wells were screened over discrete lithological units – the exceptions being some ERM wells (MW209, MW198), AECOM wells (MW45, MW61, MW64, MW68) and Coffey wells

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor's Summary and Comments**
	(MW3, MW6). The wells screen a range of upper, mid and lower fill units and underlying natural marine sediments and sandstone. The screened intervals ranged in length from 1m up to 15m, although in general the screened intervals were in the range of 3-5m or less. A number of multilevel nested groundwater wells were installed within Block 4 and downgradient. AECOM (2010a) noted that *"the water quality of the entire saturated column is required for dewatering treatment information"*. This approach to well construction is 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. Although some screened intervals were long and contaminant concentrations in discrete groundwater intervals may be higher than reported, overall, the groundwater well construction is considered to be adequate.
Sample Collection Method	**Soil**: Soil samples were obtained from push tube samplers and 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. This allows for good observation of sampled material, although only within the undisturbed sampling intervals. **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. Coffey wells were developed using a disposable bailer to remove at least six well volumes until no turbidity was observed. Wells were purged using a low flow peristaltic pump and sampled using a bailer fitted with a low flow VOC tip. AECOM wells were developed using both dedicated Teflon foot valves with 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 3-6L. Samples collected for metals analysis were field filtered using a 0.45µm filter. Overall the sample collection methods were acceptable.
Decontamination Procedures	ERM stated that all non-disposable soil, groundwater and down-hole sampling equipment was decontaminated prior to the commencement of drilling and between drilling locations. Coffey reported decontamination of drilling augers between sampling locations using water and Decon 90 solution. Water samples were collected using dedicated disposable bailers. New gloves were reportedly used for each new sample.

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor's Summary and Comments**
	AECOM reported that decontamination procedures were performed before initial use of re-useable equipment and after each subsequent use. All 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. Drilling equipment which came into contact with tar was set aside and cleaned offsite using a high pressure steam cleaner. New gloves were reportedly used for each new sample. ERM, Coffey 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 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	ERM and Coffey reported that all 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) noted that 15 of 40 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. A review of laboratory information indicated no material breaches of sample handling requirements.
Chain of Custody	ERM, Coffey and AECOM included completed chain of custody forms and reported that these were all complete and acceptable. 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 all samples were received in good order, chilled and were presented in adequate samples containers.
Detailed description of field screening protocols	ERM, Coffey and AECOM reported that for each sample depth, additional soil was placed in a sealed plastic bag and PID measurements were taken using a calibrated PID. ERM, Coffey and AECOM 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. Coffey stated that field screening equipment was calibrated at the start of each day. Records of daily PID calibrations using isobutylene gas were provided in the report, although no details of calibration of the water quality meter was provided.

Table 6.1: QA/QC – Sampling and Analysis Methodology Assessment	
Sampling and Analysis Plan and Sampling Methodology	**Auditor's Summary and Comments**
	AECOM reported that the PID was calibrated with isobutylene gas at 100ppm 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. Overall the calibration of field equipment was acceptable, noting that the absence of calibration records for the Coffey water quality meter is not material to the outcome of the audit.
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. A separate sample register documenting PID readings was provided by Coffey. Groundwater field sampling records were provided and included observations regarding potential for contamination such as odours or sheens, although sampling records for a limited number of wells/ sampling rounds could not be located by the Auditor during the course of this review. This is not considered to affect the outcome of the audit.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
Field quality control samples	ERM (2007 & 2008a): Field quality control samples undertaken by ERM included trip blanks, trip spikes, rinsate blanks, field intra-laboratory and inter-laboratory replicates at appropriate frequencies. Coffey (2008): Field quality control samples undertaken by Coffey included trip blanks, trip spikes, field intra-laboratory and inter-laboratory replicates at appropriate frequencies. Rinsate blanks were not collected as sampling equipment was disposable. AECOM (2010b & 2012a) for soil and groundwater sampling: field quality control samples included inter-laboratory and intra-laboratory duplicates, trip blanks and rinsate blanks which were undertaken at appropriate frequencies. In addition during the AECOM (2012a) investigation, for groundwater sampling, trip spikes were included at appropriate frequencies. The field quality control samples are considered acceptable.
Field quality control results	ERM, Coffey and AECOM provided detailed data quality assessments in the respective reports. ERM reported minor QA/QC non-conformances, with 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

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
	there was insufficient sample for moisture determination. Coffey: the results from the field quality control samples were generally within appropriate limits, noting: a few minor exceptions in the soil RPDs (metals and TPH/BTEX/PAH) attributable to heterogeneity in the fill material and one RPD exceedance was reported in groundwater (copper, TPH/BTEX/PAHs). Coffey reported that copper was detected at a concentration very close to the LOR and the variability in organic compounds was attributable to the presence of free phase in the well. Coffey noted that the highest concentrations in each case had been used in the assessment. AECOM (2010b): The results from the field quality control samples were generally within appropriate limits, noting some exceptions (listed in the AECOM report) relating to variability of metal concentrations. In addition elevated RPDs were also noted for TPH, PAH and BTEX in a few of the very highly impacted samples, corresponding to significantly impacted areas. AECOM (2012a): The results from the field quality control samples were generally within appropriate limits, noting some exceedances in soil primarily due to heterogeneity in fill material and in groundwater due to low reported primary sample concentrations (which can cause large exaggerations of the RPD). The ERM, Coffey and AECOM rinsate sampling was acceptable with the exception of the AECOM (2012b) investigation in which some minor TPH detects were noted in two of the 12 rinsate samples collected during the soil sampling and minor zinc detections in the rinsate samples analysed during groundwater sampling (from submersible pump). Detections were low and are not indicative of significant cross contamination issues. Overall these findings do not affect the outcome of the audit. Overall, the QC results do not indicate any systematic field or laboratory error, and considering that the results from the investigations have been viewed in a multiple lines of evidence approach taking into account visual and olfactory observations, the QC results are acceptable.
NATA registered laboratory and NATA endorsed methods	Laboratories used by ERM were: ALS and LabMark. It is noted that the appendix containing laboratory certificates for ERM (2007) was not provided to the Auditor (although this report is only relevant to one monitoring well). Detailed laboratory quality control reports were provided. Laboratories used by Coffey were: ALS and SGS. Asbestos analysis was subcontracted to Australian Safer Environment & Technology (ASET). Laboratories used by AECOM included: ALS and MGT Labmark for soil and groundwater, SGS for soil vapour and ASET for asbestos. All laboratory certificates inspected were NATA stamped.

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
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 in the certificates for TPH, VOCs and SVOCs, the exact methods used have not been detailed.
Holding times	ERM (2007 & 2008a): ERM reported that holding times had been met. However the Auditor's review of the COCs and laboratory certificates indicate several minor breaches of holding time relating to intra-laboratory soil duplicates analysed at Labmark for PAH and OC/OPs and moisture content (primary soil samples). A review of the information indicates that none of these samples are relevant to the current audit area. Coffey (2008): Coffey reported that holding times had been met. A review of a selection of laboratory reports confirms this. AECOM (2010b): 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 (2012a): 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 HHRA. 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)	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 spike, 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. SGS reports laboratory control samples, method blanks, surrogates and spikes with the results.
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

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
	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. Coffey (2008) assessed the laboratory quality control results and reported that all surrogate and matrix spike recoveries were within the control limits and all method blanks were reported <PQL. The auditor has completed a review of a selection of the laboratory reports and this is consistent with the Coffey conclusions. AECOM (2010b) assessed the laboratory quality control results and listed instances where results were outside acceptance limits as discussed below: – poor laboratory duplicate results in 13 instances and the Auditor has estimated that this represents less than 10% of analyses for laboratory duplicates. 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. – Of the 93 LCS soil samples, six were outside the laboratory's Analyte Specific Acceptance Criteria (ASAC) or outside AECOM's acceptance criteria of 70 – 130% for different analytes. 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 samples: nine of 83 soil samples and three of 78 water samples had results outside acceptance criteria. 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 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 both instances there were several other surrogates with results within the acceptable ranges, and the results are not considered to affect

Table 6.2: QA/QC – Field and Lab Quality Assurance and Quality Control	
Field and Lab QA/QC	**Auditor's Summary and Comments**
	the useability of the data. AECOM (2012a) 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. – water samples 2 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.
Data Quality Objectives and Data Evaluation (completeness, comparability, representativeness, precision, accuracy)	The ERM reports include data quality objectives. They also include detailed review of data and conclude that the data comply with the ERM quality protocols. Coffey set data quality objectives for the investigation and conducted a data quality assessment. Coffey concluded that the data was considered to be complete, comparable, representative, precise and accurate for the objectives of the assessment. AECOM (2010b and 2012a) set data quality objectives for each report and outlined data quality indicators across the five category areas. In both reports, AECOM concluded that the DQI's for the data were achieved and found the data *"...to be reliable and representative of concentrations of the compounds analysed at the locations sampled."*

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

- Investigation locations and sample depths are considered to be adequately 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 the major issues affecting remediation would have been identified by the investigations conducted. Overall, the investigations undertaken are considered to be adequate for definition of the remediation extent. Observations of gasworks impact as well and soil and groundwater analytical results

have been considered. Due to the limited investigation coverage in some areas, particularly for groundwater, and the restriction of detailed observations to sampled intervals, the summary results presented by AECOM cannot be considered to document all of the occurrences of significant gasworks impact. However, 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.

- 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. 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, and are discussed in Section 10 of this SAR.

7.1 Soil

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

There were no national or EPA approved guidelines for asbestos in soil relating to human health at the time the investigations were performed. DEC (2006) state that Auditors must exercise their professional judgement when assessing whether a site is suitable for a specific use. The DEC states that the position of the Health Department is that there should be no asbestos in surface soil. The recently amended NEPM (1999 [2013]) includes criteria for asbestos however the data obtained during the site investigations is not suitable for comparison with these criteria.

AECOM state the following in the Supplementary DGI report (2011b) with respect to asbestos criteria "For the purposes of this investigation it is important to determine the presence, nature and extent of asbestos. If asbestos is found to be present, a management approach for the affected soils may be developed".

AECOM (2013c) has referred to the Driscoll Report (2013) which recommends asbestos criteria to be applied to soils on the Barangaroo site as may be potentially accessible during construction phases of works. These criteria are considered for the protection of workers during remediation but are not relevant to the final suitability of the site.

7.1.2 Acid Sulfate Soils

AECOM (2011b) considered the NSW Acid Sulfate Soil manual (ASSMAC, 1998) for the assessment and management of Acid Sulfate Soils (ASS).

7.2 Groundwater

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. Trigger values (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. The referenced criteria are listed in Appendix B.

There are no reliable Australian criteria for TPH in groundwater. The current EPA position is that there should be no free phase product in groundwater, and that the aromatic components of dissolved-phase TPH in groundwater should be assessed using the ANZECC (2000) TVs where available. These guidelines include criteria for some BTEX compounds and for some PAHs.

These are generally the same criteria AECOM has referenced as marine water quality criteria (MWQC) when considering protection of the environment and groundwater remediation goals (see Section 10). The selected MWQC, included in Appendix E, were reviewed by the EPA and the Auditor's specialist support (EnRisks) and were considered to be reasonable.

8 Evaluation of Soil Analytical Results Against Screening Criteria

8.1 Introduction

Soil conditions have been investigated by over 113 boreholes advanced by ERM (2007 and 2008a), Coffey (2008) and AECOM (2010b, 2012a and 2012e). Soil sampling locations are shown on Attachment 8, Appendix A.

The following sections discuss the field and laboratory results for fill, natural soil and bedrock investigations. Analytical results are considered separately for the declaration area and Block 4. Field observations are also considered for offsite areas, in particular located downgradient of the site, in order to consider the extent of offsite impact from the gasworks.

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 2000mg/kg for total PAH and 150mg/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 has considered these gasworks-related impacts in determining the extent of offsite remediation required for VMP removal, discussed in Section 11.

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, ash and slag. Odours were variably described as hydrogen sulphide, tar, gaseous, chemical, naphthalene and hydrocarbon (AECOM, 2011b and 2012a). The distribution of SPGWT and sheen on the site and downgradient of the site is presented in Attachment 9, Appendix A. SPGWT was generally identified in proximity to and downgradient (west) of former gasworks infrastructure which is concentrated in the east of the site. The bedrock is shallow in this area, and SPGWT generally occurs within 4mBGL.

Offsite gasworks related impacts in fill material and marine sediments are presented in Attachments 10a and 10b, Appendix A, respectively. In offsite areas and in the west of the site where the bedrock is deeper, visual and olfactory indicators were more common in natural soils at depths of 14 to 20mBGL. Tar was generally absent from overlying fill material, with the exception of two boreholes (BH70 and BH74, Barangaroo Central) where TCM was present in shallow fill material (1-2.5mBGL). The shallow occurrence is probably

due to filling while the impact within deep fill/ marine sediments is likely due to subsurface migration down the sloping bedrock.

Some of the investigations at the site intersected historic below-ground gasworks infrastructure and encountered tar material. The depth that this infrastructure was cut into bedrock was identified from these investigations as follows:

- 1870 gasholder annulus, located in eastern portion of Block 4, crossing into western portion of Hickson Road: 9.7mBGL (Coffey BH10)
- Tar tank, located in eastern portion of Hickson Road, portion crossing into 36 Hickson Road: 5.4mBGL (Coffey BH07).

Elevated PID readings were associated with the strongest observations, which primarily occurred in areas of former gasworks infrastructure. Maximum vapour concentrations in the order of 1000-2000ppm were recorded in fill and natural soil in the centre, east and west of the site. These areas correlate with areas where SPGWT was observed in soils. Coffey recorded PID readings of up to 4700ppm associated with tar material observed within the 1870 gasholder. It is noted that observations of staining or odours often did not correlate with significantly elevated PID readings.

Field observations with respect to asbestos are discussed in Section 8.3.6, 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 and 2012a) 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 observed in the top of sandstone in ten locations in the southern part of the declaration area and in two locations near the northern site boundary (AECOM BH66 and BH69). Odours generally extended less than 1m into bedrock, with the exception of BH205 which extended 9m. The vertical extent of odours was often not delineated due to limitations of the drilling technique employed by AECOM.

Black staining was observed in bedrock at AECOM locations BH44 (4.5-5.5mBGL) and BH45 (12.15-12.2mBGL) in the south of the declaration area and in BH403 (17.0-17.3mBGL) outside the downgradient boundary.

Bedrock conditions were visually assessed in around fifty locations from across the site. AECOM (2013b) 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 (2013b) 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. Modelling of contaminant flux in sandstone, discussed in Section 11.5, has assumed a maximum 5m thickness of impact into sandstone which is considered acceptable based on the available field data.

8.3 Soil Analytical Results

8.3.1 Introduction

The analytical results from the declaration area and Block 4 have been assessed against screening criteria (Table 7.1) to identify trends in contaminant occurrence. Assessment of the results against risk based remediation criteria is discussed in Sections 11 and 12. The following sections present a summary of the soil analyses performed, followed by a discussion of the results according to contaminant type.

8.3.2 Declaration Area

The following summaries present the results of soil samples from the declaration area that were analysed for contaminants listed in the VMP, including TPH, BTEX, PAHs, ammonia, phenol and cyanide. The results for samples of fill and natural material from the declaration area are summarised in Tables 8.1 and 8.2, respectively. Tables 8.1 and 8.2 exclude duplicate analyses.

Table 8.1: Declaration Area - Fill Material, Evaluation of Analytical Results Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
TPH (C_6-C_9)	184	47	7,890	25	-
TPH (C_{10}-C_{36})	184	109	181,800	63	-
Benzene	177	41	2,080	29	-
Toluene	177	38	2,650	5	-
Ethylbenzene	177	31	261	6	-
Xylene	177	40	2,576	22	-
Total PAHs	179	128	30,782	102	102
Benzo(a)pyrene	179	119	677	108	108
Naphthalene	179	92	10,200	-	-
Ammonia	1	0	<PQL	-	-
Free Cyanide	8	0	<PQL	0	0
Total Cyanide	54	13	76	-	-
Phenol	99	24	4,170	0	0

n number of samples

- No criteria available/used

Table 8.2: Declaration Area - Natural Material, Evaluation of Analytical Results Summary Table (mg/kg)

Analyte	n	Detections	Maximum	n > Screening Criteria	n > SIL Column 1 (DEC 2006)
TPH (C_6-C_9)	58	19	1,050	11	-
TPH (C_{10}-C_{36})	58	22	9,940	15	-
Benzene	56	25	140	19	-
Toluene	56	20	232	2	-
Ethylbenzene	56	22	44.7	0	-
Xylene	56	27	345	12	-
Total PAHs	55	43	3,296.3	26	26
Benzo(a)pyrene	55	33	130	25	25
Naphthalene	55	38	1,040	-	-
Ammonia	1	0	<PQL	-	-
Free Cyanide	8	0	<PQL	0	0
Total Cyanide	32	10	249	-	-
Phenol	46	2	10	0	0

n number of samples

- No criteria available/used

8.3.3 Block 4

Soil samples from Block 4 were analysed for a variety of contaminants including petroleum hydrocarbons, PAHs, phenols, asbestos, heavy metals, inorganics (cyanide and sulphate), PCB, pesticides, SVOCs and VOCs. More specialised analyses were also performed to determine Acid Sulphate Soils (ASS) and leaching potential. The following Table 8.3 summarises the analytical program undertaken for Block 4. Table 8.3 excludes duplicate analyses.

Table 8.3: Block 4, Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
Arsenic	222	41	38
Barium	82	70	510
Beryllium	82	3	1
Cadmium	222	3	2
Total Chromium [1]	222	219	210
Cobalt	82	44	39

Table 8.3: Block 4, Summary of Soil Analytical Program and Maximum Concentrations Detected

Analyte	Number of Analyses	Number of Detections	Maximum (mg/kg)
Copper	222	139	402
Iron	31	31	118,000
Lead	222	204	12,100
Manganese	82	68	852
Mercury	222	69	5.2
Nickel	222	159	160
Vanadium	82	82	127
Zinc	222	178	906
Phenols	109	18	1,720
Total PAHs	195	134	20,934
Benzo(a)pyrene	195	111	652
Naphthalene	195	98	8,410
OCP/ OPP	18	2 [2]	4.2
PCB	60	1	0.43
Other SVOCs	16	10 [3]	327
TPH (C_6-C_9)	197	52	1,140
TPH (C_{10}-C_{36})	197	75	147,200
Benzene	194	59	140
Toluene	194	52	232
Ethylbenzene	194	45	88.3
Total Xylene	194	55	345
Other VOCs	16	12 [4]	92.9
Free cyanide	20	0	<PQL
Total cyanide	109	29	575
sPOCAS	1	0	-
Asbestos	14	2	-
Ammonia	2	0	<PQL
Sulphate	88	83	30,600

- not applicable

PQL practical quantitation limit

1 Chromium (VI) was analysed for in 29 samples from the site, all results were <PQL. Based on site history and the Chromium (VI) results, Total Chromium detections are expected to comprise Chromium (III).

2 OCP detected was Endosulfan sulphate, OPP detected was Pirmphos-ethyl

3 Other SVOCs detected mostly comprised carbazole and dibenzofuran, with some detections of 1-naphthylamine, 2-picoline, 3,3-dichlorobenzidine, 4-(dimethylamino)azobenzene, 4-aminobiphenyl and azobenzene

4 Other VOCs detected comprised trimethylbenzenes, styrene, n-propylbenzene and isopropylbenzene

8.3.4 Heavy End TPH and PAH

The primary contaminants detected at the site were heavy end TPH in the C_{10}-C_{36} range and a suite of PAH associated with coal tars and other gasworks wastes.

The maximum concentrations in soil were generally located in proximity to and down gradient of the former gasworks infrastructure in Block 4 and Hickson Road. Free tar was identified within Hickson Road and Block 4 in the vicinity of the tar tank, purifying beds and 1870 gasholder indicating these locations are the main areas of contamination.

Approximately 30% of samples from Block 4 and 50% of samples from the declaration area contained TPH in the C_{10}-C_{36} range. The maximum TPH C_{10}-C_{36} concentrations were detected in fill material from Hickson Road and the eastern portion of Block 4. Significantly elevated TPH concentrations were also detected at depth in natural material in the west of the site and offsite to the west.

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). The distribution of significantly elevated PAH concentrations was therefore found to correspond well with elevated heavy end TPH concentrations and observations of SPGWT. The maximum total PAH concentration detected was 29,653mg/kg in MW10 in Hickson Road.

The highest PAH concentration detected was naphthalene (see Section 8.3.5). The next highest PAH concentrations detected were generally pyrene, fluoranthene and phenanthrene, which contributed approximately 30% of the total PAH concentration. Significant contributions from four more PAHs were also made, with individual concentrations of approximately 5% of the total PAH concentration (benz(a)anthracene, fluorene, anthracene and acenaphthylene).

The proportion of the total PAH concentration contributed to by BaP, a known carcinogen, was generally between 1 and 10%, with a maximum BaP concentration detected at the site of 677 mg/kg.

PAHs can be naturally occurring at low concentrations, but the majority of detections indicate some contaminant impact. PAHs are contaminants associated with gasworks wastes and ash from industrial processes. The dominance of naphthalene confirms the primary impact is by coal tar.

8.3.5 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.

Where light end detections occurred, observations of SPGWT and higher concentrations of TPH C_{10}-C_{28} (and less commonly to C_{36}) and the PAHs naphthalene, acenaphthylene and

phenanthrene were also commonly present. Naphthalene contributed approximately 35% to 45% of total PAHs.

Detections of this nature were made in 23 investigation locations at the site, occurring in between 1 and 3 samples per location. The detections primarily occurred in the south of the declaration area, at locations where SPGWT was observed.

8.3.6 Heavy Metals

Soil samples were analysed for a suite of between 8 and 14 heavy metals (refer Table 8.3). The only heavy metal which was observed to regularly exceed screening criteria was lead.

The majority of the lead concentrations did not significantly exceed the criteria, with only one sample (12,100 mg/kg in BH132 at 1.5-1.95mBGL) greater than the 1,200mg/kg criteria for residential with minimal soil access.

In order to identify trends in occurrence, lead detections exceeding the Auditor's screening criteria were reviewed to determine if they occurred with or without TPH impacts, defined as TPH detections (any concentration). The majority of exceedances (70%) occur with TPH impact, although the TPH concentrations were not always significantly elevated (half the TPH concentrations were <1000mg/kg). Overall, lead exceedances appear to be associated with fill material and not related to gasworks impact.

8.3.7 Asbestos

Limited asbestos analyses were performed during investigations of the site. Fourteen samples were analysed for asbestos, and two detections were made. One sample collected from fill material in the declaration area (BH48 at 11.5-11.7mBGL) identified unknown mineral fibre (UMF), and one sample from offsite (BH401) identified asbestos (fibre bundle). Of the two detections made, a very small fibre bundle was detected in fill from BH405 at 12-12.2mBGL. The laboratory did not indicate if the asbestos detection in fill from BH203 at 1.5mBGL was in bonded or fibre form. Samples in which the asbestos detections were made comprised fill material. Anthropogenic materials, such as brick, concrete and plastic, were observed in the fill material however no fragments of suspected asbestos containing material (ACM) were observed in any samples.

AECOM (2010b) concluded "*asbestos containing materials are not considered to be widespread within fill materials at the site*".

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, including the findings from geotechnical and archaeological investigations and waste/ spoil characterisation activities carried out at the ORWS site as part of the Stage 1a basement development. These activities have identified quantities of ACM, although no airborne

asbestos fibres were identified in air quality monitoring undertaken. AECOM consider the fill materials at the adjoining ORWS site to be generally representative of fill materials within the site, and therefore conclude in the RAP that *"…it is probable that asbestos will be present within fill at 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 Sections 10.4 and 13.

8.3.8 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, 2010b). 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.
- Eighty eight samples were analysed for sulphate, with a maximum concentration of 30,600mg/kg. Detections at this concentration are not of concern for human health or the environment, but present a potential risk to concrete structures.
- Only two samples were analysed for ammonia, which were less than the PQL. Ammonia is a potential contaminant related to gasworks waste (Section 4).
- Toxicity Characteristics Leaching Procedure (TCLP) and Australian Standard Leaching Procedure (ASLP) deionised water leachability tests were performed for selected heavy metals, BTEX, PAHs, phenols and ammonia on soil samples collected during the Supplementary DGI (AECOM, 2012a). Elevated TPH, PAH and phenol concentrations were found in samples where borehole logs noted SPGWT and elevated concentrations in soil samples.

8.4 Conclusion

The soil observations and analytical results indicate widespread impact from the former gasworks, including by SPGWT, heavy end TPH, PAH, BTEX and lead.

Observations and detections were present in fill and underlying natural materials in the vicinity of former gasworks infrastructure, however the frequency and concentrations appeared to be higher in fill material. Downgradient of the former gas works contamination was more prevalent in natural soils at depth supporting the migration of contamination from the former gasworks on the natural ground surface, at the base of fill. Tar was generally absent from overlying fill material in these areas, however where identified it was limited in extent. Bedrock from the site has not been sampled extensively; however, visual observations have indicated contaminant impacts to be restricted to the upper weathered sandstone bedrock.

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 based on risk based remediation criteria, and is discussed in Sections 10 to 13.

9 Evaluation of Groundwater Analytical Results Against Screening Criteria

9.1 Introduction

Groundwater conditions at the site have been assessed in multiple stages of investigation by ERM, Coffey and AECOM, with locations shown on Attachment 8, Appendix A. Monitoring wells have been installed onsite as follows:

- ERM (2007 & 2008) – BH087/MW15, MW198, MW200, MW204D, MW204S, MW205, MW206, MW209, MW210.
- Coffey (2008) (Hickson Road) – MW3, MW6, MW7, MW10, MW15
- AECOM (2010) – Data Gap Investigation MW45, MW52-MW54, MW58, MW61, MW62, MW64, MW68
- AECOM (2010) – Groundwater Discharge Study IT3.

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 Coffey wells have been sampled once (March 2008) and the AECOM wells have generally been sampled once (March 2010), noting that MW62 and MW68 were sampled again in February 2011 with the first time sampling of IT3 (Groundwater Discharge Study).

9.2 Overview of Groundwater Monitoring

Table 9.1 following provides a summary of the wells installed at 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 a description of the lithology screened.

In addition to onsite wells, a number of offsite monitoring wells to the west (Barangaroo Central and ORWN RAP Area) and north (Block 5) have also been considered by the Auditor and details are included in Table 9.1. These include a number of monitoring wells installed on the Barangaroo Central site by JBS in 2012.

Due to the duplication of well numbers, the Auditor has prefaced the well numbers with ‘E’, ‘C’, ‘A’ or ‘J’ based on who they were installed by (ERM, Coffey, AECOM or JBS respectively).

9.3 Groundwater Analytical Results

The groundwater analytical results are summarised following in Tables 9.2-9.4. Tables 9.2 and 9.3 relate to results from wells located in the declaration area (screened within the fill and natural material respectively). Table 9.4 provides a summary of analytical results from monitoring wells located only on Block 4 (noting some overlap and duplication of results as part of Block 4 is also located within the declaration area).

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
Part Block 4[1] (within declaration area)							
EBH087 / MW15	2006	1.5-7.5	Full extent of fill	Strong hydrocarbon odour observed in full extent of fill 0-7.5m	5	Slight to moderate tar odour and sheen. DNAPL observed in well (AECOM, 2010b)	Significant TPH, BTEX and naphthalene
EBH204D / MW204D	2008	1.0-4.0	Full extent of fill	Some tar observed at 2-4m. Hydrocarbon odour increasing with depth.	1	DNAPL observed in well (AECOM, 2010b)	Significant TPH, BTEX and naphthalene. Not sampled during AECOM (2010b) due to DNAPL
EBH209 / EMW209	2008	1.8-8.7	Base fill, clayey sand and SST[2] bedrock	Strong hydrocarbon odour, staining and sheen throughout clayey sand unit. Slight hydrocarbon odour in SST.	3	Tar odour Sheen observed during sampling	Minor TPH/BTEX and naphthalene (below screening criteria)
ABH45 / MW45	2010	1.5-12.8	Fill, natural clayey sand and SST	FILL – slight to moderate HC/tar odour SST - Vein of tar at 12.2mbgl, slight tar and gaseous odour.	1	No odour or sheen reported	No organic detections
ABH52 / MW52	2010	1.5-4.9	Full extent of fill	Slight to moderate gaseous/tar odour and black staining.	1	Slight tar odour	No TPH/BTEX detected. Very minor naphthalene.
ABH58 / MW58	2010	10.2-11.2	Base of fill unit	Slight gaseous/tar odour.	1	H_2S odour	No organic detections
ABH405 / IT03 (shallow)	2012	2.5-3.5	Upper fill unit	None	1	Details not reported	Minor TPH. No BTEX or naphthalene detected.

[1] No monitoring wells installed in the Block 4 area located outside the declaration area.
[2] SST = sandstone.

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
ABH405 / IT03 (mid)	2012	7.9-8.9	Mid to lower fill unit	None	1	Details not reported	No organic detections
EBH200 / MW200	2008	4.4-7.4	Natural SST bedrock (no fill)	None in SST. Hydrocarbon odours and black staining in fill unit above.	3	Tar odour, slight sheen	Significant TPH, BTEX and naphthalene
EBH205 / MW205	2008	15-19.5	Natural SST bedrock (no fill)	Strong hydrocarbon odour noted in SST above screened section. Slight hydrocarbon odour 14-20m.	2	DNAPL observed in well (AECOM, 2010b)	Significant TPH and naphthalene. No BTEX data provided. NAPL sampled during AECOM DGI (2010b)
EBH204S / MW204S	2008	2.8-4.5	Natural SST bedrock (no fill)	None	2	Slight/moderate tar odour, slight sheen.	TPH, BTEX and naphthalene detected (below screening criteria)
EBH210 / EMW210	2008	14.8-17.7	Natural SST bedrock (no fill)	None	3	Tar odour	TPH/BTEX and naphthalene in 2010. Only minor TPH detected in 2010/2011
EBH206 / MW206	2008	7.0-8.0	Clayey Sand (below fill)	Sulphurous odour if fill unit above. Slight hydrocarbon odour and dark brown staining in clayey sand.	2	DNAPL observed in well (AECOM, 2010b)	Significant TPH, BTEX and naphthalene. NAPL sampled during AECOM DGI (2010b)
ABH54 / MW54	2010	1.9-2.8	SAND – marine sediments?	Slight to moderate tar odour. Minor black staining.	1	Tar odour. No sheen	Significant TPH, BTEX and naphthalene.
ABH405 / IT03 (deep)	2012	13.5-14.5	SAND and silty sandy CLAY (no fill)	Strong HC odour	1	Tar/hydrocarbon odour Sheen observed during sampling	TPH, BTEX and naphthalene detected (below screening criteria)

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
Part Block 5 (within declaration area)							
EBH198 / MW198	2008	1.6-6.8	Lower fill unit and underlying natural clayey sand.	Strong hydrocarbon odour and black staining at base of fill. Slight solvent/hydrocarbon odour in natural clayey sand at 6.8mbgl.	3	Tar odour Sheen observed during sampling	TPH/BTEX and naphthalene in 2008 Minor TPH in 2010/2011.
ABH62 / MW62	2010	1.5-5.5	Upper fill unit (fill logged to 12m)	Slight/moderate tar/gaseous odour and black staining.	2	H_2S odour	Very minor TPH detected. No BTEX/naphthalene.
ABH64 / MW64	2010	1.5-10	Fill and clayey sand	Strong gaseous odour 1.5-6mbgl.	1	H_2S and tar odour	Very minor TPH/BTEX and naphthalene.
ABH68 / MW68	2010	1.5-7.5	Fill and natural silty/clayey SAND	Slight tar odour at 0.9mbgl.	2	H_2S odour	No organic detections
Part Hickson Road (within declaration area)							
CBH7 / MW7	2008	1.0-5.4	Full extent of fill	Fill heavily coated in oil, hydrocarbon sheen and strong hydrocarbon odours.	1	DNAPL observed in well	Significant TPH/BTEX, naphthalene and ammonia. Not sampled during AECOM DGI (2010b)
CBH10 / MW10	2008	2.0-9.4	Full extent of fill	Hydrocarbon odour and sheen at 4.5mbgl. Very strong tar odour and DNAPL observed at base of fill (9mbgl).	1	DNAPL observed in well	Significant TPH/BTEX, naphthalene and ammonia Not sampled during AECOM DGI (2010b)
ABH53 / MW53	2010	1.0-5.4	Full extent of fill	Sheen and odour increasing from 2mbgl. Contains tar from 5mbgl with very strong tar odour and black staining.	-	LNAPL and DNAPL observed in well	Not sampled – DNAPL present
CBH3 / MW3	2008	1.0-3.1	Middle and lower fill and underlying natural clayey sand.	Strong hydrocarbon odour in fill. Hydrocarbon staining in clayey sand.	1	H_2S odour	Minor TPH/BTEX and naphthalene.

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
CBH6 / MW6	2008	1.0-4.7	Middle and lower fill and underlying weathered SST.	Black staining and strong hydrocarbon odour at base of fill unit.	1	sheen	No organic detections
ABH61 / MW61	2010	0.9-3.3	Fill and natural clayey SAND	Slight tar odour. Vein of tar and black staining at 3mbgl.	1	Tar odour, slight sheen	TPH/BTEX and naphthalene.
CMW15	2008	2.4-12	Natural SST bedrock (no fill)	None	1	Strong odour and sheen. DNAPL observed in well.	Significant TPH/BTEX and naphthalene. Not sampled during AECOM DGI (2010b)
Offsite (Part Block 5)							
ABH69 / MW69	2010	9.0-12.0	SAND (fill) and weathered SST	Naphthalene/HC odour noted in fill unit above (not screened). HC odour and sheen observed on water at 10mbgl (SST).	2	Strong tar/hydrocarbon odour and sheen	TPH, BTEX, naphthalene and ammonia
ABH401/MW401	2011	14.5-20.0	Clayey SAND and sandy CLAY (no fill)	Tar veins and odour from 17mbgl.	2	*	Naphthalene and minor TPH, BTEX
JMW518	2012	3.0-6.0	Mid to lower fill (base of fill at 6.5mbgl)	Inclusions of building rubble	1	Sulphur odour	No organic detections. TPH not analysed.
JBH539 / MW539	2012	3.0-6.0	Mid fill (base of fill 14mbgl)	Tile and brick inclusions	1	Hydrocarbon/sulphur odour	Minor naphthalene and BTEX. TPH not analysed.
JBH540D / MW540D	2012	10.6-13.6	Lower fill (base of fill 14mbgl)	None	1	None	BTEX and minor naphthalene. TPH not analysed.
JBH541 / MW541S	2012	3.0-6.0	Mid fill (base of fill 10.4mbgl)	Wood tile and brick inclusions.	1	Slight hydrocarbon odour	Minor naphthalene and ammonia. TPH not analysed.
JBH541 /	2012	7.4-10.4	Lower fill (base of fill	Slight hydrocarbon odour at 7mbgl	1	Slight organic odour	Significant naphthalene and

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
MW541D			10.4mbgl)	(SWL). Strong H_2S odour at base.			benzene. TPH not analysed
JBH542 / MW542	2012	2.5-5.5	Upper fill (base of fill at 14.5m)	None	1	Sulphur odour	Minor naphthalene and trace benzene
Offsite (Barangaroo Central)							
EBH046 / MW08	2007	2.8-5.8	Full extent of fill	None	3	*	TPH and naphthalene
EBH129 / MW24	2007	2.3-6.9	Full extent of fill	None	3	*	Minor naphthalene
EBH213 / MW213	2008	1.3-16.8	Full extent of fill (fill logged to 17.2mbgl)	None	1	*	No organic detections
ABH74 / MW74	2010	1.5-13.5	Full extent of fill	Tar, black staining and odour noted at 1-2mbgl. Slight odour 8.5-14mbgl.		H_2S odour	Minor TPH, PAH/naphthalene
JMW529D	2012	10.5-13.5	Mid to lower fill (base of fill at 15.5mbgl)	None	1	Slight organic odour	No organic detections TPH not analysed
EBH057 / MW12	2008	2.0-9.0	Upper to mid fill (base of fill 16mbgl)	None	3	*	No organic detections
JMW543	2012	3.0-6.0	Upper fill (base of fill at 16m)	None	1	Slight organic odour	No organic detections TPH not analysed
JMW544S	2012	2.5-5.5	Upper fill (base of fill at 15.5m)	None	1	Strong organic odour	No organic detections TPH not analysed
JMW544D	2012	10-13	Mid to lower fill (base of fill at 15.5mbgl)	None	1	None	No organic detections TPH not analysed
Offsite (ORWN RAP Area)							
EBH53 / MW11	2006	3.0-9.0	Full extent of fill	Faint H_2S odour at 3m.	2	*	Very minor TPH and

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
							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 17.5mbgl)	Black staining and hydrocarbon odour 1.5-6.0mbgl. Some black staining noted on bricks 11-15mbgl.	2	*	No organic detections
ABH40 / MW40	2010	14.3-20.3	Gravelly clayey SAND (below fill)	Chemical odour from 16mbgl. Veins of tar noted at 16.5mbgl 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	Minor naphthalene and TPH
IT02 (deep)	2010	16.7-17.5	Silty sandy CLAY	None	1	Tar odour, very slight sheen	Minor naphthalene TPH and BTEX
ABH410 / IT04	2012	2-3	Upper fill unit	None	-	Not sampled	Not sampled

Table 9.1: Monitoring Well Summary

Well Number	Date Inst.	Screened Interval (mBGL)	Description of Lithology Screened	Log Indicators (mBGL)	n	Sampling Observations	Analytical Results
(shallow)							
ABH410 / IT04 (mid)	2012	16.5-17.5	Silty Clay	HC odour and minor black staining	1	*	Ammonia No other results reported
ABH410 / IT04 (deep)	2012	31.2-32.2	Clayey SAND	None	1	*	No ammonia detected. No other results reported
ABH411 / IT05 (shallow)	2012	2-3	Upper fill unit	None	-	Not sampled	Not sampled
ABH411 / IT05 (mid)	2012	13.5-14.5	Mid to lower fill unit	None	-	Not sampled	Not sampled
ABH411 / IT05 (deep)	2012	26-27	Clayey SAND (no fill)	None	-	Not sampled	Not sampled

Shading indicates wells screened within natural materials

n number samples

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

Table 9.2: Declaration Area – Fill Material, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Ammonia	11	8	348	None	CMW7 294µg/L CMW10 348µg/L remaining results range <PQL-27.4µg/L
Cyanide (Free)	16	4	7	2	AMW52, EMW15
Cyanide (WAD)	14	4	8	4	AMW52, AMW61, AMW62, EMW15
Cyanide (Total)	-	-	-	-	-
TPH (C_6-C_9)	27	14	46,200	-	Significant concentration detected in EMW15 (n=5) 10,100-46,200µg/L, EMW204D (n=1) 27,900µg/L, EMW209 (n=3) 100-8,150µg/L, CMW7 (n=1) 30,300µg/L, CMW10 (n=1) 9,690µg/L Minor concentrations detected in EMW198 (n=3) <PQL-190µg/L, AMW61 520µg/L
TPH (C_{10}-C_{36})	27	18	877,570	-	Significant concentration detected in EMW15 (n=5) 55,870-119,650µg/L, CMW7 (n=1) 877,570µg/L, CMW10 (n=1) 710,600µg/L, EMW204D (n=1) 507,640µg/L, EMW209 (n=3) 320-9,880µg/L, CMW3 (n=1) 5,940µg/L Moderate to minor concentrations AMW61 2,650µg/L, AMW62 (n=2) 390-1,460µg/L, AMW64 (n=1) 2,660µg/L, EMW198 (n=3) <PQL-1,820µg/L, AIT3S (n=1) 650µg/L
Benzene	27	15	25,200	10	EMW15, EMW204D, EMW209, CMW7, CMW10.
Toluene	27	13	6,440	9	EMW15, EMW204D, EMW209, CMW7, CMW10
Ethylbenzene	27	14	3,020	10	EMW15 (n=4) (max), EMW204D, EMW209 (n=2), CMW7, CMW10, AMW61.
m & p Xylene	27	15	4,490	4	EMW15 (max), EMW204D, EMW209, CMW7
o Xylene	27	15	2,210	3	EMW15 (max), EMW204D, CMW7
Benzo(a) Pyrene	27	16	709	14	AIT3S, EMW15 (n=5), EMW204D, EMW209 (n=2), AMW62, CMW3, CMW7, CMW10 (max), AMW61.
Naphthalene	27	19	21,700	12	EMW15 (n=5), EMW204D, EMW209 (n=2), CMW7, CMW10, CMW3, AMW61
Total PAH	27	23	34,451	-	No screening criteria but wells noted to exceed 100µg/L include EMW15 (n=5), EMW204D, EMW209, CMW7, CMW10, CMW3, AMW61
Phenols	23	8	249,000	4	EMW15, EMW204D, CMW7, CMW10 (max)

Table 9.3: Declaration Area – Natural Material, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Ammonia	10	9	87	None	AMW54 87µg/L remaining results range <PQL-23.3µg/L
Cyanide (Free)	7	2	11.5	2	EMW200, CMW15
Cyanide (WAD)	6	1	4	None	-
Cyanide (Total)	5	3	2,430	-	Detections in EMW200 (max), EMW205, CMW15
TPH (C_6-C_9)	14	13	73,600	-	NAPL sampled in EMW205 73,600µg/L (max) Significant concentration detected in CMW15, EMW200 (n=3) 22,400-37,600µg/L, EMW206 (n=2) 8,380-13,300µg/L Moderate to minor concentrations detected in AIT3D 2,120µg/L, EMW204S (n=2) 890-2,380µg/L, EMW210 (n=2) <PQL-2,650µg/L, AMW54 3,730µg/L
TPH (C_{10}-C_{36})	14	14	3,582,000	-	NAPL sampled in EMW205 (n=2) 80,980-3,582,000µg/L (max) EMW206 (n=2) 8,440-153,400µg/L Significant concentration detected in CMW15 1,453,000µg/L, EMW200 (N=3) 64,600-123,000µg/L, EMW204S (n=2) 11,200-27,450µg/L, EMW210 (n=3) 880-19,410µg/L, AMW54 39,300µg/L Moderate concentrations AIT3D 8,820µg/L
Benzene	14	14	40,200	10	AIT3D, EMW200 (n=3), EMW205, EMW206 (n=2), EMW210, AMW54, CMW15 (max)
Toluene	14	12	7,890	10	AIT3D, EMW200 (n=3), EMW204S, EMW205, EMW206, EMW210, AMW54, CMW15 (max)
Ethylbenzene	14	14	1,250	13	EMW200 (n=3), EMW204S, EMW205, EMW206 (n=2) (max), AMW54, CMW15 (<500µg/L)
m & p Xylene	14	13	3,140	11	AIT3D, EMW200 (n=3), EMW204S, EMW205 (max), EMW206 (n=2), EMW210, AMW54, CMW15
o Xylene	14	13	2,000	7	EMW200 (n=3), EMW205 (max), EMW206 (n=2), CMW15
Benzo(a) Pyrene	15	11[3]	9,260	11	AIT3D, EMW200 (n=3), EMW204S (n=2), EMW205 (n=2) (max), EMW206, EMW210, CMW15
Naphthalene	15	14	283,000	13	AIT3D, EMW200 (n=3), EMW204S (n=2), EMW205 (n=2) (max), EMW206 (n=2), EMW210, AMW54, CMW15

[3] Elevated PQLs reported for benzo(a)pyrene in EMW200, EMW204S and EMW205 and these wells have been counted as detections above screening criteria.

Table 9.3: Declaration Area – Natural Material, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Total PAH	15	15	530,568	-	No screening criteria but wells noted to exceed 100µg/L include AIT3D, EMW200 (n=3), EMW204S (n=2), EMW205 (n=2) (max), EMW206 (n=2), EMW210, AMW54, CMW15
Phenols	16	11	1,880	5	EMW200 (n=3) (max), EMW205, CMW15

Table 9.4: Block 4, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Arsenic	13	13	5.4	None	-
Barium	13	13	1,850	-	MW58 (max) remaining results range 43-293µg/L
Beryllium	13	3	0.2	-	Very minor detects in EMW209, AMW45
Cadmium	13	10	11.5	1	AMW45
Total Chromium	13	7	10.2	1	EMW209
Hexavalent chromium	9	3	19	2	AMW54, EMW209
Cobalt	13	13	8	7	EMW200 (n=2), EMW204S, EMW209, AMW45, AMW52, AMW54
Copper	13	2	5.2	1	EMW204S (n=2)
Lead	13	9	17.6	1	EMW209
Mercury (inorganic)	13	5	0.2	3	Minor exceedances in EMW15 & EMW200 (n=2)
Nickel	13	13	164	2	Minor exceedances in AMW54 & AMW58
Vanadium	13	11	22.8	None	-
Zinc	13	13	613	7	EMW204S (n=2), EMW209, EMW210, AMW52, AMW54, AMW58
ammonia	16	14	103	None	AMW52 103µg/L remaining results range <PQL-37.2µg/L
Cyanide (Free)	12	3	7	3	Minor exceedances in EMW15, EMW200, AMW52

Table 9.4: Block 4, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Cyanide (WAD)	12	3	11	2	Minor exceedances in EMW15, AMW52
Cyanide (Total)	-	-	-	-	-
TPH (C_6-C_9)	28	22	73,600	-	NAPL sampled in EMW205 73,600µg/L (max) & EMW206 (n=2) 8,380-13,300µg/L Significant concentration detected in EMW15 (n=5) 10,100-46,200µg/L, EMW200 (n=3) 22,400-37,600µg/L,EMW204D (n=1) 27,900µg/L, EMW209 (n=3) 100-8,150µg/L Moderate to minor concentrations detected in AIT3D 2,120µg/L, EMW204S (n=2) 890-2,380µg/L, EMW210 (n=2) <PQL-2,650µg/L, AMW54 3,730µg/L
TPH (C_{10}-C_{36})	28	24	3,582,000	-	NAPL sampled in EMW205 (n=2) 80,980-3,582,000µg/L (max) & EMW206 (n=2) 8,440-153,400µg/L Significant concentration detected in EMW15 (n=5) 55,870-119,650µg/L, EMW200 (N=3) 64,600-123,000µg/L, EMW204D 507,640µg/L, EMW204S (n=2) 11,200-27,450µg/L, EMW209 (n=3) 320-9,880µg/L, EMW210 (n=3) 880-19,410µg/L, AMW54 39,300µg/L Moderate to minor concentrations AIT3D 8,820µg/L, AIT3S (n=1) 650µg/L.
Benzene	27	22	27,800	17	AIT3D, EMW15 (n=5), EMW200 (N=3), EMW204D, EMW205 (max), EMW206 (n=2), EMW209 (n=2), EMW210, AMW54
Toluene	27	20	17,600	16	AIT3D, EMW15 (n=5), EMW200 (N=3), EMW204D, EMW204S, EMW205 (max), EMW206, EMW209, EMW210, AMW54
Ethylbenzene	27	22	3,020	15	EMW15 (n=4) (max), EMW200 (N=3), EMW204D, EMW204S, EMW205, EMW206 (n=2), EMW209 (n=2), AMW54
m & p Xylene	27	21	4,490	16	AIT3D, EMW15 (n=5) (max), EMW200 (N=3), EMW204D, EMW204S, EMW205, EMW206 (n=2), EMW209, EMW210, AMW54
o Xylene	27	21	2,210	11	EMW15 (n=4) (max), EMW200 (N=3), EMW204D, EMW205, EMW206 (n=2)
Benzo(a) Pyrene	28	16	9260	16	AIT3S, AIT3D, EMW15 (n=5), EMW200, EMW204D, EM204S, EMW205 (n=2), EMW206 (n=2), EMW209 (n=2), EMW210

Table 9.4: Block 4, Evaluation of Groundwater Analytical Results Summary Table (µg/L)

Analyte	n	Detections	Maximum	n >ANZECC (2000)	Comments/ Wells Exceeding Screening Criteria
Naphthalene	28	24	283,000	20	EMW15 (n=5), EMW204D, EMW209 (n=2), AIT3D, EMW200 (n=3), EMW204S (n=2), EMW205 (n=2) (max), EMW206 (n=2), EMW210, AMW54
Total PAH	28	28	530,568	-	No screening criteria but wells noted to exceed 100µg/L include EMW15 (n=5), EMW204D, EMW209 (n=2), AIT3D, EMW200 (n=3), EMW204S (n=2), EMW205 (n=2) (max), EMW206 (n=2), EMW210, AMW54
Phenols	24	17	21,300	6	EMW15, EMW200 (n=3), EMW204D (max), EMW205

n number of samples
- No criteria available/used or not applicable
PQL practical quantitation limit

9.4 Separate Phase Observations

Separate phase (generally observed in field notes as DNAPL or tar) was observed in a number of wells within both the fill materials and the underlying natural soils and sandstone as shown on Attachment 9, Appendix A, as follows:

- Block 4: fill (EMW204D) and natural sandstone (EMW205) and clayey sand (EMW206).
- Hickson Road: fill (CMW7, CMW10, AMW53) and natural sandstone (CMW15).

This is consistent with the findings of the previous AECOM (2010b) report which identified likely SPGWT at eight locations within Hickson Road and Block 4 (MW204D, MW205, MW206, MW53, MW15, BH7, BH10 and BH6) in the vicinity of the tar tank, purifying beds and 1870 gasholder, indicating these locations are the main source areas of contamination. It is noted that SPGWT has also been identified within the site at other locations, beyond the historic gasworks infrastructure. Lesser observations of gasworks contamination in the form of sheen and odour were also made during sampling of groundwater as noted in Table 9.1 and on Attachment 9, Appendix A (sheen).

9.5 Contaminant Detections

The groundwater analytical results summary Tables 9.2-9.3 and comments in Table 9.1 indicate that the most significant groundwater contamination was identified in the immediate vicinity of the former gasworks infrastructure consistent with field observations. Significantly elevated concentrations of dissolved phase TPH, BTEX, PAHs/naphthalene and phenol in excess of the screening criteria were detected in the following wells:

- Block 4: fill (EMW15, EMW204D, EMW209) natural (EMW205, EMW206, EMW200, EMW204S)
- Hickson Road: fill (CMW7 and CMW10) natural (CMW15)

Concentrations of dissolved phase TPH, BTEX, PAHs/naphthalene and cyanide were also detected in excess of the screening criteria in wells located immediately down-gradient of the gasworks infrastructure (AIT3D and EMW210), in the northwest of Hickson Road (AMW61) and Block 5 (AMW62). Dissolved phase hydrocarbon contamination as TPH, BTEX, PAH was also reported in offsite downgradient wells to the west. The most elevated concentrations appear to correlate to areas where SPGWT has been also identified to be present within either the fill, generally in close proximity to gasworks infrastructure, or marine sediments underlying the site and down-gradient areas.

Cyanide concentrations (free and weak acid dissociable) were reported in various wells but showed no clear correlation with SPGWT observations or gasworks related dissolved phase detections. AECOM consider that if the reported cyanide is related to the gasworks it does not appear to be as persistent as the organic contaminants.

Heavy metal impacts do not follow any particular patterns and most likely vary based on contaminant concentrations in adjacent fill soils and the local groundwater conditions (eg, pH) that may affect leaching of metals from soil.

As noted in Section 6, long well screen intervals were used for several of the wells installed which has not allowed for detailed assessment of the vertical profile of groundwater contamination across the entire site area. However, some multilevel groundwater monitoring wells have been installed, primarily in downgradient areas. Based on results from these wells, AECOM found in the Groundwater Discharge Study (2010d) that *"In most cases, contaminants typically associated with gasworks waste … exhibit an increasing trend with depth and to the east, consistent with a contaminant source lying either at depth or upgradient…"*. Based on the Auditor's review, the results from multilevel wells and other wells with shorter screened intervals indicate that groundwater contamination is generally limited to the vertical extent of SPGWT and other evidence of gasworks impact, with significant vertical flux of contamination, for example from impacted marine sediments into un-impacted overlying fill, not apparent.

Significant detections were made in ABH/MW60, located around 85m downgradient of the declaration area. The lateral extent of impact in the vicinity of this well is discussed in Section 11. This well was screened from 14mBGL, equivalent to a relative level of below -11mAHD, and AECOM (2013c) considers the screened material to be present at an elevation below the sea floor of Darling Harbour.

9.6 Natural Attenuation

AECOM reported reduced sulphate concentrations, increased alkalinity and higher TOC concentrations in wells reporting the presence on hydrocarbon contamination, indicating that a suitable environment for biodegradation of hydrocarbons is present at the site. The reports reviewed do 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.

9.7 Conclusion

Separate phase (generally observed in field notes as DNAPL or tar) and significant dissolved phase contamination was observed in wells on Block 4 and Hickson Road, associated with the former gasworks. Dissolved phase hydrocarbon contamination as TPH, BTEX, PAH was

also reported in Block 5 in the vicinity of gasworks infrastructure and in downgradient wells to the west, indicating the westerly migration of contamination, primarily in the deeper marine sediment.

Groundwater contamination is generally limited to the vertical extent of SPGWT and other evidence of gasworks impact, with significant vertical flux of contamination, for example from impacted marine sediments into un-impacted overlying fill, not apparent.

The need for remediation of detected groundwater contamination has been considered by AECOM based on risk based remediation criteria, and is discussed in Sections 10 to 12. The groundwater results are considered adequately representative for consideration in determining groundwater remediation requirements for the site when considering multiple lines of evidence.

10 Assessment of Risk and Development of Remediation Goals

10.1 Overview

Development of remediation goals and, where appropriate, development of site specific target criteria (SSTC), for the VMP removal and Block 4 development was based on the findings from two quantitative risk assessments – the VMP HHERA (AECOM 25 October 2012) and the Declaration Site (DS) HHERA (AECOM 9 June 2011), respectively. The HHERAs considered the need for remediation based on risk to human health and the environment. The remedial requirements for each purpose (Block 4 development and VMP removal) vary due to the different land uses and associated exposure scenarios, as well as the proposed works (including most significantly the construction of a groundwater retention wall system around the entirety of Block 4). However, for both purposes, and for protection of both human health and the environment, the primary remediation goal has been determined in the RAP to be 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 present at the site and 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 was determined by comparison of soil and groundwater data with the relevant risk-based remediation criteria (SSTC). Detailed consideration of the extent of remediation required for VMP removal, in particular consideration of 'the extent practical', was documented by AECOM in the VMP Extent Report.

For VMP removal, the requirement for remediation was also considered in adjacent offsite areas. This was to address contamination which, although present in offsite areas, was derived from the declaration area and is therefore required to be addressed in order to remove the declaration.

A detailed review of the DS HHERA as it related to the ORWS area was performed by the Auditor's specialist support team (EnRisks) and was documented in the ORWS SAR (dated July 2011). This review is considered applicable to application of the DS HHERA to the Block 4 development since the nature of development and modelled land use scenarios are the same for Block 4 and ORWS, as discussed in Section 10.3, below. The VMP HHERA was subject to detailed review by the EPA and EnRisks. Comments were provided and discussed with AECOM in finalisation of the HHERA document, as outlined in a letter from EPA dated 23 May 2012. Summary review information is provided below in Section 10.2.

The following Table 10.1 presents a summary of the aspects considered in defining the remediation goals and remedial extent, based on the Auditor's review of the HHERAs, the RAP and the VMP Extent Report. Further discussion is provided in the sections following, as referenced in Table 10.1.

Table 10.1: Summary of Remediation Goals		
Item	**VMP Removal**	**Block 4 Development**
Documents which consider risk	VMP HHERA (AECOM, 2012d)	DS HHERA (AECOM, 2011) and DS HHERA Letter (AECOM, 2012c)
Contaminants of potential concern (CoPC) considered	As identified in VMP - TPH, BTEX, PAHs, ammonia, phenol and cyanide	Determined in DS HHERA
Land use/ exposure scenarios considered	Paved recreation and short term intrusive maintenance worker	High density residential and commercial use – seven potential exposure scenarios for the larger declaration area (refer Section 2.5)
Human health criteria derived	Unsaturated soil $SSTC^{VMP}$ and groundwater $SSTC^{VMP}$ for specific modelled land use scenarios (refer Section 10.2.3)	Groundwater $SSTC^{DEV}$ (health and odour) for specific modelled land use scenarios (refer Section 10.3) Soil $SSTC^{DEV}$ were derived but are not relevant for the Block 4 area since basements will extend below the groundwater table across the entire site.
Remedial goal for human health	Removal/ remediation to the extent practicable of SPGWT and soil that represents CIM, being: • Unsaturated soil concentrations exceeding SSTC. • Unsaturated or saturated soil that is a source of groundwater contamination in fill material exceeding SSTC. There was considered to be negligible flux from marine sediment into overlying fill therefore marine sediment was not considered as CIM for protection of human health. There are no saturated soil SSTCs since soil impacts in the saturated zone were not considered to present a potential source for the identified current onsite receptors (intrusive maintenance workers and paved recreational users).	Removal/ remediation to the extent practicable of SPGWT and groundwater that represents CIM (exceeding SSTC).
Remedial goal for environment	Removal/ remediation to the extent practicable of soil such that the quality of groundwater in fill leaving the site approaches the MWQC. No site specific soil or groundwater environmental criteria were derived (refer Section 10.2.4).	The proposed design for the Block 4 Development includes construction of a basement groundwater retention wall system around the perimeter of Block 4 that will extend to and be keyed into bedrock, preventing the migration of contamination from the site, therefore remediation criteria for ecological protection are not required

Table 10.1: Summary of Remediation Goals

Item	VMP Removal	Block 4 Development
Determination of 'the extent practicable'	The VMP Extent Report included consideration of the following (refer Section 10.2.5): • DEC (2007) Groundwater Guidelines, including clean-up to the extent practicable (CUTEP) • The principles of ecologically sustainable development (ESD) • The NSW *Waste Avoidance and Resource Recovery Act 2001* Technical aspects considered in this review included (refer Section 11): • Technical capability to achieve the clean-up • The quantity of NAPL removed • The mass of contaminant removed • The flux of contaminants through marine sediment.	The RAP considered other lines of evidence in defining the Block 4 remedial extent (refer Section 12.3) including: • Contaminant flux which has been demonstrated to vary between different lithologies • The reduction in contaminant mass resulting from remediation of SPGWT and other areas of significant contamination • If practical constraints of remediating identified CIM are considered to outweigh the actual benefits, considering the principles of CUTEP and ESD.
Asbestos	Not considered in HHERA since not listed in VMP, although VMP HHERA recommended that risk posed by asbestos be managed as part of the RAP (refer Section 10.4).	The DS HHERA recommended that risk posed by asbestos be managed as part of the RAP based on limited identification of asbestos at that time. Subsequent findings (discussed in Section 8.3.6) indicate a higher potential for asbestos contamination to be present, and the RAP includes an Asbestos Management Plan (refer Section 10.4).

10.2 VMP Removal (VMP HHERA)

10.2.1 Overview

The objectives of the VMP HHERA (AECOM, 2012d) were to:

- assess the risk to human health and the environment that the declaration area represents in its current form; and
- develop human health SSTCs for soil and groundwater for use in defining the remediation end-point for the declaration area, where the end-point is defined as removal of the EPA Declaration relating to the declaration area.

The focus of the VMP HHERA was on the chemicals specified within the EPA Declaration, specifically: PAHs; BTEX; TPH; Ammonia; Phenol; and Cyanide.

Other contamination identified within the declaration area by previous investigations (for example VOC), which are not listed in the NSW EPA Declaration, were assessed in the DS HHERA relating to the Block 4 Development (refer Section 10.3, below).

The VMP HHERA was subject to detailed review by the EPA and EnRisks and comments made were considered by AECOM in finalising the document.

10.2.2 Assessment of Human Health Risk

Consistent with expectations for a declared site, the VMP HHERA concludes that *"…there are multiple lines of evidence that soil and groundwater concentrations within the Site and at the boundary represent an unacceptable risk to human health and ecological receptors...".*

This conclusion was reached following an assessment of the applicable exposure scenarios and considering the concentrations and distribution of soil and groundwater contamination identified at the site.

The VMP HHERA identifies two current exposure scenarios based on the existing site use (i.e. paved open space and a short term intrusive maintenance worker) as detailed in Table 10.2 below.

Table 10.2: Declaration Area Current Land Use Scenarios

Scenario Number	Description	Most Sensitive Human Receptor	Review Comments
1	**Paved recreation** The entire site is currently covered with concrete/hardstand paving. Assumes contaminated soil may be present directly underlying concrete surface.	Recreational users assumed to be exposed 2 hours / day, 365 days/year for 70 years. Exposure by inhalation of soil and groundwater derived vapours only	Exposure assumptions in the VMP HHERA (Section 5.3.5) are consistent with those in the DS HHERA (Section 5.3.8) and are considered appropriate and the calculations have been checked. 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. The AECOM report also recommends 0.5m suitable fill below areas that are paved, however the assessment presented has not considered this in the calculations.
2	**Short term intrusive maintenance worker** 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 assumed to have seeped into the trench • Inhalation of vapours from soil and groundwater • Inhalation of dust	Exposure assumptions in the VMP HHERA (Section 5.3.6) are consistent with those in the DS HHERA (Section 5.3.10) and are considered appropriate and the calculations have been checked.

The conceptual site model (CSM) illustrating the identified exposure scenarios is included as Attachment 11, Appendix A. The alignment for the cross section shown in Attachment 11, Appendix A, is shown on Attachment 8, Appendix A. For the current land use, the CSM is considered reasonable.

Based on both the maximum soil and groundwater concentrations and the 95% upper confidence limit (UCL) of the observed chemical concentrations in soil and groundwater across the site, and the exposure assumptions listed in Table 10.2 above, the VMP HHERA identified unacceptable human health risks for a short term intrusive maintenance worker. Locations in Hickson Road where free tar has been reported are considered to be of particular significance, based on the potential for direct contact and indirect groundwater-derived vapour exposures. Risks for an outdoor recreational site user were considered to be acceptable based on the current site condition (i.e. paved). This is considered reasonable.

10.2.3 Derivation of Human Health SSTCs

Given the identified potential human health risks for an intrusive maintenance worker, site specific target criteria (SSTCs) were derived for the purpose of remediation. SSTCs were, in general, derived for the chemicals of concern identified in the VMP that were detected in soil or groundwater above the screening criteria and which were considered to contribute more than 20% to the combined cumulative risk. On this basis, the chemicals of concern for which SSTCs were derived included: acenaphthylene, ammonia, fluoranthene, naphthalene, phenanthrene, pyrene, CPAH (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), benzene, TPH C_{10}-C_{14}, TPH C_{15}-C_{28} and TPH C_{29}-$_{36}$. The SSTCs, derived on the basis of a short term intrusive worker scenario, are presented in Appendix E of this SAR.

While the intrusive maintenance worker exposure scenario is no longer relevant to Block 4 given the proposed development, SSTCs for this scenario were derived as part of the DS HHERA (2011) which was completed to account for the potential range of development. In general, the assumptions used in the derivation of the SSTC in the VMP HHERA and the DS HHERA were consistent. Where the derived SSTCs were greater than 10 times the saturation limits, no SSTC was presented except in the case of the TPH fraction as it was not considered appropriate to exclude the TPH group of chemicals on the basis of the saturation characteristics of an analytical surrogate.

A soil SSTC was not derived for ammonia due to the low risk posed by ammonia in soil at the site. This is based on the subsurface conditions at the site not being conducive to generation of ammonia gas. Ammonia was considered in the assessment of odour risks and a groundwater SSTC was derived for ammonia which is considered appropriate. Ammonia is also considered with respect to the environmental goal of meeting the MWQC at the downgradient site boundary.

Overall, the SSTCs presented within the VMP HHERA are considered reasonable remediation targets and representative of conditions which would be consistent with low and acceptable levels of human health risks given the current site layout and use. Implementation of the SSTCs in the RAP is discussed in Section 11. Tables T1 and T2 of the RAP (included in Appendix E) provide a summary of the criteria adopted which are consistent with the SSTCs presented in the VMP HHERA for soil and groundwater.

10.2.4 Ecological Risk Assessment

The VMP HHERA included an assessment of whether or not the contamination identified at the site poses an unacceptable risk to either terrestrial or aquatic ecosystems within the site and/ or downgradient of the site boundary.

The site currently comprises paved open space with minimal terrestrial organisms. AECOM note that 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. The terrestrial habitat at the site was therefore considered to have a low level of environmental sensitivity and was not considered to include ecological receptors which required protection. This is considered reasonable.

The point of compliance for the purpose of assessing aquatic ecological risks was determined to be the down hydraulic gradient boundary of the site, as required by the NSW EPA in comments made. In the absence of other information, the level of protection of groundwater at the down hydraulic gradient boundary of the site has been based on the level of protection required for the nearest surface water receptor, Darling Harbour. On this basis, the ANZECC (2000) Marine Water Quality Criteria (MWQC), discussed in Section 7.2, were selected as the groundwater screening criteria. The MWQCs adopted are derived from the following:

- ANZECC (2000) 95% species protection marine water trigger levels
- ANZECC (2000) 99% species protection marine trigger values for potentially bioaccumulative contaminants
- Other guidelines that provide a similar level of protection as the ANZECC (2000) trigger values.

This is considered reasonable.

The closest ecological receptors identified in the VMP HHERA (AECOM, 2012d) are aquatic ecosystems within the groundwater down hydraulic gradient of the site boundary, between the site and Darling Harbour. The Auditor considers that the identified ecological receptor is appropriate.

The VMP HHERA identifies exceedances of the MWQC in groundwater within the site and at the site boundary (discussed in Section 9 of this SAR), indicating a potential for unacceptable risk to the environment. The VMP HHERA also concludes that the chemicals of concern identified onsite are consistent with those expected in association with historic gasworks, and similar in composition to those reported in areas down hydraulic gradient of the site, indicating that offsite migration of contaminated groundwater is likely occurring. AECOM concluded that remediation was required to minimise the risk of adverse impact to the environment.

The Auditor agrees with the conclusions of the ecological risk assessment presented in the VMP HHERA that contaminated groundwater within the site and at the site boundary may pose an unacceptable risk to the environment and that offsite migration of contamination in groundwater is likely occurring.

The management/ remedial actions to be undertaken at the site for the protection of human health will also act to address ecological issues at the boundary. These actions are targeted at the removal of tar containing materials. The long term aim of the remediation is for groundwater at the boundary to comply with the MWQC, if practicable. Although in this case the setting of quantitative ecological remediation targets was considered unrealistic, the proposed removal of tar material will act to significantly reduce downgradient groundwater concentrations.

10.2.5 Determination of 'The Extent Practicable'

Consideration of 'the extent practicable' has been performed by AECOM in the definition of the proposed remedial extent, particularly for the extent of remediation required for the protection of the environment. The VMP Extent Report includes a detailed consideration of regulatory policy requirements in this regard. Table 10.3, below, presents a summary of the key requirements considered.

Table 10.3: Issues Considered in Determining the Extent Practicable

Document/ Requirement	Key Aspects	AECOM Response
DEC (2007) 'Guidelines for the Assessment and Management of Groundwater Contamination'		
S3.2	"Where contamination is identified, the management objectives are to protect human and ecological health and to ultimately restore the groundwater to its natural background quality". The following management responses must be considered:	See below.
S3.3	control short-term threats arising from the contamination	No acute risks identified. VMP based on requirement to mitigate long-term or chronic risks.
S3.4	restrict groundwater use	Saline groundwater not suitable for use.
S3.5	prevent or minimise further migration of contaminants from source materials to groundwater	Source control - primary contaminant sources considered to be historical gasworks infrastructure (which has been found to contain SPGWT) and secondary sources are considered to be SPGWT observed in groundwater and soil. Removal to the extent practicable is proposed for historical gasworks infrastructure. The extent of source removal/ treatment proposed for secondary sources is discussed in Section 11.
S3.5.1	where NAPLs are present in the subsurface they much be removed or treated as much as practicable	DNAPL falls within the definition of SPGWT and will be addressed by source control. The extent of DNAPL removal/ treatment proposed is discussed in Section 11.
S3.6	prevent or minimise further migration of the contaminant plume	Plume containment not relevant since remedial goal is for clean up.
S4	clean up groundwater according to	Site clean up objectives are consistent with

Table 10.3: Issues Considered in Determining the Extent Practicable		
Document/ Requirement	**Key Aspects**	**AECOM Response**
	the following hierarchy: 1. Clean up so natural background water quality is restored. 2. Clean up to protect the relevant environmental values of groundwater, and human and ecological health. 3. Clean up to the extent practicable (CUTEP).	this hierarchy. In particular: numerical criteria (SSTCs) have been developed for the protection of human health; and, long-term numerical criteria (MWQC at the down hydraulic gradient site boundary) have been developed, in consultation with the NSW EPA, for the protection of the environment.
	The evaluation of practicability (for consideration of CUTEP) should be documented against: - technical capability to achieve the clean-up	The likely remediation technologies were defined based on the remedial technology assessment performed for the RAP (refer Section 13). Most likely technologies were excavation and treatment/ disposal for Block 4 and S-ISCO/ SEPR or in situ solidification/ stabilisation for Block 5 and Hickson Road. Remediation technology capability and remediation practicability limitations were considered. S-ISCO and SEPR were noted to be most efficient when targeting the destruction of between 90 and 95% of the organic contaminant mass. The adequacy of 90% contaminant mass removal is discussed in Section 11.
	- clean-up costs	The VMP Extent Report considers the additional clean-up costs (expressed in terms of remediation volumes) versus the environmental benefit (expressed in terms of a reduction in contaminant mass) that might be realised from the remediation of additional areas within and adjacent to the site.
	- the value of the groundwater resource	As discussed in section 10.3.4, above, remedial goal is aimed at protecting aquatic ecosystems within the groundwater down hydraulic gradient of the site boundary, between the site and Darling Harbour. Applicable aquatic ecosystem management objectives identified in the VMP HHERA were - protection of aquatic ecosystems; - protection of visual amenity; and - achievement of secondary contact recreation and primary contact recreation quality goals over a period of some five years.
	- threats the contamination poses to human or ecological health.	Remediation proposed was considered adequate to address threat to human health. Threat to environment examined through consideration of:

Table 10.3: Issues Considered in Determining the Extent Practicable		
Document/ Requirement	**Key Aspects**	**AECOM Response**
		- The improvement in contaminant mass flux that will be realised by the proposed remediation; and - The contaminant mass flux from contamination that will remain in situ following the proposed remediation for protection of human health. These items are discussed in Section 11.5. AECOM also notes that construction of the groundwater retention wall as part of the Block 4 development will further minimise the threat the environment of residual contamination remaining within Block 4, however, construction of the wall is not relied upon to demonstrate CUTEP for the VMP removal.
	Where DEC agrees that clean-up to the extent practicable has occurred, this does not remove the proponent's responsibility for ongoing management of the residual contamination. The remediation proposal should be accompanied by: - a commitment to ongoing monitoring and re-evaluation of the practicability of clean-up. A satisfactory monitoring and reporting program must be implemented to continually evaluate the contamination.	Ongoing groundwater monitoring and evaluation is addressed in the RAP.
	- a groundwater management plan (GMP) that specifies measures which will be implemented to mitigate risks to human and ecological health.	The requirement for a GMP is addressed in the RAP.
	- acknowledgement that future management including clean up action may be required to ensure the protection of human and ecological health.	The potential for a Site Management Plan to be implemented in the event that future land owners plan to re-develop the site is considered in the RAP. The RAP also describes contingency management actions that may be implemented to ensure the protection of human and ecological health.
	- provision for long-term resourcing and responsibility for any ongoing management strategy.	Implementation of any ongoing management strategy (if required) will be the responsibility of the future land owner. Specific provision for future works is not provided.
The principles of ecologically sustainable development (ESD) as defined in the CLM Act		
a)	If there are threats of serious or irreversible environmental damage,	Analytical data set considered appropriate to draw conclusions about risk. Precautionary

Table 10.3: Issues Considered in Determining the Extent Practicable		
Document/ Requirement	**Key Aspects**	**AECOM Response**
	lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation (the 'precautionary principle');	principle adopted in protection of aquatic ecosystems down hydraulic gradient of the site.
b)	The principle of inter-generational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations (the 'intergenerational principle');	Proposed remediation will enhance the environment. In situ remediation has many benefits over offsite disposal with respect to intergenerational equity.
c)	The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making (the 'biodiversity principle');	Remedial goal is protection of aquatic ecosystems down hydraulic gradient of the site.
d)	Improved valuation, pricing and incentive mechanisms should be promoted (the 'valuation principle').	Removal of Declaration is required to allow site development which has economic benefit. In situ remediation technologies have cost benefit over conventional ex situ technologies.
NSW *Waste Avoidance and Resource Recovery Act 2001*		

	- to encourage the most efficient use of resources and to reduce environmental harm in accordance with the principles of ecologically sustainable development,
	- to ensure that resource management options are considered against a hierarchy of the following order:
	  o avoidance of unnecessary resource consumption,
	  o resource recovery (including reuse, reprocessing, recycling and energy recovery),
	  o disposal,
	- to provide for the continual reduction in waste generation; and
	- to minimise the consumption of natural resources and the final disposal of waste by encouraging the avoidance of waste and the reuse and recycling of waste.
		If it was proposed to achieve a higher level of protection for the environment than currently proposed, a substantial increase in remediation works would be required to realise any substantial increase in the contaminant mass reduction. Such an increase would also be likely to generate large volumes of excavation spoil which may be unsuitable for beneficial reuse at Barangaroo and, therefore, require disposal to landfill

AECOM concludes that the proposed remediation extent (discussed in Section 11) is consistent with the requirements of DEC (2007) and that should the proposed remediation extent be increased, the associated cost and potential environmental harm would substantially outweigh any real benefit to the environment and would be inconsistent with the principles of ESD and the Waste Avoidance and Resource Recovery Act 2001.

The Auditor considers that AECOM has provided a detailed consideration of these issues in the VMP Extent Report which generally supports the findings presented. Further consideration of technical aspects of this argument (including with respect to contaminant mass and mass flux) is provided in Section 11 of this SAR.

10.3 Block 4 Development (Declaration Site HHERA)

10.3.1 Criteria Developed

The objective of the DS HHERA was to develop risk-based remediation criteria that would allow the declaration area to be redeveloped for a range of potential land uses. Site specific assessment criteria have been developed for the declaration area as documented in the DS HHERA (AECOM, 2011) and DS HHERA Letter (AECOM, 2012d). Criteria were derived for the protection of human health – site specific target criteria (SSTC) - and the environment – site specific ecological screening criteria (SSESC). A detailed review of the DS HHERA as it related to the ORWS area was previously performed, and is relevant to application of the DS HHERA to the Block 4 development.

Details of the Block 4 development works have been considered in applying the declaration site SSTC and SSESC to Block 4. As described in Section 2.5, the Block 4 development is to comprise mixed commercial and high density residential usage overlying basement, with associated public open space area, also overlying basement. Several of the human health land use scenarios considered in the DS HHERA are therefore not relevant to Block 4 (refer Section 10.3.3). In addition, criteria for the protection of the environment are not relevant to the Block 4 development works due to the construction of a basement groundwater retention wall system around the perimeter of Block 4 that will extend to and be keyed into bedrock. This will effectively isolate Block 4 from Darling Harbour and hence where there is no hydraulic connection there will be no mechanism for contaminants to migrate to and discharge into Darling Harbour. It is therefore reasonable that no criteria for the protection of the environment are required for Block 4.

10.3.2 Design Considerations

The SSTC are specific to the proposed 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/ HHERA Letter will not be met as there will be the potential for unacceptable risks to human health, and the SSTC are no longer valid. 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 the basement design and engineering controls (key aspects listed below) will ensure that tar seepage into basements does not occur

- A basement groundwater retention wall system will be constructed around the perimeter of the basement area and will be keyed into the bedrock. It will comprise diaphragm and secant (or equivalent) walls
- Car park basements will include engineering controls (key aspects listed below) to ensure that contaminated groundwater does not accumulate in habitable car park areas
- Car park walls:
  - Above the bedrock
    - At least 600 mm wide perimeter retention wall
    - In some locations where required for the development as part of the internal car park basement wall an additional 350 mm reinforced concrete wall
    - Sealed plenum (to collect and drain seepage water that may permeate through the perimeter and basement car park walls and vent vapours from the seepage water using a passive pipe riser to the height of the roof level)
    - Average daily air exchange rate of 3.17 air exchanges per hour within the basement areas which includes periods of 0% ventilation (amended from HHERA by HHERA Letter)
    - The maximum car park space will span no more than two perimeter walls, the other two will be internal walls that cannot be adjacent to contaminated material
    - Locations where external services intersect the perimeter retention wall will need to be appropriately sealed to remove any preferential pathway for groundwater or vapour migration
  - Below/into bedrock
    - 100 mm Shotcrete applied to bedrock surface
    - 350 mm reinforced concrete wall
    - Sealed plenum
    - Average daily air exchange rate of 3.17 air exchanges per hour within the basement areas which includes periods of 0% ventilation (amended from HHERA by HHERA Letter)
    - The maximum car park space will span no more than two perimeter walls, the other two will be internal walls that cannot be adjacent to contaminated
    - Locations where external services intersect the perimeter retention wall these will need to be appropriately sealed to remove any preferential pathway for groundwater or vapour migration
- The lower level basement car park level can be used for loading/unloading with full time staff (amended from HHERA by HHERA Letter)
- The sump for the water collected on the inside of the sealed plenum shall not be located inside the car park and shall be separated from the car park atmosphere by a separate ventilation system, or equivalent, to remove the potential for vapour issues from pooled contaminated groundwater inside the car park
- An active venting system on the sealed plenums may be required. A passive venting system is proposed and the effectiveness of this system needs to be demonstrated.

OEH Letter dated 11 July 2011 to Lend Lease Barangaroo South approved the DS HHERA (AECOM, 2011) subject to Conditions of Approval which incorporate the design, construction and operational parameters listed above (except as amended by the DS HHERA Letter).

10.3.3 Derivation of Human Health SSTCs

SSTCs were derived for seven land use scenarios for potential development within the declaration area, as listed in Section 2.5. Several of the land use scenarios considered in the DS HHERA are not relevant to Block 4 including unpaved and paved public domain, commercial slab on ground and short term ground-intrusive maintenance (Scenarios 3, 4, 5 and 6). The relevant land use scenarios, including modifications made by the DS HHERA Letter, are as detailed in Table 10.4 below.

The SSTCs were derived for the declaration area; however, the Auditor notes that the Block 4 area under consideration includes a portion of land outside the declaration area, being the western portion of Block 4, beyond the declaration boundary. AECOM has considered this issue in the RAP and has presented justification for why the derived SSTC are applicable to the portion of Block 4 outside the declaration area. The Auditor has reviewed the justification and considers the application of the SSTC derived for the declaration area to the entirety of Block 4 is appropriate.

Table 10.4: Block 4 Land Use Scenarios

Scenario Number	Description	Exposures Assessed	Review Comments
1	**Lower Basement** Lower level basement car park in multi-storey building assuming groundwater seepage occurs and is captured within plenum.	Adult and child residents exposed during incidental use of the basement for access to vehicles. Revised modelling (HHERA Letter) included adult worker exposed during full time employment in loading dock. Only pathway of exposure assessed is vapour inhalation.	Seepage is contained behind plenum so there is no potential for direct contact. The exposure assumptions (Section 5.3.5 of the DS HHERA and Section 4 of the DS HHERA Letter) and calculations are appropriate and have been checked. 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 two walls being in contact with contamination.
2	**Upper Basement** Upper basement car park in multi-storey building assuming it is adjacent to some saturated soil (groundwater) and the remainder is unsaturated soil.	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. The exposure assumptions (Section 5.3.6 of the DS HHERA and Section 4 of the DS HHERA Letter) and calculations are appropriate and have been checked. 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 two walls being in contact with contamination.
7	**High Density Residential**	Adults and children living on the ground floor of a multi-story building, overlying basement levels.	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

Table 10.4: Block 4 Land Use Scenarios			
Scenario Number	**Description**	**Exposures Assessed**	**Review Comments**
			car park only). Exposures assumptions (Section 5.3.11 of the DS HHERA) are appropriate and the calculations have been checked.

SSTCs have been derived for chemicals of potential concern (COPC) identified in soil and groundwater. The derived criteria have addressed mixtures of key groups of COPC including BTEX (benzene, toluene, ethylbenzene and xylenes), TPH, CPAHs and non-carcinogenic PAHs.

The criteria derived have considered the protection of human health and potential odour issues. While the approach adopted for the assessment of odour issues is considered highly uncertain, the outcome of the assessment is generally considered reasonable.

As noted in Table 10.1, soil SSTC were derived for development of the declaration area but are not relevant for the Block 4 area since basements will extend below the groundwater table across the entire site. The SSTCs derived on the basis of the approach presented by AECOM (2011 and 2012c) are reasonable provided that the development specific management measures as outlined in the RAP (AECOM, 2013c) are implemented.

The HHERA is based on no tar containing materials (TCM) being present, 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.

10.4 Asbestos

Based on the results discussed in Section 8.3.6, the RAP has been prepared on the assumption that asbestos may be present at the site. The principal risk associated with asbestos that may be present at the site is the inhalation of asbestos fibres during remediation and construction works which is most appropriately managed by control measures implemented during remediation. The RAP proposes preparation and implementation of an Asbestos Management Plan.

Asbestos that may remain at the site beneath a basement following completion of development works (e.g. for the Block 4 development) will not represent an unacceptable risk to human health or the environment.

The Driscoll report on use of asbestos-contaminated soils on Barangaroo does not relate specifically to the VMP/ Block 4 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.

11 Determination of Remediation Extent for VMP Removal

11.1 Introduction

The extent of remediation for VMP removal was determined by AECOM (2013b) in the VMP Remediation Extent report based on protection of human health and the environment in the sites current condition. This was to be achieved by removal of SPGWT and CIM considering "The extent of remediation that can be practicably achieved…".

The Auditor has reviewed the data and analysis presented by AECOM in defining the extent of remediation required for VMP removal. The following Sections 11.2 and 11.3 discuss the occurrence of SPGWT and CIM within the site and in adjoining offsite areas of the declaration area. SPGWT was identified based on field and laboratory results, while CIM was identified by comparison of unsaturated soil and groundwater data with the relevant risk based remediation criteria (SSTC), discussed in Section 10. Attachments 12 and 13, Appendix A, illustrate exceedances of the SSTC for unsaturated soil and groundwater, respectively, while Attachment 9, Appendix A, shows the occurrence of SPGWT. The relevant criteria are included in Appendix E.

Section 11.4 describes the proposed remediation extent determined by AECOM and identifies where SPGWT/ CIM lies outside the proposed remedial extent and therefore is proposed to remain on- (and off-) site. The subsequent Sections 11.5 and 11.6 consider the significance/ appropriateness of the proposed remediation extent on the basis of mass flux considerations and percentage contaminant mass removal respectively.

11.2 SPGWT and CIM Located Onsite

11.2.1 Blocks 4 and 5

The identification of SPGWT within Blocks 4 and 5 within the declaration area is summarised in Table 11.1.

Table 11.1: Identification of SPGWT at Blocks 4 and 5

Item	Details	
No. locations SPGWT identified	19	
- No. in fill	13	
- No. in natural/ deep fill	6	
No. locations DNAPL identified	4 (sheen in a further 5 wells)	
- Wells DNAPL identified (MW)	15, 204D, 205, 206 (sheen in 198, 200, 204S, 209, BH405/ IT03)	
SPGWT Locations >10mBGL *(not included in proposed remedial extent, refer Section 11.4)*	MW205 – DNAPL in sandstone	well screened 15-19.5mBGL
	BH49 - Fill/ natural sandy clay	9.2-12.7mBGL
	BH405 – silty sandy clay/ sandstone	14-14.5mBGL

The assessment of analytical results from Blocks 4 and 5 against SSTC is summarised in Table 11.2. All unsaturated soil data (<2mBGL) has been considered. The most recent groundwater data (from 2010-2011) has been considered for each well. It is noted that historical exceedances of SSTC all occurred within the groundwater wells identified by recent data, or in wells where SPGWT was identified (i.e. MW204D).

Table 11.2: Assessment of Blocks 4 and 5 Results Against SSTC

Analyte	Unsaturated Soil Exceedances	Groundwater Exceedances	Groundwater Exceedance Wells (MW)
Benzene	0/59	3/17	200, 206,15
TPH C10-14	1/50	5/18	200, 205, 206, 54,15
TPH C15-28	1/63	1/18	205
TPH C29-36	1/63	1/18	205
CPAH	0/63	1/18	205
Naphthalene	NA	7/18	200, 205, 206, 54,15, 204S, IT03D
Acenaphthylene	NA	0/18	-
Ammonia	NA	0/6	-

NA no relevant SSTC

In summary, SPGWT is present in Blocks 4 and 5 as follows:

- In the east of Block 4, associated with gasworks infrastructure and where bedrock is shallow (SPGWT generally occurs 1-4mBGL)
- In the west of Block 4, downgradient of gasworks infrastructure and at depth (SPGWT generally occurs 7.5-15mBGL)
- Also likely to be present at other gasworks infrastructure locations that have not been investigated.

Unsaturated soil and/or groundwater exceedances (comprising CIM) occurred for benzene, naphthalene, TPH C10-C36 and CPAH and were generally associated with the occurrence of SPGWT, or lesser evidence of impact such as sheen (e.g. MW200). All groundwater exceedances were within Block 4.

11.2.2 Hickson Road

The identification of SPGWT within Hickson Road within the declaration area is summarised in Table 11.3.

Table 11.3: Identification of SPGWT at Hickson Road

Item	Details
No. Locations SPGWT identified	6
- No. in fill	5
- No. in natural/ deep fill	1

Table 11.3: Identification of SPGWT at Hickson Road	
Item	**Details**
No. Locations DNAPL identified	4 (sheen in a further 2 wells)
- Wells DNAPL identified (MW)	7, 10, 15, 53 (sheen in 6, 61)

The assessment of analytical results from Hickson Road against SSTC is summarised in Table 11.4. All unsaturated soil data (<2mBGL) has been considered. The most recent groundwater data (from 2008-2010) has been considered for each well. Historical exceedances of SSTC did not occur, although only limited historical data is available for this area.

Table 11.4: Assessment of Hickson Road Results Against SSTC

Analyte	Unsaturated Soil Exceedances	Groundwater Exceedances	Groundwater Exceedance Wells (MW)
Benzene	0/29	3/6	7, 10, 15
TPH C10-14	0/28	3/6	7, 10, 15
TPH C15-28	0/28	1/6	15
TPH C29-36	0/28	0/6	-
CPAH	0/27	2/6	10, 15
Naphthalene	NA	3/6	7, 10, 15
Acenaphthylene	NA	0/6	-
Ammonia	NA	2/6	7, 10

NA no relevant SSTC

In summary, SPGWT is present in Hickson Road as follows:

- Associated with the historic tar tank and gasholder annulus structures located to the east of Block 4
- In shallow fill at BH/MW61, east of Block 5.

Groundwater exceedances (comprising CIM) occurred for benzene, TPH C10-C28, CPAH, naphthalene and ammonia and were generally associated with the occurrence of SPGWT, or lesser evidence of impact such as sheen (e.g. MW200). There were no unsaturated soil exceedances.

11.3 SPGWT and CIM Located Offsite

11.3.1 Offsite Downgradient

The identification of SPGWT in offsite areas to the west of the declaration area and to the north within Block 5 is summarised in Table 11.5.

Table 11.5: Identification of SPGWT Offsite to West	
Item	**Details**
No. locations SPGWT identified	10
- No. in shallow fill	2
- No. in natural/ deep fill	9
No. locations DNAPL identified	0 (sheen in 1 location)
- Wells DNAPL identified (MW)	NA (sheen in 69)
SPGWT Locations >10mBGL	9

SPGWT was identified in offsite areas primarily within **marine sediment** or bedrock within around 20m of the downgradient (western) boundary of the declaration area. SPGWT occurred with similar frequency in locations to the west of both Block 4 and Block 5. This extent, shown on Attachment 9, Appendix A, 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 85m downgradient of the declaration area, suggests migration may have occurred beyond what is suggested by the analysis of SPGWT only. 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 CSM of contamination at the site.

In order to investigate the extent of offsite impact to marine sediments, AECOM reviewed other evidence of gasworks wastes such as odour and visual evidence, as well as analytical results for naphthalene and TPH C10-C14 at elevated concentrations, but not to the extent that would constitute TCM/ SPGWT. This analysis is presented on Attachments 10a and 10b, Appendix A, for fill and marine sediment, respectively. AECOM (2013b) 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…"*. Given the potential for migration of gasworks waste to have occurred through narrow pathways and 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 within marine sediment along the approximate alignment of the Block 4/ Block 5 and ORWN/ Central boundary towards location BH/MW60 and possibly elsewhere. AECOM notes the presence of locally shallower bedrock between BH/MW541 and BH/MW60, suggesting that there is unlikely to be a migration pathway between these two areas.

In addition to the offsite occurrences in natural materials, SPGWT was also identified in **fill** offsite, as follows:

- BH70, west of Block 5 around 20m from declaration boundary in shallow fill at 2.5mBGL (also at >16mBGL in marine sediment in this location)
- BH74, further west of Block 5, around 70m from declaration boundary in shallow fill at 1-2.5mBGL

- BH/MW541D, west of Block 5, within 20m of the declaration area boundary, in deep fill at 9.9-10mBGL.

As shown on Attachment 12, Appendix A, no offsite unsaturated soil data exceeded the SSTC. As shown on Attachment 13, Appendix A, exceedance of the groundwater SSTC occurred in three offsite locations, as follows:

- MW60 (ORWN Area) -TPH C10-14 and naphthalene;
- MW69 (Block 5, Barangaroo Central) - naphthalene; and
- MW541D (Block 5, Barangaroo Central) - benzene and naphthalene.

AECOM does not consider the groundwater concentrations exceeding the SSTCs reported at MW60 and MW69 to be representative of CIM as the groundwater impacts are present within either natural marine sediments or within the natural bedrock. Exceedances in these wells are associated with SPGWT (MW60) or sheen (MW69). BH/MW541D is screened from 7.4-10.4mBGL and the groundwater exceedance is associated with SPGWT identified in this location (9.9-10mBGL).

11.3.2 Offsite Upgradient

Properties located to the east of the site are known to contain some portions of historical gasworks infrastructure as shown on Attachment 2, Appendix A. These properties have been subject to separate investigation, remediation and development. As detailed in Section 2.3, Site Audit Statements have been prepared for the properties (30-38 Hickson Road) stating that these sites are suitable for their current land use, variously subject to conditions. AECOM (2013b) concludes that *"…it is unlikely that soil and groundwater contamination that may be present in these offsite areas warrants remediation"*. However, AECOM note that the main gasholder annulus and potentially the tar tank cross the northern site boundary into the adjoining properties and are likely to contain SPGWT. It is possible that the remediation proposed for Hickson Road may also act to address the offsite issues, however if not, management of offsite upgradient contamination, if present, is proposed as part of remediation works to prevent re-contamination of the declaration area.

11.4 Proposed Remedial Extent

11.4.1 Lateral and Vertical Extent

AECOM defined the lateral extent of remediation based on the presence of historic gasworks infrastructure and the distribution of SPGWT and CIM. The lateral extent of remediation proposed in the unsaturated and saturated zones is presented in Attachments 14 and 15, Appendix A, respectively. It includes areas of Block 4, Block 5, Hickson Road and limited offsite areas to the west. The offsite areas to the west have been defined by AECOM as circular "hotspots" around BH/MW541 and BH70. There is no basis presented for the size/ shape of the proposed "hotspot" remediation area. It seems likely that for BH/MW541 at least (SPGWT in fill to 10mBGL), the impact may be laterally continuous with impact in the declaration area. The extent of impact at BH70 may be more limited since it is within shallow fill.

The vertical extent of remediation was defined as the depth to bedrock or a maximum depth of 10mBGL (approximately -7.5mAHD), plus deeper within gasworks features that are excavated into bedrock (ie, tar tank and gasholders). The proposed remediation depths for

each area (ranging from 2 to 10mBGL) are shown on Attachment 15, Appendix A. The 10mBGL bedrock contour was considered in defining the lateral remediation extent shown on this figure. If SPGWT is encountered in fill material at the base of remedial excavations, the vertical extent of remediation is proposed to be increased to the extent practicable or until marine sediment or bedrock is encountered. In this situation, AECOM has defined the extent practicable as limited to an increase in vertical extent of 1-2m, depending on whether the excavation is to be locally backfilled with permeable fill (2m) or clay fill (1m).The Auditor notes that over-excavation is likely to be required in a number of known locations, generally in the west of the declaration area where the depth of fill approaches 10mBGL and marine sediment is present over bedrock (e.g. BH/MW205).

AECOM (2013c) has further defined the extent of remediation to comprise *"Removal/remediation of contaminated fill materials such that the contaminant mass within the Remediation Extent fill material is reduced, on average, by 90%, to the extent practicable".* This is to account for the likely 90% removal efficiency for the proposed in situ remediation methods (refer Section 13), being what can practicably be achieved. It is noted that the removal efficiency will be 100% where excavation is used as an alternative to in situ methods.

11.4.2 SPGWT and CIM Not Addressed by Proposed Remediation Extent

The lateral and vertical remediation extent defined by AECOM does not address all of the SPGWT and CIM identified in Sections 11.2 and 11.3, as follows:

- In Blocks 4 and 5, the proposed remedial extent addresses the identified SPGWT and CIM except for:
  - SPGWT at BH49 below 10mBGL (to 12.7mBGL)
  - SPGWT in marine sediment at BH405/IT03 (14-14.5mBGL)
  - Likely other marine sediment locations downgradient of the gasworks infrastructure and below 10mBGL.
- In Hickson Road, the proposed remedial extent addresses the identified SPGWT and CIM provided that the remediation of deeper tar tank/ annulus areas extends sufficiently to adjoining investigation locations (e.g. MW10).
- Downgradient of the declaration area, the proposed remedial extent addresses the identified SPGWT and CIM except for:
  - SPGWT in shallow fill at MW/BH74, located within Barangaroo Central around 70m from declaration boundary at 1-2.5mBGL. This location has been excluded from the proposed remedial extent since AECOM considers that this material is not directly related to the site. It is noted, however, that remedial extent may be required for the protection of human health and this should be addressed by the Barangaroo Central remediation works.
  - SPGWT in marine sediment at eight locations. AECOM notes that:
    - SPGWT and CIM at BH/MW60 is proposed to be addressed by the ORWN remediation works

- Remedial requirements with respect to sheen and groundwater exceendences at BH/MW69 (screened in fill/ bedrock 9-12mBGL) is proposed to be assessed by the Barangaroo Central RAP

– Likely other marine sediment locations downgradient of the gasworks infrastructure and below 10mBGL, primarily located within 20m of the declaration area boundary, but also potentially extending to distances of at least 85m downgradient.

In addressing the requirements for source removal and remediation of NAPL to the extent practical under DEC (2007) guidelines, AECOM (2013b) presented a detailed analysis of the residual contamination, listed above. In addition to addressing all of the primary contaminant sources, being historic gasworks infrastructure, AECOM considers that the proposed remedial extent includes the majority (97%) of locations at which NAPL has been recorded in fill, being representative of secondary contaminant sources.

AECOM (2013b) presented an argument to demonstrate that remediation of remaining "residual" areas of contamination, which primarily occur below 10mBGL, is not required. Several aspects of this argument were discussed in Section 10 and are generally supported by the Auditor. More technical aspects relating to contaminant mass flux and contaminant mass removal calculations are discussed in the following sections.

11.5 Contaminant Mass Flux

Remediation is not proposed if identified SPGWT and CIM are present onsite within marine sediments and below 10mBGL. In addition, remediation is not proposed to address identified SPGWT and CIM offsite within marine sediments, except for consideration of BH/MW60 with the ORWN remedial works. AECOM has based this approach on the finding that contaminant flux from the natural marine sediments is negligible. AECOM concludes that:

- SPGWT present in natural marine sediments is not considered to pose a significant risk to human health due to negligible flux vertically into overlying fill; and
- SPGWT present in natural marine sediments is not considered to pose a significant risk to the environment due to negligible flux laterally to Darling Harbour.

AECOM came to this conclusion based on the findings of the Groundwater Discharge Study (AECOM, 2010d) and two subsequent memos analysing mass flux and discharge at the site (AECOM, 2012b and 2013a). As outlined in Section 5.2, the Groundwater Discharge Study found that relative to the fill, groundwater discharge volumes and therefore contaminant mass flux from the marine sediments and basal sandstone was considered to be negligible. Results from sampling of multilevel groundwater monitoring wells installed as part of the Groundwater Discharge Study further support the limited vertical flux of contaminants, for example from marine sediment into overlying fill.

The first memo considered multiple lines of evidence to determine the significance of flux and discharge of contamination from the natural soil and marine sediments underlying the site into Darling Harbour. The memo considered the following:

- Calculated hydraulic conductivity and inferred groundwater flow velocities from wells screened within marine sediments.

- The tidal prism concept and particle migration as addressed in the Groundwater Discharge Study.
- The potential for sorption and biodegradation of contaminants.
- The limiting of groundwater movement by the tidal cycle.
- Calculated mass flux between two transects downgradient of the declaration area. The memo concluded that the mass discharge of benzene and naphthalene into Darling Harbour would not be detected in the receiving water.

Overall, the memo concluded that remediation of the deep natural soil and marine sediments was not warranted since there was unlikely to be significant flux and discharge of contamination into Darling Harbour. The Auditor considers the analyses performed and findings presented in the first memo to be reasonable.

The second memo documented additional flux modelling along two separate transects:

- Upgradient, within the declaration area, contamination to be removed from fill and contamination to remain within maximum 5m of sandstone; and
- Downgradient/ offsite, in fill and maximum 5m of marine clay.

The transects adopted and assumptions made regarding the thickness of the impacted marine sediment and sandstone strata (5m) are considered appropriate. The Auditor has reviewed the groundwater analytical input data and a number of issues have been noted for Transect A-A'. These relate primarily to the use of data from mixed strata, using the most recent data only (which in many cases was the lowest of multiple rounds of data) and using filtered sample results. These issues are not critical when considering of primary concern in this modelling is the marine clay from Transect B-B'. Input data for this key strata was reflective of worst case conditions, i.e. the concentration from MW60 was applied across the entire cross section. This is considered conservative and appropriate.

Mass fluxes were converted into a concentration assuming a stream flow rate of 100L/second, derived from an approximate 25ML of tide twice per day (from the Groundwater Discharge Study). The additional flux modelling concluded that the concentration of the cumulative discharge from marine sediment and fill into Darling Harbour will be below the ANZECC criteria (also the MWQC). In addition to the discharge concentration, the Auditor has considered the contaminant mass discharged, in line with the load based licensing concept. The calculated mass flux discharging into Darling Harbour, where the marine sediments contribute less than 0.5% of the total loading, is as follows (AECOM, 2013a):

- Naphthalene = 0.37kg/year
- TPH C_{10}-C_{14} = 3.8 kg/year
- Benzene = 0.79kg/year.

It is noted that the above quantities do not take into account tidal activity and are therefore conservative.

Based on review of the information provided and following a weight of evidence approach, the Auditor supports the finding that contaminant flux from within the marine sediment is negligible and considers that the calculated concentration and mass discharges into Darling Harbour, following completion of the proposed remediation, are unlikely to present a significant risk to the environment.

The second memo calculated post-remediation flux for the upgradient transect within the declaration area to demonstrate *"…the reduction in mass flux that is expected to be realised as a result of the proposed remediation works".* The Auditor agrees that the total mass flux will be reduced by the remedial works proposed, however notes that mass flux within sandstone (or marine sediment downgradient) will not be influenced by the remediation works proposed since the remediation is limited to remediation of contaminants within fill. AECOM (2013a) acknowledges this fact but notes that following remediation *"the groundwater quality entering Darling Harbour will improve significantly because more than 99% of groundwater flow is through the fill and the proposed remediation is focused on reducing the contaminant mass flux from the fill".*

To account for the above, the remedial goal with respect to contaminant migration and protection of the environment is that groundwater in *fill* leaving the site approaches the MWQC. This goal is considered appropriate. Groundwater in wells on the downgradient boundary of the declaration area exceeds the MWQC for some PAH although not to a great degree (compared to, for example, exceedances in groundwater in underlying marine sediment). A specific argument proving that the MWQC will be met in fill at the site boundary following remediation has not been presented by AECOM; however, significant improvement to the quality of groundwater within fill is likely given the extent of remediation proposed. AECOM (2013b) states that *"AECOM has demonstrated through consideration of multiple lines of evidence that residual contamination that will remain in situ following completion of the proposed remediation will not represent a threat to ecological health and will be protective of the identified groundwater value".*

11.6 Contaminant Mass Calculations

As outlined in Section 11.4 above, based on the proposed remediation extent, there is significant contamination proposed to be left in situ both within the site and downgradient, representing a significant contaminant mass proposed to be retained. It is appropriate to consider the mass of contaminants proposed to be removed by the remediation works compared to that to be retained in order to determine if the proposed works present a sufficient degree of contaminant source removal.

Contaminant mass calculations were presented by AECOM in the VMP Extent Report (2013b) addressing multiple depth and spatial zones. Depth zones considered were upper fill, lower fill (2m above marine sediment) and marine sediment (upper 5m only). Spatial zones considered were:

- Zone 1 - the proposed remedial extent defined to address human health risk (refer Section 11.4 and Attachments 14 and 15, Appendix A). Zone 1 was further divided into Block 4, Block 5 and Hickson Road.
- Zone 2 – areas outside the proposed remedial extent but within the declaration area
- Zone 3 – offsite (downgradient) areas within 20m of the declaration area

- Zone 4 – offsite (downgradient) areas outside 20m of the declaration area, including the area to the north of the declaration area, within Block 5.

These zones and the data points considered within them are shown on Attachment 17, Appendix A.

Calculations were based on the average concentrations of the key gasworks related contaminants at the site, being naphthalene and TPH C10-C14. These analytes were considered the key drivers in representing ongoing risk to the environment as they have the largest contaminant mass and generally exceed the MWQC by the largest order of magnitude. Since selection of soil samples for analysis was biased towards evidence of contamination, average concentrations are considered likely to be conservative (i.e. overestimate the contaminant mass).

The calculations considered the current distribution of contaminant mass and the distribution following remediation (refer Section 13) which assumed 100% contaminant removal in Block 4 (where excavation is likely) and 90% contaminant removal in Block 5 and Hickson Road (where in situ remediation is likely).

The calculations are presented in Appendix F. The Auditor has reviewed the input data and calculation method adopted. The input data is considered sufficiently accurate, noting that minor errors are unlikely to materially influence the average concentrations used given the size of the data set. The volume estimates and calculations performed are considered an appropriate means of estimating the mass of key contaminants in the subsurface for the purposes of remediation planning.

Key findings were as follows:

Current conditions:

- Between 80% and 85% (naphthalene and TPH C10-C14 concentrations, respectively) of the total gasworks related contaminant mass is currently located within Zone 1 (the human health remediation extent) and will be remediated (by between 90-100% contaminant removal) as part of the proposed remediation works.
- Less than 1% of the contaminant mass is currently located within the fill materials (both upper fill and lower fill) within Zone 2 (i.e. within the site but outside Zone 1).
- Around 5% of the contaminant mass is currently located within the fill materials (both upper and lower fill) within Zones 3 and 4 (i.e. offsite).
- Around 10% of the contaminant mass is currently located within the natural marine sediments within Zones 3 and 4 (i.e. offsite) which are generally present at depths of between approximately 13mBGL and 32mBGL.

Post remediation conditions:

- The proposed remedial extent will remove around 80% of the total gasworks related contaminant mass currently present on and offsite (downgradient) and over 90% of the gasworks related contaminant mass currently within the declaration area.
- Of the residual contamination that will remain *in situ* following the proposed remediation works, the majority (approximately half of the residual or around 10% of the total) of the

contaminant mass is present within the marine sediments of Zone 3 and 4, which as discussed above are considered to have negligible potential for contaminant flux and discharge. The majority of this is within Zone 3, within 20m of the declaration area boundary.

- The residual contamination within marine sediment in Zones 2, 3 and 4 (on and offsite) remaining after remediation equates to around 15 tonnes naphthalene and 70.5 tonnes TPH C10-C14.
- Around 20% of the residual contaminant mass will remain within the fill materials (both upper and lower fill) within Zones 3 and 4 (i.e. offsite). It is noted that these fill materials will be the subject of separate HHERAs and RAPs as part of the proposed future development works in the ORWN and Barangaroo Central areas.

11.7 Conclusion

AECOM has defined a lateral and vertical extent of remediation required for removal of the EPA declaration based on a number of considerations. The proposed remediation extent will result in around 20% of the current gasworks related contaminant mass remaining onsite and in areas downgradient, primarily within marine sediment within 20m of the declaration area boundary. In the Auditor's opinion, the extent of soil remediation is considered adequate to address the risk to human health and the environment to a degree acceptable for removal of the EPA declaration. Active remediation of groundwater is not proposed by AECOM. Groundwater contamination is proposed to be addressed by source removal/ containment. The Auditor considers the remedial extent proposed to be sufficient to address "the extent practicable" for removal/ treatment of DNAPL and other requirements relating to CUTEP. The extent of remediation in offsite areas is considered adequate for removal of the declaration, although the potential for contamination to extend beyond the BH/MW541 "hotspot" is noted. Specific offsite areas are identified by AECOM that are required to be addressed by the offsite RAPs (ORWN and Central), which is considered appropriate.

AECOM (2013b) notes that the "residual" contamination within Block 4, and much of the residual impact to marine sediment downgradient of the declaration area boundary (within Block 4) will be contained within the groundwater retention wall system proposed for the Block 4 development, effectively eliminating the pathway for the migration of contamination from Block 4 to the environment. AECOM does not rely on the Block 4 development in defining the extent of remediation for VMP removal, but notes that the likely future development will *"…further minimise the threat to the environment of residual contamination remaining within Block 4".*

Discussion of the proposed remediation, validation and future management issues is provided in Section 13.

12 Determination of Remediation Extent for Block 4 Development

12.1 Introduction

The extent of remediation for Block 4 development was discussed by AECOM (2013c) in the RAP based on protection of human health and the environment under future land uses following development. The RAP proposes removal of SPGWT and CIM.

The Auditor has reviewed the data and analysis presented by AECOM in defining the extent of remediation required for the Block 4 development. The following Section 12.2 discusses the occurrence of SPGWT and CIM within the site. SPGWT was identified based on field and laboratory results, while CIM was identified by comparison of groundwater data with the relevant risk based remediation criteria (SSTC), discussed in Section 10. There are no unsaturated soils proposed to remain in Block 4 after development therefore there are no applicable soil criteria. In addition, a groundwater retention wall system is proposed around the entire perimeter and therefore criteria for protection of the environment are not required.

Attachment 18, Appendix A, illustrates exceedances of the SSTC for groundwater while Attachment 9, Appendix A, shows the occurrence of SPGWT. The relevant criteria are included in Appendix E. Section 12.3 describes the proposed remediation extent determined by AECOM.

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 to the extent practicable (discussed in Section 10.3.2). However, the construction methodology to be employed does not allow for inspection of excavation walls or removal of tar. AECOM has therefore adopted an in situ validation approach to confirm that tar will not be present in the immediate vicinity of outer basement walls. Consideration of in situ data to validate this aspect is discussed in Section 12.4.

12.2 SPGWT and CIM Located Onsite

The identification of SPGWT within Block 4 is summarised in Table 12.1.

Table 12.1: Identification of SPGWT at Block 4

Item	Details	
No. locations SPGWT identified	21	
- No. in fill	15 (12 in Eastern Block 4)	
- No. in natural/ deep fill	8 (3 in Eastern Block 4)	
No. locations DNAPL identified	4 (sheen in a further 4 wells) (all in Eastern Block 4)	
- Wells DNAPL identified (MW)	15, 204D, 205, 206 (sheen in 200, 204S, 209, BH405/ IT03)	
SPGWT Locations >8mBGL *(not included in proposed remedial extent, refer Section 12.3)*	MW205 – DNAPL in sandstone	well screened 15-19.5mBGL
	BH48 – upper surface of bedrock	14.5mBGL
	BH49 – fill/ natural sandy clay	9.2-12.7mBGL

Table 12.1: Identification of SPGWT at Block 4		
Item	**Details**	
	BH405 – silty sandy clay/ sandstone	14-14.5mBGL
	BH406 – deep fill and natural clay	14.3-16.8mBGL
	BH408 – silty sandy clay	8 – 9.4mBGL
	BH119 – fill	7.5-10mBGL

The assessment of analytical results from Block 4 against SSTC is summarised in Table 12.2. The groundwater exceedance column considered the most recent groundwater data (from 2010-2011) for each well. AECOM calculated statistics for the groundwater data set (average and median results contemplated below) which considered an additional set of results from two wells plus two duplicates from one well. The Auditor has also considered data from BH/MW40, located immediately offsite to the west. Inclusion of this well is considered appropriate since it is located immediately outside the proposed location of the groundwater retention wall, albeit screened at a depth below the basement wall (14.3-20.3mBGL).

Table 12.2: Assessment of Block 4 Results Against SSTC				
Analyte	**Groundwater Exceedances**	**Groundwater Exceedance Wells (MW)**	**Average Exceeds SSTC?**	**Median Exceeds SSTC?**
2-methylnaphthalene	1/11	205	Y (2 times)	N
Acenaphthlyene	0/15	-	N	N
Fluorene	1/15	205	N	N
Phenanthrene	1/15	205	N	N
Naphthalene	9/15	15, 200, 204S, 205, 206, 209, 54, IT3D, 40 (offsite)	Y (70 times)	Y (2 times)
3-&4-methylphenol	0/15	-	N	N
TPH C6-C9	0/13	-	N	N
TPH C10-C14	8/14	15, 200, 204S, 205, 206, 209, 54, IT3D	Y (60 times)	Y (1.2 times)
Benzene	2/14	15, 200	N	N
Ethylbenzene	0/14	-	N	N
Toluene	0/14	-	N	N
Total Xylenes	0/14	-	N	N
1,2,4-trimethylbenzene	0/10	-	N	N
Styrene	0/10	-	N	N

Table 12.2: Assessment of Block 4 Results Against SSTC				
Analyte	**Groundwater Exceedances**	**Groundwater Exceedance Wells (MW)**	**Average Exceeds SSTC?**	**Median Exceeds SSTC?**
Aniline	0/11	-	N	N
Ammonia	0/9	-	N	N

In summary, SPGWT is present as follows:

- In the east of Block 4, associated with gasworks infrastructure and where bedrock is shallow (SPGWT generally occurs 1-4mBGL)
- In the west of Block 4, downgradient of gasworks infrastructure and at depth (SPGWT generally occurs 7.5-15mBGL)
- Also likely to be present at other gasworks infrastructure locations that have not been investigated.

Groundwater exceedances (comprising CIM) occurred for 2-methylnaphthalene, fluorene, phenanthrene and benzene (1 to 2 wells) and most significantly in frequency and magnitude for naphthalene and TPH C10-C36. Exceedances were generally associated with the occurrence of SPGWT, or lesser evidence of impact such as sheen (eg, MW200). The only exceedance in BH/MW40, located offsite, was naphthalene marginally above the SSTC. This well is screened below 14mBGL in natural clayey sand which contained tar veins, although AECOM did not consider this to be occurring in sufficient quantity to be classified as SPGWT (>10% TCM).

12.3 Proposed Remedial Extent

12.3.1 Lateral and Vertical Extent

AECOM defined the lateral extent of remediation based on the presence of historic gasworks infrastructure and the distribution of SPGWT and CIM. The lateral extent of remediation proposed, entirely in the saturated zone, is presented in Attachment 19, Appendix A. It includes approximately half of the Block 4 area, the majority within the eastern portion, and extends to the northern, eastern and southern boundaries of Block 4.

It is noted that the remainder of Block 4 is also intended to be excavated for the basement and excavated soil will require management in accordance with the RAP. Management measures should consider the potential for odours within these materials.

Given that the Block 4 basement excavation is anticipated to extend to 8mBGL and the majority of SPGWT and CIM was identified above 8mBGL, AECOM has defined the vertical extent of remediation as 8mBGL (approximately -5.5mAHD), plus deeper within gasworks features that are excavated into bedrock (e.g., gasholder at around 9.4mBGL). The proposed depths for each area (ranging from 2 to 10mBGL) are shown on Attachment 19, Appendix A; however, it is noted that the 10mBGL target remediation depth shown on Attachment 19 is not consistent with what is proposed in the RAP (8mBGL). In order to address SPGWT below 8mBGL, if SPGWT is encountered in fill material at the base of

remedial excavations, the vertical extent of remediation is proposed to be increased by 1-2m, depending on whether the excavation is to be locally backfilled with permeable fill (2m) or clay fill (1m).

The Auditor notes that over-excavation is likely to be required in a number of known locations, generally in the west of Block 4 where the depth of fill exceeds 8mBGL and marine sediment is present over bedrock (e.g. BH/MW205, BH49, BH119 and BH408).

12.3.2 SPGWT and CIM Not Addressed by Proposed Remediation Extent

The lateral and vertical remediation extent defined by AECOM does not address all of the SPGWT and CIM identified in Section 12.2, as follows:

- Within the remediation area, below 8mBGL, SPGWT in deep fill and marine sediment at BH49 (9.2 to 12.7mBGL), BH119 (7.5-10.0mBGL), BH408 (8 – 9.4mBGL)
- Within the remediation area, below 8mBGL, DNAPL in sandstone at MW205 (well screened 15-19.5mBGL)
- Outside the remediation area, SPGWT in deep fill and marine sediment at BH48, BH406 and BH405/IT03 (>14mBGL).
- CIM (groundwater exceedance) at BH405/IT3D (screened 13.5-14.5mBGL) and BH/MW40 located just offsite (screened 14.3-20.3mBGL)
- Likely other SPGWT and CIM (groundwater exceedances) in marine sediment locations downgradient of the gasworks infrastructure (generally in the west of Block 4) and below 8mBGL.

AECOM considers that remediation to address the above is not required based on the following:

- Local over-excavation by 1-2mBGL will occur in the base of the excavation where SPGWT is present.
- Shallow and medium depth screened intervals within IT03 (screened at 2.5 and 8mBGL), contained low contaminant concentrations and are likely to be more representative of groundwater in contact with the future basement than the concentrations detected at BH405/IT03D.
- Contaminant flux from bedrock and marine sediments into overlying fill is negligible (refer Section 11.5) therefore impacts to bedrock and marine sediment remaining at depth (largely below 14mBGL) below the basement do not present a risk to human health.

Further justification was presented by AECOM relating to determining ‘the extent practicable’ as discussed by the Auditor with respect to the VMP removal in Section 10.2.5. Several of these elements also relate to the Block 4 development remediation works and are generally supported by the Auditor.

12.4 In Situ Validation of Groundwater Retention Wall Alignment

Data within 30m either side of the proposed groundwater retention wall system was considered by AECOM to assess the potential for tar to be present in the immediate vicinity

of outer basement walls, which are currently proposed to extend to 8mBGL. The Auditor has assessed the relevant wall alignments as follows.

To the east, adjoining Hickson Road: The basement will extend through bedrock which is shallow in this area. SPGWT potentially in contact with the outer basement wall (groundwater retention wall) will be addressed by the VMP remediation works in Hickson Road. A complicating issue along this alignment is the presence of the 1870 gasholder which crosses this boundary. The timing of the remediation of the 1870 gasholder relative to construction of the Block 4 groundwater retention wall system is yet to be confirmed. AECOM has proposed that this timing be considered as part of a validation SAQP. The RAP includes the following options that will be considered in the event that remediation and validation of Block 4 is required prior to remediation and validation of Hickson Road:

1. Remediation of SPGWT within the 1870 gasholder in Hickson Road prior to validation of Block 4

2. Further assessment of the risk presented by SPGWT within the 1870 gasholder in Hickson Road, including possible additional investigations and consideration of the design and construction methodology of the retention wall.

These options are considered acceptable. Further consideration of this issue in the validation SAQP is considered appropriate. The Auditor notes that these options should also be considered with respect to other areas of SPGWT in Hickson Road if the VMP remediation is not complete in adjoining areas before the wall construction commences.

To the north, adjoining Block 5, including the portion within the declaration area: The basement will extend through bedrock in the east of this boundary, and will terminate within fill in the west, as shown in the cross section included as Attachment 6, Appendix A. Remediation of contaminated areas in the east is proposed to bedrock or a maximum depth of 10mBGL as part of the VMP remediation works. As above, the validation SAQP should consider the possible presence of SPGWT in the proposed remediation area within Block 5 if the VMP remediation is not complete before the wall construction commences. Outside the remediation area, the critical area for potential contact of SPGWT with the basement is around half way along this boundary, where the basement is in proximity to marine sediment over bedrock. No SPGWT was identified in boreholes in this critical area. Impacts to marine sediment were more common at greater depth and located further to the west, however, there is potential for undetected SPGWT to be present in this critical area.

To the west, adjoining the ORWN area: The basement will terminate within fill in this area. No SPGWT has been identified in fill within 8mBGL in surrounding boreholes along this alignment. However, SPGWT is present in a number of locations within marine sediment. This generally occurs at depths >14mBGL which is sufficient depth below the basement wall (maximum 8mBGL) for it not to present a contact risk.

To the south, adjoining the ORWS area: Construction of a basement to a similar depth is currently in progress on the ORWS site, therefore any SPGWT present will be removed. Some residual SPGWT may be present within ORWS at depths below both the ORWS and Block 4 basements, which does not present a contact risk.

While the presence of SPGWT below the basement floor can be addressed during the remediation works, the wall construction method does not allow for identification and removal of SPGWT against the outer basement wall. Based on the in situ validation information presented by AECOM and the Auditor's review, there is considered to be a low potential for significant SPGWT to remain in contact with the outer basement wall following the VMP remediation works. Localised contact may occur, most likely at the bedrock surface, however, this is not considered to represent an unacceptable risk to human health within the context of the quantitative risk assessment performed.

Further consideration of this issue in the adjoining VMP remediation works areas (Hickson Road and Block 5) is required once the timing of remediation is confirmed, and is proposed to be addressed in the validation SAQP, which will be subject to Auditor review.

12.5 Conclusion

AECOM has defined a lateral and vertical extent of remediation required for Block 4 development based on a number of considerations. In the Auditor's opinion, the extent of soil remediation is considered appropriate to address the identified risk to human health to a degree acceptable to allow development of Block 4. Active remediation of groundwater is not proposed by AECOM. Groundwater contamination is proposed to be addressed by source removal/ containment. The in situ validation performed is considered sufficient to confirm that tar is unlikely to be in contact with outer basement walls, although the scheduling of adjoining VMP remediation works with respect to the Block 4 development remediation works is noted as an issue requiring further consideration.

Discussion of the proposed remediation, validation and future management issues is provided in Section 13.

13 Evaluation of Proposed Remediation

13.1 Remediation Strategy and Methodology Overview

As discussed in Section 10.1, there are two remedial goals for the site which overlap in area, as follows:

- VMP removal for the declaration area (comprising a portion of Hickson Road and a portion of Blocks 4 and 5).
- Development of Block 4, which includes the portion within the declaration area and additional land to the west of the declaration area.

In describing the proposed remediation, the RAP (AECOM, 2013c) has considered two areas, as follows:

- Block 4 – addressing the combined goals of VMP removal (for the portion within the declaration area) and development.
- Block 5 and Hickson Road – addressing the goal of VMP removal.

The following sections outline the proposed remediation strategy and methodology in these areas. The Auditor's evaluation of the RAP is provided in Section 13.4.

13.1.1 Block 4 – VMP and Development

The preferred remedial option to remove the NSW EPA Declaration from Block 4 is excavation of SPGWT and CIM, onsite treatment (where required) and disposal offsite or reuse (non SPGWT). The definition of SPGWT and CIM is provided in Sections 8 and 10, respectively.

The proposed remediation process for the development of Block 4 is essentially the same as that proposed for the removal of the NSW EPA Declaration from Block 4, with the addition of a basement groundwater retention wall system along the boundary of Block 4. The wall is required to allow construction of a basement within Block 4. The RAP reports that the wall could serve as the retention wall required to allow excavation of the site for the Block 4 VMP remediation works.

Since the development of Block 4 will require extensive excavation for basements, soil falling within proposed basement areas is required to be excavated from the site regardless of contamination status. Excavated material that meets reuse criteria and is free of SPGWT may be beneficially reused on other areas of the Barangaroo development (excluding Headland Park). Material that cannot be reused will be treated (if required) and disposed offsite.

An alternate remediation option if the proposed Block 4 development works significantly changed was identified as full scale remediation of SPGWT and CIM using surfactant-enhanced in situ chemical oxidation (S-ISCO) and surfactant enhanced product removal (SEPR) (if proven in trial).

Groundwater monitoring would be undertaken following VMP Remediation Works.

13.1.2 Block 5 and Hickson Road – VMP

The proposed remedial works to remove the NSW EPA Declaration from Block 5 and Hickson Road includes completion of a S-ISCO and SEPR proving phase and pilot trial, followed by full scale remediation of SPGWT and CIM if the trial is successful. Sampling of groundwater would be undertaken during and following remediation. Sampling of soil would be undertaken prior to and following remediation. Soil gas would be sampled during remediation.

If the proving phase and pilot trial are not successful or if in situ remediation is not appropriate due to project requirements, excavation of SPGWT and CIM, onsite treatment (where required) and disposal offsite or reuse (non SPGWT) are contemplated as alternatives.

13.2 Excavation and Reuse Process

13.2.1 Overview

The RAP describes the steps to be taken in the excavation and reuse or treatment and disposal process, including physical separation of recyclable and oversize material, stockpiling, reuse of material that meets criteria, ex situ treatment via stabilisation/solidification or surfactant-enhanced ex situ chemical oxidation (S-ESCO) (if required), offsite disposal of material unsuitable for reuse or that exceeds the available capacity, and validation.

AECOM (2013c) state that *"full time supervision of the remediation works will be undertaken including visual and olfactory observations of excavated material to confirm that it is consistent with that anticipated based on previous investigations"*.

13.2.2 Retention Walls

An excavation retention wall will be installed to facilitate the Block 4 VMP Remediation Works. The Block 4 Development Remediation Works require installation of a basement groundwater retention wall system, which could also serve as the excavation retention wall.

The basement groundwater retention wall system will be aligned along the Block 4 perimeter (Attachment 3, Appendix A), will be keyed into bedrock and the existing wall along the southern boundary of Block 4, and will be a minimum of 600 mm thick. Exposed bedrock surfaces will be covered with concrete or shotcrete where basement excavations extend into bedrock. The basement groundwater retention wall system will effectively prevent groundwater migration to/from Block 4.

13.2.3 Materials Tracking

The RAP (AECOM, 2013c) 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:

- Offsite Transport/Disposal Form.
- Imported Fill Form.

- Material Excavation Form.
- Material Treatment Form.
- Material Stockpiling Form.
- Material Placement Form.

13.2.4 Excavated Material Treatment

Treatment of excavated material may be required prior to offsite disposal. Two treatment options discussed in the RAP are stabilisation and surfactant enhanced ex situ chemical oxidation (S-ESCO).

Stabilisation of SPGWT and CIM is proposed by screening to minus 40 mm, followed by mixing of additives in a pugmill and validation of treated soil (Table 13.2). EnviroPacific Services assessed the performance of different additives in stabilisation trials, with the aim of meeting the criteria specified in the NSW EPA General Immobilisation Approval # 2005/14. The additives assessed included Portland cement, fly ash and a chemical fixative RemBind-FO11. Different volumes and combinations of additives were required depending on the initial contaminant concentrations.

S-ESCO of SPGWT and CIM is proposed by screening to minus 40 mm, followed by the mixing of additives (surfactants, oxidants and catalysts) in a pugmill. The treated soil will be validated (Table13.2) prior to offsite disposal. The feasibility of S-ESCO was assessed by VeruTEK (2010a) to identify the most effective additives and the optimal dosing volume.

13.3 In Situ Treatment

The RAP proposes in situ treatment technologies (S-ISCO and/or SEPR) for remediation of the Block 5 and Hickson Road portions of the declaration area. As outlined by VeruTEK (2010b), the S-ISCO process involves the injection of an oxidising agent (and activator if required) and a cosolvent (surfactant) into the subsurface to reduce the amount of source NAPL and reduce the flux of groundwater constituents. SEPR uses plant-based surfactants and hydrogen peroxide to enhance product recovery of NAPL. SEPR is also used as a pre-treatment for S-ISCO. Both processes utilise enhanced desorption and solubilisation of the gasworks organic chemicals from soils and simultaneous chemical oxidation of the solubilised chemicals.

The feasibility of S-ISCO and SEPR (as well as E-ESCO for treatment of excavated material) for remediation of SPGWT and CIM was demonstrated through a laboratory treatability study (VeruTEK, 2010a). The study was undertaken to provide inputs into a proving phase and pilot trial, including selection of the type of oxidant, activator, cosolvent and proposed dosage.

A proving phase and pilot trial are required to demonstrate the effectiveness of the proposed technologies in treating or destroying SPGWT and CIM, to provide information for full scale remediation, and to demonstrate that it will not result in unacceptable risks to human health or the environment. The Auditor has reviewed a proposed pilot trial, as documented in the review letter included in Appendix G (13 October 2010). The S-ISCO and SEPR Pilot Trial was approved as a major project in March 2011 (MP10_0087). The conditions of approval required that the EPA approve a Trial Management Plan. BDA subsequently required a

proving phase (VeruTEK, 2012), which has recently been completed however the findings have not been reported to date.

If the proving phase and then pilot trial are successful, full scale S-ISCO and SEPR treatment of SPGWT and CIM in the Block 5 and Hickson Road portions of the declaration area is proposed.

Monitoring of the following parameters is proposed prior to, during and post injection:

- Process monitoring of chemistry in the system and in injection wells, including injection rates, concentration and pressure.
- Performance monitoring involving measurement of groundwater and process water for pH, oxidation reduction potential (ORP), dissolved oxygen, conductivity, hydraulic head, depth to groundwater, temperature, oxidant concentrations, TPH and inter facial tension. Performance monitoring will be undertaken to understand the success of contacting the contaminant mass with the injected chemicals and mitigating risks to the environment and sensitive receptors.
- Groundwater sampling and analyses for TPH, VOCs, SVOCs, metals, TOC, sulphates and total residual chlorine to confirm that treatment is proceeding and effective, that contaminants and/or metals are not being mobilised by the treatment, and to demonstrate that Darling Harbour and other sensitive receptors are not being impacted.
- Soil vapour sampling near the basements of nearby buildings, the sewerage pumping station, and service pits. The parameters to be monitored are not specified.
- Soil sampling and analyses for TPH, VOCs and SVOCs to provide an estimate of contaminant reduction.

Full details of the proposed monitoring for full scale implementation will depend on the results of the pilot trial and are to be provided in a Detailed Work Plan which will be subject to approval by the Auditor and EPA.

13.4 Evaluation of Remedial Action Plan

The Auditor has reviewed the RAP (AECOM, 2013c) 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 13.1, below.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
Remedial Goal RAP s1.1	The key objectives of the remediation given in the RAP (2013c) are: • *"To enable the NSW EPA's declaration of the Declaration Area as a Remediation Site (Declaration Number 21122; Area Number 3221) to be revoked; and* • *To ensure that Block 4 is remediated to a standard suitable for the proposed development in Block 4."*	The identified remedial objectives (remedial goal) are considered appropriate. The Auditor notes that making Block 5 suitable for future development was not an objective of the RAP.

Table 13.1: Evaluation of Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
	Additional objectives of the remediation works are: • To ensure the remediated declaration area is protective of human health in the context of its current form and land use. • To ensure the remediated Block 4 is protective of human health in the context of the proposed development. • To protect the environment (specifically groundwater and the adjacent Darling Harbour) by remediation of the site to a standard that will minimise the risk of ongoing contamination. • Comply with applicable legislative and policy requirements including the appropriate requirements of the NSW Department of Planning and Infrastructure (DoPI) and NSW EPA.	
Discussion of the extent of remediation required RAP s8 and s9 Discussion of remediation extent for VMP and Block 4, respectively	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 design and land uses and the location of the associated basement groundwater retention wall system (Development Remediation only). • Consideration of regulatory policy requirements including the principles of CUTEP, ESD and the principles of the *Waste Avoidance and Resource Recovery Act 2001*. The remediation extent was discussed in Sections 10, 11 (VMP) and 12 (Block 4) of this SAR and is summarised as follows: **VMP Remediation Works** The extent of remediation was determined by AECOM (2013b) in the VMP Extent report based on protection of human health and the environment in the sites current condition. This was to be achieved by removal of SPGWT and CIM, and removal of 90% of the contaminant mass in fill. The lateral extent of remediation in the unsaturated and saturated zones is presented in Attachments 14 and 15, Appendix A, respectively. It includes areas of Block 4, Block 5, Hickson Road and offsite areas to the west. Remediation of offsite areas to the east is not proposed, however the RAP recommends management measures be considered to mitigate the risk of recontamination of the site if offsite sources are present (i.e. installation of a permanent perimeter wall). Remediation of impact identified to the south of the site is currently	The defined extent of remediation is considered appropriate, as discussed in Sections 10, 11 and 12 of this SAR. The potential for contamination to extend beyond the BH/MW541 “hotspot” is noted. Specific offsite areas are identified by AECOM that are required to be addressed by the offsite RAPs (ORWN and Central), which is considered appropriate.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	underway as part of ORWS development works. The vertical extent of remediation was defined as the depth to bedrock or a maximum depth of 10mBGL. If SPGWT is encountered in fill material at the base of the excavation, the vertical extent of remediation will be increased by 1-2 m or to natural material. **Block 4 Development Remediation Works** The extent of remediation was determined by AECOM (2013c) in the RAP based on risk to human health or the environment under future land uses following development. The RAP proposes removal of SPGWT and CIM (concentrations of groundwater which exceed the groundwater SSTC). The lateral extent of remediation is presented in Attachment 19, Appendix A. The remedial excavation covers around half of the site, primarily in the east, and will extend to the basement groundwater retention wall system to the north, east and south. The vertical extent of remediation is proposed to be limited to the depth of the basement, which was given as 8mBGL. If SPGWT is encountered in fill material at the base of the excavation, the vertical extent of remediation will be increased by 1-2 m. The Auditor notes that excavation of SPGWT and CIM for removal of the declaration is proposed to a depth of up to 10mBGL in the portion of Block 4 in the declaration area. The proposed remediation extent will result in SPGWT and CIM remaining within Block 4 primarily within marine sediment at depth. Removal of the SPGWT is not proposed as it is significantly below the proposed basement depth and contaminant flux from marine sediment has been shown to be negligible. CIM present in two wells (BH405/IT03D and MW40 (offsite)) is not proposed to be removed as the screened intervals were below the proposed depth of the basement. Shallower wells installed at BH405/IT03 had contaminant concentrations generally less than the PQL and less than the SSTC.	
Remedial Options RAP s10	The RAP includes a remedial technology assessment including consideration of numerous in situ and ex situ remedial technologies. A screening assessment was performed, and more detailed consideration was given to seven remedial technologies: 1. Excavation and ex situ thermal desorption	The assessment of remedial options is considered adequate.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	(onsite) 2. Excavation and ex situ thermal desorption (offsite) 3. Excavation and ex situ stabilisation or solidification (ESCO) 4. Excavation and surfactant enhanced ex situ chemical oxidation (S-ESCO) 5. Surfactant enhanced in situ chemical oxidation (S-ISCO) and surfactant enhanced product recovery (SEPR) 6. In situ stabilisation or solidification 7. Physical containment.	
Selected Preferred Option RAP s11	The RAP identified two preferred remediation strategies for the site: • Excavation and ex situ stabilisation and/or S-ESCO (onsite) • S-ISCO and SEPR Excavation and ex situ stabilisation and/or S-ESCO are discussed in Section 13.2 above. This includes excavation of SPGWT and CIM from Block 4 for removal of the NSW EPA Declaration and to facilitate the proposed development basement. Excavated material is to be sorted to remove recyclable and oversize material, followed by either: • beneficially reused onsite or on other areas of the Barangaroo development (excluding Headland Park), or • disposed offsite following stabilisation or S-ESCO treatment (if required). S-ISCO and SEPR are discussed in Section 13.3, above, and are proposed for remediation of the Block 5 and Hickson Road portions of the declaration area. Proving phase and pilot trials are required to demonstrate the effectiveness of the proposed technologies.	The selected preferred remediation options are considered appropriate; however trials are required to demonstrate the effectiveness of S-ISCO and SEPR.
Rationale RAP s11	The selected preferred remedial strategies were justified for each area based on feasibility and sustainability considerations.	The rationale presented is considered appropriate.
Proposed Validation Criteria RAP s7 and s19.1	The proposed validation criteria are the remediation goals and criteria (SSTCs) discussed in Section 10 of this SAR. **VMP Remediation** Removal/remediation of SPGWT and CIM to the extent practicable. Removal/remediation of contaminated fill such that	The defined remediation/ validation criteria are considered appropriate as discussed in Section 10 of this SAR.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	the contaminant mass within the proposed Remediation Extent is reduced by 90%. Groundwater concentrations at the down hydraulic gradient boundary of the site should "approach" the relevant MWQC for acenaphthene, acenaphthylene, anthracene, fluorene, naphthalene, phenanthrene, phenol, BTEX, TPH C_6-C_9, TPH C_{10}-C_{36} and ammonia. **Block 4 Development** Removal/remediation of SPGWT and CIM to the extent practicable.	
Validation Principles RAP s19.2	Statistical validation is proposed for soil as per the requirements of the NEPM (1999). The 95% UCL and arithmetic average will be used to assess the chemicals of potential concern (where appropriate). Data sets will be defined for different areas and different strata. The RAP notes that *"…the use of statistics will not be used in the assessment of groundwater analytical data sets…"*.	The statistical validation proposed is considered acceptable provided data sets are representative, noting that statistics have limited application in the proposed validation.
Proposed Validation Testing RAP s19.2.3	A validation SAQP is to be prepared for each stage of remediation based on the sequence of remediation and the adopted remediation options. It will detail the soil validation requirements required to demonstrate that remediation has been undertaken in accordance with the RAP. Auditor approval of the validation SAQPs will be sought.	General validation approach is considered appropriate. Auditor approval of validation SAQPs is appropriate.
Staging of remediation/ validation RAP 19.2.1	The timing of the VMP remediation works in Hickson Road (including the 1870 gasholder) and Block 5 relative to construction of the Block 4 groundwater retention wall system is yet to be confirmed. AECOM has proposed that the timing of the 1870 gasholder remediation be considered as part of the validation SAQP and options are presented in the RAP for consideration in the event that remediation and validation of Block 4 is required prior to remediation and validation of the 1870 gasholder:	The options are considered acceptable. Further consideration of remediation timing in the validation SAQP is considered appropriate. The Auditor notes that this approach should be adopted for VMP remediation works more generally within Hickson Road and Block 5, in addition to the 1870 gasholder.
Soil validation RAP s19.4 and 19.5	Soil validation sampling is proposed at various stages of the remediation works. The proposed soil sampling is summarised in Table 13.2, below.	The approach to validation sampling is considered reasonable. While the various sampling densities (e.g. 1 per 400 m^3) appear adequate, confirmation of their adequacy will depend on the results obtained and

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
		their consistency. Visual validation will require adequate supporting documentation.
Groundwater validation RAP s17.4	A groundwater management plan (GMP) is to be prepared detailing the groundwater monitoring works to be undertaken during and after remediation. Auditor approval will be sought for the GMP prior to implementation.	Approach is considered appropriate. Auditor approval of GMP is appropriate.
RAP s19.8, 19.9	Quarterly groundwater monitoring is currently proposed during VMP Remediation Works to build a robust data set for groundwater quality at the site and to demonstrate that the continuing remediation works are not having a detrimental impact on the environment. Quarterly post-remediation groundwater monitoring is also proposed for a period of six months (3 rounds). A summary of the proposed monitoring is provided in the RAP, as follows: • The monitoring well network will consist of existing and new wells. • Groundwater samples will be analysed for the COPC (Table 13.2). • Results will be compared with the SSTC and/or MWQC. Further details are to be provided in the GMP. Groundwater monitoring is not proposed during or following Block 4 Development Remediation Works.	The summary of the proposed monitoring is considered acceptable. The Auditor will provide detailed comment on the appropriateness of the proposed monitoring in review of the VMP GMP.
Validation sampling methods RAP s19.7 and 19.10	The RAP details the proposed soil and groundwater sampling methods. Sampling methods will be confirmed in the validation SAQP (soil) and GMP (groundwater). A discussion of data quality objectives (DQOs), QA/QC samples and control limits for data quality indicators (DQIs) is also provided.	The proposed sampling methods described are considered appropriate. The QA/QC information outlined is considered acceptable.
Validation of HHERA Assumptions RAP s19.3	The RAP describes a validation process to confirm that key assumptions regarding the proposed development, and on which the DS HHERA (AECOM, 2011) and DS HHERA Letter (AECOM, 2012c) was based, have been or will be implemented. Review of "issue for construction" or "as constructed" drawings is proposed to achieve this. 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. Any significant changes to the final development	The proposed approach to validation of key risk assessment and remedial design assumptions is considered appropriate.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	plans will require confirmation that: • The analytical data set and sampling density for the materials of potential concern (specifically additional soil which may remain below basements [as appropriate]) are adequate for assessing the suitability of the materials affected by the design changes • Any required additional site investigations are suitable to supplement the current analytical data set. If required, the scope of these works will be endorsed by the NSW EPA Accredited Site Auditor • Confirmation that the assumptions of the DS HHERA and DS HHERA Letter are still valid. AECOM proposes to prepare an Addendum to the RAP, to be approved by the Auditor, if the final development design is changed from the assumptions, as discussed in Section 13.5, below.	
Interim Site Management Plan (before remediation)	None proposed.	Not required since the site is currently vacant and secure.
Site Management Plan (operation phase) including stormwater, soil, noise, dust, odour and OH&S RAP s14 Soil (including asbestos) RAP s17 Water RAP s20 EMP RAP s21 OHS	The RAP outlines environmental protection measures proposed to be implemented in relation to materials management, treatment systems, water management and other aspects such as odours, dust, noise and vibration. In particular, a Remediation Enclosure is proposed to be used when excavating particularly odorous materials, and the ex situ treatment facility is also proposed to be enclosed, with both enclosures to be fitted with Emissions Control Systems. Management of asbestos containing materials is discussed with respect to the recommendations of the Driscoll report. 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 and noise and vibration impacts is also proposed.	The outlined measures are considered appropriate. The level of detail provided is considered appropriate for the RAP. Based on experience during excavation of other gasworks and the location of the site within a high population area, odour control is considered critical.
Contingency Plans to Respond to Site Incidents. RAP s23	The RAP identifies a number of potential issues and outlines proposed responses. They include flooding, control of dust, fugitive emissions, odours, noise, vibration, spills and leaks. An emergency response plan will be prepared prior to remediation outlining possible emergency situations and procedures to ensure the safety of	Contingency measures are considered appropriate.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	personnel.	
Contingency Plan if Selected Remedial Strategy Fails RAP s23	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: • Increased volumes of contaminated material • Change in the approved land uses • Presence of contaminated material at greater depth • Variation of contaminant characteristics • Identification of unexpected contaminants and materials • Failure of the preferred treatment approach • Insufficient storage capacity for stockpiling • Concentrations of groundwater COPC increase • Alternative remediation options required for practical or commercial reasons • Failure of visual validation (with respect to surface water sheen and tar containing materials) • Change of the basement design or associated basement groundwater retention wall system • Various potential issues associated with S-ISCO.	The issues identified and proposed responses are considered reasonable.
Remediation Schedule and Hours of Operation RAP s12.2 and s13.4	The RAP outlines the task-wise project schedule however the project duration is not specified. Proposed hours of operation for construction and demobilisation were between 7 am and 6 pm Monday to Friday, and 7 am to 5 pm Saturdays. No construction works would occur on Sundays and Public Holidays. Excavation activities would be undertaken between 7 am and 5 pm, six days a week. The Emission Control System will reportedly operate 24 hours per day 7 days per week. S-ISCO and SEPR injections will be undertaken approximately 10 to 12 hours per day, 6 days per week. The RAP reports that "*the duration of the treatment process will depend on the chemical mass, the number of injection systems operating and their capacity*".	The identified tasks appear appropriate. The level of detail provided is considered appropriate for the RAP. Operational hours may vary in accordance with the development approval. Noise from the emission control system may be a factor in allowable working hours.
Licence and Approvals RAP s2, s13.1.2	The RAP outlines the relevant legislation and planning approvals required for the remediation works. The proposed remediation is expected to comprise soil treatment of a volume greater than 30,000 m^3 within the larger Barangaroo site area (therefore	The identified approvals and waste classification process appear appropriate. The proposed approvals for additional planning documentation (SAQP,

Table 13.1: Evaluation of Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
	"onsite"), therefore AECOM considers that variation to the existing Environment Protection License (EPL) will be required under the NSW *Protection of the Environment Operations Act 1997* (POEO Act). Variation to the existing EPL (13336) is also required to allow discharge of treated groundwater to Darling Harbour, emissions from odour control structures, emissions from the soil vapour extraction system (if required) and for treatment of material. 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 the *"Barangaroo Independent Remediation Review Panel concluded the approach to remediation for the project was being undertaken with consideration of contamination and the objective of SEPP 55 (1998) has been appropriately provided for in the determination of approvals".* Council will be notified of the proposed remediation works. The RAP (AECOM, 2013c) 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 8. As such, an application will be made to the NSW DoPI for remediation and land forming works within the declaration area. An Environmental Impact Statement (EIS) will be prepared to address these assessment requirements, in support of the application and to seek planning approval."* The EMP for site works will require approval from DoPI. The S-ISCO and SEPR Pilot Trial was approved as a Major Project by the Minister for Planning, pursuant to Part 3a of the Environmental Planning and Assessment Act (1979) (MP10_0087). The proving phase is being undertaken to meet the requirement for EPA approval of a Trial Management Plan. Discharge to stormwater or sewer, with or without treatment, is proposed as per regulatory guidelines and in accordance with a POEO license and Trade Waste License. Materials to be disposed offsite will be assessed in accordance with the DECC NSW (2008) 'Waste Classification Guidelines Part 1: Classifying Waste'. Offsite disposal of gas works waste will be undertaken in accordance with NSW EPA General Immobilisation Approval # 2005/14. If contaminant concentrations exceed criteria in the general	GMP, detailed work plan) discussed in Section 13.5 below are considered appropriate.

Table 13.1: Evaluation of Remedial Action Plan

RAP Element	Details	Auditor Comments
	immobilisation, a site specific Immobilisation Approval may be required. Offsite disposal will require consent from a licenced 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 the NSW Occupational Health and Safety Commission (NOHSC) Asbestos Code of Practice and Guidance Notes.	
Contacts/ Community Relations RAP s22	Community engagement is currently undertaken in accordance with the Community and Stakeholder Engagement Strategy prepared by LLMP (May 2012). Lend Lease will develop a Remediation Community Engagement Sub Plan for community engagement prior to and during remediation activities.	The level of detail provided in the RAP is considered appropriate.
Staged Progress Reporting s1.8 s19.2.1	The RAP anticipates staged remediation and validation reporting may be required, for example according to Blocks 4, 5 and Hickson Road. Validation reporting is proposed in accordance with the EPA (1997) 'Guidelines for Consultants Reporting on Contaminated Sites'.	Considered acceptable.
Long term site management plan RAP s20.5	The RAP anticipates that *"… a Site Management Plan may be required to describe contingency management methods which may need to be applied by future land owners if they wish to re-develop the site for any other land use different to its current site condition or as per the proposed Block 4 Development Works".* The SMP is to be prepared as an outcome of the site validation and in consultation with the Site Auditor.	In the Auditor's opinion, a Site Management Plan for future land owners will be required.
	The RAP states that no other form of Long Term Management Plan is envisaged *"on the basis that both the key assumptions and requirements of this RAP and the VMP HHERA … and Declaration Site HHERA … are successfully delivered and implemented during the execution of the works, and validated accordingly upon completion"*.	The Auditor agrees that no active Long Term Management Plan should be required if the RAP is implemented and validated successfully, unless ventilation and seepage control systems are

Table 13.1: Evaluation of Remedial Action Plan		
RAP Element	**Details**	**Auditor Comments**
		necessary.
RAP Section 17.4	Quarterly post-remediation groundwater monitoring is proposed for a six month period for assessment against groundwater SSTCs and MWQC. Monitoring is proposed in accordance with the GMP to be prepared prior to the commencement of remediation.	Development of the GMP in consultation with the Auditor is considered appropriate.

Table 13.2: Summary of Proposed Validation				
Area	**Item**	**Proposed Validation Method**	**Analytes**	**Criteria**
Declaration Area	Excavation bases	Visual inspection free of SPGWT and ACM. Photographic documentation of bedrock Sampling of fill material and natural soil on a 20 m grid below a depth of 100 mm if visual evidence of potential SPGWT.	PAH	TCM criteria for identification of SPGWT
	Excavation walls	Visual inspection free of SPGWT and ACM and photographic documentation of bedrock No validation sampling if the cut-off wall is located on the site boundary. In situ validation using available groundwater data and observations of SPGWT in logs if the cut-off wall is located within the site boundary.	NA	Unsaturated soil and Groundwater SSTC^{VMP} 90% removal of contaminant mass within remediation area
	Pre and post S-ISCO and SEPR	Soil boreholes on a 20 m grid, with soil samples collected from 0.5 mBGL, 1.5 mBGL and at 1 m intervals in the saturated zone.	Benzene, TPH C_{10}-C_{36} aromatic and aliphatic, CPAHs	SSTC^{VMP}
	Groundwater during and following S-ISCO and SEPR	Wells spaced at 40 m intervals across the treated areas. Details to be confirmed in future documents (validation SAQP/ Detailed Work Plan and /or GMP).	Benzene, TPH C_{10}-C_{36}, naphthalene, acenaphthylene, cPAH, ammonia	SSTC^{VMP}
	Groundwater on the down hydraulic gradient boundary	Wells spaced 40 m apart (2 wells). Details to be confirmed.	PAH, phenol, TPH, BTEX, ammonia	SSTC^{VMP} and MWQCs

Table 13.2: Summary of Proposed Validation

Area	Item	Proposed Validation Method	Analytes	Criteria
Block 4 Development	Excavation bases	Visual inspection free of SPGWT and ACM. Photographic documentation of bedrock Sampling of fill material and natural soil on a 20 m grid below a depth of 100 mm if visual evidence of potential SPGWT.	PAH	TCM criteria for identification of SPGWT If SPGWT is within rock defects, not mobile and less than 5% of exposed rock face. No sheen on surface water.
	Excavation walls	Not stated but assume visual inspection free of SPGWT and ACM and photographic documentation of bedrock In situ validation performed as discussed in Section 12.4 of SAR.	NA	If SPGWT is within rock defects, not mobile and less than 5% of exposed rock face. No sheen on surface water.
Excavated material	Untreated soil for reuse onsite and offsite	Visual inspection that it is free from SPGWT and ACM. 1 per 400 m^3 if material is "*significantly different*" from anticipated. Compliance with criteria developed for other areas of Barangaroo if used in those areas.	Benzene, TPH C_{10}-C_{36} aromatic and aliphatic, CPAHs, asbestos (if observed) Additional criteria may be required for other areas of Barangaroo	SSTC
	Untreated soil for offsite disposal	1 per 500 m^3	Metals, PAHs, phenols, TPH, BTEX, cyanide, asbestos	DECC (2008) 'Waste Classification Guidelines'
	Treated soil for offsite disposal	1 per 500 m^3	TCLP metals, TCLP PAH, TCLP phenols, TCLP cyanide and unconfined compressive strength	DECC (2008) NSW EPA General Immobilisation Approval # 2005/14
Treatment and stockpiling areas	Hardstand	Visual inspection for any contamination relating to treatment operations	-	-
	Soil beneath hardstand if	20 m grid samples	Analytes are those with soil	Not specified. Assumed to be

Table 13.2: Summary of Proposed Validation				
Area	**Item**	**Proposed Validation Method**	**Analytes**	**Criteria**
	contamination of hardstand present	0-0.15 m depth	SSTC	$SSTC^{VMP}$ or $SSTC^{DEV}$
Entire site	Imported material – VENM/ quarry product	VENM certificate demonstrating physical and chemical quality, including supporting test data Inspection at importation to confirm no evidence of contamination	-	VENM criteria and SSTC
	Imported material – non VENM (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 and SSTC

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.

13.5 Additional Remediation Documentation

AECOM (2013c) identify the following supporting documentation that will be prepared prior to commencement of the remediation works:

- Occupational Health and Safety Plan
- Community Consultation Plan
- Environmental Management Plan
- Project Management Plan
- Quality Management Plan
- Asbestos Management Plan
- Emergency Response and Contingency Plan
- Excavation Plans.

Other remediation documentation or further studies referenced throughout the RAP 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.

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/ approval authority may be warranted.

A Reuse Materials Management Plan, to be prepared by BDA, is required prior to reuse of material derived from the site elsewhere on Barangaroo.

Monitoring/ management documentation relating to the site suitability that will be prepared prior to commencement of the remediation works and that requires review by the Site Auditor is proposed as below. Items which AECOM has identified as also requiring approval by the EPA are noted:

- S-ISCO/ SEPR Pilot Trial report *(EPA also)*
- S-ISCO and SEPR Detailed Work Plan *(EPA also)*
- Validation SAQP(s)
- Groundwater Monitoring Plans (GMPs)
  - VMP remediation works *(EPA also)*
  - Block 4.
- A Site Management Plan (SMP) to describe contingency management methods which may need to be applied by future land, to be prepared as an outcome of the site validation.

The Auditor also notes that reporting on the S-ISCO/ SEPR proving phase is also required to allow further remediation planning.

The RAP (AECOM, 2013c) notes that *"If the final development design is changed in a way that affects the assumptions of the Declaration Site HHERA … and Declaration Site HHERA Letter … and this RAP, an Addendum will be prepared as required, 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.

13.6 Conclusion

In the Auditor's opinion, the proposed remediation and validation approach described in the RAP (AECOM, 2013c) is appropriate. The proposed remediation strategies are consistent with the Overarching RAP.

A number of monitoring/ management documents are to be prepared prior to remediation and the results from the S-ISCO/ SEPR proving phase/ pilot trial are also to be reported. Where they relate to the site suitability, these documents require approval by the Site Auditor, and where they relate to the VMP removal they also require approval by the EPA.

Site Auditor review of a Site Management Plan (SMP) for future land owners is required. This document is to be prepared based on the outcome of the site validation. This approach is considered appropriate and review of this document is not required to complete the current audit.

If significant changes are made to the development design, AECOM (2013c) proposes to prepare Addendum documents, to be approved by the Site Auditor: This is considered an appropriate approach to management of significant changes to the development design.

14 Contamination Migration Potential

The potential for offsite down-gradient 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 development of remedial goals and site specific remediation criteria (Section 10).

Migration of contamination in groundwater is known to have occurred offsite to the southeast from Hickson Road, into the basement of number 38 Hickson Road. If it goes ahead, there is potential for the proposed in situ remediation to change the nature and extent of this migration. The potential for impact to 38 Hickson Road during remediation will be considered by the Auditor in review of the S-ISCO/ SEPR Detailed Work Plan.

In the Auditor's opinion, completion of the remediation works as described in Section 13 will minimise the potential for future offsite down-gradient migration of contamination from the site. As discussed in Section 11.5, there is a considered to be an acceptably low potential for migration of contamination from residual impacts to be retained below 10mBGL, which are primarily in marine sediments. The RAP proposes that post-remediation groundwater monitoring be undertaken down-gradient of the VMP area. The Auditor will review the need for post-remediation monitoring down-gradient of the site and in the vicinity of 38 Hickson Road in review of the GMP.

15 Residual Risk Following Remediation

Potential risks to human health and the environment have been addressed through the development of remedial goals and site specific remediation criteria (Section 10) and the design of the remediation works (Section 13).

Following implementation of the RAP, there is potential for odorous soils or ACM fragments to be encountered during any future disturbance of fill soils to be retained within the declaration area. There is also potential for more significant contamination in the form of SPGWT or TCM to be encountered, particular below 10mBGL. AECOM (2013c) proposes development of a Site Management Plan (SMP) to describe contingency management methods which may need to be applied by future land owners, discussed in Section 16, following. An SMP is considered an appropriate means to manage future risk from contamination.

16 Ongoing Site Management

Following implementation of the RAP, ongoing operational site management is not anticipated to be required, however, a SMP will be prepared to cover future redevelopment of the site. The SMP is to be prepared as an outcome of the site validation and in consultation with the Site Auditor.

The appropriate conditions for the implementation of an Environmental Management Plan stated under Section 3.4.6 of DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Ed.)* will have to be met, namely:

- The remnant contamination to be managed must not pose an unacceptable risk to onsite or offsite environments.
- The EMP must be reviewed by the Auditor.
- The provisions of the EMP can be made to be legally enforceable.
- There will be appropriate public notification of restrictions applying to the site through a notification on the Section 149 Certificate for the site.

Implementation of the SMP is likely to be a condition of suitability on a Section A Site Audit Statement certifying suitability for the proposed use. A SMP is considered an appropriate means to manage any future risk provided the document is practical and legally enforceable.

17 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.

As discussed in Section 1.3, the Site Audit is a requirement of the VMP (Approval No. 20101719, dated 23 July 2010). The following Table 17.1 summarises the status of the Stage 1 VMP objectives and provides comments from the Auditor where relevant.

Table 17.1: Evaluation of Status of Stage 1 VMP Objectives

No.	Objective	Status/ Auditor Comments
O1.	Conduct a Data Gap Investigation for the site in order to adequately characterise the nature and extent of the site contamination.	DGI and Supplementary DGIs prepared for declaration area and adjoining sites (AECOM, 2010b and 2012a). Auditor also considered data from ORWN DGI (AECOM, 201c) and Barangaroo Central DGI (JBS, 2012) in considering the nature and extent of the site contamination. Refer proposed VMP remedial extent discussed in Section 11 of this SAR. Objective met by works to date.
O2.	Prepare a Human Health and Ecological Risk Assessment ("HHERA") which would identify the site specific soil and groundwater acceptance criteria for the site and for the remediation works.	HHERA prepared for declaration area (AECOM, 2011). Objective met by works to date.
O3.	Conduct remediation technology trials to determine applicability and selection of proposed remediation technologies for the site.	Pilot Trial Work Plan prepared for S-ISCO and SEPR (VeruTek, 2010b), reviewed by Auditor, dated 13 October 2010 (refer Appendix G). Subsequent revision to Work Plan and preparation of Trial Management Plan (2011, 2013) and implementation of a proving phase, recently completed although not reported on to date. Objective partially met by works to date (remediation technology trials not completed).
O4.	Prepare and submit a RAP (which outlines the agreed detailed design and specifications of the remedial measures and how these will be implemented, and is conditional upon a strategy to confirm the preferred remediation technologies (subject to completion of remediation technology trials)) to	RAP for declaration area and Block 4 and document describing proposed VMP Remediation Extent prepared (AECOM, 2013c and b). RAP submitted to Site Auditor and EPA. This SAR documents the Site Auditor's review. Remediation technology trials are not yet complete therefore the RAP presents options for remediation works. The approach taken in the RAP is considered

Table 17.1: Evaluation of Status of Stage 1 VMP Objectives		
No.	**Objective**	**Status/ Auditor Comments**
	the Site Auditor and the EPA; obtain the Site Auditor's endorsement of the RAP or confirmation that he has no objection to the RAP; and obtain the EPA's approval of the RAP.	by the Auditor to be acceptable since additional plan documents (next item) can provide further details of the proposed method. Objective largely met by works to date.
O5.	Based on the RAP, prepare and submit a RWP (which sets out the technical specifications of the remediation works on the site) to the Site Auditor and the EPA; obtain the Site Auditor's endorsement of the RWP or confirmation that he has no objection to the RWP; and obtain the EPA's approval of the RWP.	A RWP has not been prepared and the RAP does not contemplate preparation of a RWP, however, a Detailed Work Plan is proposed for S-ISCO/ SEPR which could meet the intentions of the RWP. Objective not met by works to date.

Other regulatory approvals and licenses required for the proposed remediation works are discussed in Table 13.1.

18 Conclusions and Recommendations

AECOM (2011d) concluded in the RAP:

"It is concluded that the preferred remediation strategy described by this RAP, upon successful implementation will:

- *enable the NSW EPA's declaration of the Declaration Area as a Remediation Site to be revoked; and*
- *if the Block 4 Development Works proceed, ensure that Block 4 is remediated to a standard suitable for the proposed development (i.e. suitable for the proposed land uses including a mixture of commercial, retail and high density residential and public open space)".*

Based on the information presented in the reports reviewed, the Auditor concludes that NSW EPA Declared Remediation Site 21122 (comprising a portion of Hickson Road and a portion of Blocks 4 and 5) can be remediated to a standard that:

- reduces the risk currently posed to human health and the environment under the existing land use;
- meets the objectives of the VMP; and
- will allow removal of the NSW EPA declaration

if the site is remediated and managed in accordance with the following remedial action plan:

- 'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW' dated 24 July 2013, by AECOM Australia Pty Ltd.

It is noted that some tasks, principally completion of remediation technology trials and then preparation of a remedial work plan, need to be completed to fulfil the Stage 1 VMP objectives.

Based on the information presented in the reports reviewed, the Auditor concludes that Block 4 can be made suitable for the purposes of:

- 'residential with minimal access to soil' land use;
- 'commercial/ industrial' land use; and
- 'public open space' land use over basement area

if the site is remediated, developed and managed in accordance with the following remedial action plan:

- 'Remedial Action Plan, NSW EPA Declared Remediation Site 21122 and Block 4 (Stage 1b) Development Works, Barangaroo, Millers Point, NSW' dated 24 July 2013, by AECOM Australia Pty Ltd.

19 Other Relevant Information

This Audit was conducted on the behalf of Lend Lease (Millers Point) Pty Limited to provide an independent review by an NSW Environment Protection Authority (EPA) Accredited Auditor of the suitability and appropriateness of a plan of management, long-term management plan or a voluntary management proposal i.e. a “Site Audit” as defined in Section 4 (1) (b) (v) of the *NSW Contaminated Land Management Act 1997*.

This summary report may not be suitable for other uses. ERM and AECOM 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 Historical Gasworks Infrastructure Locations

Attachment 3: Site Assessment Areas, Proposed Land Use and Basement Groundwater Retention Wall System

Attachment 4: 2010 Site Survey

Attachment 5: Former Layout of the Larger Barangaroo Site

Attachment 6: Block 4 Proposed Development Cross Section

Attachment 7: Indicative Bedrock and Marine Sediment Contours

Attachment 8: Investigation Locations

Attachment 9: Location of Separate Phase Gasworks Wastes and Tar

Attachment 10a: Offsite Gasworks Related Impacts in Fill Material

Attachment 10b: Offsite Gasworks Related Impacts in Marine Sediment

Attachment 11: Conceptual Site Model for VMP Remediation

Attachment 12: VMP Remediation Works – Unsaturated Soil SSTC Exceedances

Attachment 13: VMP Remediation Works – Groundwater SSTC Exceedances

Attachment 14: Proposed VMP Extent of Remediation - Unsaturated

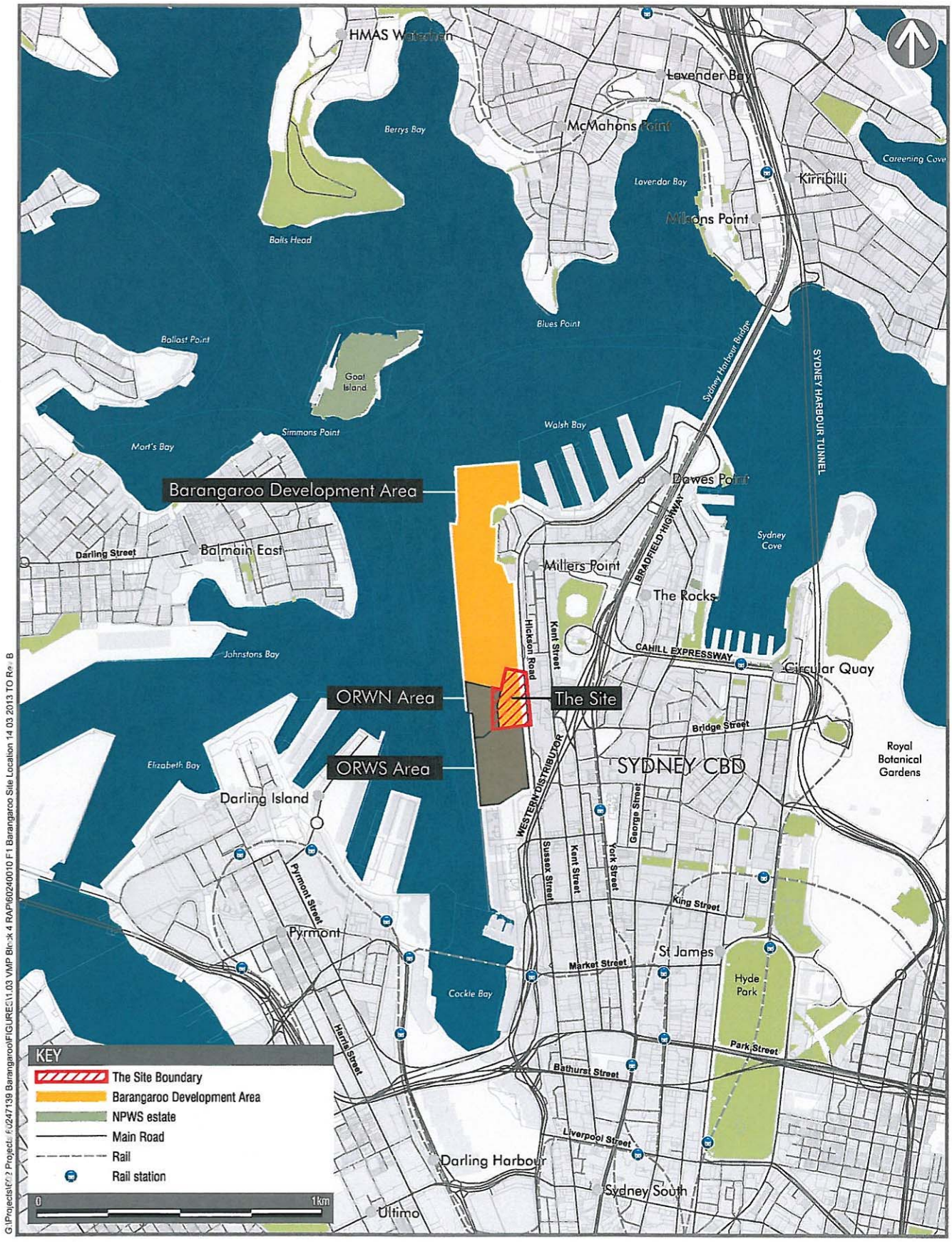
Attachment 15: Proposed VMP Extent of Remediation - Saturated

Attachment 16: Transects Modelled in Mass Flux Discharge Memo, March 2013

Attachment 17: Zones Considered in Contaminant Mass Calculations

Attachment 18: Block 4 Development Remediation Works – Groundwater SSTC Exceedances

Attachment 19: Proposed Block 4 Development Extent of Remediation - Saturated



G:\Projects\EC2 Projects\60247139 Barangaroo\FIGURES\11.03 VMP Block 4 RAP\60240010 F1 Barangaroo Site Location 14 03 2013 TO Rev B

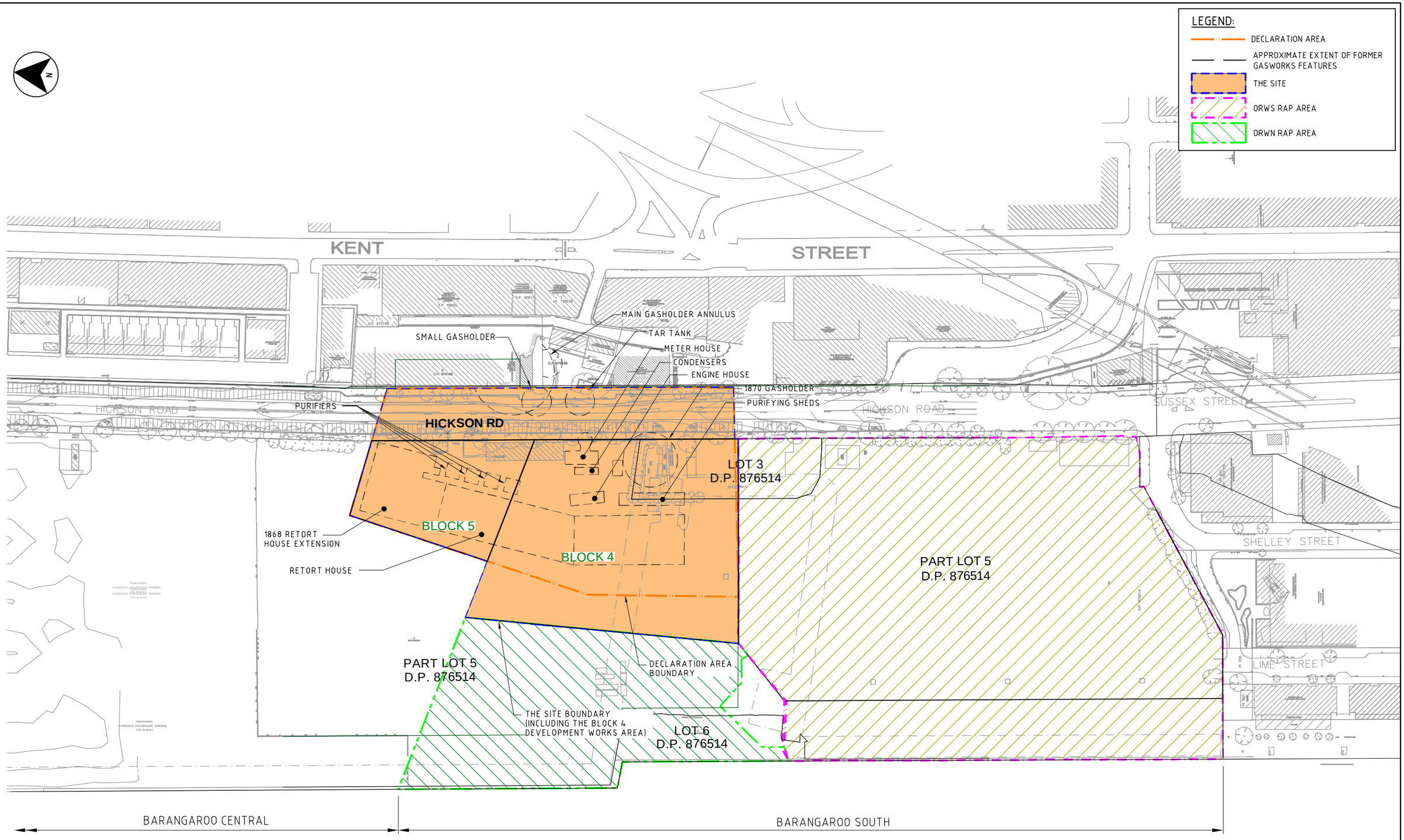
AECOM

BARANGAROO SITE LOCATION
VMP/Block 4 Remedial Action Plan

FIGURE F1

Attachment 1: Site Location

Cad ref: P:\60153531_Barangaroo_S_ICS\CADD\S3 Working\Drg\Figures\60247139-drg-20-RAPC-F2.dwg Last modified: 23 Jul 13 - 14:40



Attachment 2: Site Layout and Historical Gasworks Infrastructure Locations

REVISIONS

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03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

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1 : 2000 FULL SIZE A3

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APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER:

AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F2:
SITE LAYOUT AND SURROUNDING AREA

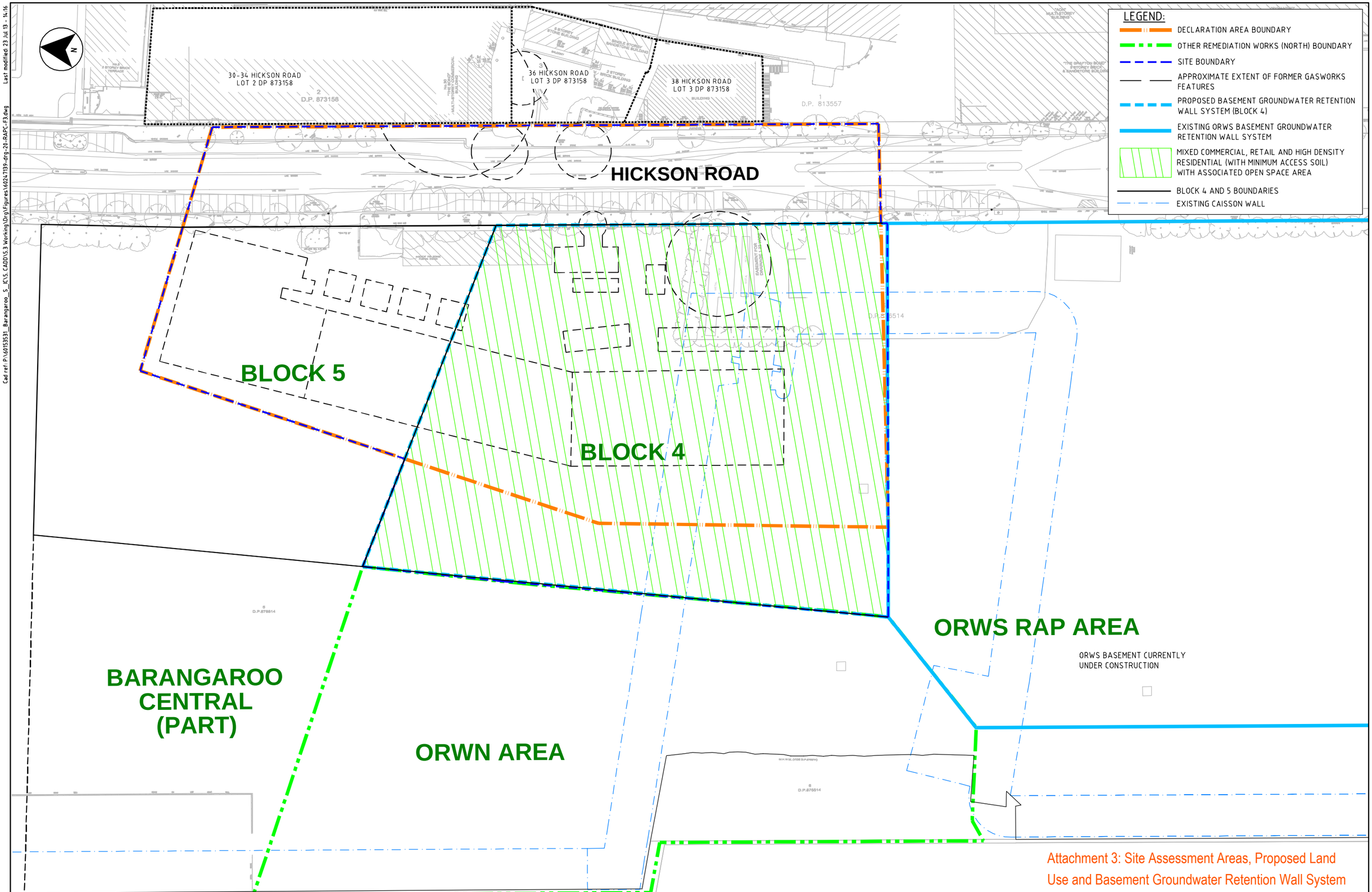
STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F2

REV: 04

Last modified: 23 Jul 13 - 14:16

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\S3 Working\Dgn\Figures\60247139-drg-20-RAPC-F3.dwg



Attachment 3: Site Assessment Areas, Proposed Land Use and Basement Groundwater Retention Wall System

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
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DESIGNER: AECOM

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CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F3:
PROPOSED FUTURE LAND USE - BLOCK 4

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F3

REV: 04

M.G.A. NORTH

KENT STREET

DECCW
Declaration Area
N21122

5 4 3 2 1

TEMPORARY
OVERSEAS PASSENGER TERMINAL
(No Access)

TEMPORARY
OVERSEAS PASSENGER TERMINAL
(No Access)

Attachment 4: 2010 Site Survey

REV.	DATE	AMENDMENTS

0 100
REDUCTION RATIO 1: 1000 @ A1

THIS TITLE BLOCK AND NOTES FORM AN INTEGRAL PART OF THE PLAN AND MUST BE REPRODUCED IN ANY USE, DUPLICATION OR AMENDMENT.

DATUM : AUSTRALIAN HEIGHT DATUM
CONTOUR INTERVAL : N/A
ORIGIN OF LEVELS : S.S.M. 46693
R.L. 2.454 A.H.D.

RYGATE & COMPANY PTY. LIMITED
REGISTERED LAND SURVEYORS
81 YORK STREET, SYDNEY 2000
MEMBER OF ASSOCIATION OF CONSULTING SURVEYORS
PHONE 9262 6800
FAX 9262 6843
ABN 61 001 204897
www.rygate.com.au
Email: surveyors@rygate.com.au

SURVEYOR	DRAWN	CHECKED	APPROVED
SG	GD		

CLIENT: LEND LEASE (Millers Point) PTY. LTD.

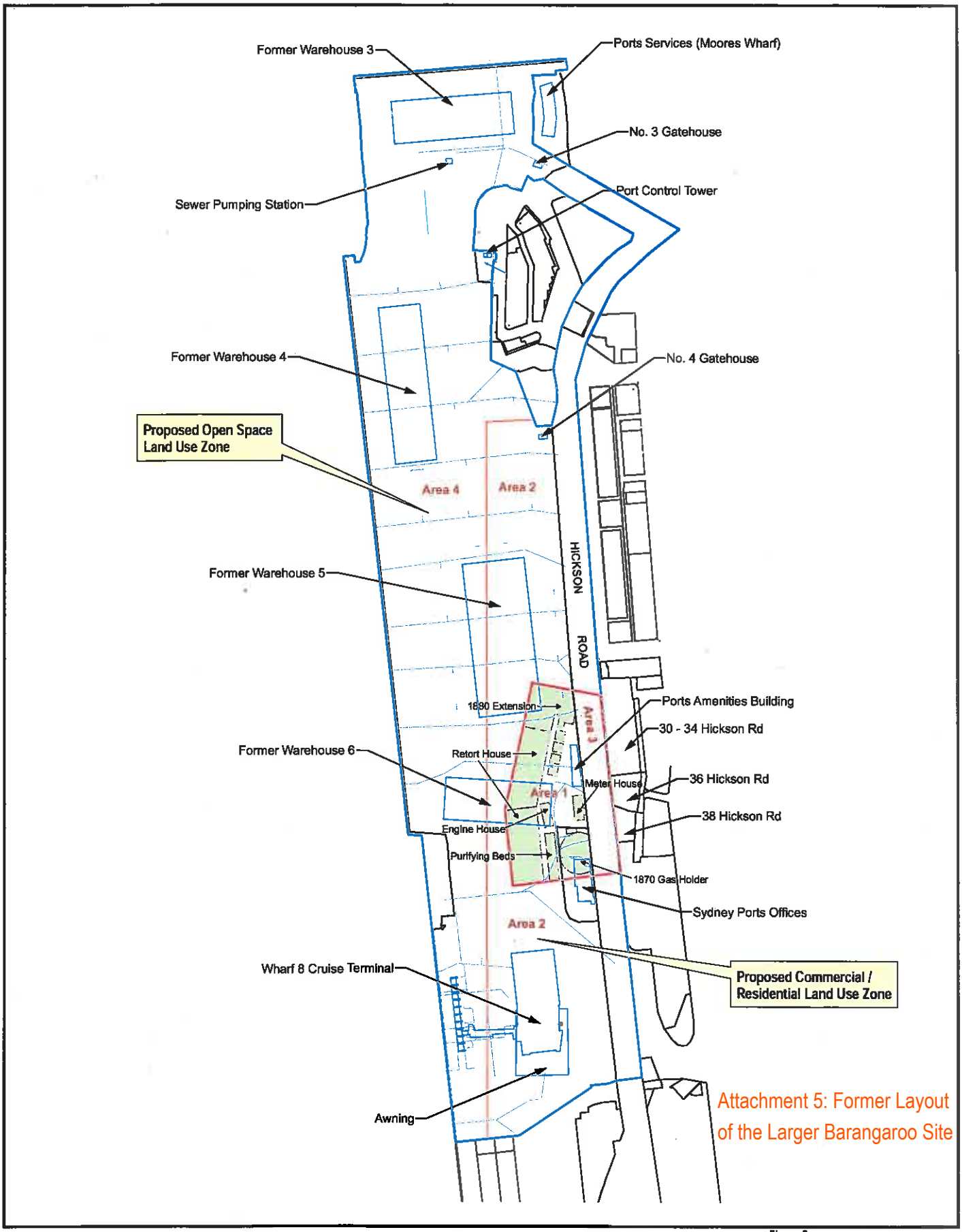
LOCALITY: BARANGAROO

L.G.A.: CITY OF SYDNEY

PLAN

SHOWING DETAIL, LEVELS & SERVICES
LOTS 3 & 5 DP 876514
AND ALONG HICKSON ROAD

REFERENCE No.	PLAN No.	DATE	SHEET No. 1
74479	74479-1	18/10/2010	OF 1 SHEETS



Attachment 5: Former Layout of the Larger Barangaroo Site

Legend
- Remediation Site
- Lot Boundaries
- Existing or Former Site Features
- Approximate Boundary of Landuse Zones
- Site Drainage
- Approximate Location of Former Gasworks Structures
- Barangaroo Project Site

Client: Barangaroo Delivery Authority
Project: Barangaroo Overarching RAP

Drawing No: 0114385s_RAP_GIS001_R0.mxd
Date: 31/03/2010 Drawing size: A3
Drawn by: JF Reviewed by: PL
Projection: GDA 1994 MGA Zone 56
Scale: Refer to Scale Bar

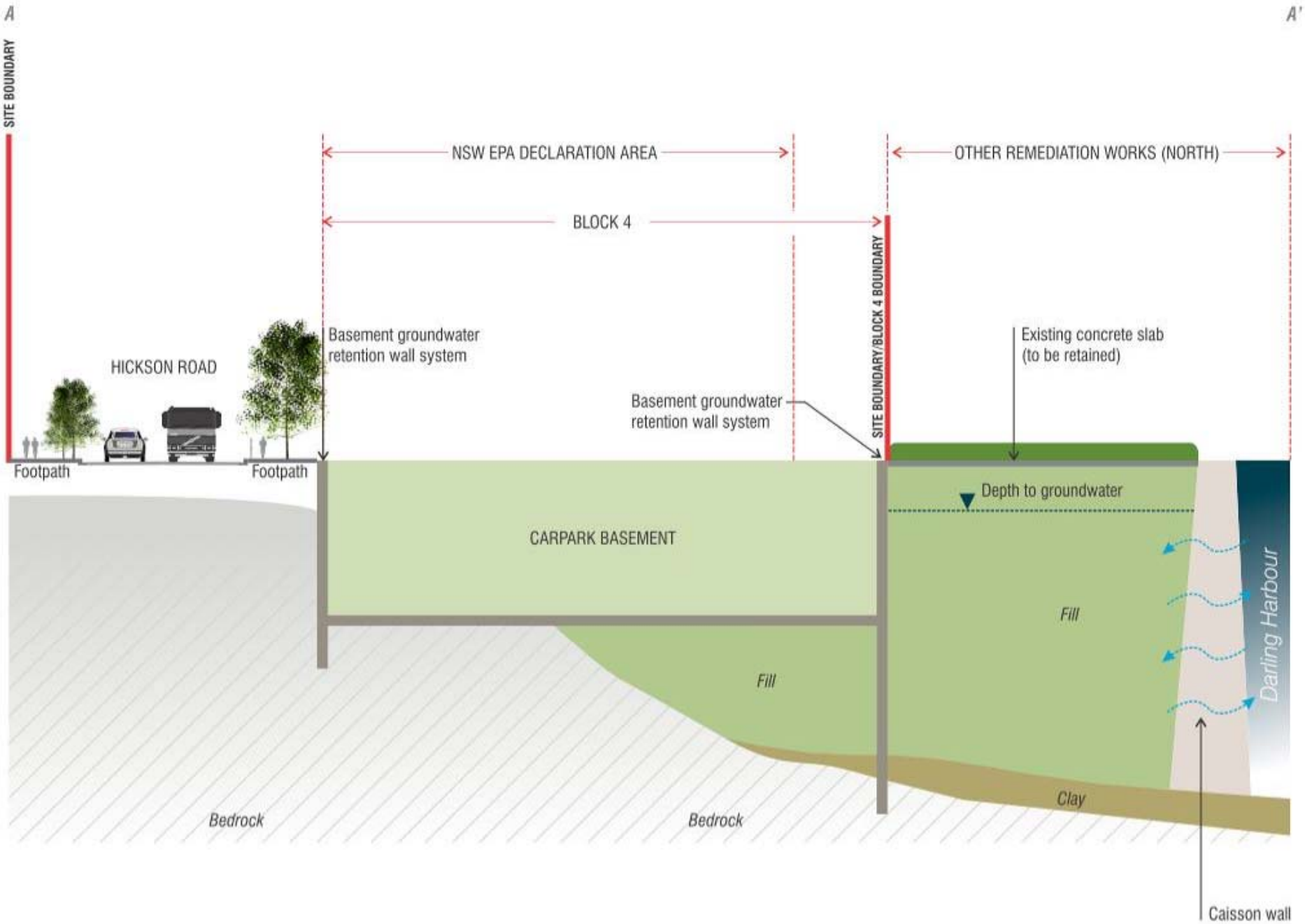
N
0 40 80 120m

Maps and figures contained within this document may be based on third party data, may not be to scale and is intended for use as a guide only. ERM does not warrant the accuracy of any such maps or figures.

Figure 2
Site Layout Plan

Environmental Resources Management Australia Pty Ltd
Building C, 33 Saunders St, Pyrmont, NSW 2009
Telephone +61 2 8584 8888

ERM



Attachment 6: Block 4 Proposed Development Cross Section

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Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\S3 Working\Drg\Figures\60247139-drg-20-VMPRE-F9.dwg

30-34 HICKSON ROAD
LOT 2 DP 873158

MAIN GASHOLDER ANNULUS

36 HICKSON ROAD
LOT 3 DP 873158

38 HICKSON ROAD
LOT 3 DP 873158

SMALL GASHOLDER

HICKSON ROAD

TAR TANK

METER HOUSE

1870 GASHOLDER

ENGINE HOUSE

PURIFYING SHEDS

PURIFIERS

1880 EXTENSION

RETORT

BLOCK 5

BLOCK 4

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

BARANGAROO CENTRAL (PART)

ORWN AREA

A A'

B B'

C C'

D D'

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- BLOCK 4 AND 5 BOUNDARIES
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- A' A CROSS SECTION ALIGNMENT (REFER TO FIGURE F10 TO F13)
- MARINE SEDIMENT CONTOURS mAHD
- BEDROCK CONTOURS mAHD

Attachment 7: Indicative Bedrock and Marine Sediment Contours

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
05	PAS	23.07.13	FINAL ISSUE	AR
04	PAS	20.06.13	DRAFT ISSUE	AR
03	PAS	12.03.13	DRAFT ISSUE	AR
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CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F9:
INDICATIVE BEDROCK AND MARINE SEDIMENT CONTOURS

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-VMPRE-F9

REV: 05

Last modified: 23 Jul 13 - 14:41

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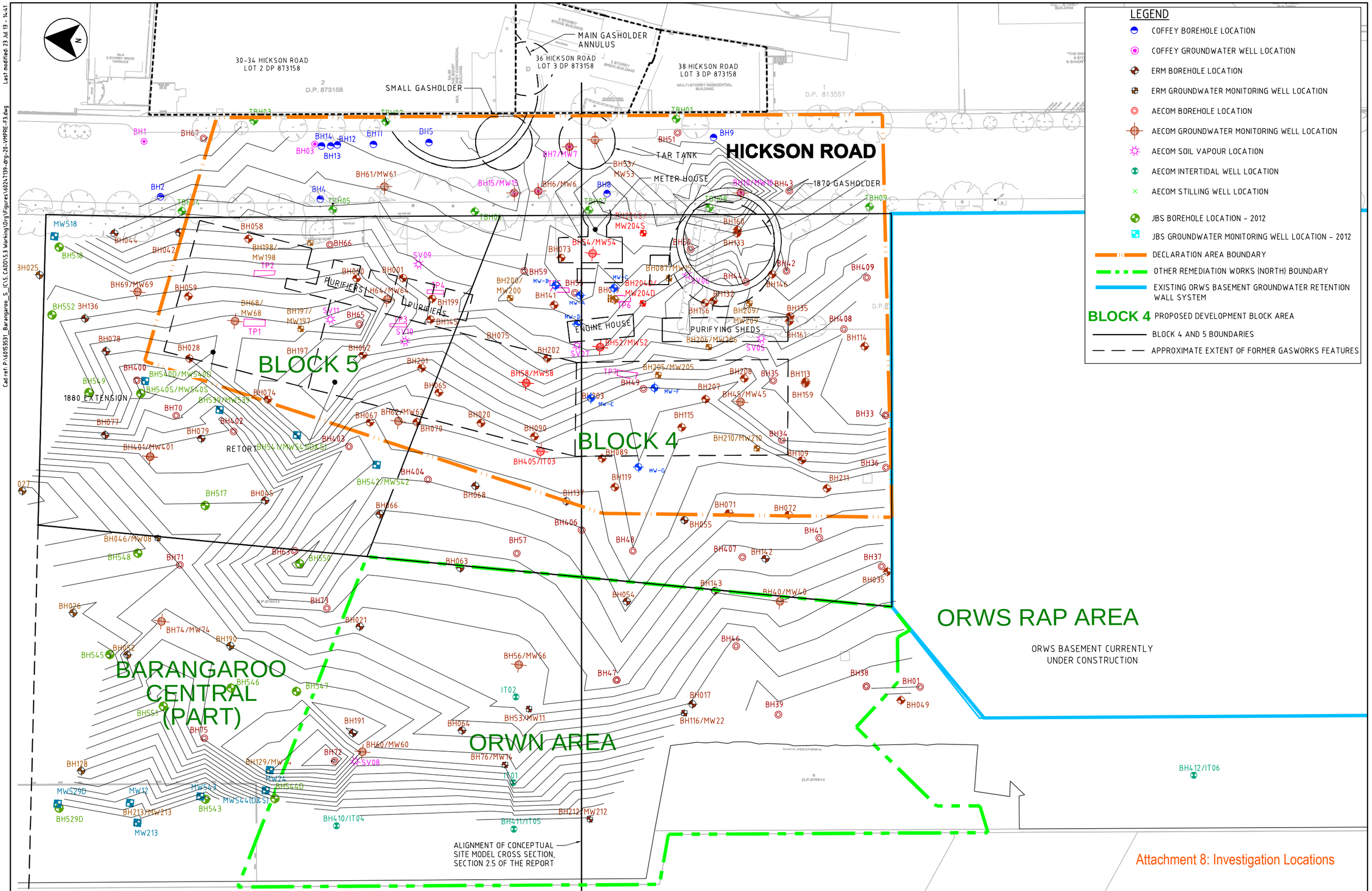

Attachment 8: Investigation Locations

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
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03	PAS	12.03.13	DRAFT ISSUE	AR
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01	TT	06.10.12	DRAFT ISSUE	DM

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CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F3:
SITE PLAN AND SAMPLING LOCATIONS

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-VMPRE-F3

REV: 05

Last modified: 23 Jul 13 - 14:42

Cad ref: P:\60153531_Barangaroo_S_(C)\S_CADD\S3 Working\Drg\Figures\60247139-drg-20-VMPRE-F6.dwg

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM

BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA

- BLOCK 4 AND 5 BOUNDARIES
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES

1.0 - 2.0 DEPTH OF IMPACT (M BGL)

- PRESENCE OF DNAPL NOTED
- PRESENCE OF TCM NOTED IN FILL MATERIAL
- PRESENCE OF SHEEN NOTED
- PRESENCE OF TCM NOTED IN MARINE SEDIMENTS

NOTE:
LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

Attachment 9: Location of Separate Phase Gasworks Wastes and Tar

This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS					
05	PAS	23.07.13	FINAL ISSUE		AR
04	PAS	20.06.13	DRAFT ISSUE		AR
03	PAS	12.03.13	DRAFT ISSUE		AR
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01	TT	06.10.12	DRAFT ISSUE		DM
No.	BY	DATE	DESCRIPTION		APPD

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DRAWN	TT	CHECKED	PAS
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

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VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F6:
LOCATIONS OF SEPARATED PHASE GASWORKS RELATED WASTES AND TAR (SPGWT)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-VMPRE-F6

REV: 05

Last modified: 23 Jul 13 - 14:42

Cad ref: P:\60153531_Barangaroo_S_(CS_CAD)\S3 Working\Drg\Figures\60247139-drg-20-VMPRE_F7.dwg

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

JENKINS STREET

HICKSON ROAD

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- AECOM SUPPLEMENTARY VMP DGI BOREHOLE LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING CAISSON WALL
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- BLOCK 4 AND 5 BOUNDARIES
- NOTED GASWORKS RELATED IMPACTS - BASED ON ODOUR AND VISUAL OBSERVATIONS
- NAPHTHALENE OR TPH C10-14 EXCEEDS NOMINAL 20 AND 50 MG/KG SCREENING CRITERIA

Attachment 10a: Offsite Gasworks Related Impacts in Fill Material

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
05	PAS	23.07.13	FINAL ISSUE	AR
04	PAS	20.06.13	DRAFT ISSUE	AR
03	PAS	12.03.13	DRAFT ISSUE	AR
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APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F7:
OFFSITE GASWORKS RELATED IMPACTS
IN FILL MATERIAL

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-VMPRE-F7

REV: 05

Last modified: 23 Jul 13 - 14:43

Cad ref: P:\60153531_Barangaroo_S_(CS_CAD)\S3 Working\Drg\Figures\60247139-drg-20-VMPRE-F8.dwg

HICKSON ROAD

JENKINS STREET

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- AECOM SUPPLEMENTARY VMP DGI BOREHOLE LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING CAISSON WALL
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- BLOCK 4 AND 5 BOUNDARIES
- NOTED GASWORKS RELATED IMPACTS - BASED ON ODOUR AND VISUAL OBSERVATIONS
- NAPHTHALENE OR TPH C10-14 EXCEEDS NOMINAL 20 AND 50 MG/KG SCREENING CRITERIA

Attachment 10b: Offsite Gasworks Related Impacts in Marine Sediment

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
06	PAS	23.07.13	FINAL ISSUE	AR
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01	TT	06.10.12	DRAFT ISSUE	DM

SCALES:

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DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	PAS
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER:

AECOM

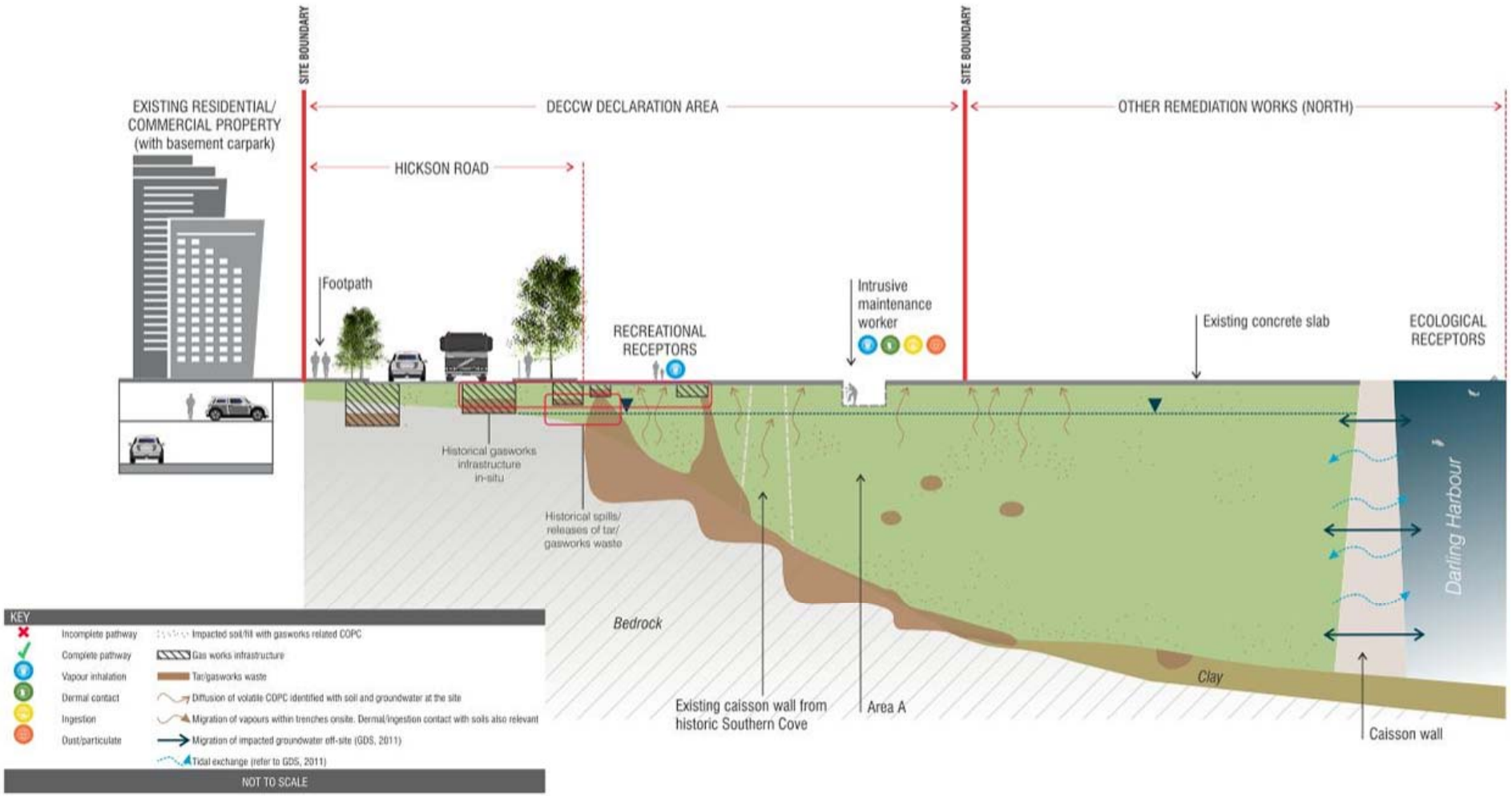
AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F8:
OFFSITE GASWORKS RELATED IMPACTS
IN MARINE SEDIMENTS

STATUS:	DRAWING NO:	REV:
FINAL	60247139-DRG-20-VMPRE-F8	06



Attachment 11: Conceptual Site Model for VMP Remediation

Last modified: 23 Jul 13 - 14:48

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\5.3 Working\Dgn\Figures\60247139-drg-20-RAPC_F7.dwg

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

BH001_1	1/05/2006
CPAH (TEF)	67.0

BH64_1-1.2	1/03/2010
CPAH (TEF)	108.0

BH200_1	7/04/2008
CPAH (TEF)	166.0

BH073_1.5-1.95	2/05/2006
CPAH (TEF)	140.1

BH54_1-1.4	23/02/2010
CPAH (TEF)	842.6

BH204S_1	18/03/2008
CPAH (TEF)	119.4

BH087_1.5-1.95	8/06/2006
CPAH (TEF)	114.5

BH55_1-1.2	25/02/2010
CPAH (TEF)	372.1

BH145_0.3-0.5	1/05/2006
CPAH (TEF)	110.0

BH204D_1.5	7/04/2008
TPH C10-C14	54200.0
TPH C15-C28	72400.0
CPAH (TEF)	921.6

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES
- EXISTING CAISSON WALL

NOTE:

LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

TPH C10-C14 EXCEEDS SITE SPECIFIC CRITERIA

TPH C15-C28 EXCEEDS SITE SPECIFIC CRITERIA

CPAHs EXCEEDS SITE SPECIFIC CRITERIA

Attachment 12: VMP Remediation Works - Unsaturated Soil SSTC Exceedances

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

SCALES: 10 0 10 20 30 40m — 1 : 1000 FULL SIZE A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F7:
VMP REMEDIATION WORKS -
UNSATURATED SOILS SSTC VMP EXCEEDANCES

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F7

REV: 04

Last modified: 23 Jul 13 - 14:48

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\5.3 Working\Drg\Figures\60247139-drg-20-RAPC-F8.dwg

30-34 HICKSON ROAD
LOT 2 DP 873158

36 HICKSON ROAD
LOT 3 DP 873158

38 HICKSON ROAD
LOT 3 DP 873158

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

MW7/BH7	26/03/2008
TPH C10-C14	830000
Benzene	25200
Ammonia as N	294
Naphthalene	4800

MW15/BH15	1/05/2008
TPH C10-C14	494000
TPH C15-C28	754000
Naphthalene	192000
Benzene	40200
CPAH (TEF)	11162

MW10/BH10	26/03/2008
CPAH (TEF)	1054.69
TPH C10-C14	528000
Benzene	5450
Ammonia as N	348
Naphthalene	15800

MW204S/BH204S	25/02/2011
Naphthalene	8580

MW54/BH54	19/03/2012
TPH C10-C14	28000
Naphthalene	8640

MW15/BH087A	15/03/2010
TPH C10-C14	41000
Benzene	13100
Naphthalene	7800

MW69/BH69	19/03/2010
Naphthalene	1920

MW206/BH206	19/03/2010
TPH C10-C14	68000
Benzene	5450
Naphthalene	10600

MW200/BH200	28/02/2011
TPH C10-C14	47400
Benzene	17900
Naphthalene	5450

IT03D/BH405	25/02/2011
Naphthalene	2560

MW205/BH205	17/03/2010
CPAH (TEF)	11556
Naphthalene	283000
TPH C10-C14	1730000
TPH C15-C28	1520000
TPH C29-C36	332000

MW541D	25/05/2012
Benzene	4300
Naphthalene	1900

MW60/BH60	18/03/2010
TPH C10-C14	18500
Naphthalene	1500

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES
- EXISTING CAISSON WALL

BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA

NOTE:
LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

BENZENE EXCEEDS SITE SPECIFIC CRITERIA
NAPHTHALENE EXCEEDS SITE SPECIFIC CRITERIA
AMMONIA AS N EXCEEDS SITE SPECIFIC CRITERIA
TPH C10-C14 EXCEEDS SITE SPECIFIC CRITERIA
TPH C29-C36 EXCEEDS SITE SPECIFIC CRITERIA
TPH C15-C28 EXCEEDS SITE SPECIFIC CRITERIA
CPAHs EXCEEDS SITE SPECIFIC CRITERIA

Attachment 13: VMP Remediation Works - Groundwater SSTC Exceedances

No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

REVISIONS

SCALES: 1:1000 A3

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DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F8:
VMP REMEDIATION WORKS -
GROUNDWATER SSTC VMP EXCEEDANCES

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F8

REV: 04

Last modified: 23 Jul 13 - 14:19

Cad ref: P:\60153531_Barangaroo_S_(CIS_CADD\S3 Working\Drg\Figures\60247139-drg-28-RAPC-F10.dwg

30-34 HICKSON ROAD
LOT 2 DP 873158

36 HICKSON ROAD
LOT 3 DP 873158

38 HICKSON ROAD
LOT 3 DP 873158

SEWERAGE PUMPING STATION SP1129 (TO BE RETAINED)

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES
- EXISTING CAISSON WALL
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- ESTIMATED REMEDIATION DEPTH (0-2m bgl)

NOTE:
LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

Attachment 14: Proposed VMP Extent of Remediation - Unsaturated

REVISIONS					
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM
No.	BY	DATE	DESCRIPTION	APPD

SCALES:
5 0 5 10 15m
1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER:
AECOM
AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F10:
VMP EXTENT OF REMEDIATION (UNSATURATED)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F10

REV: 04

Last modified: 23 Jul 13 - 14:20

Cad ref: P:\60153531_Barangaroo_S_JCIS_CAD\S3_Working\Drg\Figures\60247139-drg-28-RAPC-F11.dwg

AA A B C D E F G H I J K L M N

1 2 3 4 5 6 7 8 9 10 11 12

SEWERAGE PUMPING STATION SP1129 (TO BE RETAINED)

REMEDIATION TO APPROXIMATE 5.5m BGL

REMEDIATION TO GREATER DEPTH WITHIN FORMER TAR TANK AND ANNULUS STRUCTURES

HICKSON ROAD

JENKINS STREET

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

REFER TO NOTE 1

Attachment 15: Proposed VMP Extent of Remediation - Saturated

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- AECOM SUPPLEMENTARY VMP DGI BOREHOLE LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING CAISSON WALL
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES

BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA

ESTIMATED REMEDIATION DEPTH:

- 2.0-3.0m BGL
- 3.0-5.0m BGL
- 5.0-10.0m BGL
- MARINE SEDIMENT CONTOURS mAHD
- BEDROCK CONTOURS mAHD

NOTES:

1. REMEDIATION UNDERTAKEN AS PART OF THE ORWS DEVELOPMENT WORKS.
2. THE ESTIMATED REMEDIATION DEPTHS ARE INDICATIVE. REMEDIATION WILL BE UNDERTAKEN TO THE DEPTH OF THE UNDERLYING BEDROCK TO A MAXIMUM DEPTH OF 10m BGL, SUBJECT TO THE REQUIREMENTS OF THE RAP.

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
05	PAS	23.07.13	FINAL ISSUE	AR
04	PAS	20.06.13	DRAFT ISSUE	AR
03	PAS	12.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

SCALES: 5 0 5 10 15m — 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F11:
VMP EXTENT OF REMEDIATION (SATURATED)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F11

REV: 05

PRIVILEGED AND CONFIDENTIAL: PREPARED FOR THE PURPOSE OF LEGAL ADVICE

Last modified: 06 Mar 13 - 12:26

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\S3 Working\Drg\Drg_60247139\60247139-drg-10-VMPRE-F5.dwg

HICKSON ROAD

TRANSECT A

TRANSECT B

BLOCK 5

BLOCK 4

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA
- BLOCK 4 AND 5 BOUNDARIES

NOTE:
LOCATION OF COFFEY GROUNDWATER WELLS ARE APPROXIMATE ONLY.

BENZENE EXCEEDS SITE SPECIFIC CRITERIA
NAPHTHALENE EXCEEDS SITE SPECIFIC CRITERIA
TPH C10-C14 EXCEEDS SITE SPECIFIC CRITERIA
TPH C15-C28 EXCEEDS SITE SPECIFIC CRITERIA
CPAHs EXCEEDS SITE SPECIFIC CRITERIA

Attachment 16: Transects Modelled in Mass Flux Discharge Memo, March 2013

REVISIONS				
02	PAS	06.03.13	DRAFT ISSUE	
01	TT	06.10.12	DRAFT ISSUE	AR
No.	BY	DATE	DESCRIPTION	APPD

SCALES: 5 0 5 10 15m — 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	
DRAWN	TT	CHECKED	
APPROVED	AR	DATE	06.10.12

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F5:
GROUNDWATER SSTC EXCEEDENCES

STATUS: DRAFT

DRAWING NO: 60247139-DRG-10-VMPRE-F5

REV: 02

Last modified: 23 Jul 13 - 14:40

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\S3 Working\Drg\Figures\60247139-drg-20-VMPRE-F15.dwg

AA A B C D E F G H I J K L M N

1 2 3 4 5 6 7 8 9 10 11 12

SEWERAGE PUMPING STATION SP1129

REMEDIATION TO APPROXIMATE 5.5m BGL

REMEDIATION TO GREATER DEPTH WITHIN FORMER TAR TANK AND ANNULUS STRUCTURES

HICKSON ROAD

JENKINS STREET

ZONE 1

ZONE 2

ZONE 3

ZONE 4

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

REFER TO NOTE 1

Attachment 17: Zones Considered in Contaminant Mass Calculations

LEGEND

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- AECOM STILLING WELL LOCATION
- AECOM SUPPLEMENTARY VMP DGI BOREHOLE LOCATION
- JBS BOREHOLE LOCATION - 2012
- JBS GROUNDWATER MONITORING WELL LOCATION - 2012
- DECLARATION AREA BOUNDARY
- OTHER REMEDIATION WORKS (NORTH) BOUNDARY
- EXISTING CAISSON WALL
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 PROPOSED DEVELOPMENT BLOCK AREA

ESTIMATED REMEDIATION DEPTH:

- 2.0-3.0m BGL
- 3.0-5.0m BGL
- 5.0-10.0m BGL
- MARINE SEDIMENT CONTOURS mAHD
- BEDROCK CONTOURS mAHD

NOTES:

1. REMEDIATION UNDERTAKEN AS PART OF THE ORWS DEVELOPMENT WORKS.
2. THE ESTIMATED REMEDIATION DEPTHS ARE INDICATIVE. REMEDIATION WILL BE UNDERTAKEN TO THE DEPTH OF THE UNDERLYING BEDROCK TO A MAXIMUM DEPTH OF 10m BGL. SUBJECT TO THE REQUIREMENTS OF THE RAP

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
04	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	12.03.13	DRAFT ISSUE	AR
01	PAS	06.03.13	DRAFT ISSUE	DM

SCALES: 5 0 5 10 15m — 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TR	CHECKED	PAS
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP REMEDIATION EXTENT, BARANGAROO

FIGURE F15:
EXTENT OF REMEDIATION (SATURATED)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-VMPRE-F15

REV: 04

Last modified: 23 Jul 13 - 14:19

Cad ref: P:\60153531_Barangaroo_S_ICS_CADD\S3 Working\Dgn\Figures\60247139-drg-20-RAPC-F9.dwg

30-34 HICKSON ROAD
LOT 2 DP 873158

36 HICKSON ROAD
LOT 3 DP 873158

38 HICKSON ROAD
LOT 3 DP 873158

HICKSON ROAD

BLOCK 5

BLOCK 4

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND:

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- OTHER REMEDIATION WORKS (NORTH) AREA AND SITE BOUNDARY
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- PROPOSED BASEMENT GROUNDWATER RETENTION WALL SYSTEM (BLOCK 4 AND 5)
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- BLOCK 4 AND 5 BOUNDARIES
- EXISTING CAISSON WALL
- BENZENE EXCEEDS OF SSTC
- TPH C_{10}-C_{14} EXCEEDS OF SSTC
- PAHs EXCEEDS OF SSTC

Attachment 18: Block 4 Development Remediation Works - Groundwater SSTC Exceedances

REVISIONS

No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

SCALES:

5000 0 5000 10000 15000mm

1 : 500 FULL SIZE A1

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001-2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER:

AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F9:
BLOCK 4 DEVELOPMENT REMEDIATION WORKS
GROUNDWATER SSTC DEV EXCEEDANCES

STATUS:	DRAWING NO:	REV:
FINAL	60247139-DRG-20-RAPC-F9	04

Last modified: 23 Jul 13 - 14:20

Cad ref: P:\60\153531_Barangaroo_S_\CIS\CADD\S3 Working\Drg\Figures\60247139-drg-28-RAPC-F12.dwg

HICKSON ROAD

SEWERAGE PUMPING STATION SP1129 (TO BE RETAINED)

BLOCK 5

BLOCK 4

HYDROCARBON ODOUR AND BLACK STAINING FROM AT 7.5 - 8.5m BGL

MODERATE TAR ODOUR FROM 4.2 - 9.4m BGL

HYDROCARBON ODOUR AND SHEEN FROM 7.0 - 8.0m BGL

MODERATE HYDROCARBON ODOUR AT 3.0m BGL

BARANGAROO CENTRAL (PART)

ORWN AREA

ORWS RAP AREA

ORWS BASEMENT CURRENTLY UNDER CONSTRUCTION

LEGEND:

- COFFEY BOREHOLE LOCATION
- COFFEY GROUNDWATER WELL LOCATION
- ERM BOREHOLE LOCATION
- ERM GROUNDWATER MONITORING WELL LOCATION
- AECOM BOREHOLE LOCATION
- AECOM GROUNDWATER MONITORING WELL LOCATION
- AECOM SOIL VAPOUR LOCATION
- AECOM INTERTIDAL WELL LOCATION
- OTHER REMEDIATION WORKS (NORTH) AREA AND SITE BOUNDARY
- DECLARATION AREA BOUNDARY
- THE SITE BOUNDARY
- APPROXIMATE EXTENT OF FORMER GASWORKS FEATURES
- ESTIMATED EXTENT OF REMEDIATION
- PROPOSED BASEMENT GROUNDWATER RETENTION WALL SYSTEM (BLOCK 4)
- EXISTING ORWS BASEMENT GROUNDWATER RETENTION WALL SYSTEM
- EXISTING CAISSON WALL
- BLOCK 4 AND 5 BOUNDARIES

ESTIMATED REMEDIATION DEPTH

- 0.0-3.0m BGL
- 3.0-5.0m BGL
- 5.0-10.0m BGL
- MATERIAL TO BE EXCAVATED FOR BASEMENT, WHICH MAY REQUIRE MANAGEMENT PER THIS RAP
- BEDROCK CONTOURS mAHD
- ODOROUS MATERIAL OBSERVED IN BOREHOLE WITHIN PROPOSED BASEMENT EXCAVATION DEPTH (APPROX. 8m BGL)

NOTES:

1. IT HAS BEEN ASSUMED, FOR THE PURPOSES OF ASSESSING THE EXTENT OF REMEDIATION, THAT THE BASEMENT WILL BE CONSTRUCTED TO A DEPTH BELOW THE GROUNDWATER TABLE. THAT IS, THE EXTENT OF REMEDIATION IS BASED ON CONSIDERATION OF RISK BASED CRITERIA FOR GROUNDWATER.
2. THE ESTIMATED REMEDIATION DEPTHS ARE INDICATIVE. REMEDIATION WILL BE UNDERTAKEN TO THE DEPTH OF THE UNDERLYING BEDROCK TO A MAXIMUM DEPTH OF 10m BGL, SUBJECT TO THE REQUIREMENTS OF THE RAP.

Attachment 19: Proposed Block 4 Development Extent of Remediation - Saturated

REVISIONS					
No.	BY	DATE	DESCRIPTION	APPD
04	PAS	23.07.13	FINAL ISSUE	AR
03	PAS	20.06.13	DRAFT ISSUE	AR
02	PAS	18.03.13	DRAFT ISSUE	AR
01	TT	12.09.12	DRAFT ISSUED	DM

SCALES: 5 0 5 10 15m, 1:1000 A3

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001:2000

DESIGNED	KM	CHECKED	AR
DRAWN	TT	CHECKED	JA
APPROVED	AR	DATE	23.07.13

CONTRACTOR:

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

CLIENT:

VMP / BLOCK 4 RAP, BARANGAROO

FIGURE F12:
BLOCK 4 DEVELOPMENT EXTENT OF REMEDIATION (SATURATED)

STATUS: FINAL

DRAWING NO: 60247139-DRG-20-RAPC-F12

REV: 04

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	–

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
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) ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Phenanthrene	0.6	
Fluroanthene	1	
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 offsite.

Appendix C:

EPA Approved Guidelines

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

(*as of 2 July 2013*)

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.

Guidelines made by the EPA

- Guidelines for Assessing Service Station Sites (94119ServiceStnGuidelines.pdf, 1.2MB) (December 1994)
- 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), subject to the same terms.

Guidelines approved by the EPA

ANZECC publications

- Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites, published by Australian and New Zealand Environment and Conservation Council (ANZECC) and the National Health and Medical Research Council (NHMRC) (January 1992)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality, published by ANZECC and 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

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)

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		

Appendix E:

Proposed Risk Based Remediation Criteria (SSTCs) and Marine Water Quality Criteria (MWQC)

TABLE T1

SOIL REMEDIATION CRITERIA

VMP/BLOCK 4 REMEDIAL ACTION PLAN

BARANGAROO, NSW

	SOIL REMEDIATION CRITERIA	
CoPC	**SRC**	**Land Use Scenario**
Relevant Site Area	**VMP Area - Unsaturated Soil**	
Relevant Land Use Scenarios	**mg/kg**	**Scenarios 1 and 2**
Benzene	380	SSTC (Scenario 2)
TPH C_{10}-C_{14} aliphatic	54,000	SSTC (Scenario 2)
TPH C_{10}-C_{14} aromatic		
TPH C15-C28 aliphatic	72,000	SSTC (Scenario 2)
TPH C15-C28 aromatic		
TPH C29-C36 aliphatic	21,000	SSTC (Scenario 2)
TPH C29-C36 aromatic		
CPAH**	67	SSTC (Scenario 2)

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)

Land Use Scenarios:
Scenario 1: Paved Recreation
Scenario 2: Intrusive Maintenance Worker

TABLE T2

GROUNDWATER REMEDIATION CRITERIA

VMP/BLOCK 4 REMEDIAL ACTION PLAN

BARANGAROO, NSW

	GROUNDWATER REMEDIATION CRITERIA			
CoPC	**GRC**	**VMP Remediation Works**	**GRC**	**Block 4 Development Works**
Relevant Site Area(s)	**VMP Area**		**Block 4**	
Relevant Land Use Scenarios	**mg/L**	**VMP Scenarios 1 and 2**	**mg/L**	**Development Scenarios 1 and 2**
Acenaphthylene	47	$SSTC^{VMP}$ (Scenario 2)	80	$SSTC^{DEV}$ (Scenario 1)
Aniline			180000	$SSTC^{DEV}$ (Scenario 1)
Benzene	2.1	$SSTC^{VMP}$ (Scenario 2)	7.7	$SSTC^{DEV}$ (Scenario 1)
Ethylbenzene			750	$SSTC^{DEV}$ (Scenario 1)
Fluorene			13	$SSTC^{DEV}$ (Scenario 1)
2-methylnapthalene			4.5	$SSTC^{DEV}$ (Scenario 1)
3&4-methylphenol			130	$SSTC^{DEV}$ (Scenario 1)
Naphthalene	1.3	$SSTC^{VMP}$ (Scenario 2)	0.24	$SSTC^{DEV}$ (Scenario 1)
Phenanthrene			5.8	$SSTC^{DEV}$ (Scenario 1)
Styrene			840	$SSTC^{DEV}$ (Scenario 1)
Toluene			4,000	$SSTC^{DEV}$ (Scenario 1)
Ammonia	150	$SSTC^{VMP}$ (Scenario 2)	630	$SSTC^{DEV}$ (Scenario 1)
TPH C_6-C_9 aliphatic			7,300	$SSTC^{DEV}$ (Scenario 1)
TPH C_{10}-C_{14} aliphatic	17	$SSTC^{VMP}$ (Scenario 2)	1.8	$SSTC^{DEV}$ (Scenario 1)
TPH C_{10}-C_{14} aromatic				
TPH C_{15}-C_{28} aliphatic	220	$SSTC^{VMP}$ (Scenario 2)		
TPH C_{15}-C_{28} aromatic				
TPH C_{29}-C_{36} aliphatic	250	$SSTC^{VMP}$ (Scenario 2)		
TPH C_{29}-C_{36} aromatic				
1,2,4-trimethylbenzene			22	$SSTC^{DEV}$ (Scenario 1)
Xylenes (total)			176	$SSTC^{DEV}$ (Scenario 1)
CPAH**	1	$SSTC^{VMP}$ (Scenario 2)		

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)

VMP Land Use Scenarios:
$SSTC^{VMP}$ Scenario 1: Public area with concrete/hardstand paving
$SSTC^{VMP}$ Scenario 2: Short term intrusive maintenance worker

Development Scenarios:
$SSTC^{DEV}$ Scenario 1: Lower Basement
$SSTC^{DEV}$ Scenario 2: Upper Basement

The selected MWQC are summarised in **Table 1** below.

Table 1 Marine Water Quality Criteria

Analyte	Criteria (µg/L)	Source
Low MW PAHs		
Acenaphthene	5.8	CCME (1999) Freshwater Guideline
Acenaphthylene	5.8	Adopted criteria for Acenaphthene as surrogate
Anthracene	0.1 [a]	ANZECC (2000) 99% Marine Water Trigger Value (0.01 µg/L) identified to be lower than LOR.
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
Other Organics		
Phenol	400	ANZECC (2000) 95% Marine Water Trigger Value
Petroleum Hydrocarbons		
Benzene	700	ANZECC (2000) 95% Marine Water Trigger Value, moderate reliability
Ethylbenzene	80	ANZECC (2000) 95% Fresh Water Trigger Value, low reliability
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	Adoption of the ANZECC (2000) 95% Marine Water Trigger Value, low reliability for xylene (o).
TPH C_6 - C_9	110	CCME (2008a 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 (2008a) 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}	100	No guidelines values available, therefore the standard laboratory Limit of Reporting (LOR) has been adopted.
TPH C_{29}-C_{36}	50	No guidelines values available, therefore the standard LOR has been adopted.
Ammonia		
Ammonia as N	4,830	ANZECC (2000) 95% Marine Water Trigger Value, moderate reliability

Notes: (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.

Appendix F:

Contaminant Mass Calculations

TABLE F1 - CURRENTSITE CONDITIONS (ZONE 1 AND 2)
CONTAMINANT MASS CALCULATIONS
VMP REMEDIATION EXTENT
LEND LEASE

									COMPARISON OF ZONE 1 AND 2 PRE & POST REMEDIATION SITE CONDITIONS				
		CoPC	Ave conc (mg/kg)	Estimated volume (m3)	Weight (T)	Weight (kg)	Total contaminant mass (mg/kg)	Total contaminant mass (kg)	Total Unremediated Site (kg)	% Contaminant Mass currently in Zone 1	Remediated Site (kg)	Remediated Site (average mg/kg)	Site wide reduction - Post Remediation
Zone 1 - eastern fill materials to be remediated (refer to Table F3 for Zone 1 detail)	Zone 1 - Block 4 fill materials to be remediated	Naphthalene	809	43,000	86,000	86,000,000	69,574,000,000	69,574					
		TPH C10 - C14	2,621	43,000	86,000	86,000,000	225,406,000,000	225,406					
	Zone 1 - Block 5 fill materials to be remediated	Naphthalene	64	23,200	46,400	46,400,000	2,969,600,000	2,970					
		TPH C10 - C14	262	23,200	46,400	46,400,000	12,156,800,000	12,157					
	Zone 1 - Hickson Road fill materials to be remediated	Naphthalene	1,190	15,800	31,600	31,600,000	37,604,000,000	37,604					
		TPH C10 - C14	5,956	15,800	31,600	31,600,000	188,209,600,000	188,210					
	Total	**Naphthalene**	**-**	**82,000**	**164,000**	**164,000,000**	**110,147,600,000**	**110,148**	110,251	99.9%	4,160	14.4	96.2%
	Total	**TPH C10 - C14**	**-**	**82,000**	**164,000**	**164,000,000**	**425,772,400,000**	**425,772**	429,164	99.2%	23,428	80.9	94.5%
Zone 2 - western fill materials proposed to remain *In Situ*		**Naphthalene**	**0.8**	**62,800**	**125,600**	**125,600,000**	**102,992,000**	**103**					
		TPH C10 - C14	**27.0**	**62,800**	**125,600**	**125,600,000**	**3,391,200,000**	**3,391**					

TABLE F2 - POST REMEDIATION SITE CONDITIONS (ZONE 1 AND 2)

CONTAMINANT MASS CALCULATIONS

VMP REMEDIATION EXTENT

LEND LEASE

		% Reduction Achieved	CoPC	Ave conc (mg/kg)	Estimated volume (m3)	Weight (T)	Weight (kg)	Total contaminant mass (mg/kg)	Total contaminant mass (kg)
Zone 1 - eastern fill materials after contaminant mass reduction	Zone 1 - Block 4 fill materials to be remediated	100%	Naphthalene	0	43,000	86,000	86,000,000	0	0
		100%	TPH C10 - C14	0	43,000	86,000	86,000,000	0	0
	Zone 1 - Block 5 fill materials to be remediated	90%	Naphthalene	6.4	23,200	46,400	46,400,000	296,960,000	297
		90%	TPH C10 - C14	26.2	23,200	46,400	46,400,000	1,215,680,000	1,216
	Zone 1 - Hickson Road fill materials to be remediated	90%	Naphthalene	119.0	15,800	31,600	31,600,000	3,760,400,000	3,760
		90%	TPH C10 - C14	595.6	15,800	31,600	31,600,000	18,820,960,000	18,821
		Total	Naphthalene	**-**	**82,000**	**164,000**	**164,000,000**	**4,057,360,000**	**4,057**
		Total	TPH C10 - C14	**-**	**82,000**	**164,000**	**164,000,000**	**20,036,640,000**	**20,037**
Zone 2 - western fill materials			**Naphthalene**	**1**	**62,800**	**125,600**	**125,600,000**	**102,992,000**	**103**
			TPH C10 - C14	**27**	**62,800**	**125,600**	**125,600,000**	**3,391,200,000**	**3,391**

TABLE F3 - SUMMARY OF CURRENT ZONE 1 TO 4 CONDITIONS
CONTAMINANT MASS CALCULATIONS
VMP REMEDIATION EXTENT
LEND LEASE

AECOM

		CoPC	Ave conc (mg/kg)	Estimated volume (m3)	Weight (T)	Weight (kg)	Total contaminant mass (mg/kg)	Total contaminant mass (kg)	% of Total mass (Zone 1 to 4)
Zone 1 - Onsite within Remediation Area	Zone 1 - Block 4 fill materials to be remediated	Naphthalene	809	43,000	86,000	86,000,000	69,574,000,000	69,574	53.5%
		TPH C10 - C14	2,621	43,000	86,000	86,000,000	225,406,000,000	225,406	42.6%
	Zone 1 - Block 5 fill materials to be remediated	Naphthalene	64	23,200	46,400	46,400,000	2,969,600,000	2,970	2.3%
		TPH C10 - C14	262	23,200	46,400	46,400,000	12,156,800,000	12,157	2.3%
	Zone 1 - Hickson Road fill materials to be remediated	Naphthalene	1,190	15,800	31,600	31,600,000	37,604,000,000	37,604	28.9%
		TPH C10 - C14	5,956	15,800	31,600	31,600,000	188,209,600,000	188,210	35.6%
	Totals	**Naphthalene**	**801**	**82,000**	**164,000**	**164,000,000**	**131,364,000,000**	**110,148**	**84.8%**
	Totals	**TPH C10 - C14**	**3,163**	**82,000**	**164,000**	**164,000,000**	**518,732,000,000**	**425,772**	**80.5%**
Zone 2 - Onsite within upper fill outside Remediation Area									
		Naphthalene	0.8	51,600	103,200	103,200,000	82,560,000	83	0.1%
		TPH C10 - C14	26	51,600	103,200	103,200,000	2,683,200,000	2,683	0.5%
Zone 2 - Onsite within lower fill outside Remediation Area									
		Naphthalene	9.3	11,200	22,400	22,400,000	208,320,000	208	0.2%
		TPH C10 - C14	79	11,200	22,400	22,400,000	1,769,600,000	1,770	0.3%
Zone 2 - Onsite within marine sediments outside Remediation Area									
		Naphthalene	120	10,120	20,240	20,240,000	2,428,800,000	2,429	1.9%
		TPH C10 - C14	394	10,120	20,240	20,240,000	7,974,560,000	7,975	1.5%
Zone 3 - Offsite upper fill within 20m of Declaration Area									
		Naphthalene	5.5	53,920	107,840	107,840,000	593,120,000	593	0.5%
		TPH C10 - C14	61	53,920	107,840	107,840,000	6,578,240,000	6,578	1.2%
Zone 3 - Offsite lower fill within 20m of Declaration Area									
		Naphthalene	41	8,800	17,600	17,600,000	721,600,000	722	0.6%
		TPH C10 - C14	38	8,800	17,600	17,600,000	668,800,000	669	0.1%
Zone 3 - Offsite marine sediments within 20m of Declaration Area									
		Naphthalene	474	9,960	19,920	19,920,000	9,442,080,000	9,442	7.3%
		TPH C10 - C14	2,502	9,960	19,920	19,920,000	49,839,840,000	49,840	9.4%
Zone 4 - Offsite upper fill outside 20m of Declaration Area									
		Naphthalene	1.2	309,920	619,840	619,840,000	743,808,000	744	0.6%
		TPH C10 - C14	30	309,920	619,840	619,840,000	18,595,200,000	18,595	3.5%
Zone 4 - Offsite lower fill outside 20m of Declaration Area									
		Naphthalene	22	50,400	100,800	100,800,000	2,217,600,000	2,218	1.7%
		TPH C10 - C14	25	50,400	100,800	100,800,000	2,520,000,000	2,520	0.5%
Zone 4 - Offsite marine sediments outside 20m of Declaration Area									
		Naphthalene	17.0	99,400	198,800	198,800,000	3,379,600,000	3,380	2.6%
		TPH C10 - C14	64.0	99,400	198,800	198,800,000	12,723,200,000	12,723	2.4%

Sub-total - Zone 3 & 4 mass within offsite fill materials		Naphthalene	3.3%
		TPH C10 - C14	5.4%
Sub-total - Zone 3 & 4 mass within marine sediments (max 5m		Naphthalene	9.9%
		TPH C10 - C14	11.8%

Total Zone 1 to 4 mass (kg):	Naphthalene	129,965
In fill and marine sediments	TPH C10 - C14	529,125

Total Zone 1 to 4 mass (kg):	Naphthalene	114,715
In fill material only	TPH C10 - C14	458,587

Current mass in Zone 2 to 4 marine sediments	Naphthalene	15,250	11.7%
	TPH C10 - C14	70,538	13.3%

TABLE F4 - SUMMARY OF ZONE 1 TO 4 CONDITIONS (POST-REMEDIATION)

CONTAMINANT MASS CALCULATIONS

VMP REMEDIATION EXTENT

LEND LEASE

AECOM

		CoPC	Ave conc (mg/kg)	Estimated volume (m3)	Weight (T)	Weight (kg)	Total contaminant mass (mg/kg)	Total contaminant mass (kg)	% of Total mass (Zone 1 to 4)
Zone 1 - Onsite within Remediation Area	Zone 1 - Block 4 fill materials to be remediated	Naphthalene	0	0	0	0	0	0	0.0%
		TPH C10 - C14	0	0	0	0	0	0	0.0%
	Zone 1 - Block 5 fill materials to be remediated	Naphthalene	6.4	23,200	46,400	46,400,000	296,960,000	297	1.2%
		TPH C10 - C14	26.2	23,200	46,400	46,400,000	1,215,680,000	1,216	1.0%
	Zone 1 - Hickson Road fill materials to be remediated	Naphthalene	119.0	15,800	31,600	31,600,000	3,760,400,000	3,760	15.8%
		TPH C10 - C14	595.6	15,800	31,600	31,600,000	18,820,960,000	18,821	15.3%
	Totals	Naphthalene		39,000				4,057	**17.0%**
	Totals	TPH C10 - C14		39,000				20,037	**16.2%**
Zone 2 - Onsite within upper fill outside Remediation Area		Naphthalene	0.8	51,600	103,200	103,200,000	82,560,000	83	0.3%
		TPH C10 - C14	26	51,600	103,200	103,200,000	2,683,200,000	2,683	2.2%
Zone 2 - Onsite within lower fill outside Remediation Area		Naphthalene	9.3	11,200	22,400	22,400,000	208,320,000	208	0.9%
		TPH C10 - C14	79	11,200	22,400	22,400,000	1,769,600,000	1,770	1.4%
Zone 2 - Onsite within marine sediments outside Remediation Area		Naphthalene	120	10,120	20,240	20,240,000	2,428,800,000	2,429	10.2%
		TPH C10 - C14	394	10,120	20,240	20,240,000	7,974,560,000	7,975	6.5%
Zone 3 - Offsite upper fill within 20m of Declaration Area		Naphthalene	5.5	53,920	107,840	107,840,000	593,120,000	593	2.5%
		TPH C10 - C14	61	53,920	107,840	107,840,000	6,578,240,000	6,578	5.3%
Zone 3 - Offsite lower fill within 20m of Declaration Area		Naphthalene	41	8,800	17,600	17,600,000	721,600,000	722	3.0%
		TPH C10 - C14	38	8,800	17,600	17,600,000	668,800,000	669	0.5%
Zone 3 - Offsite marine sediments within 20m of Declaration Area		Naphthalene	474	9,960	19,920	19,920,000	9,442,080,000	9,442	39.5%
		TPH C10 - C14	2,502	9,960	19,920	19,920,000	49,839,840,000	49,840	40.4%
Zone 4 - Offsite upper fill outside 20m of Declaration Area		Naphthalene	1.2	309,920	619,840	619,840,000	743,808,000	744	3.1%
		TPH C10 - C14	30	309,920	619,840	619,840,000	18,595,200,000	18,595	15.1%
Zone 4 - Offsite lower fill outside 20m of Declaration Area		Naphthalene	22	50,400	100,800	100,800,000	2,217,600,000	2,218	9.3%
		TPH C10 - C14	25	50,400	100,800	100,800,000	2,520,000,000	2,520	2.0%
Zone 4 - Offsite marine sediments outside 20m of Declaration Area		Naphthalene	17.0	99,400	198,800	198,800,000	3,379,600,000	3,380	14.2%
		TPH C10 - C14	64.0	99,400	198,800	198,800,000	12,723,200,000	12,723	10.3%

Sub-total - Zone 3 & 4 mass within offsite fill materials		Naphthalene	17.9%
		TPH C10 - C14	23.0%
Sub-total - Zone 3 & 4 mass within marine sediments (max 5m		Naphthalene	53.7%
		TPH C10 - C14	50.7%

Total Zone 1 to 4 mass (kg):	Naphthalene	23,875
In fill and marine sediments	TPH C10 - C14	123,389

Total Zone 1 to 4 mass (kg):	Naphthalene	8,624
In fill material only	TPH C10 - C14	52,852

Residual mass remaining in Zone 2 to 4 marine sediments	Naphthalene	15,250	63.9%
	TPH C10 - C14	70,538	57.2%

Appendix G:

ENVIRON Letter "Review of Block 5 and Hickson Road Pilot Test, S-ISCO and SEPR, Barangaroo" dated 13 October 2010

ENVIRON

13 October 2010 Our Ref: AS121111B & C

Lend Lease (Millers Point) Pty Ltd
Attn: Warwick Bowyer
Level 4, 30 The Bond
Hickson Road
Millers Point NSW 2000

Dear Warwick

Re: Review of Block 5 and Hickson Road Pilot Test, S-ISCO and SEPR, Barangaroo

1 Introduction

1.1 Background

As a NSW-EPA accredited Contaminated Sites Auditor, I am conducting a contamination audit in relation to the southern portion of the site known as "Barangaroo", at Millers Point, NSW on behalf of Lend Lease (Millers Point) Pty Ltd (Lend Lease). Barangaroo is a large site to be developed in stages and for a variety of uses, with different portions subject to separate audits.

The portion of Barangaroo (and part of the adjacent Hickson Road) that is the subject of this audit has been designated as the "Declaration Area" (the site). The Declaration Area is identified in the NSW Environment Protection Authority (EPA), part of Department of Environment, Climate Change and Water (DECCW), Declaration Number 21122, Area Number 3221, and is also known as the former Millers Point gasworks. The site includes parts of Block 3, Block 4, Block 5, Southern Cove and Hickson Road. The portions of Blocks 3, 4 and 5 within the Declaration Area are intended to be re-developed for high density residential and commercial purposes. The site location is shown on Attachment 1, and the proposed development layout is shown on Attachment 2.

1.2 Objective

The Barangaroo Delivery Authority (BDA) has entered into a Voluntary Management Proposal (VMP) with the EPA, Approval No. 20101719, dated 23 July 2010, that addresses those works required to remove the declaration. The VMP is proposed in two phases. The following objectives are included in Phase 1 of the VMP:

O3. Conduct Surfactant-enhanced In Situ Chemical Oxidation ("S-ISCO") bench scale and pilot trials to determine the applicability of S-ISCO.

O5. Conduct Surfactant Enhanced Product Recovery ("SEPR") pilot trial.

The proposed methodology for conducting the S-ISCO and SEPR pilot trials for the Declaration Area has been documented by VeruTEK Technologies, Inc. (VeruTEK) in 'Work Plan, Block 5 and Hickson Road Pilot Trial' dated 7 October 2010. VeruTEK has been subcontracted by AECOM Australia Pty Ltd (AECOM) who is undertaking remediation of the site on behalf of Lend Lease.

The objective of this review is to provide my comments on the suitability and appropriateness of the proposed S-ISCO and SEPR pilot trial methodology as a trial of potential remediation methods for clean-up of the site and removal of the declaration. A remediation action plan (RAP) and remediation work plan (RWP) will also be prepared addressing remediation of 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 re use of material from one part in another, an Overarching RAP has also been prepared to identify strategies and remedial options for remediation of the whole site. Review of the Overarching RAP has been conducted as a separate audit.

1.3 Scope of Work

This letter is based on a review of the documents listed below and observations made during a site visit on 18 March 2010, as well as correspondence with Lend Lease, AECOM and VeruTEK:

- '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 'Preliminary Environmental Investigation, 30-38 Hickson Road, Millers Point, NSW, 2000' dated 12 May 2008, by Coffey Environments Pty Ltd (Coffey)
- 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
- Draft Report 'Sampling, Analytical and Quality Plan Declaration Area – Issue 1 VMP Works, NSW EPA Declaration Area 21122, former Millers Point Gasworks' dated 2 March 2010, by AECOM
- EPA Declaration of Remediation Site, Declaration No. 21122, Area No. 3221, dated 6 May 2009 (the declaration)
- Report 'Sampling, Analytical and Quality Plan Declaration Area – Issue 2 VMP and PDA Works, NSW EPA Declaration Area 21122, former Millers Point Gasworks' dated 6 July 2010, by AECOM

- Report 'Data Gap Investigation, EPA Declaration Area (Parts of Barangaroo Site and Hickson Road), Millers Point, NSW' dated 23 September 2010 (and drafts dated 16 April and 30 July 2010), by AECOM (the DGI)
- Report 'Overarching Remedial Action Plan for The Barangaroo Project Site, Sydney' dated 1 June 2010 by ERM (the Overarching RAP)
- EPA Notice of Approval of Voluntary Management Proposal, Approval No. 20101719, Area No. 3221, dated 23 July 2010 (the VMP)
- Final Report 'Treatability Study Recommendations for the Implementation of an In Situ Remedy Barangaroo – Block 5 and Hickson Rd Site, Lend Lease, Sydney, Australia' dated 23 September 2010 (and draft dated 16 June 2010) by VeruTEK
- Final Report 'Work Plan, Surfactant Enhanced In Situ Chemical Oxidation, Surfactant Enhanced Product Recovery, Block 5 and Hickson Road, Pilot Trial' dated 7 October 2010 (and drafts dated June 2010, 27 August 2010 and 28 September 2010) by VeruTEK.

2 Site Details

2.1 Location

The site details are as follows:

Street address:	Wharf 8, Hickson Road (Sussex Street), Barangaroo, NSW 2000
Identifier:	Part Lot 3 and Part Lot 5 in DP 876514, section of Hickson Road in State Plan 118 and 162 (refer Attachment 3)
Local Government:	City of Sydney
Owner:	Barangaroo Delivery Authority, City of Sydney Council
Site Area:	Approximately 2.1 ha

The current zoning of the site was identified by AECOM in the DGI as:

- Portion within Hickson Road: Maritime and Transport Zone
- Portion within Barangaroo: Zone B4 Mixed Use.

2.2 Adjacent Uses

The site is located within an area of mixed uses as follows:

- North: Barangaroo open space (concrete/hardstand), including remainder of Block 5. Currently vacant except for public walkway access and temporary Overseas Passenger Terminal. Former commercial and port related activities.
- South: Barangaroo open space (concrete/hardstand), comprising Blocks 1-3. Recently vacated Wharf 8 Overseas Passenger Terminal (including cruise ship loading dock, terminal, car park and landscaped areas). Former commercial and port related activities.

- East: Commercial and high density residential buildings.
- West: The remainder of Blocks 4 and 5 and Southern Cove, followed by Darling Harbour. Former commercial and port related activities.

There may have been localised sources of contamination at the adjacent portions of Barangaroo, however, these are not considered to have potential to have caused significant contamination at the site, given the primary contaminant source in the local area is the gasworks formerly located at the site.

2.3 Site Condition

The site is flat and at an elevation a few metres above Darling Harbour water level. Hickson Road is a public roadway for both vehicle and pedestrian traffic. AECOM noted the following current features at the portion of the site on Barangaroo in their DGI report:

- The site is covered by hard surfacing including concrete and bitumen with only a few structures and large light towers. The site is vacant and former large warehouses have been demolished
- There is a disused brick amenities building in the east of the site near Hickson Road
- There is a sewage pumping station (SPS) north of the amenities building. ERM reported in the draft RAP (2008) that this feature is identified on the NSW State Heritage List
- There is part of the vacant 'former maintenance building' in the southeast of the site near Hickson Road.
- The site is secured by fencing, with the exception of a fenced public walkway access that crosses the site.

3 Environmental Investigation Results

The following brief summary is based on review of the ERM and Coffey investigations and the AECOM DGI, as listed in Section 1.

3.1 Site History and Contaminants of Concern

The site was historically used to manufacture gas from approximately 1840 to 1921. It is understood that some of the former gasworks infrastructure remains in place beneath the current slab and roadways (including Hickson Road). Attachment 3 indicates the location of these features. The gasworks were demolished in the mid 1920s when new finger wharves were constructed, and the area was subsequently used for various workshop facilities. In addition to the original filling for development of the gasworks, filling also occurred in 1961-1968 for the construction of longshore berthage, with some additional filling in the south of the site (area of former Southern Cove) in the late 1980s or early 1990s.

The primary sources of contamination at the site include the former gasworks operations and uncontrolled fill used in various stages of site reclamation. Relevant contaminants of concern are:

- **Gasworks**: could include metals, TPH, BTEX, PAHs, phenols, sulphate, cyanide, ammonia, asbestos. These are generally consistent with the VMP which identifies the chemical composition of gasworks waste to include: PAH, BTEX, TPH, ammonia, phenol and cyanide.
- **Fill**: could include metals, TPH, BTEX, PAHs, PCBs, OCPs, VOCs, SVOCs, asbestos.

There is also potential for Acid Sulphate Soils (ASS) and hazardous building materials such as lead, PCBs and asbestos to be present.

3.2 Soil and Groundwater Investigations

Soil and groundwater conditions at the site have been assessed in multiple stages of investigation by ERM, Coffey and AECOM, with locations shown on Attachment 2.

Soil sampling has focussed primarily on fill materials which extend to between 0.43 and 17.5m below ground level (mBGL), increasing from the east (Hickson Road) to west (towards Darling Harbour). Investigations have also assessed underlying natural sediments, however there has been minimal sampling of bedrock.

Groundwater at the site is shallow, generally within 3mBGL, and is subject to tidal fluctuations indicating a high degree of connectivity between groundwater at the site and the adjoining waters of Darling Harbour. The tidal influence extends as far east (inland) as Hickson Road, although the degree of fluctuation is much less in the eastern portion of the site.

3.3 Investigation Results

According to AECOM, “Contamination has been reported in fill material, natural soil and groundwater underlying the Site, other adjacent portions of Barangaroo, adjacent portions of Hickson Road and sediment in the nearby Darling Harbour.” The key investigation findings reported by AECOM in the DGI were as follows:

- The following contaminants were detected in soil at concentrations exceeding the site assessment criteria: lead, TPH, BTEX, PAHs (including benzo(a)pyrene) and sulfate.
- The maximum concentrations in soil were generally located in proximity to and down gradient of the former gasworks infrastructure in Block 4 and Hickson Road. Free tar was identified at eight locations within Hickson Road and Block 4 in the vicinity of the tar tank, purifying beds and 1870 gasholder indicating these locations are the main areas of contamination.
- Soil vapour results indicated some gasworks-derived impacts (indicated by the presence of naphthalene) in locations closest to the former gasworks area, and low concentrations of toluene, chloroform and tetrachloroethene in some locations.
- The following dissolved phase contaminants were detected in groundwater at concentrations exceeding the site assessment criteria: lead, cadmium, chromium (III+VI), cobalt, copper, mercury nickel, zinc, benzene, naphthalene and phenol.
- The most significant groundwater contamination was identified in the immediate vicinity of the former gasworks infrastructure and contamination is present in both dissolved and free phase forms (non-aqueous phase liquid – NAPL).

- Concentrations of contaminants in excess of the site assessment criteria were also identified in down-gradient groundwater wells, indicating the westerly migration of contamination. The results of the investigation indicate that the variable nature and distribution of fill materials at the site cause localised variations in groundwater flow and associated contaminant migration, which is further complicated by tidal movements.

3.4 EPA Findings

The EPA has declared that the site is contaminated with gasworks waste and particularly waste tar as a result of the previous use of the site as a gasworks. This contamination was considered significant enough to warrant regulation under the NSW *Contaminated Land Management Act 1997* hence the site was previously declared as an Investigation Area (2007), and is currently declared as a Remediation Site (No. 21122, 2009). This declaration was made based on the following:

- *"Groundwater on the site has been found to be contaminated by TPHs, PAHs, BTEX, ammonia, phenol and cyanide at concentrations significantly exceeding the relevant trigger values for the protection of human health and aquatic ecosystems in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000).*
- *These groundwater contaminants include human carcinogens and substances toxic to aquatic ecosystems.*
- *The contaminated groundwater is impacting on the surrounding areas including the basement of a residential building adjacent to the site, potentially exposing humans in that building to harmful vapours; however it is currently being effectively controlled.*
- *Contaminated groundwater is likely to be migrating from the site to Darling Harbour and could ultimately affect aquatic ecosystems".*

4 Evaluation of Pilot Trial

4.1 Introduction

As discussed in Section 1.2, completion of pilot trials at the site for S-ISCO and SEPR are requirements of the VMP (Approval No. 20101719). The purpose of this review letter is to provide my comments on the suitability and appropriateness of the proposed pilot trial methodology. The proposed methodology has been documented in a Work Plan.

The following sections provide an overview of the proposed trial methodology, an evaluation of the Work Plan document and consideration of the monitoring program. An assessment of potential risks and mitigation measures is included in Section 5.

4.2 Proposed Pilot Trial Methodology

4.2.1 Remediation Technology Overview

As outlined by VeruTEK in the Work Plan, the S-ISCO process involves the injection of an oxidising agent (and activator if required) and a cosolvent (surfactant) into the subsurface to reduce the amount of source NAPL and reduce the flux of groundwater constituents. SEPR

uses plant-based surfactants and hydrogen peroxide to enhance product recovery of NAPL. SEPR is also used as a pre-treatment for S-ISCO. Both processes utilise enhanced desorption and solubilisation of the gas works organic chemicals from soils and simultaneous chemical oxidation of the solubilised chemicals.

According to VeruTEK, S-ISCO and SEPR, as a pretreatment step, are proposed for treatment of the Hickson Road portion, and S-ISCO is proposed for use within the Barangaroo Site, specifically (but not necessarily limited to) Block 5 within the Declaration Area.

The proposed pilot trial remediation technology is consistent with the remedial options identified in the Overarching RAP.

4.2.2 Bench Scale Treatability Study

The type of oxidant, activator, cosolvent and proposed dosage for the pilot trial has been selected based on the findings of a bench scale treatability study (VeruTEK, 23 September 2010). Treatability tests were performed on soil samples from Block 4, Block 5 and Hickson Road, and a sample of NAPL from Block 5.

The samples used in the treatability study are considered adequately representative of the soils to be treated in the Pilot Trial based on the sample collection location, sample material type and contaminant concentrations.

I have not reviewed the appropriateness of the bench scale testing undertaken, the agents selected or the proposed dosages due to the specialised technical nature of the study and the proprietary additives considered.

4.2.3 Pilot Trial Methodology

The pilot trial is proposed to be conducted in two separate areas - within Block 5, and within the tar tank on Hickson Road. The Pilot trial will involve injection of water, oxidant, activator and cosolvent, which are proposed to move naturally with the flow of groundwater. Extraction wells are not proposed to force the flux of treatment chemicals through the ground, however, extraction within the tar tank (Hickson Road) is proposed to allow product recovery and to maintain hydraulic control over the fluids in the tar tank. Monitoring will be conducted to follow the magnitude and rate of the movement and influence of the treatment front. Initial injection rates will be low, and they will gradually be increased once it is established how fast the chemistry moves within the subsurface. A number of groundwater or soil vapour extraction contingencies are defined, to be enacted in the event the treatment front approaches receptors or excess vapours are generated (refer Section 5).

The following Table 4.1 provides a summary of the pilot trial details and proposed monitoring networks in each area. Attachment 4 shows the location of the two trial areas and monitoring features, with further detail in the two trial areas shown on Attachments 5 and 6, respectively.

Table 4.1: Summary of Proposed Pilot Trial and Monitoring Networks		
Trial Aspect	**Block 5 (Attachment 5)**	**Hickson Road (Attachment 6)**
Trial area	10 x 10m (100m^2), adjoining eastern boundary of Block 5	16m diameter tar tank (approx. 200m^2), adjacent to 36 Hickson Road, under roadway and footpath
Relevant investigation bores	*Inside trial area:* ERM BH198, AECOM BH66 *Nearby:* AECOM BH65, ERM BH60	*Inside trial area:* Coffey BH7, AECOM BH53
Trial area contamination status and below ground features	TPH, BTEX and PAH soil and groundwater contamination with some tar impact Fill depth of around 3-5mBGL Gasworks infrastructure including retort house and 1880 extension and purifiers	TPH, BTEX and PAH soil and groundwater contamination, and tar sludge at base of tank (approx. 5.4mBGL) Shallow bedrock, around 1mBGL, around tar tank Steel lined tar tank, expected limited connectivity with surrounding bedrock
Rationale for selection of trial area	Based on location, level of contamination and lithology. In particular: • Proximity to utilities • Adjacent to Hickson Road, facilitating simultaneous trials • Far away from Darling Harbour, minimising chance of impact • Includes BH198, where soil exhibited high levels of contamination • Contains contamination that is representative of contamination elsewhere within Block 5, and relatively shallow fill depth is desirable for defining a Pilot trial area.	Trial not intended to be applicable to all of Hickson Road. Location selected for evaluation of NAPL treatment and to allow design of full-scale tar tank treatment. Other considerations were: • Results will be applicable for other confined or semi-confined structures from the former gasworks, including the former gasholder annulus or geological features (i.e. bedrock depressions) where pockets of NAPL requiring treatment may be discovered during full-scale implementation. • Need to trial how tar and tar-contaminated material within historic structures would be remediated. • Need to determine how the proposed in situ technology would (if at all) impact the basement of 38 Hickson Road.

Table 4.1: Summary of Proposed Pilot Trial and Monitoring Networks		
Trial Aspect	**Block 5 (Attachment 5)**	**Hickson Road (Attachment 6)**
Remediation trial approach	Two phases of S-ISCO: 1. 6 weeks hydrogen peroxide activated by Fe-TAML, enhanced by VeruSOL 2. 2 weeks alkaline persulfate	SEPR followed by S-ISCO <u>SEPR:</u> 1. 5 days injection, hydrogen peroxide enhanced by VeruSOL 2. 5 days extraction of injected fluid and solubilised product <u>S-ISCO:</u> 3. 4 weeks hydrogen peroxide activated by Fe-TAML, enhanced by VeruSOL
Number of injection wells	4	3
Injection well construction	Screen from 2.5 to 3.5mBGL Separate injection into fill and natural materials (see Section 4.4, below)	Screen from 3 to 5mBGL (approx.) Will screen to base of tar tank (see Section 4.4, below)
Number of extraction wells	0 (Extraction can occur from groundwater wells as a contingency)	3 – combined with monitoring wells Dual phase extraction is proposed - NAPL and emulsified fluids Initial extraction volume will be equal to injection volume, will be adjusted to maintain hydraulic control (Extraction can also occur from groundwater wells as a contingency)
Groundwater monitoring network		
Total wells to be monitored	12 5 existing, 7 new	8 3 existing, 5 new
Locations inside trial area	2	3
Locations outside trial area	10 1 upgradient 2 cross gradient 7 downgradient	5 2 cross gradient 3 downgradient
New groundwater well construction	Clusters of up to 3 wells (depending on depth to bedrock) – screened at shallow, intermediate and deep (to bedrock) depths. 3m screen length, 50mmUPVC construction.	Clusters of up to 3 wells (depending on depth to bedrock), anticipated to only be shallow depth. 3m screen length, 50mmUPVC construction.
Soil vapour monitoring network		
Total wells to be monitored	4 3 existing, 1 new	4 all new

Table 4.1: Summary of Proposed Pilot Trial and Monitoring Networks		
Trial Aspect	**Block 5 (Attachment 5)**	**Hickson Road (Attachment 6)**
Locations inside trial area	1	1
Locations outside trial area	3 to south and west	3 Buildings at 30 and 38, to north and south
Soil vapour point construction	0.25 inch Teflon tubing with vapour tip. Two screened depths – 0.3-0.5 and 1.3-1.5mBGL (approx.)	0.25 inch Teflon tubing with vapour tip. Two screened depths – 0.3-0.5 and 1.3-1.5mBGL (approx.)

In the Auditor's opinion:

- The proposed pilot trial methodology documented in the Work Plan and summarised in Table 4.1 above is considered to be a reasonable approach to trialling the identified technologies at the site.
- The proposed monitoring network is considered adequate, with soil vapour and groundwater monitoring points adequately located in proximity to sensitive receptors.

The monitoring program is discussed further in Section 4.4 and risk mitigation and contingency measures are discussed in Section 5.

4.3 Evaluation of Work Plan

The Auditor has undertaken a review of the Work Plan to determine the suitability and appropriateness of the Work Plan to meet the objectives of the pilot trial. The review has not addressed the adequacy of the Work Plan with respect to occupational health & safety, dangerous goods management, traffic management and other areas that are not relevant to the subsurface contamination and associated risks to human health and the environment during the pilot trial.

The Auditor's review is summarised in Table 4.2, below.

Table 4.2: Evaluation of Pilot Trial Work Plan		
Work Plan Element and Where Addressed	**Details**	**Auditor Comments**
Objective s1.2	The objective of the Pilot Trial is "to verify the effectiveness of the S-ISCO® and SEPR™ remedies in the field, and to acquire data that can be used to optimise the design of the Full-Scale S-ISCO® and SEPR™ implementations". A number of more specific objectives are presented, including: • the objective of the SEPR pilot trial to treat up to 25 % of the soil contaminant mass in order to demonstrate that SEPR	The primary and specific objectives are considered appropriate. The remediation criteria for removal of the Declaration is not yet determined and will be subject to EPA approval.

Table 4.2: Evaluation of Pilot Trial Work Plan

Work Plan Element and Where Addressed	Details	Auditor Comments
	is capable of removing the tar from the tar tank in Hickson Road. • The objective of the S-ISCO pilot trials in both Hickson Road and Block 5 is to demonstrate that S-ISCO is capable of remediating contamination such that the EPA Declaration can be removed.	
Process Description s3.1-3.7 s5.6	The Work Plan describes the various systems that make up the pilot trial, including: • Injection system • Extraction system • Soil vapour extraction (SVE) and treatment system • Trenching system, particularly in Hickson Road	The level of detail provided for the process description is generally adequate, although the trigger for replacement of the SVE system carbon filters is not addressed. The Auditor has not reviewed technical design elements of the system.
Test site rationale s2.1 and 2.3	Test site rationale was discussed in the Work Plan and is summarised by the Auditor in Table 4.1, above	Based on the rationale presented, the selected test sites are considered appropriate.
Consideration of laboratory to field pilot trial scaling issues s1.3.1 Also treatability study report.	VeruTEK considers the results of the short-term treatability tests (up to 28 days in the laboratory) to be extremely conservative with respect to field scale implementation since chemical oxidation reactions are rate limited and the field treatment duration will be in the order of many months. VeruTEK also notes that the results of the laboratory study are conservative since the study used soils taken from the most highly contaminated areas.	The Auditor notes that the contact (mixing) conditions during the laboratory testing are not conservative when compared to the likely conditions in the field. However, the Auditor is satisfied that the laboratory testing undertaken is sufficient to allow for the appropriate selection of additives and dosage.
Consideration of field pilot trial to full scale scaling issues s1.3.1	"VeruTEK does not anticipate that any scale-up or staging factors will affect the relationship between the results attained in the pilot trial and what can be achieved during the Full-Scale implementation. One key objective of the pilot trial is to provide sufficient and necessary information to design the Full-Scale implementation and therefore minimise the risk	The Auditor notes that the fill depth in the Block 5 trial area is relatively shallow compared to the remainder of the site. However, based on the pilot trial objectives

Table 4.2: Evaluation of Pilot Trial Work Plan

Work Plan Element and Where Addressed	Details	Auditor Comments
	of any issues that might otherwise occur between the bench scale trials and full scale implementation".	and the test site rationale, the Auditor is satisfied that, if implemented successfully, the field pilot trial should be scalable to Full Scale remediation at the site.
Site management plan, including contingency plan to respond to site incidents s3.12 S4	A separate Construction Management Plan (CMP) is to be prepared covering incident management, communication plan and environmental management plans relating to: • Traffic; • Noise and Vibration; • Waste; • Water; • Air Quality and Odour; and • Aesthetics. The Work Plan also includes information relating to roles and responsibilities and data management.	The Auditor has not reviewed the CMP or operational management issues such as dangerous goods management. Consideration of these elements is not relevant to the current review. The proposed roles, responsibilities and data management are considered appropriate.
Health and safety plan s4.4	A separate Health and Safety Plan (HSP) is to be prepared. The Work Plan states that the HSP will be certified, peer reviewed and independently endorsed by an occupational health and safety expert.	The Auditor has not reviewed the HSP. This is not relevant to the current review.
Management of extracted fluids s4.5.1	It is anticipated that up to 80,000L of fluid will be extracted as part of the SEPR process. The Work Plan identifies the following options for management of extracted fluids, which are discussed further in the waste management plan in the CMP: • Progressively treated on site and re-used in subsequent injections to the greatest extent possible; or, where this is not possible, • Disposed of to sewer in accordance with a trade waste agreement; • Disposed of to storm water in accordance with appropriate license conditions; or • Disposed of off- site prior to completion of the pilot trial.	The Auditor has not reviewed the waste management plan contained within the CMP. The options identified are considered reasonable, although are subject to licences and / or approval by others.

Table 4.2: Evaluation of Pilot Trial Work Plan

Work Plan Element and Where Addressed	Details	Auditor Comments
Monitoring and validation s3.8, s.9, 3.10, 5 Table 7A (Block 5) Table 7B (Hickson Road)	The proposed monitoring schedule and validation sampling are discussed in the Work Plan and are addressed by the Auditor in Section 4.4, below. Tables 7A and 7B are attached to this review letter.	Refer Section 4.4
Consideration of environmental risks and mitigation measures s1.1.1, 1.3.4, 3.11	Potential risks and mitigation/ contingency measures are discussed in the Work Plan and are summarised by the Auditor in Section 5, below.	Refer Section 5
Licence and Approvals s7	A specific discussion of the approvals required for the pilot trial is not provided in the Work Plan. The following reviews/ approvals are mentioned: • Department of Planning review • Construction Certificate • DECCW permit • Road closure permit • Police permit	The Auditor has not reviewed the licensing/ approval requirements for the pilot trial works.
s5.6	The Work Plan states that "It is expected that the soil vapour extraction system will not require an Environmental Protection License and hence will not be subject to requirements under the POEO Clean Air Regulations. Notwithstanding, and based on the requirements of the POEO Clean Air Regulations, a trigger level of 10mg/m^3 of total VOC will be adopted for operation of the SVE system with a limit of 20mg/m^3 of total VOC proposed as a maximum limit never to be exceeded".	The Auditor has not reviewed the licensing/ approval requirements related to discharges from the SVE system. Control limits are subject to approval by others.
s4.5.1	Disposal of extracted fluids to sewer, stormwater and off-site are identified as options for the management of extracted fluids. Waste disposal requirements are addressed in the CMP. The Work Plan makes reference to a trade waste agreement, license (presumably under POEO) and classification for disposal in accordance with DECC (2008).	The Auditor has not reviewed the CMP or the detailed licensing/ approval requirements related to waste management. Classification of liquid wastes for disposal is required in accordance with DEC (1999) 'Environmental Guidelines: Assessment, Classification and

Table 4.2: Evaluation of Pilot Trial Work Plan

Work Plan Element and Where Addressed	Details	Auditor Comments
		Management of Liquid and Non Liquid Waste'. The Work Plan does not address the disposal of spent carbon filters from the SVE system.
Hours of operation and Schedule s3.13, s7	Hours of operation are specified in the Work Plan. The overall trial schedule including initial approvals and post-trial reporting is estimated at 36 weeks, with a 16 week period of on-site activities (installation, operation and post-trial monitoring).	The level of detail provided is considered adequate. Hours of operation are subject to approval by others.
Contacts/ Community Relations s4.2	The Work Plan refers to the CMP which reportedly contains a list of key persons and relevant stakeholders affiliated with the site activities and includes a communication plan. The Work Plan states that community consultation will be managed by Lend Lease and will be part of a broad, comprehensive community consultation strategy.	The Auditor has not reviewed the CMP or the community consultation strategy. Consideration of these elements is not relevant to the current review.
Reporting s4.2 s6	A single Pilot Trial Summary Report is proposed to be prepared following completion of the pilot trial activities. A summary of the communication plan is provided in the Work Plan, with full details in the CMP. The summary indicates the following: • Daily reporting within the project team, eg, to site manager and project manager. • Reporting of results and data collected to relevant stakeholders and regulators, as appropriate • Weekly meetings between stakeholders, minuted in a weekly report that will be distributed electronically to project managers of VeruTEK, AECOM, Lend Lease and any other relevant stake-holders (as appropriate). • Representatives from AECOM, VeruTEK, Lend Lease, and any other relevant stake-holders are to be notified within 24 hours of any incidents.	The proposed content of the Pilot Trial Summary Report is considered appropriate. Specific stakeholders are not identified in the Work Plan and the Auditor has not reviewed the CMP or the detail of the communication plan. The degree of communication to external stakeholders and regulators appears reasonable, however, this is subject to approval by others.

The Work Plan is considered by the Auditor to be an adequate documentation of the proposed pilot trial for the purposes of this review. Some items were not addressed, in particular, relevant licenses, approvals and waste management aspects. In addition, I have not reviewed documents referred to such as the CMP and HSP. Consideration of these elements is not relevant to my consideration of the suitability and appropriateness of the proposed pilot trial with respect to site contamination.

4.4 Monitoring Program

Establishment of an appropriate monitoring program is essential to the success of the pilot trial, since reliable results are required for the appropriate design of the full-scale remediation system. The Auditor undertook a detailed review of multiple drafts of the monitoring program as part of this review.

The Work Plan describes the monitoring network and the monitoring program to be implemented during three phases of the pilot trial, as follows:

1. pre-injection
2. concurrent with injection/ extraction
3. post-injection.

Monitoring is proposed according to the following components:

- process monitoring – to inform adjustments to the system operational parameters
- performance monitoring – to track the movement of injected chemicals and nature of reactions
- groundwater sampling – to assess the effectiveness of the treatment
- soil sampling – to assess the effectiveness of the treatment
- soil vapour sampling – to assess potential impacts from the generation of vapours as a result of S-ISCO and SEPR oxidation reactions.

A detailed monitoring schedule is presented in the Work Plan for each trial area in Tables 7A and 7B, which are attached to this letter. Key features of the monitoring program are as follows:

- A combination of new and existing monitoring fixtures are to be used as outlined in Table 4.1 of this letter.
- Measurements are to be taken *ex situ* using field instruments, *in situ* using continuous logging equipment, and analysis of samples will be undertaken at an on-site laboratory as well as specialist off-site laboratories.
- Process monitoring will commence at an initial high frequency (hourly) during start-up and immediately after any major process changes, which will decrease to less frequent (daily) during day-to-day operation at steady-state injection conditions.

- The results of all monitoring will be reported immediately to the site manager and project manager to enable optimisation of the system or implementation of any contingency actions.
- Daily gauging for NAPL in five wells near the tar tank will be performed during the SEPR phase and daily gauging of the groundwater level in all wells in the Hickson Road trial area will be performed during the SEPR and S-ISCO phases (when injection is occurring).
- Collection of SUMMA canister soil vapour samples and analysis by an off-site laboratory will occur once in the pre-injection phase and weekly during the injection/ extraction and post-extraction phases.
- Daily monitoring by a PID and multi-gas meter (or equivalent) will be undertaken within utility pits, service access points and monitoring well heads, as well as in the breathing zone (ambient air) above these locations. The frequency of monitoring may be reduced based on the results of the monitoring program and pilot trial activities to a frequency not less than weekly.
- In the event that PID readings 5.0 ppm above background concentrations are detected in the breathing zone for a period of more than 5 minutes, Draeger Tube samples will be collected to confirm whether the PID reading is representative of benzene.
- Quantitative odour monitoring will be conducted daily using a nasal ranger in at least six locations, in the early morning when dispersion conditions are expected to be at their worst. Odour measurements will be compared with baseline monitoring data collected prior to work commencing at the site.
- The overall effectiveness of the treatment (validation) will be determined by comparison of pre-trial and post-trial sampling results. Post-trial samples will be collected approximately one month after completion of the injection process by AECOM as an independent evaluation of the VeruTEK trial. A complete monitoring round will be undertaken for groundwater, while soil will be assessed by five grid-based boreholes pre- and post-trial in each trial area. Pre- and post-trial samples will be collected in approximately the same areas (location shifted slightly) and at the same depth intervals.
- Proposed QA/QC procedures and samples are discussed for the soil, groundwater and soil vapour sampling programs. The proposed QA/QC is considered adequate. Soil vapour QA/QC includes leak testing and 10% duplicates. Further QA/QC samples are not considered necessary given the primary purpose of soil vapour sampling is performance monitoring (see below).

There were some minor inconsistencies in the Work Plan, or some items that were clarified to the Auditor by VeruTEK but which were not documented in the final Work Plan. These are as follows:

- Daily PID monitoring is to be undertaken as it enters and exits the carbon canister (written in s5.6 but not clear in Tables 7a and 7b of the Work Plan). It is presumed this information will be used in assessing the need for carbon replacement.
- The breathing zone action level of 5 ppm was reportedly set based on the Short Term Exposure Limit [STEL] concentration for benzene (s5.5.2), however, the Auditor notes

that there is no STEL for benzene, and the Time Weighted Average [TWA] is 1 ppm. Revision of this action level may be warranted.

- The screened interval for the tar tank (Hickson road) injection wells is reported as 3-5mBGL (approx.). The Auditor queried this installation and asked if the wells were proposed to be installed to the base of the tar tank which may vary slightly from 5mBGL. VeruTEK responded that the 5m installation depth was approximate. The Auditor notes that screening of the tar tank injection wells to the base of the tar tank is desirable.
- The Auditor queried the integrity of soil vapour monitoring points being used for SVE and the validity of the soil vapour samples collected. VeruTEK responded that the flow of the SVE system is designed to create a slightly negative pressure toward the system which will not compromise the integrity of the well construction. The purpose of the monitoring is not to quantify the amount of soil gas or measure representative soil vapour concentrations, but rather to monitor changes in soil vapour as an indicator of whether soil vapour concentrations are changing (increasing), and to thereby verify that the pilot trial implementation is not creating a soil vapour issue. This response is considered acceptable.
- The Auditor queried the Block 5 injection well construction with respect to screening of fill versus natural materials and the potential for preferential flowpaths. VeruTEK responded that due to the heterogeneous, isotropic distribution of contamination and geologic properties, during injection well installation the soil cores will be examined before the final well screen interval is selected. This Site-specific analysis may indicate that it is necessary to install multiple injection well completions at a given location, screened at different depths, to enable complete and comprehensive treatment of contamination in heterogeneous media. This response is considered acceptable.
- Between 5 and 10 soil samples are proposed to be collected from each bore during the post-trial validation. The Work Plan does not specify how many samples will be analysed. In the Auditor's opinion, analysis of at least three samples from each bore would be required to adequately represent the treated depth (around 5m).

Overall, the monitoring program documented in the Work Plan is considered by the Auditor to be a sufficiently rigorous program to allow for timely identification of potential impacts to receptors and adequate assessment of the trial performance. Detailed consideration has not been given to the operational monitoring aspects, however, the general approach of initial high frequency (hourly) monitoring is considered appropriate.

5 Evaluation of Risks

The Work Plan identifies potential receptors, risks and mitigation/ contingency measures discussed throughout the document and specifically in s1.3.4 and 3.11. Potential receptors were identified as follows:

- Darling Harbour;
- The trees planted along Hickson Road;
- Site workers and visitors;

- The Sydney Water Company (SWC) SPS adjacent to the Block 5 Pilot Trial area;
- Underground services within Hickson Road;
- Workers and residents of properties surrounding and adjacent to the Hickson Road Pilot Trial area, including the child care centre located at 30 Hickson Road and the basements at 30 and 38 Hickson Road;
- Archaeological resources and relics in the subsurface of Block 5; and
- The basement water treatment system at 38 Hickson Road.

The receptors identified are the potential risk to these considered in the Work Plan are considered appropriate.

The key risk issues and proposed mitigation and contingency measures discussed in the Work Plan have been summarised by the Auditor in Table 5.1, below. The need for implementation of certain measures will be determined based on the results of the monitoring program, discussed above in Section 4.4.

Table 5.1: Summary of Risk Mitigation and Contingency Measures

Risk Issue	Proposed Measures	Comments
Migration of injected chemicals or enhanced migration of groundwater contamination from Block 5 trial towards Darling Harbour or the SPS	Close monitoring of reaction rates and the treatment front. Implementation of pumping from groundwater monitoring wells if required. The system includes the connections required to implement this contingency.	Monitoring and contingency measures considered adequate. Quantitative action levels for implementation of contingency action are not identified.
Migration of injected chemicals or enhanced migration of groundwater contamination from Hickson Road trial towards Darling Harbour, amenities building or buildings on Hickson Road, including 30 and 38	Limited connectivity with surrounding bedrock is expected, however, water injection pump tests are proposed in the tar tank prior to trial commencement to establish the connectivity with the surrounding groundwater and soil vapour Continuous extraction from within the tar tank Close monitoring of reaction rates and the treatment front. Implementation of pumping from groundwater monitoring wells if required. The system includes the connections required to implement this contingency.	Monitoring and contingency measures considered adequate. Quantitative action levels for implementation of contingency action are not identified.
Potential byproducts from additives	VeruTEK report that the chemicals used in S-ISCO and SEPR, as well as the products of their chemical reactions, are harmless to the environment in the context of the pilot trial	The arguments presented appear reasonable, however, the Auditor has not undertaken a detailed review to verify this aspect.

Table 5.1: Summary of Risk Mitigation and Contingency Measures

Risk Issue	Proposed Measures	Comments
		Injection of the chemicals is subject to approval by DECCW.
Damage to underground services within Hickson Road	Only the non-corrosive oxidant peroxide will be used in Hickson Road to prevent adverse effects to services encased in metal or concrete Informed intrusive works will avoid services during installation of the system	Risk mitigation measures considered adequate.
Damage to underground infrastructure associated with the SPS	Informed intrusive works will avoid services during installation of the system	Risk mitigation measures considered adequate.
Generation of vapours and odours. The reaction of hydrogen peroxide generates oxygen that may displace contaminated vapours. There is potential for impact by potentially odourous, toxic and/ or flammable vapours on below ground services, building basements and ambient air from transport of vapours through the soil or through preferential flow paths (such as service trenches).	A low pressure SVE system will operate continuously throughout the duration of the S-ISCO and SEPR injections and extractions to prevent migration of vapours outside the trial areas through the subsurface or releasing to ambient air The system includes an extra SVE line in Hickson Road which can be mobilised in an emergency to increase capacity and coverage of the SVE system The extraction points will be closely monitored Additional SVE points may be installed in key locations (eg, Hickson Road footpath and 30 Hickson Road) if elevated/ unsafe vapour concentrations are detected Daily PID monitoring of: • utility pits, service access points and monitoring well heads (accumulation monitoring) • ambient air above these locations Draeger Tube testing will be performed to determine if PID readings exceeding 5ppm above background comprise benzene. If confirmed, the project manager and relevant stakeholders will be notified and corrective action will be implemented. Daily odour monitoring will be undertaken. The project manager and relevant stakeholders will be notified and corrective action will be implemented in the event that elevated odour dilution concentrations (compared to baseline data) are noted for more than two consecutive daily monitoring events.	Monitoring and contingency measures considered adequate. Quantitative action levels are provided for ambient air PID and odour measurements. Action levels for accumulation monitoring and soil vapour sampling are not specified, however elevated/ unsafe levels are referenced. Site specific risk assessment may be required to assess if levels are “unsafe”.

Table 5.1: Summary of Risk Mitigation and Contingency Measures		
Risk Issue	**Proposed Measures**	**Comments**
	SVE may be implemented at the accumulation points if unsafe vapour concentrations or odours attributable to the pilot trial are detected. Other potential corrective actions identified are: • suspension and/or modification of injections; • amendment of the SVE system; • increase of laboratory and field monitoring frequency; and • conduct of ambient VOC monitoring from the location in question to determine whether the increased soil vapour concentrations have impacted on ambient air quality (relative to background VOC concentrations)	
Movement of treatment front exclusively through preferential, more porous pathways in Block 5 trial area	If the influence of the treatment chemistry is not detected adequately in monitoring wells throughout the treatment zone and at varied depth intervals, additional injection wells will be installed to ensure that all areas of contamination are contacted and treated.	Monitoring and contingency measures considered adequate.

The risk issues identified and mitigation/ contingency measures proposed are considered generally adequate, however, the following is noted:

- The requirement for carbon filter replacement for the SVE system is not discussed in the Work Plan, and licensing/ approvals and discharge limits are not defined (refer Table 4.2). These issues need to be resolved to ensure inappropriate discharge of contaminant vapours does not occur.
- Although the degree of monitoring and proposed contingency measures are considered appropriate, quantitative action levels are not specified for when contingency action would be implemented in relation to migration of groundwater impacts or treatment chemicals, or in relation to vapour accumulation and soil vapour sampling. This highlights the need for careful consideration of monitoring results and the possible requirement for site specific risk assessment to be undertaken during the trial. Sufficient resources should be allocated to allow for the assessment of monitoring results within an appropriate timeframe and all ‘elevated’ results should be reported to the stakeholders.

6 Conclusions and Recommendations

Based on the investigation reports, bench scale treatability study and Pilot Trial Work Plan reviewed by the Auditor, the proposed pilot trial and monitoring approach is considered generally appropriate, and the level of detail presented in the Work Plan is considered adequate for the purposes of my review. In my opinion, if implemented successfully, the pilot trial should produce reliable results that could be applied to the full-scale design of the Barangaroo remediation.

The risk issues identified and mitigation/ contingency measures proposed are considered adequate, however, quantitative action levels for the implementation of contingency actions are not specified for all monitoring aspects. Careful and timely consideration of all monitoring results will be required and all 'elevated' results should be reported to the stakeholders to ensure appropriate action levels are adopted.

This review has not addressed the licences or approvals required for the works, technical aspects of the treatment technology or remediation system design, or considerations such as dangerous goods management, health and safety, operational environmental management, waste management and traffic management.

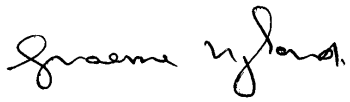
I recommend that the pilot trial be implemented considering the comments made throughout this letter.

* * *

Consistent with Department of Environment, Climate Change and Water (DECCW and formerly NSW EPA) requirement for staged "signoff" of sites that are the subject of progressive assessment, remediation and validation, I advise that:

- This advice letter does not constitute a Site Audit Report or Site Audit Statement.
- At the completion of the remediation and validation I will provide a Site Audit Statement and supporting documentation.
- This interim advice will be documented in the Site Audit Report.

Yours faithfully



ENVIRON Australia Pty Ltd
Graeme Nyland
Accredited Auditor 9808

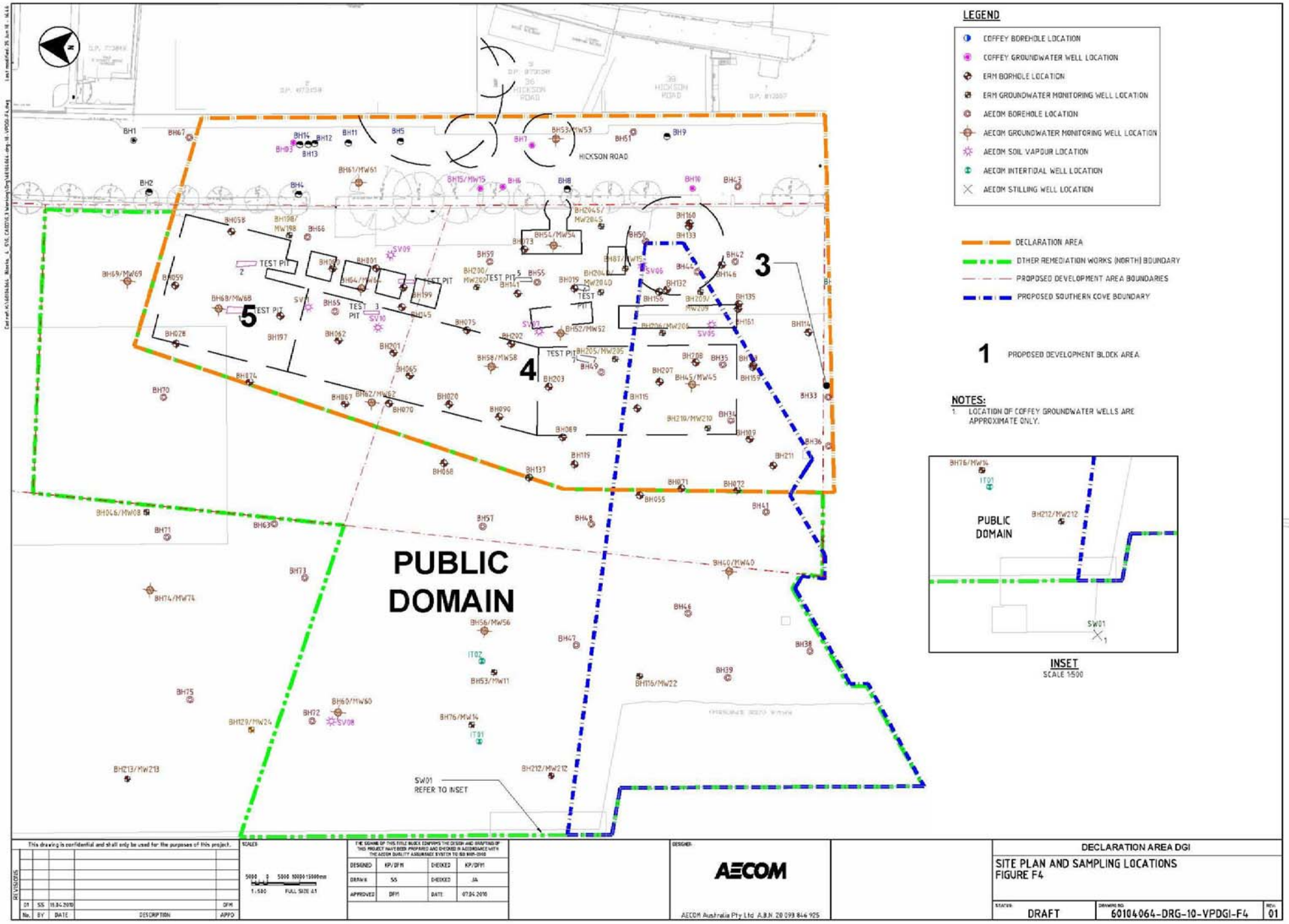
Enc:
Attachment 1: Site Location
Attachment 2: Site Layout and Investigation Locations
Attachment 3: Lot Layout and Previous Gasworks Layout
Attachment 4: Pilot Trial Locations
Attachment 5: Block 5 Pilot Trial Layout
Attachment 6: Hickson Road Pilot Trial Layout
Table 7A: Block 5 Monitoring Schedule
Table 7B: Hickson Road Monitoring Schedule

Attachment 1: Site Location

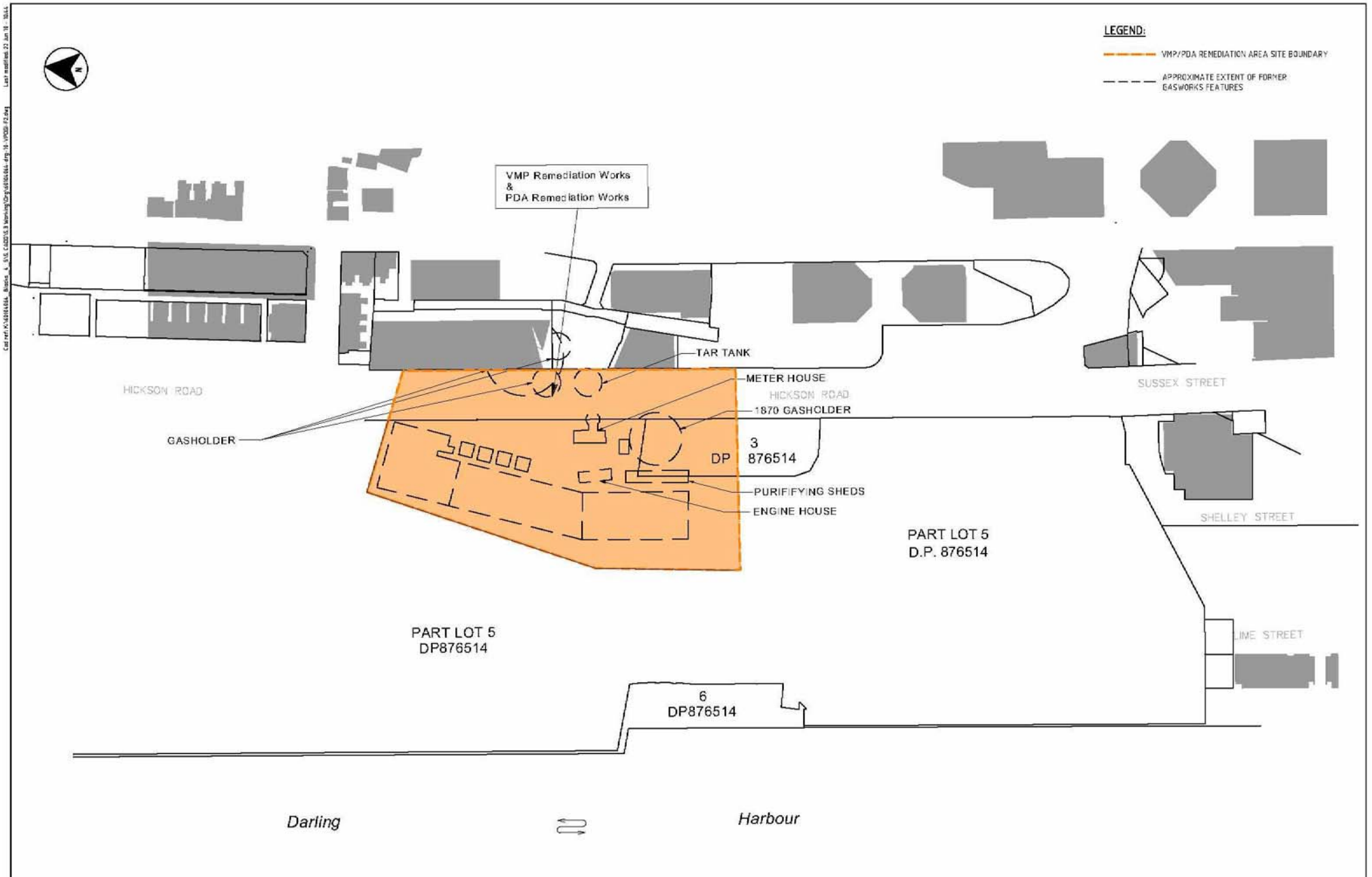
PROJECT ID: S4150010 CREATED BY: TO LAST MODIFIED: TO 22 06 2010 AECOM www.aecom.com 0 600m		**Site Location** **Lend Lease (Millers Point) Pty Ltd** *Sampling Analysis and Quality Plan* *Barangaroo Data Gap Investigation* Hickson Road, Millers Point NSW **Figure F1**

Map Document: G:\S4\S41500_S41599\S41500 Barangaroo\S4150010 SAQP\S4150010 F1 Rev A

A4 Size



Attachment 2: Site Layout and Investigation Locations



This drawing is confidential and shall only be used for the purposes of this project.

REVISIONS				
No.	BY	DATE	DESCRIPTION	APPD
01	SS	15.04.2010		DFM

SCALES: 10 0 10 20 30 40m; 1:1000 FULL SIZE A1

THE SIGNING OF THIS TITLE BLOCK CONFIRMS THE DESIGN AND DRAFTING OF THIS PROJECT HAVE BEEN PREPARED AND CHECKED IN ACCORDANCE WITH THE AECOM QUALITY ASSURANCE SYSTEM TO ISO 9001:2000

DESIGNED	KP/DFM	CHECKED	KP/DFM
DRAWN	SS	CHECKED	JA
APPROVED	DFM	DATE	07.04.2010

DESIGNER: AECOM

AECOM Australia Pty Ltd A.B.N. 20 093 846 925

VMP AND PDA REMEDIATION WORKS AREA DGI

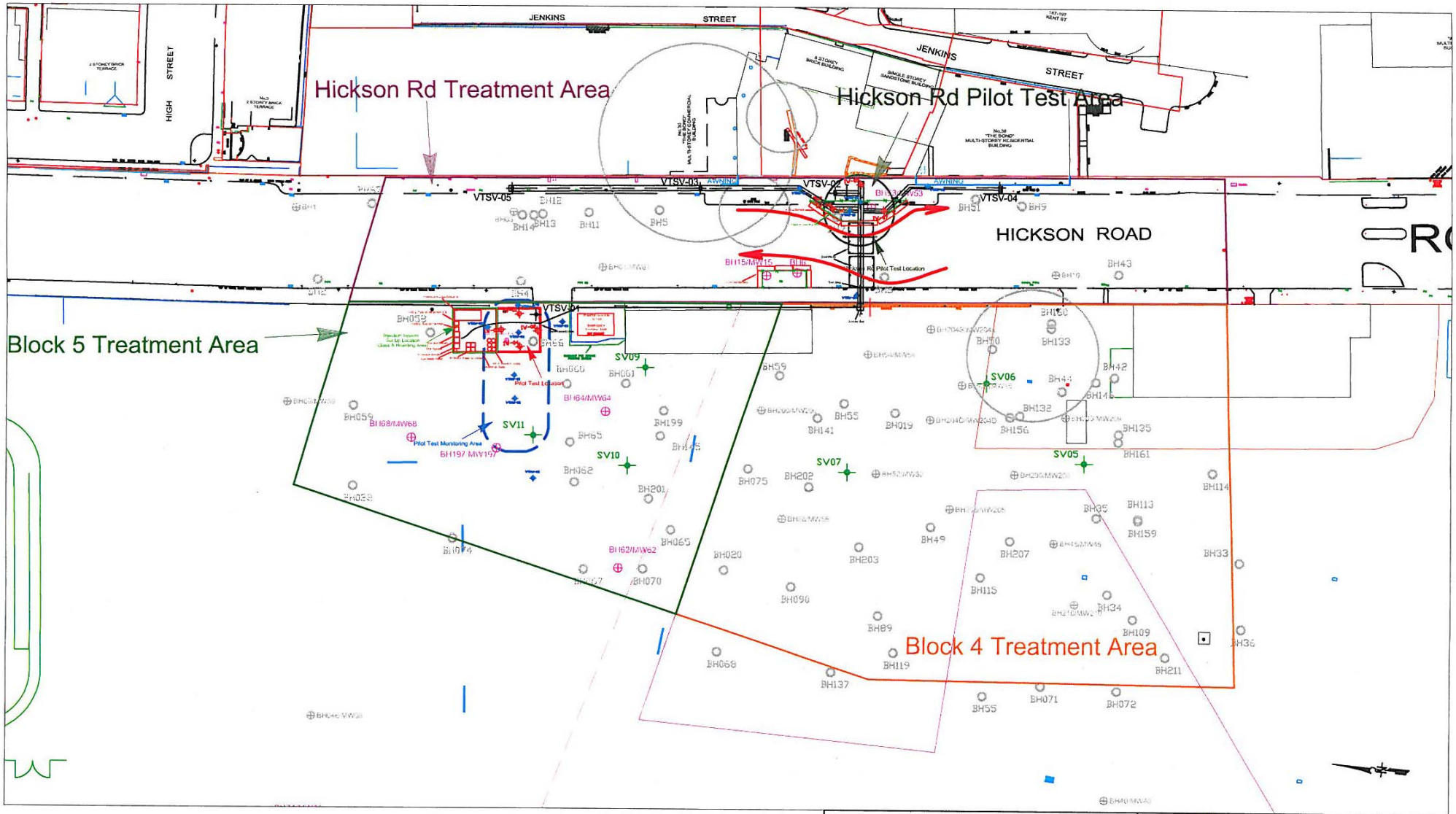
SITE LAYOUT AND SURROUNDING AREA
FIGURE F2

STATUS: DRAFT

DRAWING NO. 60104064-DRG-10-VPDGI-F2

REV. 01

Attachment 3: Lot Layout and Previous Gasworks Layout



LEGEND

- Existing Monitoring Wells
- Historic Soil Boring Locations
- Existing Soil Vapor Locations
- Proposed Injection Well
- Proposed Monitoring Well
- Proposed Soil Vapour Point

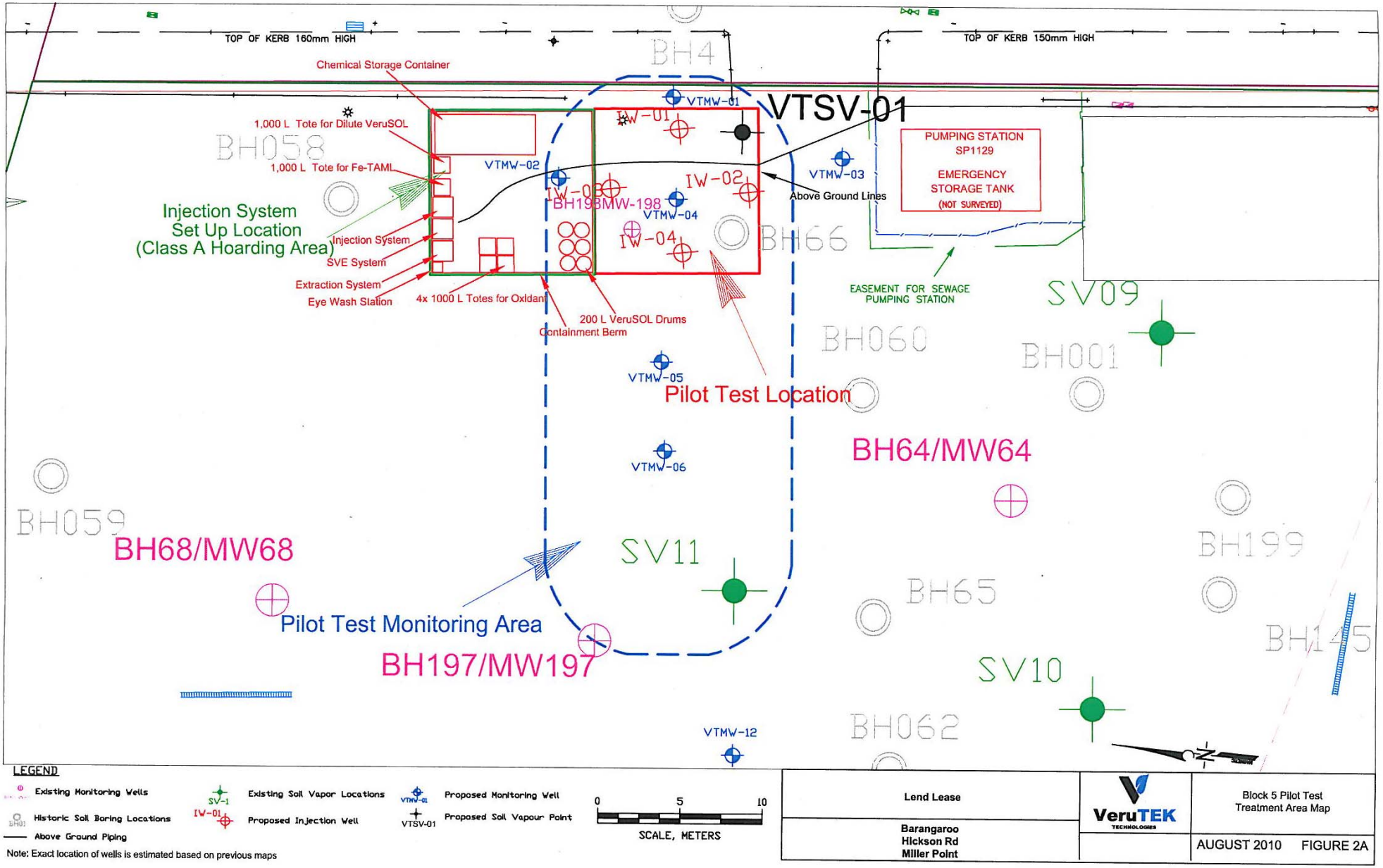
Note: Exact location of wells is estimated based on previous maps

0 20 40

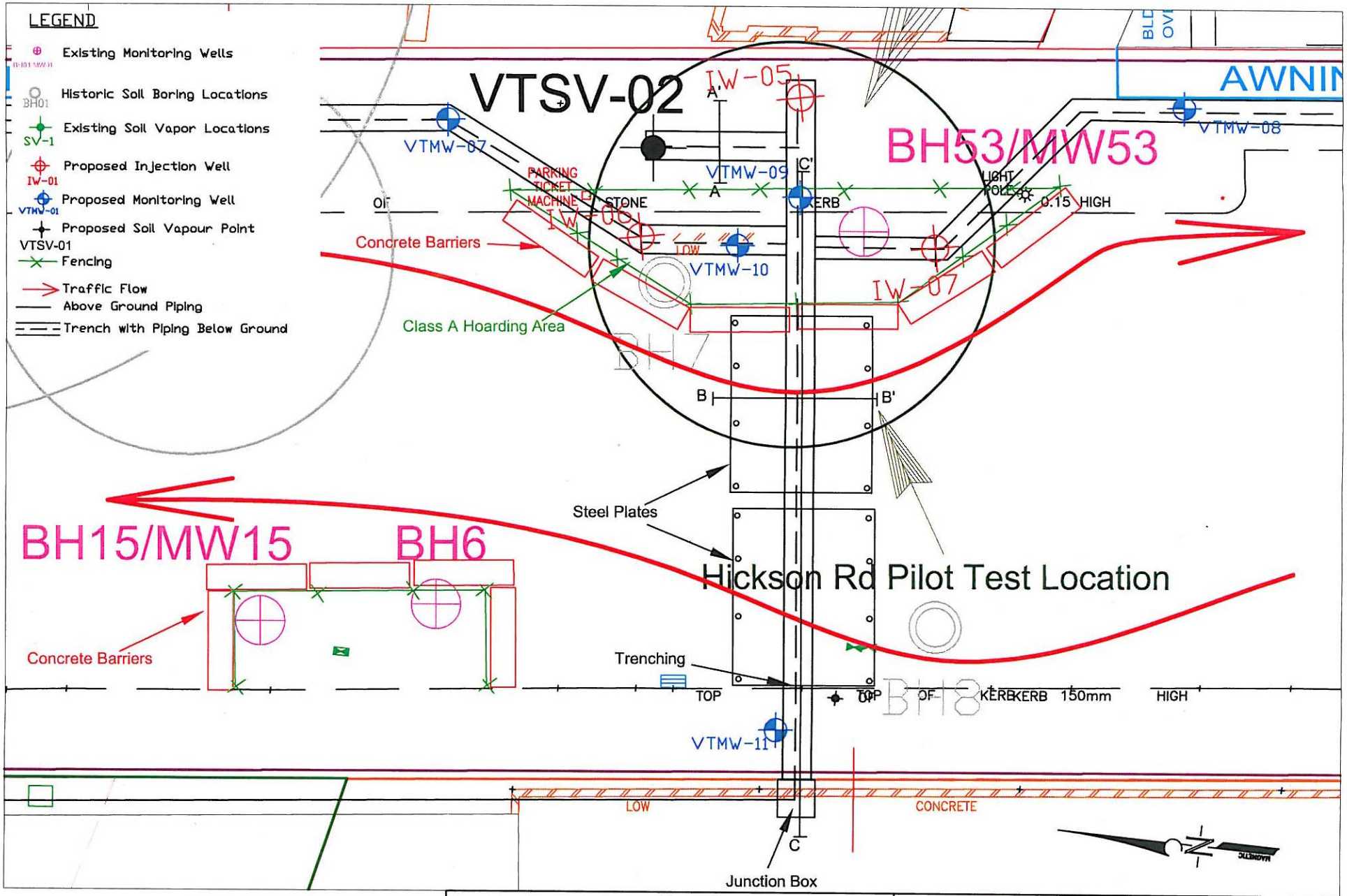
SCALE, METERS

Lend Lease	VeruTEK TECHNOLOGIES	Block 5 and Hickson Road Pilot Test Area Map
Barangaroo Hickson Rd Miller Point		AUGUST 2010 FIGURE 1

Attachment 4: Pilot Trial Locations



Attachment 5: Block 5 Pilot Trial Layout



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SCALE, METERS

Note: Exact location of wells is estimated based on previous maps

Lend Lease	VeruTEK TECHNOLOGIES	Hickson Pilot Test Treatment Area Map
Barangaroo Hickson Rd Miller Point		AUGUST 2010 FIGURE 2B

Attachment 6: Hickson Road Pilot Trial Layout

Table 7a: Block 5 Monitoring Schedule

Test Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analysis Location
Pre-Injection Monitoring	Performance Monitoring	Temperature, pressure, Turbidity, pH, ORP, DO, specific conductivity	Once	VTMW-01, VTMW-02, VTMW-03, VTMW-04, VTMW-05, VTMW-06, VTMW-12, MW198, MW64, MW68, MW62, MW197	VeruTEK	Troll 9500, with flow cell
		IFT, ORP, pH, specific conductivity, temperature, turbidity	Once			On-Site Laboratory
	Groundwater Sampling	VOC, SVOC and TPH analysis	Once	VTMW-01, VTMW-02, VTMW-03, VTMW-04, VTMW-05, VTMW-06, VTMW-12, MW198, MW64, MW68, MW62, MW197		Off-Site Laboratory
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odour	Once	VTSV-01, SV09, SV10, SV11; Utility Pits, Service Access Points, Monitoring Well Heads***	AECOM	PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Once	VTSV-01, SV09, SV10, SV11		Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations on Grid Basis	VeruTEK	Off-Site Laboratory
S-ISCO® Phase	Process Monitoring	Flow rate, pressure, and temperature	Hourly	Injection Feed	System Operator	Injection Equipment Meters
		Fe-TAML, persulfate, hydroxide & peroxide concentrations, and IFT	Daily		Laboratory Technician	On-Site Laboratory
	Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Continuous**	2-3 Monitoring Wells (locations TBD)	Field Technician	Troll 9500 in monitoring well**
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	Wells along Conductivity Front		Troll 9500, with flow-through cell
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Weekly	VTMW-01, VTMW-02, VTMW-03, VTMW-04, VTMW-05, VTMW-06, VTMW-12, MW198, MW64, MW68, MW62, MW197		

Table 7a: Block 5 Monitoring Schedule

Task Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analysis Location
		Persulfate, peroxide, hydroxide, Fe, IFT, pH, turbidity, specific conductivity, TPH (C_{10}-C_{36})	Weekly		Laboratory Technician	On-Site Laboratory
		Day-lighting (Emergence of Injected Chemistry from the Ground)	Daily	Visual Inspection of Injection Wells for Evidence of Day-lighting	Field Technicians	Injection Wells
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odour	Daily	VTSV-01, SV09, SV10, SV11, SVE System Effluent, Utility Pits, Service Access Points, Monitoring Well Heads***	Field Technicians	PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Weekly	VTSV-01, SV09, SV10, SV11, SVE System Effluent	AECOM	Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations Selected Randomly	AECOM	Off-Site Laboratory
Post-Injection Monitoring	Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	TBD	AECOM	Troll 9500 in monitoring well**
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	Wells along Conductivity Front		Troll 9500, with flow cell
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Weekly	VTMW-01, VTMW-02, VTMW-03, VTMW-04, VTMW-05, VTMW-06, VTMW-12, MW198, MW64, MW68, MW62, MW197		
		Persulfate, peroxide, hydroxide, Fe-TAML, IFT, pH, turbidity, specific conductivity	Weekly			On-Site Laboratory
	Groundwater Sampling	VOC, SVOC and TPH analysis	Once	VTMW-01, VTMW-02, VTMW-03, VTMW-04, VTMW-05, VTMW-06, VTMW-12, MW198, MW64, MW68, MW62, MW197		Off-Site Laboratory
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odours	Once	VTSV-01, SV09, SV10, SV11, SVE System Effluent (if in use), Utility Pits,		PID and MultiGas

Table 7a: Block 5 Monitoring Schedule

Test Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analysis Location
				Service Access Points, Monitoring Well Heads***		Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Weekly	VTSV-01, SV09, SV10, SV11, SVE System Effluent (if in use)		Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations on Grid basis		Off-Site Laboratory

*** Minimum monitoring conditions. Frequency may be changed based on the result of the continuing monitoring program and consistency of the pilot trial operation.**
**** The *In situ* Trolls may be rotated among wells based on monitoring data collected.**
***** PID and Multi-gas monitoring will take place in both: the breathing space at each of these locations; as well as, *within* the nominated utility pits (shown as service monitoring locations) to monitor accumulation.**

Table 7b: Hickson Road Monitoring Schedule

Test Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analysis Location
Pre-Injection	Performance Monitoring	Temperature, pressure, Turbidity, pH, ORP, DO, specific conductivity	Once	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6	VeruTEK	Troll 9500, with flow-through cell
		IFT, ORP, pH, specific conductivity, temperature, turbidity	Once			On-Site Laboratory
	Groundwater Sampling	VOC, SVOC and TPH analysis	Once	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6		Off-Site Laboratory
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odours	Once	VTSV-02, VTSV-03, VTSV-04, VTSV-05, Utility Pits, Service Access Points, Monitoring Well Heads***		PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Once	VTSV-02, VTSV-03, VTSV-04	AECOM	Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations on Grid Basis	AECOM/ VeruTEK	Off-Site Laboratory
SEPR™ Phase	Process Monitoring	Flow rate, pressure, and temperature	hourly	Injection Feed	System Operator	Injection Equipment Meters
		Peroxide concentration and IFT	Daily		Laboratory Technician	On-Site Laboratory
	Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Continuous	2 to 3 Monitoring Wells (locations TBD)	Field Technicians	Troll 9500 in monitoring well**
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6		Troll 9500, with flow-through cell
		Peroxide, Fe, IFT, pH, turbidity, specific conductivity, TPH (C_{10}-C_{36})	Weekly		Laboratory Technician	On-Site Laboratory

Table 7b: Hickson Road Monitoring Schedule

Task Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analytes Location
		NAPL presence	Daily		Field Technicians	NAPL Probe
		Water Level	Daily			Depth Probe
		Day-lighting (Emergence of Injected Chemistry from the Ground)	Daily	Visual Inspection of Injection Wells for Evidence of Day-lighting		Injection Wells
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odours	Daily	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent, Utility Pits, Service Access Points, Monitoring Well Heads***		PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Weekly	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent	AECOM	Off-Site Laboratory
S-ISCO® Phase	Process Monitoring	Flow rate, pressure, and temperature	Hourly	Injection Feed	System Operator	Injection Equipment Meters
		Fe-TAML, peroxide concentration and IFT	Daily		Laboratory Technician	On-Site Laboratory
	Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Continuous	2 to 3 Monitoring Wells (locations TBD)	Field Technicians	Troll 9500 in monitoring well**
		Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6		Troll 9500, with flow-through cell
		Peroxide, Fe, IFT, pH, turbidity, specific conductivity, TPH (C_{10}-C_{36})	Weekly		Laboratory Technician	On-Site Laboratory
		Water level	Daily		Field Technicians	Depth Probe
		Day-lighting (Emergence of Injected Chemistry from the Ground)	Daily	Visual Inspection of Injection Wells for Evidence of Day-lighting		Injection Wells

Table 7b: Hickson Road Monitoring Schedule

Test Phase	Monitoring Type	Parameters	Frequency*	Measurement/Sample Location	Sampler	Analysis Location
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odours	Daily	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent, Utility Pits, Service Access Points, Monitoring Well Heads***		PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Weekly	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent	AECOM	Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations Selected Randomly	AECOM	Off-Site Laboratory
Post-Injection Monitoring	Performance Monitoring	Temperature, pressure, turbidity, pH, ORP, DO, specific conductivity	Daily	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6	AECOM	Troll 9500, with flow-through cell
		Peroxide, Fe, IFT, pH, turbidity, specific conductivity, TPH (C_{10}-C_{36})	Weekly			On-Site Laboratory
	Groundwater Sampling	VOC, SVOC and TPH analysis	Once	VTMW-07, VTMW-08, VTMW-09, VTMW-10, VTMW-11, MW15, MW53, BH6		Off-Site Laboratory
	Soil Gas Sampling	PID, LEL, O_2, CO, H_2S, Odours	Once	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent, Utility Pits, Service Access Points, Monitoring Well Heads***		PID and MultiGas Meters; Nasal Ranger
		TO-14A VOC analytes and naphthalene, according to USEPA Method TO-15	Weekly	VTSV-02, VTSV-03, VTSV-04, VTSV-05, SVE System Effluent		Off-Site Laboratory
	Soil Sampling	VOCs (USEPA Method 8260), SVOCs (USEPA Method 8270), TPH (USEPA Methods 3510/8015 & 5030/8260)	Once	5 Locations On Grid basis		Off-Site Laboratory

*** Minimum monitoring conditions. Frequency may be changed based on the result of the continuing monitoring program and consistency of the pilot trial operation.**
**** The *In situ* Trolls may be rotated among wells based on monitoring data collected.**
***** PID and Multi-gas monitoring will take place in both: the breathing space at each of these locations; as well as, *within* the nominated utility pits (shown as service monitoring locations) to monitor accumulation.**