Site Audit Report

Former Council Landfill, Shell Cove Project, Shell Cove, NSW

Prepared for:
Australand Corporation

Prepared by:
ENVIRON Australia Pty Ltd

Date:
3rd November 2009

Project Number:
AS130019

Audit No:
PWH_NSW_018

ENVIRON

Prepared and Authorised by:

Name: Mr Philip Hitchcock

Title: EPA Accredited Site Auditor 0502

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Signature:  Date: 3rd November2009

VERSION CONTROL RECORD

Document Name	Date	Version	Author	Reviewer
Site Audit Report	3rd Nov 2009	Final	P Hitchcock	M Hayter

ENVIRON

3rd November2009 Our Ref: AS130019

Attention: Glenn Colquhoun
Australand Corporation
Shell Cove Office
P.O.Box A148
Shellharbour, NSW, 2529

Dear Glenn Colquhoun

Re: Site Audit Report

Former Council Landfill, Shell Cove Project, Shell Cove, NSW

This document presents the findings of a Site Audit undertaken by NSW EPA Accredited Site Auditor (Contaminated Lands), Mr Phillip Hitchcock, in accordance with the NSW DEC (2006) Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Edition), for the property located at Insert Address (the Site). A Site Audit Statement stating the suitability of the Site for the proposed development is attached.

The Audit was commissioned by Glenn Colquhoun of Australand Corporation to assess the suitability of the Site for its intended medium density residential and marina landuse.

The Audit was conducted at the request of Australand Corporation but was not required by the planning authority and therefore is not a statutory audit.

Thank you for giving me the opportunity to conduct this Audit. Please call me on (02) 4934 4354 if you have any questions.

Yours faithfully
ENVIRON Australia Pty Ltd

Phillip Hitchcock
EPA Accredited Site Auditor 0502

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ENVIRON Australia Pty Ltd
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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 26 March 2009. For more information about completing this form, go to Part IV.

PART I: Site audit identification

Site audit statement no. ...PWH_NSW_018

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 .....Phillip Hitchcock..... Company ...ENVIRON Australia Pty Ltd

Address ...Level 1, 456 High St (PO Box 564), Maitland NSW Postcode ...2320

Phone ...02 49 344354 . Fax 02 49 344359

Site details

Address Boollwarro Parade, Shell Cove, NSW Postcode 2259

Property description	Part Lot 8032 in DP 1072187
Local Government Area	Shellharbour City Council
Area of site (e.g. hectares)	3.7 hectares
Current zoning	2(f) Mixed Use Residential

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

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

NA

Site audit commissioned by

Name Glenn Colquhuon Company Australand Corporation

Address Shell Cove Office, P.O. Box A148, Shellharbour, NSW Postcode 2529

Phone (2) 4297-7364 Fax (2) 4297-7366

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

NA

Purpose of site audit

☑ A. To determine land use suitability for low – medium density residential use

~~**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])*~~

Information sources for site audit

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

Coffey Partners, Golders, URS

Title(s) of report(s) reviewed

Appendix 5 of LFA (Australia) Pty Ltd (June 1995) Environmental Impact Statement, Shell Cove Boat Harbour / Marina, Shadforth Wetland, Haul Road Landfill, including the following:

Golder Associates (December 1994) *Additional Water Quality Information, Shell Cove EIS* (ref: 94650300(A);

Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Preliminary Geotechnical Investigation, Shellharbour* (ref:94650116);

Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Geo-Environmental Investigation, Shellharbour* (ref:94650116.A);

Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Pilot Study, Acid Sulphate Soils, Shellharbour* (ref: 94650348.B);

Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Preliminary Acid Sulphate Soils Investigation, Shellharbour* (ref: 94650116.F);

Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Additional Acid Soil and Geotechnical Investigation, Shellharbour* (ref: 94650348.B).

URS (7 July 2005) *Subsurface Field Investigations - Old Landfill* (ref: 43167202);

URS (14 November 2003) *Waste Containment Cell, Shell Cove QBZ, Engineering Approach* (ref: 49221.001);

URS (February 2009) *Shell Cove Waste Relocation Project, Pre-Validation Report* (ref: 43167202);

URS (August 2009a) *Shell Cove Waste Relocation Project, Pre-Validation Report* (ref: 43167202 Rev 2);

URS (April 2009) *Remediation Characterisation and Validation Report, Shell Cove Waste Relocation Project, Shell Cove, NSW* (ref: 43167202 Draft);

URS (August 2009b) *Remediation Characterisation and Validation Report, Shell Cove Waste Relocation Project, Shell Cove, NSW* (ref: 43167202 Final).

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

NA

Site audit report

Title Site Audit Report, Former Council Landfill, Shell Cove Project, Shell Cove, NSW

Report no. AS130019 Date 3rd November 2009

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:**

Nil

~~**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

The site was a former shallow landfill and following remediation all waste has been removed. The remaining soils and groundwater contain low contaminants levels. It is noted that deeper soils at the site may be Acid Sulphate producing and could potentially impact if disturbed. If this were the case then an Acid Sulphate Management Plan would be required to be prepared by a suitably qualified consultant prior to excavation

Section B

Purpose of the [1] which is the subject of the audit .....

.....

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)*

  .....

  .....

  subject to compliance with the following condition(s):

Overall comments

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

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. 0502).

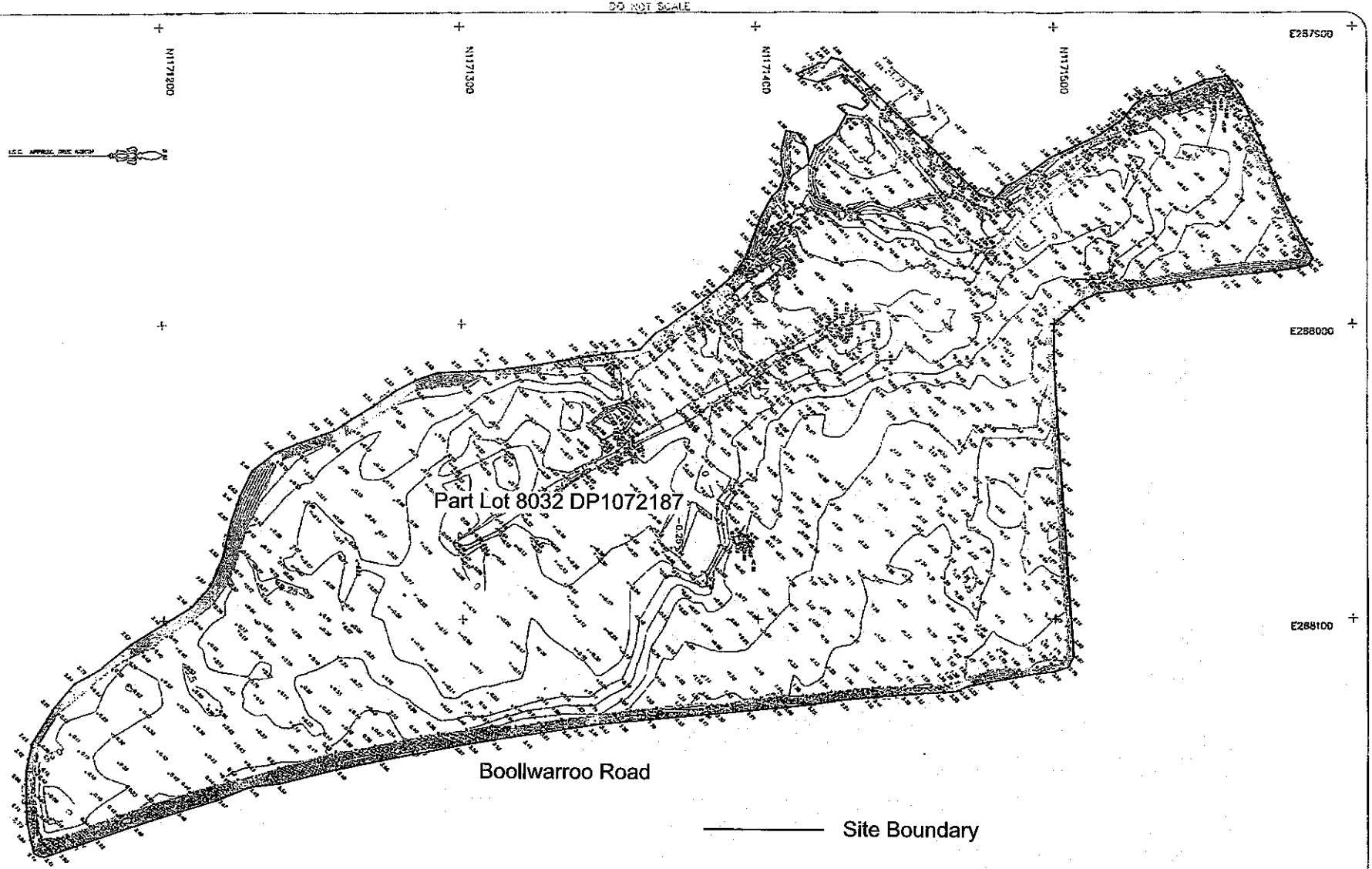
I certify that:

- 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 03/11/09

DO NOT SCALE



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K.F. WILLIAMS & ASSOCIATES PTY. LTD.

SHELLCOVE WASTE CONTAINMENT CELL
WORK AS EXECUTED OF FINAL
EXCAVATION LEVELS AT OLD TIP SITE
(SURVEY FILE: "OLDFINAL"

KF108837

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1 Introduction

1.1 Overview

This Site Audit Report and attached Site Audit Statement present the findings of a Site Audit (the Audit) undertaken for the property located at Former Council Landfill, Shell Cove Project, Shell Cove, NSW (the Site).

The Audit was undertaken, and Site Audit Report and Site Audit Statement produced, in accordance with the NSW DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme* (2nd Edition). Table 1 presents a summary of the Site identification and details of the Audit.

Table 1: Site Identification and Audit Details

Site Address	Boollwarro Parade, Shell Cove, NSW (see Attachment 1, Appendix A)
Identifier	Part Lot 8032 in DP 1072187 (see Attachment 2, Appendix A)
Municipality	Shellharbour City Council
Site Zoning	2(f) Mixed Use Residential
Site Area	3.7 hectares
Auditor	Phillip Hitchcock
Expert Support Persons	None required
Date Audit Requested	20 March 2006
Audit Purpose	To assess the suitability of the Site for medium density residential and marina landuse
Audit Requirement	Non-statutory. The Audit was conducted voluntarily.
Owner of the Site	Australand Corporation
Person Requesting Audit	Glenn Colquhoun
Consultant/s	Coffey, Douglas Partners, Golder Associates, URS
Audit Completion Date	3rd November 2009

1.2 Conflict of Interest

The Auditor advises that there are no perceived or real conflicts of interest associated with the Audit.

1.3 Background and Proposed Development

The Shell Cove Waste Relocation project comprises the excavation and relocation of waste from the Old Landfill, Boollwarro Parade, Shell Cove to the new Shell Cove Waste Containment Cell (SCWCC), Quarry Haul Road, Shell Cove. The project was approved as part of the approval for the Shell Cove Boatharbour/ marina, Shadforth Wetland and Quarry Haul Road Acoustic Barriers development.

The Site was previously designated as 'Unhealthy Building Land' under the now defunct Unhealthy Building Land Act (1990) as a result of former landfilling activities. Consent has been granted by Council to excavate and relocate the waste to a new waste cell (the SCWCC) located approximately 800m to the south of the Site. These works are intended to render the Site suitable for the proposed landuse. The resulting excavation at the Site is to be eventually backfilled with Virgin Excavated Natural Material (VENM) (as per NSW EPA (1999)) in order to allow for the proposed development works.

The excavation and offsite disposal of the waste material associated with the former landfill is herafter referred to as 'the Waste Excavation Works'.

The Waste Excavation Works commenced in January 2007 following numerous intrusive contamination assessments. The Waste Excavation works were completed in February 2008 and validation of the works was undertaken by URS. Following validation, URS indicated that the Site is suitable for low density residential landuse with gardens and accessible soil.

Development in the area of the Old Landfill will include a mix of standard residential lots and medium density terraces, townhouses and apartments with gardens and accessible soil. A copy of the proposed development plan is included as Attachment 3, Appendix A.

1.4 Audit Scope

The scope of the Audit included:

- Review of the following reports with respect to commonwealth and NSW EPA guidance (see Appendix B):
  - Appendix 5 of LFA (Australia) Pty Ltd (June 1995) Environmental Impact Statement, Shell Cove Boat Harbour / Marina, Shadforth Wetland, Haul Road Landfill, including the following:
  - Golder Associates (December 1994) *Additional Water Quality Information, Shell Cove EIS* (ref: 94650300(A);
  - Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Preliminary Geotechnical Investigation, Shellharbour* (ref:94650116);
  - Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Geo-Environmental Investigation, Shellharbour* (ref:94650116.A);
  - Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Pilot Study, Acid Sulphate Soils, Shellharbour* (ref: 94650348.B);
  - Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Preliminary Acid Sulphate Soils Investigation, Shellharbour* (ref: 94650116.F);

- Golder Associates (May 1995) *Shell Cove EIS, Boat Harbour/Marina, Additional Acid Soil and Geotechnical Investigation, Shellharbour* (ref: 94650348.B).
- URS (7 July 2005) *Subsurface Field Investigations - Old Landfill* (ref: 43167202);
- URS (14 November 2003) *Waste Containment Cell, Shell Cove QBZ, Engineering Approach* (ref: 49221.001);
- URS (February 2009) *Shell Cove Waste Relocation Project, Pre-Validation Report* (ref: 43167202);
- URS (August 2009a) *Shell Cove Waste Relocation Project, Pre-Validation Report* (ref: 43167202 Rev 2);
- URS (April 2009) *Remediation Characterisation and Validation Report, Shell Cove Waste Relocation Project, Shell Cove, NSW* (ref: 43167202 Draft);
- URS (August 2009b) *Remediation Characterisation and Validation Report, Shell Cove Waste Relocation Project, Shell Cove, NSW* (ref: 43167202 Final);
- URS (21 October 2009) Shell Cove Exposure Classification Assessment (ref: 43167202).

- Site visits by the Auditor date or Auditor's Representative on 6 September 2006, 4 October 2007, 31 January 2008 and 3 September 2009. Observations made during these visits as they pertain to verifying the Site conditions and investigation/remediation/validation works reported by the Consultant/s are provided throughout the text, as relevant;
- Discussions with the Client and Consultant (see Appendix C for written correspondence).

2 Environmental Setting

2.1 Topography

URS (August 2009a, Section 2.5) indicates that the Site is located in low lying swampy ground behind the low sand dunes of Shellharbour Beach at approximately 4m AHD. The Site is generally flat, although the landfill formed a pronounced mound rising 1.5m to 2m above the wetland.

2.2 Meteorology

No meteorological information was provided by URS or other consultants that have completed contamination assessments at the Site.

The lack of meteorological information is not considered to be significant given the Site is located in an established area.

2.3 Regional Geology, Hydrogeology and Hydrology

URS (August 2009a, Section 2.5) indicates that the Site is underlain by Bombo Latite, part of the Gerringong Volcanics Formation. The Bombo Latite is a basaltic lava flow and consists of dark grey, fine grained porphyritic latite with plagioclase pehoncrysts.

URS (August 2009a, Section 2.5.5) indicates that the surface water catchment of the Site is bounded by the southern portion of the Shellharbour township to the north, Shellharbour Road to the west and Boollwarroo Parade to the south. There is natural development of surface drainage features with some drainage lines running into Shellharbour Swamp.

2.4 Site Specific Geology, Hydrogeology and Hydrology

The following table presents a summary of the subsurface conditions identified at the Site by URS (August 2009a, Section 2.3).

Table 2: Generalised Site Specific Geology

Depth (m)	Subsurface Conditions
0m to 2.5m	Landfill cover material – brown/ black silty clay fill with bricks, timber, concrete blocks
0.5m to 5.5m	Landfill waste – containing fractions varying from 5% to 80% putrescible and non putrescible wastes within a soil matrix. Waste comprises a mix of plastic bags (domestic refuse), plastic, tyres, wire, glass, timber, concrete, paper, metals, fabric and bricks.
	Littoral sands, consisting typically of an upper layer of sand and a lower layer of silty sand/ sandy silt.
	Estuarine sediments, comprising clayey silt/ silty clay and clay of high plasticity. Generally dark grey to black in colour and high in moisture content.
	Alluvium, consisting of clay, sandy clay and gravelly clay of medium to high plasticity. Brown colour mottled with light grey and brown.

	Generally stiff to very stiff.
	Residual/ extremely weathered rock, consisting of gravelly clay/ clayey gravel derived from in-situ weathered latite.
	Rock, highly weathered to fresh latite, fractured to highly fractured.

The Auditor considers that the observed subsurface conditions correlate reasonably well with the regional geological information noting that the Site is low lying and the volcanic soils have been overlain by alluvial and then estuarine sediments.

A groundwater assessment undertaken by URS involved the installation of three groundwater monitoring wells (MW1-MW3) at the Site. The table below presents a summary of the Site specific hydrogeological data obtained by URS (August 2009b, Section 9.7).

Table 3: Site Specific Hydrogeology

Aspect	Details
Aquifers Identified	Shellharbour Swamp
Geology Investigated	Fill
Depth to Water	1.55m AHD to 1.95m AHD
Phase Separated Hydrocarbon	None identified or inferred based on the analytical data
Hydraulic Gradient	Not determined
Hydraulic Conductivity	Not tested
Effective Porosity	Not determined
Seepage Velocity	Not determined
Interpreted Flow Direction	To the south-east
Groundwater Quality	pH 7.03 to 7.38, EC 1637µs/cm to 5970µs/cm

NOTES: BTOC – Below Top Of Casing, m/d – metres per day

The nearest receiving water body is Shellharbour Swamp located immediately south and west of the Site. The Shellharbour Swamp discharges to the Pacific Ocean via a bridge culvert under Boollwarroo Parade. Groundwater flow direction was generally identified to the south east, which is consistent with regional hydrogeological regime.

2.5 Auditor's Conclusions Regarding Environmental Setting Information

The Auditor considers that the observed subsurface conditions correlate reasonably well with the regional geological information.

The Auditor considers that the environmental setting information provided was generally adequate.

3 Assessment Of Potential Onsite and Offsite Contamination Sources & Potential Sensitive Receptors

3.1 Site Features and Uses

At the time the majority of the assessment work was completed at the Site (1987 to 1995), the NSW EPA (1997) Guidelines for Consultants Reporting on Contaminated Sites did not exist.

As such, a review of the Site history and assessment of potential on site and off site contamination sources and potential sensitive receptors has not been completed in accordance with these guidelines by any of the consultants who have completed assessment work at the Site.

3.1.1 Historical

Golder Associates undertook a review of the history of filling of the landfill based on aerial photographs and Council records, which was summarised in URS (August 2009a, Sections 2.2 and 2.3). The following information was provided:

- Historical aerial photographs from 1942 and 1960 show that the Site was part of the wetlands and included low level sand dunes;
- Filling occurred over a two to three year period from 1973 through to 1975;
- A stormwater diversion drain constructed in 1972 was fill over and a new drain constructed in 1975;
- The Site was used as a general purpose garbage tip for the disposal of solid wastes including domestic, commercial and building refuse;
- Garbage and fill materials were end-tipped directly onto swamp vegetation, then spread by excavator or bulldozer with minimal track rolling;
- Tip filling extended progressively towards the south and it is in this regions that the more recent domestic wastes are located;
- From 1974 to 1975, large volumes of "clean" fill (clay and weathered rock) from civil engineering works in Shellharbour District were tipped at the Site to be utilised as night cover.

3.1.2 Present

The following presents a summary of observations made by URS (2009b, Section 10.1) regarding the Site condition following remediation works:

- The void of the excavation remains, with a pond of approximately 300mm of groundwater in the base of the excavation;
- The base of the excavation comprises sand in the east and silty clay in the west;
- No waste remains on the base of the excavation and the finished excavation surfaces are not stained or odourous;
- The elevation of the base of the excavation varies between -0.47m AHD and 1.8m AHD.

Current Site features are presented in Attachment 4, Appendix A.

3.1.3 Proposed Future

It is understood that the Site is proposed to be developed for residential use including a mix of standard residential lots and medium density terraces, townhouses and apartments with gardens and accessible soil. The excavation will need to be backfilled prior to development.

3.2 Adjacent Property Features and Uses

3.2.1 Historical

Information included in the Golder 1987 report indicated that the surrounding landuse prior to the construction of the landfill was wetland and sand dunes.

3.2.2 Present Use

Surrounding landuses at the time of URS (April 2009, Section 2.1.3) comprised:

- North – Keith Hockey Field;
- East – Boollwarroo Parade;
- West – Shellharbour Swamp;
- South – Shellharbour Swamp.

No offsite contamination sources were identified based on the observation of current surrounding landuses.

3.3 Summary of Areas / Contaminants of Concern and Potential Sensitive Receptors

URS (2009a, Section 2.4) identified potential contaminants of concern based on the use of the Site as a landfill. A summary of the identified contaminants of concern is provided in Table 4 below.

Table 4: Summary of Areas/Concerns and Potential Sensitive Receptors

Historical Activity of Concern	Area/Environmental media Potentially Affected	Contaminants of Concern	Potential human Receptors	Potential Environmental Receptors
Landfilling of Site	Soil and groundwater	Heavy Metals, TPH, BTEX, VOCs, SVOCs, OCPs, PCBs, Asbestos	Site workers and future occupiers	Shellharbour Swamp
Potential Acid Sulfate Soils	Soil	Heavy Metals and acidity	Site workers and future occupiers	Shellharbour Swamp

3.4 Data Integrity Assessment and Uncertainty

The Auditor considers that the available information regarding the site history is limited due to the age of the assessment work and does not provide an adequate indication of past activities. However, the absence of site specific history has been compensated for by a high density of sampling, wide range of analysis and the obvious limited previous use of the Site.

4 Evaluation of Quality Assurance and Quality Control

4.1 Review of Consultants Data

The Auditor has assessed the adequacy of the sampling and analysis methodology and field and laboratory quality assurance/quality control measures for the works subject to the Audit. The Auditor has made this assessment with respect to the relevant requirements presented in the following documents referred to (directly and indirectly) in NSW DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme* (2nd Edition) (see **Appendix B**).

4.2 Investigation Adequacy

At the time of the Auditor's engagement, the majority of the field investigations had been completed and the Auditor had no opportunity to provide comment on a Sampling, Analysis and Quality Plan (or similar).

The following episodes of investigation works have been completed at the Site:

- 1984 to 1995 – field investigations were completed by several consultants, including Dames & Moore, Golder Associates and Coffey. These investigations were typically combined geotechnical and environmental assessments, which included limited soil and groundwater investigations for environmental purposes. These investigations were also completed prior to the release of the NSW EPA 1997 guidelines and they have not been relied upon for the completion of the audit;
- 2006 URS Pre-Validation Investigation – 49 soil sampling locations (BH0601 to BH0650 and BH0654), installation and sampling from three groundwater wells (MW01 to MW03) and gas monitoring from nine boreholes (BH13, BH21, BH23, BH31, BH34, BH35, BH40. BH41 and BH45).

Table 5 provides an assessment of the adequacy of the URS 2006 investigation works. A plan showing the sampling locations is included as Attachment 5 in Appendix A.

Table 5: Assessment of URS 2006 field investigations

Aspect	URS plan	Rationale
Sampling pattern	Systematic soil sampling on a 30m grid; Three groundwater monitoring wells installed at targeted locations; Landfill gas monitoring at nine locations.	To provide Site coverage
Sampling density	49 soil sampling locations, 3 groundwater sampling locations and 9 gas monitoring locations over 3.7 hectares	To provide at least 95% confidence of detecting a circular hot spot of diameter 35.6m, as required by NSW EPA (1995) for soil.
Sampling locations	See Figure 3	General grid over the Site due to a lack of point sources
Sampling depths	Sampling locations were extended	To identify the depth and extent of

Table 5: Assessment of URS 2006 field investigations		
Aspect	**URS plan**	**Rationale**
	generally 1m into natural ground below the landfill waste material. The maximum depth of the investigation was 6.3m.	landfill.
Analytical methods	NATA accredited methods	NATA accredited methods
Analytes for samples	Analytes for soil included Heavy Metals, TPH, BTEX, PAH, SVOCs, VOCs, OCPs, OPPs and PCBs. Analytes for groundwater included Heavy Metals, TPH, VOCs, SVOCs, OCPs, OPPs, PCBs, major cations and anions, pH, ammonia, nitrate and salinity.	Chemicals of concern based on Site history.

The Site visits completed by the Auditor's Representative during the investigations works verified the reported investigation works.

4.3 Data Usability

The Auditor's assessment regarding the field and laboratory quality assurance and quality control measures and results during the works subject to the Audit is presented in **Appendix E** and summarised below:

- The field and laboratory quality assurance measures implemented are considered to provide a reasonable level of confidence that the data is appropriately complete, comparable and representative;
- The field and laboratory quality control measures implemented are considered to provide a reasonable level of confidence that the data is appropriately accurate and precise.

Based on the above, the data for the works subject to the Audit is considered to most likely be reliable and usable for the purposes of the Audit.

5 Environmental Quality Criteria

5.1 General

The applicable Environmental Quality Criteria are discussed below and presented in **Appendix F.**

5.2 Soil

5.2.1 Protection of Human Health

The Auditor has assessed the significance of selected heavy metals, PAHs, OCPs, OPPs, PCBs and Phenol concentrations in soil with reference to protection of human health based Soil Investigation Levels for 'residential with gardens and accessible soils' use presented in Column 1 (HIL A) of DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (2nd Ed.)*. It is imported to note that DEC (2006) is directly based upon the National Environment Protection Council (1999) *National Environment Protection Measure (Assessment of Site Contamination)*, which indicates that the criteria are based on conservative exposure scenario's and intended for use as screening criteria only.

NSW EPA (1994) *Guidelines for Assessing Service Station Sites* have also been referred to for assessing TPH and BTEX results. These guidelines relate to sensitive land uses (i.e. residential). When using these guidelines, it is important to note that:

- the application of the NSW EPA (1994) criteria assumes that the source of the TPH is petroleum hydrocarbons and current analytical methods do not allow for the differentiation of petroleum and non-petroleum hydrocarbons;
- the TPH C10-C36 criteria is based upon '*the Netherlands Intervention Level for the TPH C10-C40 range and on commonly reported analytical detection limits*';
- the TPH C6-C9 criteria is based upon providing a screening criteria which may indicate BTEX compounds are above thresholds and are to '*be interpreted as only an approximate potential indicator of contamination*'.

There are no EPA-endorsed guidelines for asbestos in soil. The EPA states that the position of the Health Department is that there should be no asbestos in surface soil.

Where a contaminant is detected at an elevated concentration and there are no relevant assessment criteria under DEC (2006) or other NSW EPA endorsed guidelines, reference will be made to other repudiable sources for comparison purposes.

5.2.2 Protection of the Environment

The provisional phytotoxicity based environmental investigation levels (EILs) presented in DEC (2006) (based directly upon NEPC 1999) have been used to assess potential for detrimental impacts to the environment as a result of selected Heavy Metal concentrations in soil. It is important to note that the scientific basis for the EIL's is poor and NEPC (1999), Schedule B(1), Section 3.2 states that '... *the EILs for an urban setting have not been derived to protect nominated ecological values and are somewhat arbitrary*'. As such, the Auditor has used the EIL's as screening criteria and relied upon a qualitative assessment of the contaminant distribution and background conditions when assessing the significance of EIL exceedances. It

is also pertinent to note that phytotoxicity is primarily associated with the fraction of Heavy Metals which are sorbed to soil particles or bound within a rock matrix which are soluble in water and as such may be taken up by plants. As such, the comparison of total Heavy Metals results in soil against the EIL's in order to assess phytotoxicity has some limitations.

The protection of terrestrial organisms based guidelines presented in NSW EPA (1994) have been used to assess potential detrimental impacts to the environment as a result of Toluene, Ethylbenzene and Xylene concentrations in soil.

5.2.3 Buildings and Structures

Australian Standard AS 2159 (1995) *Piling – Design and Installation* provides exposure classification values for concrete and steel piles in soil (non-aggressive to very severely aggressive). In the absence of a directly applicable EPA endorsed criteria, these guidelines are considered to be appropriate in assessing the potential for detrimental impacts of Site soils to buildings and structures.

In addition to the above, the presence of other aggressive chemical compounds (e.g. acids) may be potentially detrimental to buildings or structures.

5.2.4 Aesthetics

The Auditor has considered the need for remediation based on the 'aesthetic' contamination as outlined in Schedule B(1) of the NEPM (1999) that states that *'there are no numeric Aesthetic Guidelines but the fundamental principle is that the soils should not be discoloured, malodorous (including when dug over or wet) nor of abnormal consistency. The natural state of the soil should be considered'*.

5.3 Groundwater

The following table presents an assessment of environmental vales to be protected at the Site and the associated Groundwater Investigation Levels which are required to be applied as per DEC NSW (2007).

Table 6: Identification of environmental values to be protected and GILs to be applied

Environmental value	Trigger	Requirement for protection	GILs to be applied
Aquatic Ecosystems	Have Groundwater Dependant Ecosystems (GDE's) been identified in groundwater or surface water at, or in the nearby vicinity of, the Site? If not investigated, GDE's are assumed to exist.	Applicable based on proximity of Shellharbour Cove	Guidelines for 95% Protection of Species for marine waters presented in Table 3.4.1 (or low reliability guidelines presented in Section 8.3.7) of ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (based on anticipated point of groundwater discharge being Orphan School Creek). Where guidance is not available under ANZECC/ARMCANZ (2000), the following sources have been referred to: ▪ NSW EPA (1994) Contaminated Sites: Guidelines for Assessing Service Station Sites (Total PAHs); ▪ Ministry of Housing, Spatial Planning and the Environment (Dutch) (2000) Environmental Quality Standards in the Netherlands (TPH C6-C36 – not NSW EPA endorsed, useful for comparison purposes only). ▪ Where available, the US EPA (2008) Regional Screening levels conservative risk based values for tap water may also be referred to for comparison purposes in the absence of directly applicable criteria under ANZECC/ARMCANZ (2000) or NSW EPA (1994).
Buildings and structures	Are there currently, or may there be in the future, buildings and/or structures at, or in the nearby vicinity of, the Site which may be in contact with	Applicable based on shallow groundwater table.	Lack of threshold criteria guidance available. Chemistry of groundwater to be assessed with respect to potential detrimental effects to buildings and structures (e.g. corrosion, dissolution etc.). Australian Standard AS 2159 (1995) Piling – Design and Installation provides

Table 6: Identification of environmental values to be protected and GILs to be applied

Environmental value	Trigger	Requirement for protection	GILs to be applied
	groundwater?		exposure classification values for concrete and steel piles in groundwater based on pH, sulphate and chloride concentrations.
Aquaculture and human consumers of food	Are there currently, or may there be in the future, aquaculture activities at, or in the nearby vicinity of, the Site?	Not applicable based on the proposed urbanised nature of the surrounding uses.	No further assessment required.
Agricultural water	Are there currently, or may there be in the future, agricultural activities at, or in the nearby vicinity of, the Site?	Not applicable based on elevated TDS of the groundwater and the availability of a reticulated water supply.	No further assessment required.
Recreation and aesthetics	Are there nearby surface water bodies (including oceans, lakes, creeks, rivers and springs) which may be used for recreational activities?	Applicable based on proximity to Pacific Ocean.	Guidelines for recreational purposes presented in Table 5.2.3 of ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality.
Drinking water	Aquifer/s beneath Site listed on DNR's list of major aquifers of drinking water quality? Registered users of groundwater identified within nearby vicinity of Site? TDS readings indicate groundwater may be suitable for drinking purposes (i.e. TDS < 2,000mg/L).	Not applicable due to the elevated TDS (>730mg/L) of the aquifer, no registered users of groundwater identified within nearby vicinity of the Site, and a readily available reticulated water supply.	No further assessment required.
Industrial water	Are there currently, or may there be in the future, industrial activities at, or in the nearby vicinity of, the Site?	Not applicable, due to high TDS of the groundwater and availability of reticulated water supply.	No further assessment required.

5.4 Criteria Used by Consultant

Investigation works completed by Coffey and Golder Associates between 1987 and 1995 have not been relied upon for the completion of the audit.

The following guidelines were adopted by URS for the investigation/ remediation works for soil:

- NSW EPA (1998) Soil Investigation Levels for 'residential with gardens and accessible soil (home-grown produce contributing less than 10% fruit and vegetable intake; no poultry), including children's day care centres, preschools and primary schools or town houses or villas;
- NSW EPA (1998) Phytotoxicity Based Investigation Levels. NSW EPA (1994) *Guidelines for Assessing Service Station Sites* were referred to for assessing TPH and BTEX results.

The soil guidelines adopted by URS are considered suitable.

The following guidelines were adopted by URS for the groundwater investigation works:

- ANZECC (2000) Guidelines for Fresh and Marine Water Quality for protection of 95% of marine species.

URS did not adopt other groundwater guidelines that the Auditor considers relevant, including NSW DEC (2007), Guidelines for recreational purposes presented in Table 5.2.3 of ANZECC/ARMCANZ (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* and Australian Standard AS 2159 (1995) *Piling – Design and Installation,* which provides exposure classification values for concrete and steel piles in groundwater based on pH, sulphate and chloride concentrations.

6 Evaluation of Remediation Works

6.1 Assessment of Investigation Works

The results of the soil investigation works confirm the information provided in the site history review, which identified potentially contaminating activities (i.e. use of the Site as a landfill). An assessment of the adequacy of the investigation works compared to the identified areas of concern is provided in Table 7.

Table 7: Assessment adequacy

Historical activity	Site area	Potential contaminants and associated analytes	Adequate assessment undertaken	Key findings
Use of Site as landfill	Entire Site	Heavy Metals, TPH, BTEX, PAH, OCP, PCB, SVOC	49 systematic grid based soil sample locations across the Site, with samples collected from the shallow filling and underlying natural clays to maximum depths of 6.3m bgl. Soil samples were analysed for a range of potential contaminants including Heavy Metals, TPH, BTEX, PAHs, OCPs, OPPs, SVOC, VOC. Three groundwater monitoring well locations to cover Site area. Groundwater samples analysed for Ammonia, Nitrate, TPH, Heavy Metals, VOCs, SVOCs, OCPs, OPPs, PCBs, major cations and anions.	Minor TPH and Heavy Metal contamination was identified. No significant impacts identified in groundwater.
Acid Sulfate Soils	Entire Site	H_2SO_4	SPCOAS testing completed on estuarine and non-estuarine soils	Estuarine sediments at depth are Acid Sulfate Soils

Based on the soil investigations undertaken at the Site, the Auditor considers that the areas of environmental concern and associated contaminants of concern in soils have been adequately assessed and contamination issues adequately identified.

6.2 Assessment of Remediation Approach

Remediation works were required to relocate landfill waste material from the Old Landfill to the SCWCC.

Remediation options for the Site were included in several investigation reports completed prior to 1995. Remediation options included in-situ treatment of soils, excavation and removal of the waste material off-site and excavation and re-burial of the waste material at a prepared location on the same Site. Excavation and relocation of the waste was approved as part of the 1996 EIS approval for the boatharbour development.

A Remedial Action Plan was not prepared for the Site. URS (2003) prepared an engineering approach for the Waste Containment Cell to assist with the excavation and relocation of the waste material from the Old Landfill.

The Auditor considers that the relocation of the waste to a new, prepared location was a suitable remediation option given that it was required to allow the development in any case.

6.3 Assessment of Remediation Activities

Remediation activities were completed between January 2007 and February 2008. Remediation works were supervised by URS and undertaken by Cleary Bros. and included the following:

- Site preparation works, including implementation of environmental control measures;
- Excavation of waste from the Old Landfill Site. The excavation was completed progressively from the south to the north of the Old Landfill by a 30 tonne excavator. The waste was not stockpiled in the Old Landfill but was loaded directly into dump trucks. Waste materials identified during the excavation works comprised largely timber, metal, bricks, concrete, plastic bags, newspaper, plastic, tyres, glass and fabric in a soil matrix. The percentage of soil was higher than observed during the investigation works. No drums, liquid wastes or waste other than that classified as Solid Waste was observed during the excavation of the waste by URS. The presence of suspected Asbestos containing materials exceeding minor amounts (>1kg in 100m^3) was not sighted during the excavation works. The waste excavations were continued into the underlying natural material and only natural materials remained in the base of the excavation;
- Loading and hauling of the waste to the SCWCC. A total of 261, 691 tonnes of Solid Waste material was relocated to the SCWCC.

Following the completion of the remediation, the Site comprised an open excavation inundated with groundwater to a depth of approximately 300mm. The excavation is to be backfilled at a later date. A survey of the excavation is presented in Attachment 6 in Appendix A.

URS April 2009 report included a photographic record of the remediation, waste tracking logs and a summary of volumes removed.

A site visit by the Auditor's representative during the remedial works, and by the Auditor following remediation, verified that the remedial works were completed as reported by URS.

6.4 Assessment of Validation Activities

The identified AECs, including use of the Site as a landfill, have been remediated and validated. Validation activities undertaken at the completion of the excavation works were undertaken by URS.

Validation activities undertaken to validate that landfill waste fill material was removed from Site are outlined in Table 8.

Table 8: Summary of Validation Activities

Validation Activities	Results	Auditor Comment
Visual validation of the base of the excavation to ensure the excavation had advanced into natural materials	Verified that the excavation was terminated in natural material and no waste remained	In the Auditor's opinion, visual validation of the removal of waste fill material from the base of the excavation was appropriate given that the waste removed was visually distinct from the underlying natural soils.
Collection of validation soil samples from locations BH09 and BH26, completed due to anomalous results recorded as these locations during the Pre-Validation Investigation	Anaytical results were below the PQLs and below the adopted NEMP HIL guideline values and NEMP EIL guideline values	In the Auditor's opinion, validation soil sampling from locations BH09 and BH26 was appropriate.
Visual characterisation of the walls of the excavation	Road fill was observed in the eastern wall of the excavation along Boollwarroo Parade and some waste, including timber with some plastic, glass, metal and fabric in soil, was observed in the northern wall of the excavation adjacent to Keith Hockey Field	In the Auditor's opinion, fill material was excavated to the extent practicable with the walls of the excavation battered at 2H:1V.
Collection of 22 characterisation soil samples (WB1 to WB13, WP14 to WP22) from the walls at a frequency of 1 sample per 30 lineal metres	Copper concentrations exceeded the EIL guideline value at 19 locations; Zinc concentrations exceeded the EIL guideline value at 3 locations and Mercury concentrations exceeded the EIL guideline value at one location.	The significance of this is discussed in Section 7.2.3.
Collection of one groundwater characterisation sample from groundwater ponded in the excavation post-remediation	Concentrations of Heavy Metals, pH, salinity, SVOCs, VOCs, TPH, OCP, OPP, PCB, Ammonia, Nitrate. Major Cations and Anions were below the adopted ANZECC (2000) 95% protection marine guidelines.	Results from this groundwater sample will be used for comparative purposes only as no QA/QC was undertaken during this work.

Surface landfill gas monitoring on the walls of the excavation post-remediation	Methane concentrations measured between 0.0%v/v and 0.1%v/v, oxygen concentrations ranged between 20.3%v/v and 20.6%v/v, carbon dioxide concentrations measured 0%v/v and hydrogen sulphide concentrations measured 0ppm. Methane concentrations did not exceed the threshold concentration for further investigation or action of 500ppm or 1% LEL.	In the Auditor's opinion, the surface landfill gas monitoring completed following the excavation works was appropriate.

Following the soil remediation, the Site comprised an irregular shaped open excavation.

The validation works are considered to have been appropriate to achieve the remediation goals.

6.5 Offsite Disposal

Excavated waste material was relocated to the purpose built engineered waste cell located to the south of the Site, the SCWCC. The SCWCC was licenced to receive inert and solid waste from the Old Landfill under EPL 12426 Condition L5.2.

URS (August 2009b, Section 7.7) indicated that waste transported to the SCWCC was weighed over a temporary weighbridge installed on Site. The temporary weighbridge was calibrated 12 times between August and December 2007. URS indicated that the total volume of the excavation at the Old Landfill was approximately 142,352m^3, with a total tonnage of 261, 691 tonnes. The volume placed in the SCWCC was approximately 124,583m^3, with the volume difference due to compaction of the landfill waste material in the SCWCC.

A review of the waste transport documentation confirms the appropriate disposal of the excavated material.

6.6 Acid Sulfate Soils

As part of the boatharbour design investigations, Coffey (2003) and (2004) investigated and reported on Potential Acid Sulfate Soils (PASS) and Actual Acid Sulfate Soils (ASS) in the area of the Old Landfill.

The estuarine soils beneath the waste fill material in the Old Landfill were identified as likely ASS, with pH values of less than 3 following oxidation with hydrogen peroxide. All samples of non-estuarine soils recorded pH values greater than 3 following oxidation with hydrogen peroxide suggesting non-estuarine soils are not ASS.

Laboratory testing using the Suspended Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) method indicated that the estuarine sediment samples recorded peroxide oxidisable sulphur concentrations ranging from 0.05% to 1.63%, confirming that the estuarine soils are ASS.

URS (August 2009b, Section 2.3.4) reviewed Coffey (2004) bore logs, which indicated that the top of the estuarine silty sands are located at or below 0.5m AHD and the top of the estuarine silt/clays are located at or below -1.0m AHD across the Old Landfill. URS noted that the top of the estuarine sediments is below the groundwater table and level of the final excavation.

The Auditor notes that the base of the open excavation is between -0.47m AHD and 1.8m AHD confirming that the ASS material currently remains undisturbed below the base of the open excavation.

6.7 Backfilling of the Excavation

URS (August 2009b, Section 7.8) indicates that backfilling of the remaining open excavation at the Site will be completed at a later date by another party. In the interim, the walls of the excavation have been battered at approximately 2H:1V and the Site is fenced.

7 Evaluation of Soil Analytical Results

7.1 Summary of Soil Analytical Results

7.1.1 Overview

A summary of results following the completion of remediation works is provided below in Tables 9 to 10, which is representative of the overall current site conditions. It is noted that the summary provides an assessment of residual contamination remaining in the base of the excavation and the walls of the excavation. The summary is based on validation works undertaken by URS at the completion of remediation works and the earlier pre-remediation investigation.

7.1.2 Summary of Results from the Base of the Excavation

Following the successful completion of the remediation and validation works, the remedial excavation remained open. The base of the remedial excavation was natural clay and sand.

The natural material at the base of the excavation was validated prior to the remediation during the Pre-remediation Investigation. A summary of results from the Pre-remediation Investigation sampling of the natural material in the base of the excavation is outlined in Table 9.

Table 9: Evaluation of analytical results, base of excavation – summary table (mg/kg)

Analyte	n	n > PQL	Max.	n > protection of the human health based criteria (Sensitive use – Other)	n > protection of the human health based criteria (Sensitive use – High density)	n > protection of the environment based criteria
pH						
Arsenic	96	12	10	0	0	0
Cadmium	96	2	2	0	0	0
Total Chromium	96	65	32	0	0	0
Copper	96	88	122	0	0	**3 (114mg/kg to 156mg/kg)**
Lead	96	49	381	0	**1 (381mg/kg)**	0
Mercury (inorganic)	96	6	0.2	0	0	0
Nickel	96	44	13	0	0	0
Zinc	96	79	266	0	0	**4 (224mg/kg to 266mg/kg)**
TPH (C_6-C_9)	96	2	29	0	0	0

Table 9: Evaluation of analytical results, base of excavation – summary table (mg/kg)

Analyte	n	n > PQL	Max.	n > protection of the human health based criteria (Sensitive use – Other)	n > protection of the human health based criteria (Sensitive use – High density)	n > protection of the environment based criteria
TPH (C_{10}-C_{36})	96	6	930	0	0	0
BTEX	86	0	<0.5	0	0	0
Benzo(a)pyrene	15	1	0.6	0	0	0
Total PAHs	15	1	10.1	0	0	0
OCP	15	0	<0.2	0	0	0
PCB	15	0	<0.1	0	0	0

Notes:
n number of samples
PQL Practical Quantitation Limit
nc no criteria available/used

Based on the above, concentrations of some Heavy Metals (Copper, Lead and Zinc) were identified above the Maintenance of Ecosystems criteria and one of 96 samples exceeded the HIL A criteria in the natural material at the base of the excavation.

URS (August 2009a, Section 6.1) indicated that the exceedances of the HIL A guideline value for Lead were not considered significant as the concentration detected (381mg/kg) was less than 250% of the 300mg/kg criteria and the standard deviation (39.8mg/kg) for the Site is less than 50% of the 300mg/kg criteria. The 95% UCL_{mean} concentrations (16.88mg/kg) for Lead is below the adopted guidelines.

URS (August 2009a, Section 6.1) indicated that the exceedences of the EIL guideline values were not considered significant due to the following:

- With the exception of the Zinc concentration recorded at BH26, the exceedences of the adopted EIL guidelines are relatively minor in magnitude;
- The EILs have been developed for the investigation of sites in an urban setting and are based on consideration of phytotoxicity and soil survey data from four Australian capital cities. In the absence of regional EILs for the area, the NEPM EILs have been adopted for the Site. The EILs were considered appropriate as the levels derived are investigation levels and are lower than concentrations that would warrant specific remedial action. It is noted that EILs have not been derived to protect nominated ecological values and are somewhat arbitrary;
- Following the excavation of the waste, the Site will need to be backfilled prior to being able to be developed. Approximately 4m of backfill will be placed above these

excavation levels prior to development thus limiting accessibility for potential receptors to the underlying material;

- Background levels of Zinc in soil range from 2 to 180ppm (ANZECC/NHMRC, 1992). US EPA have quoted a range between 10 to 300ppm (Langley et al., 1996). It is noted that all of the remaining zinc levels recorded are below the upper value of 300ppm;
- Background levels of Copper in soil range from 1 to 190mg/kg (ANZECC/NHMRC, 1992). It is noted that the majority of the copper levels recorded are below the upper value of 190mg/kg;
- URS notes that elevated Copper and Zinc concentrations are not unusual in the parent rock formation comprising the Bombo latite (of the Gerringong Volcanics). URS has sampled and analysed this rock unit many times and found these concentrations to be representative of the local bedrock.

7.1.3 Summary of Results from the Walls of the Excavation

The walls of the excavation were extended to the Site boundary to the extent practicable. Road base material was observed in the eastern wall of the excavation along Boollwarroo Parade and waste material remained in the northern wall adjacent to the Keith Hockey Field. Characterisation samples of these two walls of the excavation were collected by URS during validation works.

A summary of results from the sampling of the walls of the excavation is presented in Table 10.

Table 10: Evaluation of analytical results, walls of excavation where waste remained or road base was observed – summary table (mg/kg)

Analyte	n	n > PQL	Max.	n > protection of the human health based criteria (Sensitive use – Other)	n > protection of the human health based criteria (Sensitive use – High density)	n > protection of the environment based criteria
pH						
Arsenic	22	1	6	0	0	0
Cadmium	22	2	2	0	0	0
Total Chromium	22	21	32	0	0	0
Copper	22	22	241	0	0	**19 (101mg/kg to 241mg/kg)**
Lead	22	22	186	0	0	0
Mercury (inorganic)	22	4	1.1	0	0	**1 (1.1mg/kg)**
Nickel	22	22	9	0	0	0
Zinc	22	22	511	0	0	**3 (207mg/kg**

Table 10: Evaluation of analytical results, walls of excavation where waste remained or road base was observed – summary table (mg/kg)

Analyte	n	n > PQL	Max.	n > protection of the human health based criteria (Sensitive use – Other)	n > protection of the human health based criteria (Sensitive use – High density)	n > protection of the environment based criteria
						to 511mg/kg)
TPH (C_6-C_9)	22	0	<10	0	0	0
TPH (C_{10}-C_{36})	22	0	<250	0	0	0
BTEX	22	0	<0.5	0	0	0
Benzo(a)pyrene	6	1	1.6	0	**1 (1.6mg/kg)**	0
Total PAHs	6	1	17.1	0	0	0
OCP	6	0	<0.2	0	0	0
PCB	6	0		0	0	0

Notes:
n number of samples
PQL Practical Quantitation Limit
nc no criteria available/used

Based on the above, concentrations of some Heavy Metals (Copper, Mercury and Zinc) and Benzo(a)pyrene (BaP) were identified above the Maintenance of Ecosystems criteria and the HIL A criteria (1 sample for BaP only) in waste fill material and road base in the walls of the excavation.

URS (April 2009, Section 9.6) indicated that the exceedence of the HIL A criteria for benzo(a)pyrene is not considered significant as the concentration recorded (1.6mg/kg) is less than 2.5 times the criteria of 1mg/kg and the 95% UCL of 0.68mg/kg which is below the criteria.

URS (April 2009, Section 9.6) indicated that the exceedences of the EIL guideline values were not considered significant due to the following:

- These exceedences were relatively minor in magnitude;
- The EILs have been developed for the investigation of sites in an urban setting and are based on consideration of phytotoxicity and soil survey data from four Australian capital cities. In the absence of regional EILs for the area, the NEPM EILs have been adopted for the Site. It is noted that EILs have not been derived to protect nominated ecological values and are somewhat arbitrary;
- Following the excavation of the waste, the Site will need to be backfilled prior to being able to be developed. Approximately 4m of backfill will be placed above these

excavation levels prior to development thus limiting accessibility for potential receptors to the underlying material;

- Background levels of Zinc in soil range from 2 to 180ppm (ANZECC/NHMRC, 1992). US EPA has quoted a range between 10 to 300ppm (Langley et al., 1996). It is noted that all of the zinc levels recorded are below the upper value of 300ppm with the exception of locations WB6 and WP17;
- Background levels of Copper in soil range from 1 to 190mg/kg (ANZECC/NHMRC, 1992). It is noted that the majority of the copper levels recorded are below the upper value of 190mg/kg, with the exception of WB1, WB3, WB3, WB5, WB6, WB8, WB9, WP16 and WP20.

7.2 Significance of Soil Analytical Results

7.2.1 Protection of Human Health

The remaining soils contain low contaminant levels with the only exceedances of the HIL A criteria being in 1 of 188 samples for Lead and 1 in 21 samples for BaP. None of these are at hot spot levels and the 95% UCL_{mean} is below the criteria. Therefore human health will not be impacted.

7.2.2 Protection of the Environment

Although there are minor exceedences of the EILs in the remaining soils, they are not considered to impact on the environment for the following reasons:

- The exceedences are minimal;
- The levels are generally within the background range given by ANZECC/NHMRC (1992) and the US EPA.

The Auditor notes that the Site is to be backfilled prior to development and the current soils will be at significant depth.

7.2.3 Protection of Buildings and Structures

No assessment of pH and Sulphate was undertaken by the consultants during investigation or validation works, and therefore an assessment against the criteria outlined in Section 5.2.3 could not be undertaken.

The Auditor notes that estuarine sediments (ASS) remain in situ beneath the base of the excavation. The estuarine sediments are currently below the groundwater table. In the event that building foundations extend into the natural soils or below the groundwater table, the project structural engineer should give consideration to the conditions and the potential affect of the natural soils including ASS and groundwater on buildings and structures in the design of building foundations at the Site.

7.2.4 Protection of Aesthetics

Remnant materials at the base of the excavation comprise natural clay and sand and are not discoloured, malodourous or of abnormal consistency.

Remnant materials in the walls of the excavation include road base in the eastern wall along Boollwarroo Parade and waste fill in the northern wall adjacent to the Keith Hockey Fields. The waste fill in the northern wall comprises predominantly timber with some plastic, glass, metal and fabric in a soil matrix. The excavation was extended to the Site boundaries to the extent practicable, so the extent of waste fill material in the northern wall of the excavation within the boundary of the Site would be limited.

7.3 Potential for Offsite Migration of Soil Contamination

There is limited potential for offsite migration of contamination from the Site as contaminant levels in soil are generally low and the remaining soils will be contained below at least 4m of clean fill.

8 Evaluation of Groundwater Analytical Results

8.1 Overview

This section presents of the Auditor's assessment of groundwater analytical data from the URS 2006 Pre-Validation Works report and URS 2009 Remediation, Characterisation and Validation report.

8.2 Summary of Groundwater Analytical Results

Two rounds of groundwater sampling were completed at the Site on 6 October 2006 and 8 August 2007 following the installation of three groundwater monitoring wells.

Groundwater samples were analysed for Ammonia, Nitrate, Heavy Metals, VOCs, SVOCs, OCPs, OPPs, PCBs, Major Anions, Major Cations, pH and Salinity. A summary of the analytical results from the second round of sampling is presented in Table 11.

Following remedial works at the Site, URS collected one grab sample of groundwater from the excavation on 8 December 2008. As no QA/QC was undertaken on this sample, analytical results from this sample are only to be used for comparative purposes.

Table 11: Summary of Groundwater Analytical Results							
Analyte		**Trigger values**		**MW1**	**MW2**	**MW3**	**Grab Sample**
Date sampled				**8/08/2007**	**8/08/2007**	**8/08/2007**	**8/12/08**
Location	**Units**	**Aquatic ecosystems**	**Recreation and Aesthetics**				**Base of excavation**
Major cations/anions							
Calcium	mg/L			120	64	96	82
Potassium	mg/L			31	55	18	47
Magnesium	mg/L			131	75	38	136
Sodium	mg/L			1110	367	149	1230
Carbonate Alkalinity as CaCo3	mg/L			<1	<1	<1	-
Bicarbonate Alkalinity as CaCo3	mg/L			696	846	578	-
Sulphate SO4	mg/L		400	5	6	8	**447**
Chloride	mg/L		400	**2070**	**472**	189	**2210**
Ammonia as N	mg/L	4.55	0.01	**23**	**21.3**	**15**	**0.02**
Nitrate as N	mg/L		10	<0.01	0.01	<0.01	0.01
Heavy Metals							
Arsenic	µg/L	13	50	2	<1	<1	<1
Cadmium	µg/L	0.2	5	<0.1	<0.1	<0.1	<0.1
Chromium	µg/L	3.3	50	<5	<5	<5	<5
Copper	µg/L	1.4	1000	1	<1	<1	**4**
Lead	µg/L	3.4	50	<1	<1	<1	<1
Mercury	µg/L	0.06	1	<0.1	<0.1	<0.1	<0.1
Nickel	µg/L	11	100	2	<1	<1	<1
Zinc	µg/L	8	5000	<5	5	6	<5
Monocyclic Aromatic Hydrocarbons (MAHs)							
Benzene	µg/L	500	10	<5	<5	<5	<5
Toluene	µg/L	180		<5	<5	<5	<5
Ethylbenzene	µg/L	5		<5	<5	<5	<5
meta&para Xylene	µg/L	625		<5	<5	<5	<5
Styrene	µg/L			<5	<5	<5	<5
ortho Xylene	µg/L	350		<5	<5	<5	<5

Table 11: Summary of Groundwater Analytical Results							
Analyte	Units	Trigger values		MW1	MW2	MW3	Grab Sample
Date sampled		Aquatic ecosystems	Recreation and Aesthetics	8/08/2007	8/08/2007	8/08/2007	8/12/08
Location							Base of excavation
Cyclohexane	µg/L	13000		<5	<5	<5	<5
Isopropylbenzene	µg/L	30		<5	<5	<5	<5
n-Propylbenzene	µg/L			<5	<5	<5	<5
1,3,5-Trimethylbenzene	µg/L	12		<5	<5	<5	<5
sec-Butylbenzene	µg/L			<5	<5	<5	<5
1,2,4-Trimethylbenzen	µg/L	15		<5	<5	<5	<5
tert-Butylbenzene	µg/L			<5	<5	<5	<5
p-Isopropyltoluene	µg/L			<5	<5	<5	<5
n-Butylbenzene	µg/L			<5	<5	<5	<5
Total MAHs	µg/L			ND	ND	ND	ND
Polyaromatic Hydrocarbons (PAHs)							
Naphthalene	µg/L	16		<2	<2	<2	<2
Acenaphthylene	µg/L			<2	<2	<2	<2
Acenaphthene	µg/L			<2	<2	<2	<2
Fluorene	µg/L			<2	<2	<2	<2
Phenanthrene	µg/L	2		<2	<2	<2	<2
Anthracene	µg/L	0.4		<2	<2	<2	<2
Fluoranthene	µg/L	1.4		<2	<2	<2	<2
Pyrene	µg/L			<2	<2	<2	<2
Benz(a)anthracene	µg/L			<2	<2	<2	<2
Chrysene	µg/L			<2	<2	<2	<2
Benzo(b&k)fluoranthene	µg/L			<2	<2	<2	<2
Benzo(a)pyrene	µg/L	0.2	0.01	<2	<2	<2	<2
Indeno(1,2,3,cd)pyrene	µg/L			<2	<2	<2	<2
Dibenz(a,h)anthracene	µg/L			<2	<2	<2	<2
Benzo(g,h,i)perylene	µg/L			<2	<2	<2	<2
Total PAHs	µg/L			ND	ND	ND	ND
OCPs	µg/L			<PQLs 1	<PQLs 1	<PQLs 1	<PQLs 1

Table 11: Summary of Groundwater Analytical Results							
Analyte	Units	Trigger values		MW1	MW2	MW3	Grab Sample
Date sampled		Aquatic ecosystems	Recreation and Aesthetics	8/08/2007	8/08/2007	8/08/2007	8/12/08
Location							Base of excavation
OPPs	µg/L			<PQLs 2	<PQLs 2	<PQLs 2	<PQLs 2
PCBs	µg/L			<PQLs 3	<PQLs 3	<PQLs 3	<PQLs 3
SVOCs	µg/L			<PQLs 4	<PQLs 4	<PQLs 4	<PQLs 4
VOCs	µg/L			<PQLs 5	<PQLs 5	<PQLs 5	<PQLs 5

Notes:

1 PQLs for OCPs <0.001

2 PQLs for OPPs range from <0.05 to <0.1

3 PQLs for PCBs <0.1

4 PQLs for SVOCs range from <2 to <20

5 PQLs for VOCs range from <5 to <50

It is noted that for the Limits of Reporting (LOR) applied by the laboratory for Mercury, Benzo(a)pyrene, anthracene and fluorathene were greater than one or more of the trigger values, and therefore no comparison to the trigger values could be made. URS (August 2009b, Section 9.7) noted that these are not principal contaminants of concern at the Site and that characterisation and validation soil results recorded for these contaminants were generally below the laboratory detection limits. The Auditor concurs that limitations of the LORs are not significant.

8.3 Discussion

8.3.1 Major Anions/ Cations

Groundwater across the Site has been found to be of Na-Cl type water.

8.3.2 Inorganics

Heavy Metal concentrations from the 2007 sampling round were low and fairly consistent across the Site, with concentration ranges reported as follows:

- Concentrations of Cadmium, Chromium, Lead and Mercury were below laboratory detection levels at all groundwater monitoring locations;
- Concentrations of Arsenic were generally consistent across the Site, ranging from <1µg/L at MW2 and MW3 to 2µg/L at MW1, with all concentrations below the applicable trigger value;

- Concentrations of Copper were generally consistent across the Site, ranging from <1µg/L at MW2 and MW3 to 1µg/L at MW1, with all concentrations below the applicable trigger value;
- Concentrations of Nickel were generally consistent across the Site, ranging from <1µg/L at MW2 and MW3 to 2µg/L at MW1, with all concentrations below the applicable trigger value;
- Concentrations of Zinc were generally consistent across the Site, ranging from <5µg/L at MW1 to 6µg/L at MW3, with all concentrations below the applicable trigger value;
- Ammonia level were elevated in all bores, with concentrations ranging from 15mg/L to 23mg/L;
- Nitrate levels were all below the levels of detection of the instrumentation.

8.3.3 Organics

PAHs, MAHs, OCPs, OPPs, PCBs, SVOCs and VOCs were not detected above PQLs at all groundwater monitoring locations.

8.4 Significance of Groundwater Analytical Results

8.4.1 Protection of Marine Ecosystems

The only analyte exceeding the ANZECC levels was Ammonia, which is a common contaminant associated with degradation of putrescible material in landfills.

The elevated concentrations of Ammonia were identified the criteria prior to the completion of remedial works at the Site. URS indicated that as these Ammonia concentrations were recorded within the waste fill material prior to its removal, the concentrations of Ammonia were considered to represent the worst case. URS considered that following source removal, Ammonia concentrations would attenuate prior to groundwater reaching the nearest ecological receptor, the Pacific Ocean. The Auditor considers that this is a reasonable assumption due to the following:

- The source of the contamination has been removed;
- Comparison of Ammonia concentrations pre-remediation to the grab sample collected from groundwater pooled following remediation indicated that Ammonia concentrations have reduced from around 20mg/L prior to remediation to 0.02mg/L post remediation, although it is noted that the reliability of this data may be questionable.

8.4.2 Protection of Buildings and Structures

URS assessed the Sulphate and Chloride concentrations in groundwater against the AS2159- 1995 Piling – Design and Installation, which indicated that an indicative expsore classification for Concrete and Steel at the Site would be Non Aggressive to Mild.

URS has indicated that in the instance that building foundations extend below the groundwater table, the project structural design engineer would give consideration to the

exposure classification for concrete and steel in the design of foundations and the potential affect on buildings and structures.

8.4.3 Protection of Recreation and Aesthetics

The only analytes exceeding the ANZECC levels were Chloride and Ammonia, which are common contaminant associated with degradation of putrescible material in landfills.

The elevated concentrations of Ammonia were identified the criteria prior to the completion of remedial works at the Site. URS indicated that as these Ammonia concentrations were recorded within the waste fill material prior to its removal, the concentrations of Ammonia were considered to represent the worst case. URS considered that following source removal, Ammonia concentrations would attenuate prior to groundwater reaching the nearest ecological receptor, the Pacific Ocean. The Auditor considers that this is a reasonable assumption due to the following:

- The source of the contamination has been removed;
- Comparison of Ammonia concentrations pre-remediation to the grab sample collected from groundwater pooled following remediation indicated that Ammonia concentrations have reduced from around 20mg/L prior to remediation to 0.02mg/L post remediation, although it is noted that the reliability of this data may be questionable.

9 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 B**. The Auditor has used these guidelines.

The investigation was generally reported in accordance with the NSW EPA (1997) *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites*. The checklist included in that document has been completed and is kept on file. The NSW DEC's Checklist for Site Auditors using the NSW DEC (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme* (2nd ed.) has also been completed and is kept on file.

The regulatory approvals and licences obtained for works at the Site included:

- The Shell Cove Waste Relocation Project was approved as part of the development approval for the Shell Cove Boatharbour/Marina, Shadforth Wetland and Quarry Haul Road Acoustic Barriers (Development Consent 95/133, as amended);
- Waste classifications were completed by URS in accordance with NSW DEC (2004) Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-liquid Waste. It is noted that these guidelines have been superseded by NSW DECC (2008) Waste Classification Guidelines but that the new guidelines did not come into effect until after the excavation of the Old Landfill was complete;
- Condition L5.2 of the EPL 12426 indicated that "*material classified as inert or solid waste excavated from the "Old Landfill" shown on DWG No. 005-FIG5 titled "Haul Route" and contained in the Shell Cove Waste Relocation Environmental Management Plan Report*" could be relocated to the SCWCC. A waste tracking log was kept by the contractor and weighbridge dockets recorded the time, date, truck number and gross weight of each load;
- Bore construction licences are required from the Department of Planning for the installation of groundwater monitoring wells. URS has not indicated whether well licences were obtained from Department of Planning.

10 Conclusion and Recommendations

URS has concluded that on the basis of the visual assessment and the results of the analytical testing, the Site is considered suitable for low density residential use with gardens and accessible soil.

Based on the information presented in the URS reports, observations made on Site, and following the 'Decision Process for Assessing Urban Redevelopment Sites' in NSW EPA (2006) *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme*, the Auditor concludes that the Site in its current state is suitable for 'residential with gardens and accessible soils' landuse and also the proposed residential development, including a mix of standard residential lots and medium density terraces, townhouses and apartments with gardens and accessible soil.

It is noted that ASS exist at depth at the site but are unlikely to be disturbed during site development. Should they be disturbed in the future an ASS management plan will be required.

11 Other Relevant Information

This Audit was conducted on the behalf of the Client for the purpose of assessing the suitability of the Site for residential landuse with gardens and accessible soils. This summary report may not be suitable for other uses. URS included limitations in their report/s. 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.

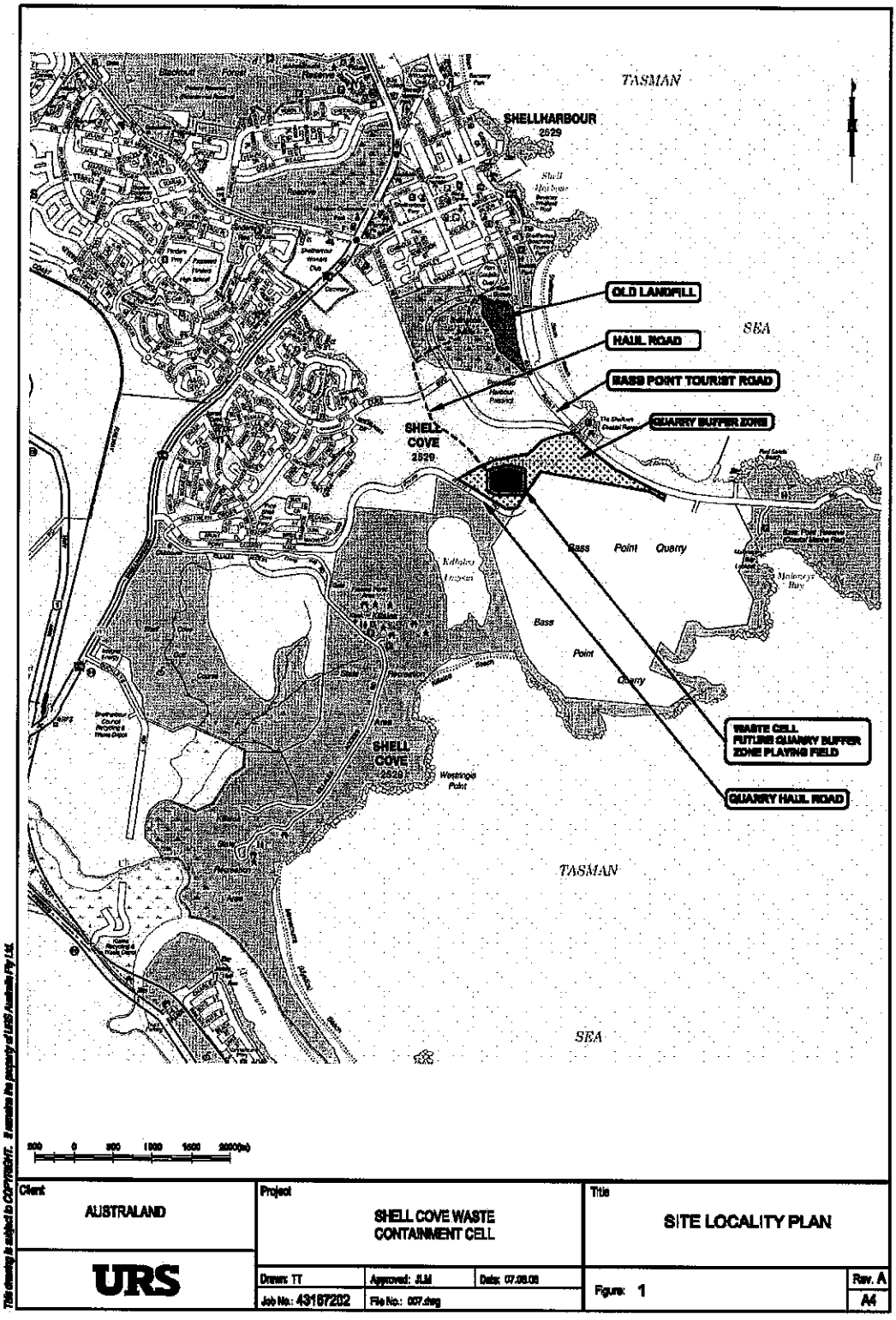
The Auditor has assumed that the Client and URS have provided full disclosure of material which may be pertinent to the Audit.

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 investigation 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.

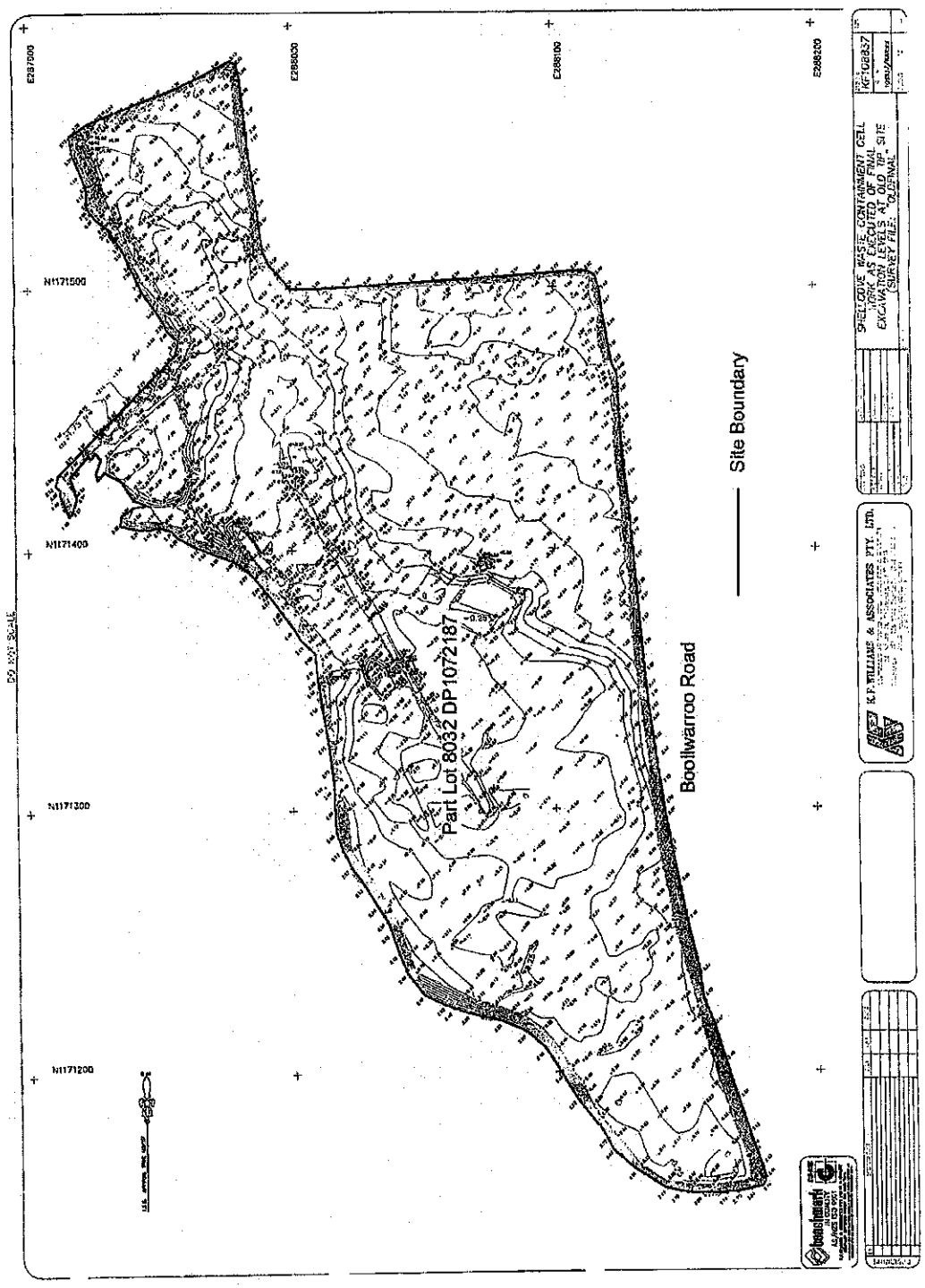
The Auditor notes that any comments and conclusions provided in this document regarding the suitability of the Site for the proposed landuse are implicitly limited to consideration of Contamination related issues as defined under the NSW Contaminated Land Management Act 1997.

Appendix A
Attachments

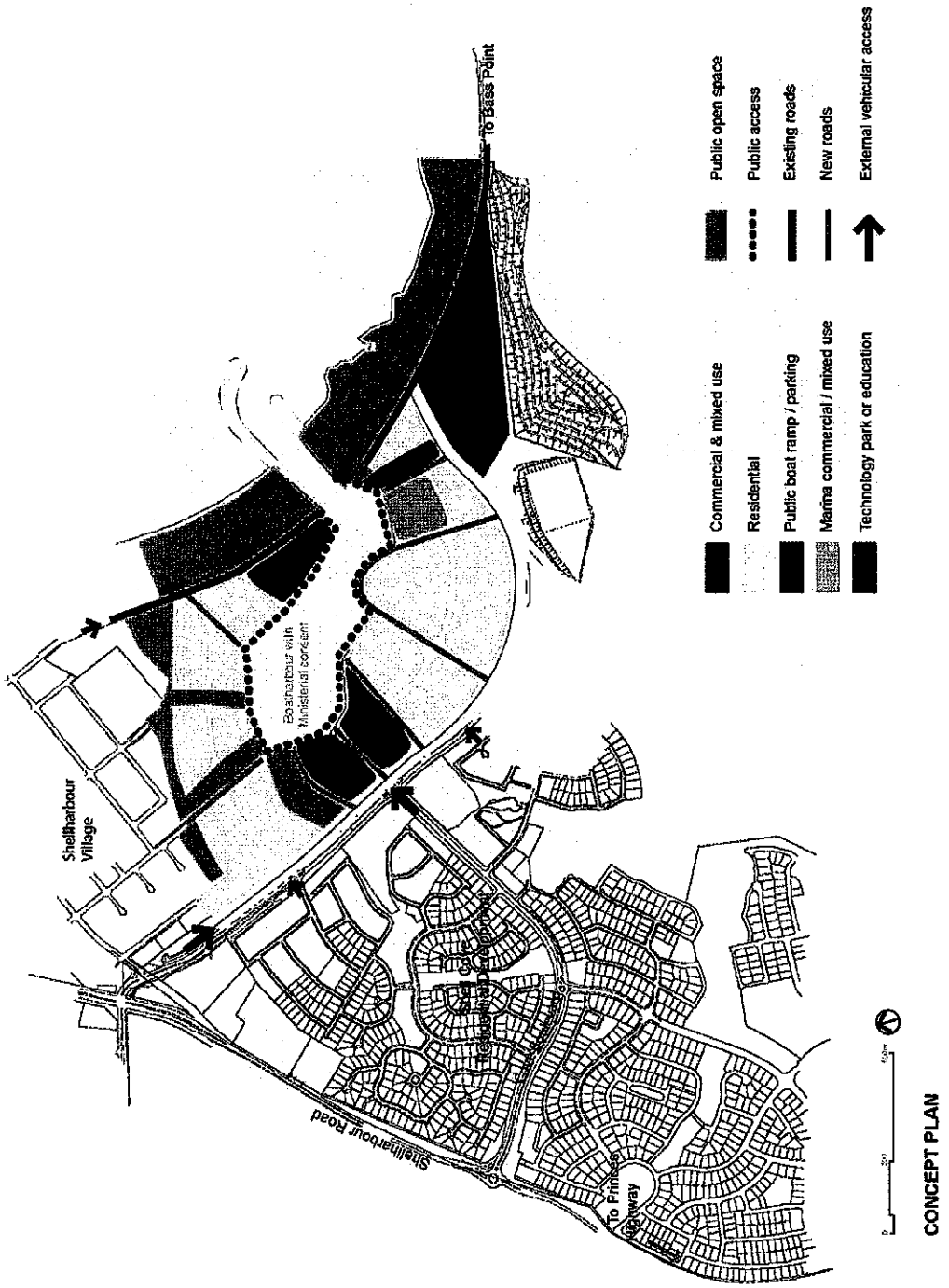
Attachment 1: Site Location Plan



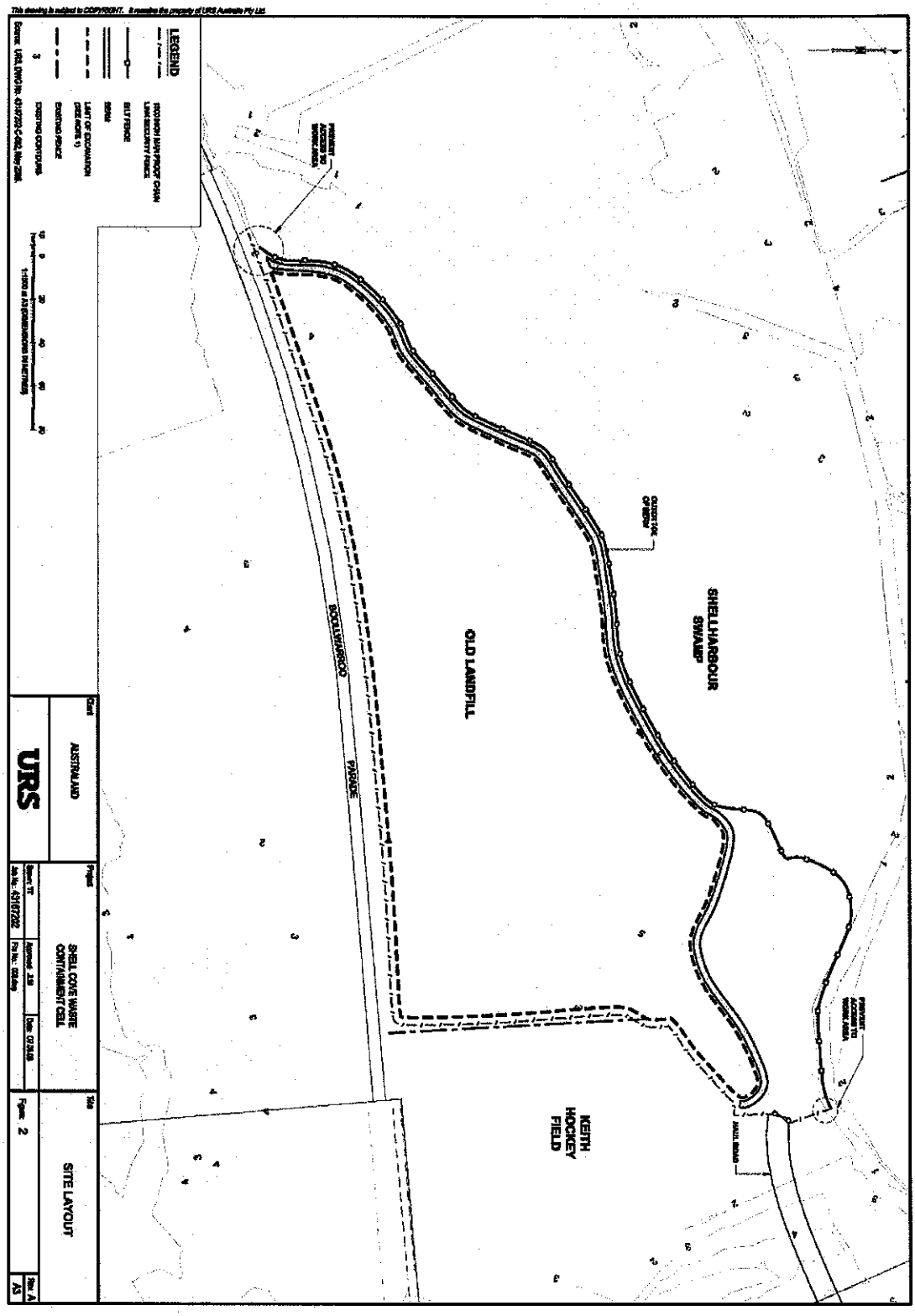
Attachment 2: Site Survey Plan



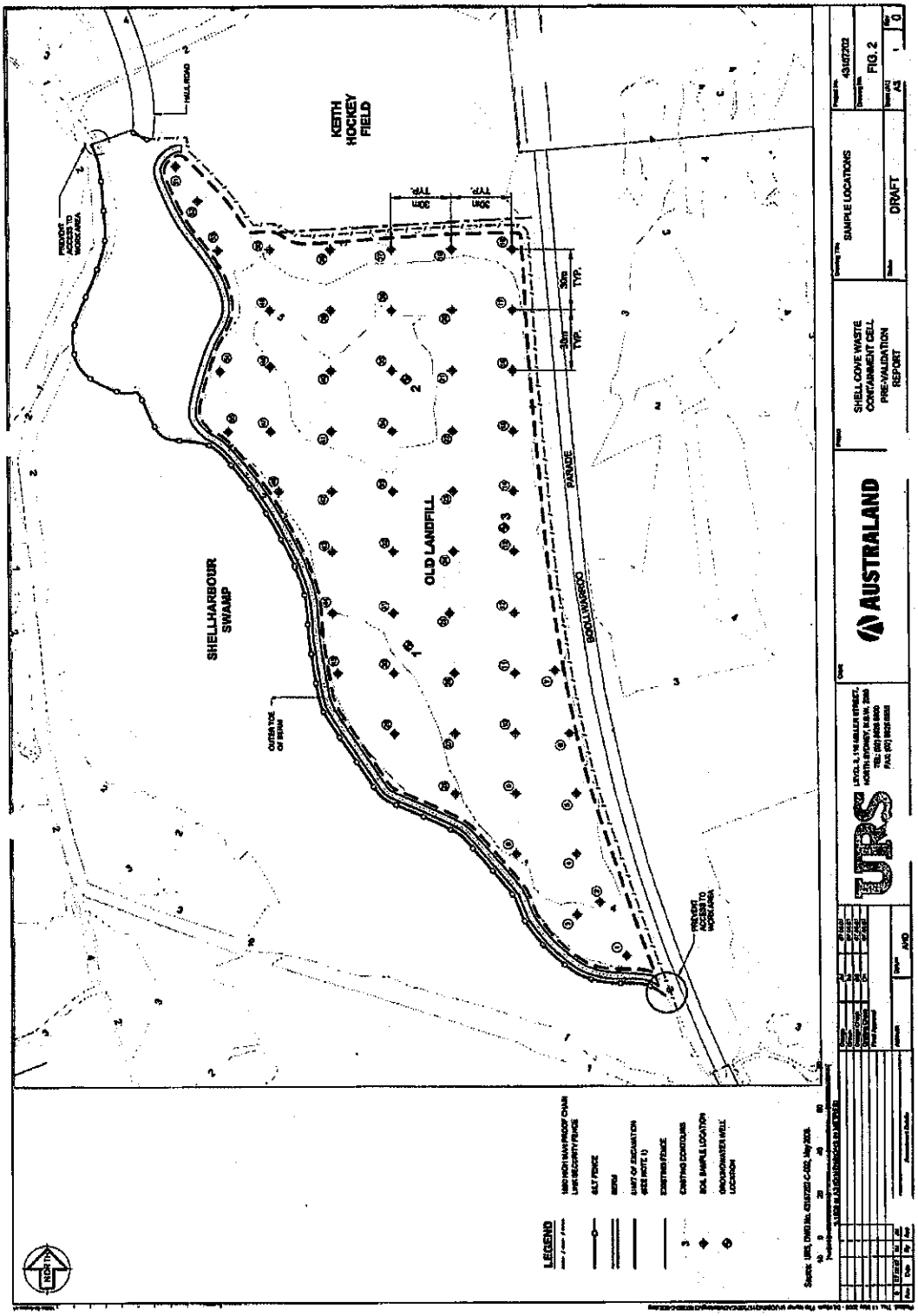
Attachment 3: Proposed Development Plans



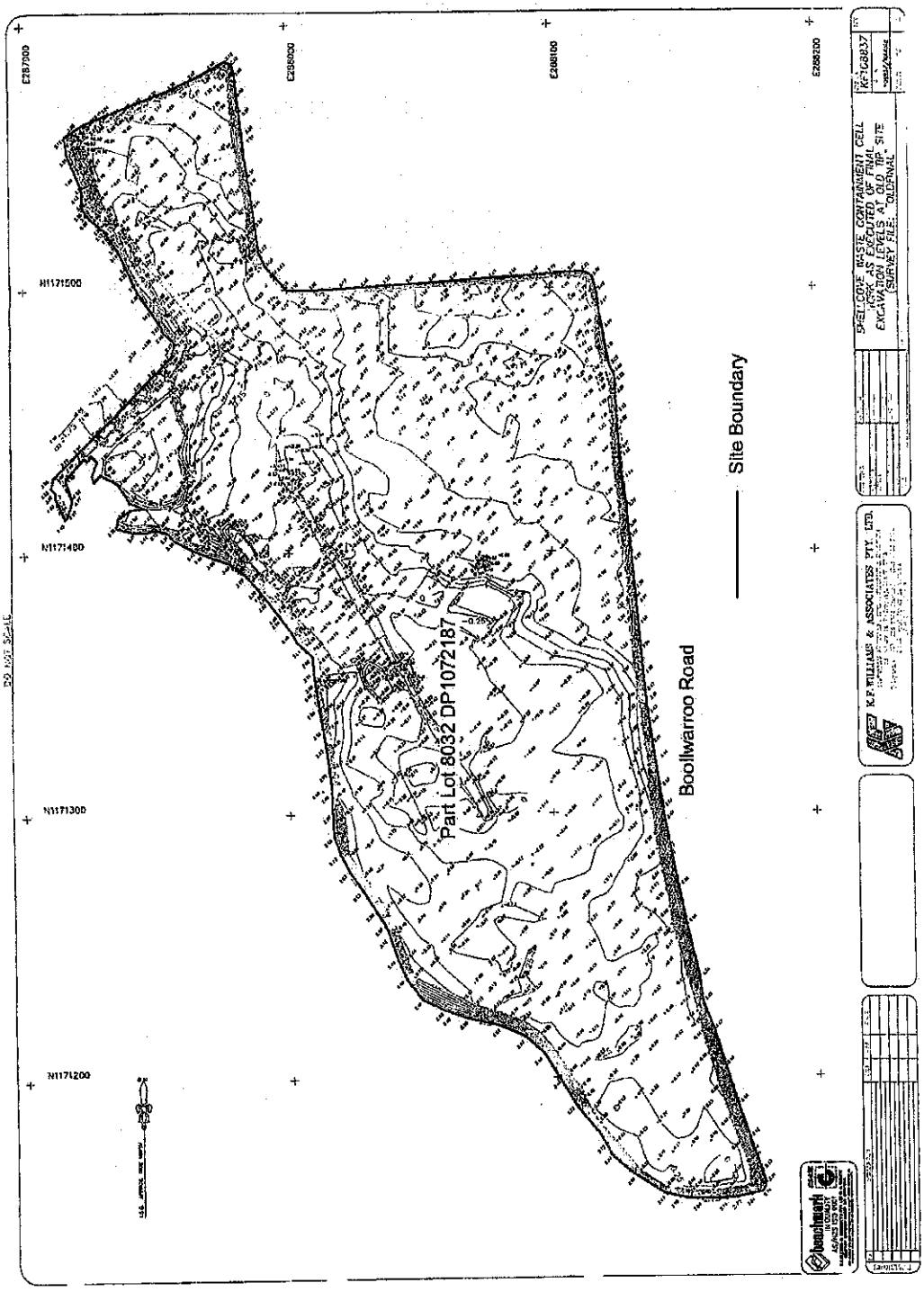
Attachment 4: Current Site Features



Attachment 5: URS 2000 Sampling Location Plan



Attachment 6: Survey of Remedial Excavation



Appendix B
NSW EPA Prepared and Endorsed Guidelines

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

(as per Appendix X of NSW EPA *Contaminated Sites: Guidelines for the NSW site auditor scheme,* April 2006)

Guidelines made by the EPA

The Contaminated Land Management Act 1997 (CLM Act) allows the EPA to make or approve guidelines for purposes connected with the objects of the Act. These guidelines must be taken into consideration by DEC, acting on behalf of the EPA, whenever they are relevant and by accredited site auditors when conducting a site audit. They are also used by contaminated land consultants in undertaking investigation, remediation, validation and reporting on contaminated sites. A list of guidelines made or approved by the EPA under the CLM Act current at April 2006 appears below.

- *Contaminated Sites: Guidelines for Assessing Service Station Sites*, December 1994
- *Contaminated Sites: Guidelines for the vertical mixing of soil on former broad-acre agricultural land*, January 1995.
- *Contaminated Sites: Sampling Design Guidelines*, September 1995
- *Contaminated Sites: Guidelines for Assessing Banana Plantation Sites*, October 1997
- *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites*, November 1997
- *Contaminated Sites: Guidelines on Significant Risk of Harm from Contaminated Land and the Duty to Report*, April 1999.
- *Contaminated Sites: Guidelines for Assessing Former Orchards and Market Gardens,* June 2005
- *Contaminated Sites: Guidelines for the NSW site auditor scheme,* April 2006
- *Contaminated sites: guidelines for the assessment and management of groundwater contamination, March 2007.*

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 Water Quality Guidelines for Fresh and Marine Waters,* Australian and New Zealand Environment and Conservation Council (ANZECC), November 1992, which are only approved for the purposes of contaminated site assessment, investigation, remediation and site auditing under the Contaminated Land Management Act (or other relevant legislation) commenced before September 2001

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Paper No 4, October 2000

EnHealth publications (formerly National Environmental Health Forum monographs)

- *Composite Sampling*, by 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, June 2002

National Environment Protection Council publications

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

The Measure 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:

B(1) *Guideline on Investigation Levels for Soil and Groundwater*

B(2) *Guideline on Data Collection, Sample Design and Reporting*

B(3) *Guideline on Laboratory Analysis of Potentially Contaminated Soils*

B(4) *Guideline on Health Risk Assessment Methodology*

B(5) *Guideline on Ecological Risk Assessment*

B(6) *Guideline on Risk Based Assessment of Groundwater Contamination*

B(7a) *Guideline on Health-Based Investigation Levels*

B(7b) *Guideline on Exposure Scenarios and Exposure Settings*

B(8) *Guideline on Community Consultation and Risk Communication*

B(9) *Guideline on Protection of Health and the Environment During the Assessment of Site Contamination*

B(10) *Guideline on Competencies & 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 & Agriculture and Resource Management Council of Australia and New Zealand, 1996

Australian Standards - not referred to in Appendix X of NSW EPA (2006)

The NEPM (1999) refers to Australian Standard AS 4482.1 (1997) *Guide to the sampling and investigation of potentially contaminated soil. Part 1: Non-volatile and semi-volatile compounds*, which has since been revised in 2005. In addition, Australian Standard AS 4482.2 (1999) *Guide to the sampling and investigation of potentially contaminated soil. Part 2: Volatile Substances* has been prepared since the publication of the NEPM (1999).

Documents released post April 2006 – (i.e. not able to be referred to in Appendix X of NSW EPA 2006)

The Department of Environment and Conservation NSW released the following document in March 2007:

- Department of Environment and Conservation NSW (March 2007) *Contaminated Sites: Guidelines for the Assessment and Management of Groundwater Contamination.*

Appendix C
Audit Correspondence

ENVIRON

Thursday, 20 April 2006 Ref: 32-06-025

AUSTRALAND
Shell Cove Office
P.O.Box A148
Shellharbour, NSW, 2529

Attention: Glenn Colquhoun

Dear Glenn,

Review of URS Valdiation Strategy
Shell Cove Boatharbour

I have reviewed the Validation Strategy proposed by URS (URS Ref 45929_019, dated 27/10/05) for remediation of the landfill.

In general I approve of the strategy but can the following please be included.

Drilling Method

Please provide more detail of the actual drilling method.

Sampling Method

Please provide more detail of the actual sample collection procedure.

Assessment Criteria

Please provide the assessment criteria to be adopted.

QA/QC

Please provide more detail of the intended QA/QC program for the collection of the grid samples.

Including the following:

- Decontamination Procedures
- Sample handling and containers

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- Chain of Custody
- Description of field screening protocols
- Field quality control samples
- NATA registered laboratory
- Practical Quantitation Limits (PQLs)
- Data Quality Objectives and Data Evaluation (completeness, comparability, representativeness, precision, accuracy)

Soil Analytes

Please include VOC's in the analytes suite for 1 in every 4 samples.

Odour

Please ensure that during fieldwork and remediation, a qualitative assessement of odour is recorded.

Methane

As some potentailly methane producing material will remain at the site boundary (ie the hockey field), it is considered prudent to take some limited measurement of methane levels during excavation/investigation in this area eg say use a Landfill Gas Analyser during one day of fieldwork.

Groundwater

I have reviewed the groundwater data presented in the Golders report. While this provides useful background information, considering its age and the fact that some of the detection limits used are above the current guidelines, further limited assessment of groundwater is considered necessary. This could be included in the proposed soil collection fieldwork and at least two sample locations are recommended. Wells should be screened to intersect the water table and constructed in accordance with Australian Standards guidelines.

Analytes should include TPH, VOC, Heavy Metals, SVOC, PCB's, OCP's, OPP's, major cations and anions, pH and salnity. Appropriate QA/QC should be underataken in accordance with the NEPM.

Yours faithfully,
ENVIRON Australia Pty Ltd

Phillip Hitchcock
Manager – Hunter Region
EPAV Environmental Auditor (Contaminated Land)

ENVIRON

Thursday, 31 August 2006 Ref: 32-0019

AUSTRALAND
Shell Cove Office
P.O.Box A148
Shellharbour, NSW, 2529

Attention: Glenn Colquhoun

Dear Glenn,

Review of URS SAQP
Shell Cove Boatharbour

I have reviewed the Draft Sampling and Analysis Qulaity Plan proposed by URS (URS Ref 43167202, dated 23/08/05) for remediation of the landfill.

In general I approve of the strategy but can the following please be included.

Detection Limits

Please ensur that all detection limits used for groundwater assessment are below the applicable ANZECC 2000 levels.

Methane

Can methane levels be assessed in the monitoring bores also.

Groundwater

Analytes should also include ammonia, nitrate and major cations and anions.

Also please instal at least and sample three groundwater wells with one located upgradient of the site. Wells should be surveyed and gauged to allow groundwater flow direction to be established.

Please l;et me know when the field work is planned.

Yours faithfully,
ENVIRON Australia Pty Ltd

Phillip Hitchcock
Manager – Hunter Region
NSWEPA Accreditated Contaminated Site Auditor

ENVIRON

Thursday, 26 July 2007 Ref: 32-0019

AUSTRALAND
Shell Cove Office
P.O.Box A148
Shellharbour, NSW, 2529

Attention: Glenn Colquhoun

Dear Glenn,

Review of URS 'Pre-Validation Report'
Shell Cove Boatharbour

I have undertaken a review of the following document:

- URS Australia Pty Ltd (May 2007) *Draft Report, Shell Cove Waste Relocation Project, Pre-Validation Report* (Ref: 43167202).

I make the following comments regarding the above mentioned document:

- In general, the report is very brief and lacking detailed discussion;
- Landfill gas levels have been monitored during drilling, however, no discussion of the results has been provided. It is noted that some landfill gas readings appear to be erroneous (i.e. CH_4 > 100%);
- Please provide a discussion of the waste composition, particularly with regard to putrescibles materials;
- It appears as though URS have used the 95% UCL as a basis for not undertaking remediation in the vicinity of numerous sampling locations where significant contamination was detected (e.g. TPH C10-C36, benzo(a)pyrene, Total PAH). This approach is not entirely appropriate as the application of the 95% UCL is not suitable where:
  - The concentration of a contaminant at a location is identified at a concentration 2.5 x greater than the criteria; and/or
  - The standard deviation of a contaminant is more than 50% of the criteria.

  Please review the application of the 95% UCL, provide an appropriate discussion of soil analytical results and identify areas where natural soils may require remediation.
- What is the significance of the significant Lead contamination identified in BH49;

- A more detailed discussion of the potential phytotoxicity of natural soils is required. Are the elevated Heavy Metals in natural soils likely to be related to the waste mass? What is the apparent lateral and vertical extent of elevated Heavy Metals in natural soils? Wil some natural soils require to be removed?

- There is effectively no discussion of groundwater. Please provide an appropriate discussion of the Site hydrolgeogolgy (i.e. depth, flow direction, water bearing zone characteristics) and the significance of groundwater contamination;

- URS's discussion of Heavy Metal results in groundwater does not correlate well with the data presented in Table 3A. Please revise;

- The proposed contour plan for the excavation does not correlate well with the observed subsurface conditions presented in the borehole logs. Please review and revise accordingly. It is noted that the proposed contour plan is likely to require revision to allow for remediation of significantly impacted natural soils;

- The first page of Table 3A is incomplete (missing guidelines);

- The PQL's for PAHs in groundwater are above ANZECC (2000) criteria and as such are inapparopriately high. The Auditor requested (31/8/2006) that URS ensure appropriate PQL's were used for PAH's. The Auditor notes that PQL's were inappropriately high for some OCP and OPP compounds. Please justify not using appropriate PQL's;

- Groundwater samples have not been analysed for Nitrate and Ammonia as requested by the Auditor (31/8/2006). Nitrate and Ammonia are key analytes of concern for landfill sites, please justify not undertaking appropriate analysis;

- The location of MW3 is not displayed on Figure 2, please revise;

- There are numerous quality control non-conformances for each laboratory batch a more detailed discussion of the significance of these non-conformances is required.

If you have any questions regarding the above, please contact me on (02) 4934 4354.

Yours faithfully,
ENVIRON Australia Pty Ltd

Phillip Hitchcock
Manager – Hunter Region
NSW EPA Accredited Site Auditor (Contaminated Land)

ENVIRON

Wednesday, 12 August 2009 Our Ref: AS130019

Australand
Shell Cove Office
PO Box A148
Shellharbour NSW 2529

Attention: Glenn Colquhoun

Dear Sir,

Re: Review Advice – Shell Cove Boatharbour

I have undertaken a review of the following documents:

- URS Australia Pty Ltd (February 2009) Shell Cove Waste Relocation Project, Pre-Validation Report (ref: 43167202);
- URS Australia Pty Ltd (April 2009) Draft Report, Remediation, Characterisation and Validation Report, Shell Cove Waste Relocation Project, Shell Cove, NSW (ref: 43167202).

Can you please advise the purpose of the audit, ie is it required to verify that the validation report is suitable **or** that the site is now, in its current state, suitable for standard residential use.

Comments regarding the abovementioned reports are as follows:

Pre-Validation Report

- The Auditor notes that the majority of the comments made in the Interim Advice dated 26 July 2007 appear to have been addressed;
- Section 6.1 – What are the 95% UCLmean concentration and standard deviation result in the discussion of the lead exceedance at BH49? Please include these values in the text;
- Section 6.1 – The discussion regarding the EIL exceedences has not included results of leach tests. Do you think the heavy metals are likely to be available in the pore fluid based on the leach test results? Section 6.2 – The significance of the landfill gas results has not been discussed;
- Section 6.3 - Please provide an appropriate discussion of the Site hydrolgeogolgy (i.e. depth, flow direction, water bearing zone characteristics).

Remediation, Characterisation and Validation Report

- Section 8.2 – What was the uniform stratigraphy in the walls of the excavation?;
- Section 9.6 – Discussion of Wall Characterisation Results, bullet point 3 – reference to natural materials is incorrect, should be reference to waste and road base material;

- Section 9.6 – Discussion of Wall Characterisation Results, bullet point 4 – WP17 also has a zinc result above 300ppm;
- Section 9.6 – Discussion of Wall Characterisation Results, bullet point 5 – reference to WB16 and WB20 should be changed to WP16 and WP20;
- Section 9.6 – Discussion of Wall Characterisation Results, bullet point 6 – reference to Heavy Metal results in the parent rock is not relevant given this is a discussion of waste and road base material;
- Table 9 – Please include the guideline values for Anthracene, Benzo(a)pyrene and Fluoranthene;
- Please assess groundwater using the DEC 2007 Groundwater guidelines ie determine the relevant beneficial uses and assess against them.
- The PQLs for PAHs in groundwater are above ANZECC (2000) criteria and as such are inappropriately high. The Auditor requested (31/8/2006) that URS ensure appropriate PQL's were used for PAHs. The Auditor notes that PQLs were inappropriately high for some OCP and OPP compounds. Please justify not using appropriate PQLs and discuss the significance of this;
- Please provide a suitable justification for relying on a 'groundwater' sample collected at the surface rather than from a well. Could you please assess if the water is of the same geochemical type as the pre-validation groundwater (eg Piper plot) and wether redox and pH conditions are similar. I am concerned that ammonia would not be stable in a oxidated environment and the results are likely to be understated.
- There was no QA/QC undertaken for the 'groundwater' sampling. The SAQP for the work identified that field duplicate, field triplicate, rinsate blanks and trip blanks would be taken. As there is no way of verifying the quality of the results I cannot rely on them especially considering that concentrations have changed markedly since the pre-validation results. Further sampling from a properly constructed well with appropriate QA is required.
- Please include a discussion of the Acid Sulfate Soils remaining at the Site, particularly in the context of their potential affect on buildings and structures. Ie is the site currently detrimental to buildings and structures. Review of the Cl/SO4 ratio in the groundwater pre and post validation may aid in this and also reference to the AS 2159 (1995) Piling – Design and Installation.
- Please include a discussion on the impact on groundwater on buildings and structures eg is it corrosive, aggressive to concrete etc

Should you have any questions regarding the above, please contact me via email or phone.

Yours faithfully,

Phillip Hitchcock

NSW DECC Accredited Site Auditor (Contaminated Land)

URS

31 August 2009
Project No. 43167202

Environ
Suite 2, Level 1,
456 High Street,
Maitland 2320

Attention: Phil Hitchcock
NSW DECCW Accredited Site Auditor (Contaminated Land)

Dear Phil,

Subject: Response to Review Advice - Shell Cove Old Landfill Validation

In response to your letter dated 12 August 2009 and our subsequent telephone discussion, URS provides the following responses to your review comments for the Pre Validation and Validation Reports for the Old Landfill for the Shell Cove Waste Relocation Project.

The following table briefly outlines URS' response, in addition please find enclosed, revised versions of the report text in track changes for your ease of reference.

Table 1 Summary of Responses

No.	Auditor Comment	URS response
1	Can you please advise the purpose of the audit, ie is it required to verify that the validation report is suitable **or** that the site is now, in its current state, suitable for standard residential use.	That the site now in it's current state is suitable for residential land use.
	Pre-Validation Report	
2	The Auditor notes that the majority of the comments made in the Interim Advice dated 26 July 2007 appear to have been addressed.	Agreed.
3	Section 6.1 – What are the 95% UCL mean concentration and standard deviation result in the discussion of the lead exceedance at BH49? Please include these values in the text.	39.85 mg/kg and 16.88 mg/kg respectively. Also included in report text.
4	Section 6.1 – The discussion regarding the EIL exceedences has not included results of leach tests. Do you think the heavy metals are likely to be available in the pore fluid based on the leach test results?	As discussed on the phone, leach tests have not been undertaken.
5	Section 6.2 – The significance of the landfill gas results has not been discussed.	Included in report text.

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6	Section 6.3 - Please provide an appropriate discussion of the Site hydrolgeogolgy (i.e. depth, flow direction, water bearing zone characteristics).	Included in report text.
	Remediation, Characterisation and Validation Report	
7	Section 8.2 – What was the uniform stratigraphy in the walls of the excavation?	Included in report text.
8	Section 9.6 – Discussion of Wall Characterisation Results, bullet point 3 – reference to natural materials is incorrect, should be reference to waste and road base material.	Corrected.
9	Section 9.6 – Discussion of Wall Characterisation Results, bullet point 4 – WP17 also has a zinc result above 300ppm.	Corrected.
10	Section 9.6 – Discussion of Wall Characterisation Results, bullet point 5 – reference to WB16 and WB20 should be changed to WP16 and WP20.	Corrected.
11	Section 9.6 – Discussion of Wall Characterisation Results, bullet point 6 – reference to Heavy Metal results in the parent rock is not relevant given this is a discussion of waste and road base material.	Corrected.
12	Table 9 – Please include the guideline values for Anthracene, Benzo(a)pyrene and Fluoranthene.	Added.
13	Please assess groundwater using the DEC 2007 Groundwater guidelines ie determine the relevant beneficial uses and assess against them.	Refer Section 9.7 of the report.
14	The PQLs for PAHs in groundwater are above ANZECC (2000) criteria and as such are inappropriately high. The Auditor requested (31/8/2006) that URS ensure appropriate PQL's were used for PAHs. The Auditor notes that PQLs were inappropriately high for some OCP and OPP compounds. Please justify not using appropriate PQLs and discuss the significance of this.	Discussion added. Refer Section 9.7 of the report.
15	Please provide a suitable justification for relying on a 'groundwater' sample collected at the surface rather than from a well. Could you please assess if the water is of the same geochemical type as the pre-validation groundwater (eg Piper plot) and whether redox and pH conditions are similar. I am concerned that ammonia would not be stable in an oxidated environment and the results are likely to be understated.	Refer Section 9.7 of the report.
16	There was no QA/QC undertaken for the 'groundwater' sampling. The SAQP for the work identified that field duplicate, field triplicate, rinsate	Sample has been included for indicative purposes only. It is not possible to install a

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	blanks and trip blanks would be taken. As there is no way of verifying the quality of the results I cannot rely on them especially considering that concentrations have changed markedly since the pre-validation results. Further sampling from a properly constructed well with appropriate QA is required.	well at the site due to access issues.
17	Please include a discussion of the Acid Sulfate Soils remaining at the Site, particularly in the context of their potential affect on buildings and structures i.e. is the site currently detrimental to buildings and structures. Review of the Cl/SO4 ratio in the groundwater pre and post validation may aid in this and also reference to the AS 2159 (1995) Piling – Design and Installation.	Refer Section 9.4 of the report for soil and Refer Section 9.7 of the report for groundwater for discussion. URS notes that appropriate analysis to enable comparison with relevant guidelines to conclusively draw conclusion on this point has not been undertaken by URS as part of the Pre Validation and Validation Scope of Work.
18	Please include a discussion on the impact on groundwater on buildings and structures e.g. is it corrosive, aggressive to concrete etc	Refer Section 9.7 of the report. URS notes that appropriate analysis to enable comparison with relevant guidelines to conclusively draw conclusion on this point has not been undertaken by URS as part of the Pre Validation and Validation Scope of Work.

Should you wish to discuss further, please do not hesitate to contact me on 0418 171 588.

Yours sincerely
URS Australia Pty Ltd

Jacinta McMahon
Principal Engineer

cc: Glenn Colquhoun, Australand

URS

21 October 2009
Project No. 43167202

Environ

Attention: Phil Hitchcock

Dear Phil,

Subject: Shell Cove Exposure Classification Assessment

In response to your request for further consideration of the impacts of contaminants in groundwater and soil on building structures, URS has reviewed the available groundwater and soil data against Table 6.1 and 6.3 of AS2159-1995 Piling – design and installation. This assessment indicates an indicative exposure classification for Concrete and Steel at the site would be Non Aggressive to Mild. Durability shall therefore be allowed for in the design of concrete and steel building structures at the Site with consideration of this exposure classification.

This assessment is based on the following information and advice:

- Review of laboratory test results from the acid sulphate soils testing undertaken on estuarine sediments at the boatharbour site by Coffey (refer *Stage 2 Geotechnical and Acid Sulphate Soils Assessment and Groundwater Study, Coffey, 2004*). These results were as follows:

  — S_{KCl} (Potassium Chloride Extractable Sulphur) ranged between 0.01 and 0.10 %.

- Advice provided on 20 October 2009 by the laboratory Bio-Track Pty Ltd (This laboratory undertook the acid sulphate soils analytical testing for Coffey) as follows:

  — For this project convert between S_{KCl} % and SO_3 by diving S_{KCl} by 0.4.

- Based on this conversion, $S0_3$ in the estuarine soils at the boatharbour site ranged between 0.025 and 0.25 %.
- Groundwater results recorded as part of the validation and pre validation works (Sulfate ranged between 5 and 8 mg/L, pH greater than 5, chloride ranged between 472 and 2070 mg/L).

Limitations of this assessment:

- Assessment of the exposure classification for steel has been made in the absence of chloride data for the soil and resistivity data.
- Acid sulfate soils laboratory test data used for this assessment was sampled from the wider boatharbour site and is not specific to the Old Landfill site, however is considered to represent Site conditions generally. Estuarine sediment sampling locations EFV24, EFV22 and CGBH14 from the Coffey Report on the edge of the other side of the swamp some distance from the Site however have not been included in this assessment.

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Considering these limitations this assessment should be considered for indicative purposes only. The project geotechnical engineer should undertake their own assessment as part of the design works for the site.

Yours sincerely
URS Australia Pty Ltd

Jacinta McMahon
Principal Engineer

Appendix D
Analytical Lists and Methods

ANALYTICAL LISTS

HEAVY METALS (8)

Arsenic, Cadmium, Chromium, Copper, Nickel, Lead, Zinc, Mercury

POLYCYCLIC AROMATIC HYDROCARBONS

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.I)perylene.

BTEX

Benzene, Toluene, Chlorobenzene, Ethylbenzene, Meta- & para-Xylene, Ortho-Xylene.

TOTAL PETROLEUM HYDROCARBONS

C6-C9 Fraction, C10-C14 Fraction, C15-C28 Fraction, C29-C36 Fraction

VOLATILE ORGANIC COMPOUNDS

Monocyclic Aromatic Hydrocarbons

Benzene, Toluene, Ethylbenzene, meta- & para-Xylene, Styrene, ortho-Xylene, Isopropylbenzene, n-Propylbenzene, 1.3.5-Trimethylbenzene, sec-Butylbenzene, 1.2.4, Trimethylbenzene, tert-Burylbenzene, p-Isopropltoluene, n-Butylbenzene.

Fumigants

2.2-Dichloropropane, 1.2-Dichloropropane, cis-1.3-Dichloropropylene, trans-1.3, Dichloropropylene, 1.2-Dibromoethane (EDB).

Halogenated Aliphatic Hydrocarbons

Dichlorodifluoromethane, Chloromethane, Vinyl chloride, Bromoethane, Chloroethane, Trichlorofluoromethane, 1.1-Dichloroethene, Iodomethane, trans 1.2-Dichloroethene, 1.1 Dichloroethene, 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, 1.1.2-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, Hexachlorobutadiene.

Halogenated Aromatics Hydrocarbons

Chlorobenzene, Bromobenzene, 2-Chlorotoluene, 4-Chlorotoluene, 1.3-Dichlorobenzene, 4-Dichlorobenzene, 1.2-Dichlorobenzene, 1.2.4-Trichlorobenzene,

1.2.3-Trichlorobenzene, Trihalomethanes (Volatiles), Chloroform, Bromodichloromethane, Dibromochloromethane, Bromoform, Napthalene.

Trihalomethanes (Volatiles)

Chloroform, Bromodichloromethane, Dibromochloromethane, Bromoform, Napthalene.

SEMIVOLATILE ORGANIC COMPOUNDS

Phenols

Phenol, 2-Chlorophenol, 2-Methylphenol, 4-Methylphenol, 2-Nitrophenol, 2.4-Dimethylphenol, 2.4-Dichlorophenol, 2.6-Dichlorophenol, 4-Chloro-3-methylphenol, 2.4.6-Trichlorophenol, 2.4.5-Trichlorophenol, Pentachlorophenol

Organochlorine Pesticides

alpha-BHC, HCB, beta-BHC & gamma-BHC, delta-BHC, Heptachlor, Aldrin, Heptachlor epoxide, Endosulfan 1, Hexachlorobenzene (HCB), Trans-Chlordane, Cis-Chlordane, Endrin-aldehyde, Endrine Ketone, methoxychlor, 4.4'-DDE, Dieldrin , Endrin, Endosulfan 11, 4.4'-DDD, Endosulfan sulphate, 4.4'-DDT

Organophosphorus Pesticides

Methanesulfonate methyl, Methanesulfonate ethyl, Dichlorvos, Demeton-s-methyl, Monocrotophos, cis-Isosafrole, trans-Isosafrole, Safrole, Dimethoate, Diazinon, Chlorpyrifos methyl, Parathion methyl, Malathion, Fenthion, Chlorpyrifos, Parathion, Pirimiphos ethyl, Chlorofenvinphos-E, Bromophos-ethyl, Fenamiphos, Chlorfenvinphos-Z, Prothiofos, Ethion, Carbophenothion, Methyl azinphos.

Polychlorinated Biphenyls

Arochlor 1016, Arochlor 1232, Arochlor 1242, Arochlor 1248, Arochlor 1254 and Arochlor 1260.

ANALYTICAL METHODS

Analytical Group	ENVIROLAB	SGS
BTEX	GC.16: Methanol extraction into water, analysis by P&T/GC-MS (soil) GC. 16: P&T/GC-MS (water)	SE-017: P&T/GC/FID/PID
TPH C6-C9	GC.16: Methanol extraction into water, analysis by P&T/GC-MS (soil) GC. 16: P&T/GC-MS (water)	SE-017: P&T/GC/FID/PID
TPH C10-C36	GC.3: DCM/Acetone extraction, GC-FID analysis (soil) GC.3: DCM extraction, /GC-FID analysis (water)	SEO-020: extraction with DCM/Acetone. Analysis by GC.
PAHs	GC.12: DCM/Acetone extraction, GC-MS analysis (soil) GC.12: DCM extraction, GC-MS analysis (water)	SEO-030: DCM/Acetone extraction. Analysis by GC/MS.
Heavy Metals (As, Cd, Cr, Cu, Pb, Ni, Zn)	METALS.20: ICP/AES	SEM-010: ICP-AES
Heavy Metals (Hg)	METALS.21: CVGAAS	SEM-005: CVGAAS
VOCs	GC.14: Methanol extraction into water, analysis by P&T/GC-MS (soil) GC. 14: P&T/GC-MS (water)	SEO-019: P&T, GC/MS
OCP, OPP and PCB	GC.5: Hexane/Acetone extraction, analysis by GC-ECD (soil) GC.5: DCM extraction, analysis by GC-ECD (water)	SEO-005: Acetone/Hexane extraction. Analysis by GC/ECD.
Asbestos	ASB.1: PLM/DST	-

NOTES: CVGAAS – Cold Vapour Generation Atomic Absorption Spectroscopy, DST – Dispersion Staining Technique, ECD – Electron Capture Detection, FID – Flame Ionisation Detection, GC – Gas Chromatography, MS – Mass Spectrometry, Polarised Light Microscopy, P&T – Purge & Trap, PID – Photo Ionisation Detection, Polarised Light Microscopy / Dispersion Staining Techniques, SIM – Selective Ion Mode

Appendix E
Review of Quality Assurance / Quality Control

Review of Quality Assurance / Quality Control – URS 2009a and 2009b Reports

Aspect	Data Quality Indicator	Comment
Field QA Program	Soil sampling methodology appropriate with respect to COC.	DQI requirement met, samples collected from SPT for boreholes and directly from walls and base of the excavation for validation sampling.
	Soil samples screened for contamination using visual/olfactory observations and/or field instruments (i.e. PID for volatiles).	DQI requirement met
	Soil sampling logs provided indicating subsurface conditions, sample collection depth and evidence of contamination (at a minimum).	DQI requirement met, logs included in Appendices.
	Cross contamination avoided through use of disposal gloves during soil sampling.	DQI requirement met, disposable gloves used.
	Monitoring wells constructed in general accordance with DEC guidelines (e.g. constructed using Class 18 uPVC, screened across water bearing zone, not screened across multiple water bearing zones, screen interval backfilled with coarse sand/gravel, bentonite seal constructed at/immediately above screen/casing interface).	DQI requirement met
	Groundwater wells developed and allowed 7 days to equilibrate prior to sampling.	DQI requirement met
	Groundwater sampling methodology appropriate with respect to COC and in accordance with relevant guidance (e.g. measurement of water quality parameters, purging sufficient water prior to sampling).	DQI requirement met
	Groundwater samples field filtered using a 0.45µm filter for heavy metals analysis.	DQI requirement met
	Groundwater sampling logs provided verifying reported groundwater sampling methodology.	DQI requirement met, groundwater sampling logs included in Appendices.
	Calibration certificates provided for field instruments used.	DQI requirement met, calibration sheets included in Appendices.
	Cross contamination avoided through appropriate decontamination of reused sampling equipment.	DQI requirement met, decontamination of reused sampling equipment completed using Decon90.
	Samples collected into laboratory supplied and appropriately preserved sampling containers.	DQI requirement met, samples collected into laboratory supplied containers.

Aspect	Data Quality Indicator	Comment
	Samples placed in a chilled insulated container (ideally <4°C) during sample handling and transport to laboratory.	DQI requirement met
	Samples transported to laboratory under Chain of Custody conditions (signed by representative of Consultant/s).	DQI requirement met, COCs included in Appendices
	Ensure comparability through experienced sampler as well as consistent sampler, sampling methods and climatic conditions during project.	DQI requirement met
Field QC Program	Blind duplicates collected/analysed at a rate of ≥5%.	DQI requirement met, 10 intra-laboratory duplicate samples were collected for 98 primary soil samples for the pre-validation works, 1 intra-laboratory duplicate sample was collected for 6 primary groundwater samples, 3 intra-laboratory duplicate samples for 29 primary soil samples for the validation works.
	Split duplicates collected/analysed at a rate of ≥5%.	DQI requirement met, 6 inter-laboratory duplicate samples were collected for 98 primary soil samples for the pre-validation works, 1 inter-laboratory duplicate sample was collected for 6 primary groundwater samples, 6 inter-laboratory duplicate samples were collected for 29 primary soil samples for the validation works.
	Rinsate blanks collected/analysed at a rate of 1 per reused piece of sampling equipment per batch.	DQI requirement met, 3 rinsate blank samples collected during pre-validation soil sampling, 1 rinsate blank sample collected during groundwater sampling, 1 rinste blank sample collected during the validation works
	Trip Blanks collected/analysed at a rate of 1 per batch (important where CoC includes volatiles).	DQI requirement partially met, 3 trip blanks were collected during pre-validation soil sampling, 1 trip blank and 1 trip spike collected during groundwater sampling, 1 trip blank and 1 trip spike were collected during the validation works.
	Trip Spikes (important where CoC includes volatiles).	
	Field Blanks collected/analysed at a rate of 1 per batch (important where CoC includes volatiles).	
Field QC Results	Blind duplicate RPD% ≤50%.	DQI requirement not met, RPDs for Copper and Zinc in one primary/ duplicate pair and Benzo(a)anthracene, Fluoranthene, phenanthrene and Pyrene in one primary/ duplicate pair were >50%. This is considered to be due to a combination

Aspect	Data Quality Indicator	Comment
		of low metals and PAH concentrations and the heterogeneity of the fill material. These RPD exceedences are not considered to affect the usability of the data.
	Split duplicate RPD% ≤50%.	DQI requirement not met, RPDs for Copper in two primary/ duplicate pairs and Zinc in one primary/ duplicate pair was >50%. This is considered to be due to a combination of low metals concentrations and the heterogeneity of the fill material. These RPD exceedences are not considered to affect the usability of the data.
	CoC <PQL's in Rinsate Blank.	DQI requirement not met, Phenol, Cadmium, Chromium, Copper, Nickel, Lead and Zinc were detected above PQLs in one or more rinsate blanks in the pre-validation sampling.
	CoC < PQL's in Trip Blank.	DQI requirement met
	Trip Spike recoveries 70% to 130%.	DQI requirement met
	CoC <PQL's in Field Blank.	DQI requirement met
Laboratory QA	Samples received by laboratory under Chain of Custody conditions (signed by representative of Laboratory)	DQI requirement met
	Laboratories NATA accredited and utilised NATA endorsed analytical methods.	DQI requirement met
	Comparability of data through consistency in laboratories/analytical methods throughout project.	DQI requirement met
	Samples extracted and analysed within recommended holding times.	DQI requirement met
	PQL's for CoC below respective Environmental Quality Criteria.	DQI requirement partially met, PAH, OCP and OPP PQLs were higher than respective Environmental Quality Data for groundwater. As these contaminants were not considered contaminants of concern in groundwater and soil results were generally below PQLs, this was not considered significant.
Laboratory QC	Preparation and analysis of laboratory QC samples at rates in general accordance with NEPM (1999), including surrogate spikes, matrix spikes, matrix spike duplicates,	DQI requirement met

Aspect	Data Quality Indicator	Comment
Program	laboratory duplicates, method blanks (as applicable).	
Laboratory QC Results	Surrogate spike recoveries 70% to 130% (exceptions for some contaminants).	DQI requirement generally met, surrogate recoveries for VOCs for groundwater and soil were high. The high recoveries were considered marginal and did not affect the overall data quality. Matrix spike recoveries for groundwater sampling were low for OPP and OCP. Matrix spike recoveries for soil sampling were high for OPP and OCP. These recoveries were considered marginal and did not affect the overall data quality.
	Matrix spike recoveries 70% to 130% (exceptions for some contaminants).	
	Contaminants <PQL's in Method Blanks.	
	Matrix Duplicate / Laboratory Duplicate RPD% ≤50%.	
	95% of laboratory QA results within DQI's.	DQI requirement met
Consultant Conclusion regarding data usability	Data assessed with reference to DQO's and DQI's, with clear statement provided regarding usability of data, including any limitations of data use.	DQI requirement met, data usability assessed and reported

Appendix F
Environmental Quality Criteria

Soil Investigation Levels for Urban Redevelopment Sites in NSW (NSW DEC 2006)

APPENDIX II
Soil investigation levels for urban development sites in NSW

	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)	
Substance	**Column 1**	**Column 2**	**Column 3**	**Column 4**	**Column 5**
Metals and metaloids					
Arsenic (total)	100	400	200	500	20
Beryllium	20	80	40	100	–
Cadmium	20	80	40	100	3
Chromium (III)[4]	12%	48%	24%	60%	400
Chromium (VI)	100	400	200	500	1
Cobalt	100	400	200	500	–
Copper	1,000	4,000	2,000	5,000	100
Lead	300	1,200	600	1,500	600
Manganese	1,500	6,000	3,000	7,500	500
Methyl mercury	10	40	20	50	–
Mercury (inorganic)	15	60	30	75	1[5]
Nickel	600	2,400	600	3,000	60
Zinc	7,000	28,000	14,000	35,000	200
Organics					
Aldrin + dieldrin	10	40	20	50	–
Chlordane	50	200	100	250	–
DDT + DDD + DDE	200	800	400	1,000	–
Heptachlor	10	40	20	50	–
PAHs (total)	20	80	40	100	–
Benzo(a)pyrene	1	4	2	5	–
Phenol[6]	8,500	34,000	17,000	42,500	–
PCBs (total)	10	40	20	50	–
Petroleum hydrocarbon components[7]					
> C16–C35 (aromatics)	90	360	180	450	–
> C16–C35	5,600	22,400	11,200	28,000	–
> C35 (aliphatics)	56,000	224,000	112,000	280,000	–
Other					
Boron	3,000	12,000	6,000	15,000	–[8]
Cyanides (complex)	500	2,000	1,000	2,500	–
Cyanides (free)	250	1,000	500	1,250	–

Soil Investigation Levels for Urban Redevelopment Sites in NSW (NSW DEC 2006) (cont.)

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)

Table 3 Threshold concentrations for sensitive land use — soils

Analytes	Threshold concentrations [a] (mg/kg dry wt)	Sources
TPH [b, c]: C6–C9	65	see note [d]
TPH[c]: C10–C40 (C10–C14, C15–C28, C29–C40)	1,000	see note [e]
Benzene	1 [f]	ANZECC/NHMRC 1992
Toluene	1.4 [g] / 130 [h]	Netherlands 1994
Ethyl benzene	3.1 [i] / 50 [j]	Netherlands 1994
Total Xylenes	14 [k] / 25 [j]	Netherlands 1994
Phenol	— [l]	— [l]
Total Lead	300	ANZECC/NHMRC 1992
Benzo(a)pyrene	1	ANZECC/NHMRC 1992
Total PAHs [m]	20	ANZECC/NHMRC 1992

NB. Scientifically justified alternative threshold concentrations may be acceptable. Thresholds may be reviewed as new scientific information becomes available.

Explanatory notes for Table 3

a Refer to relevant source documents for details.

Definitions of terms used in discussion of Netherlands criteria (Denneman 1993) are:

- The **maximum permissible concentration** (MPC) is the 'concentration of a toxic substance that fully protects 95% of the species in an ecosystem'.
- The **intervention level** represents 'a level where action is needed because impermissible risks may occur. It depends on other than chemical characteristics if action should take place immediately or not'. In the case of ecological risk, the intervention level 'fully protects 50% of the species in an ecosystem'.

Further information regarding MPCs and intervention levels may be found in Denneman & van den Berg 1993.

The Netherlands sourced values in Table 2 refer to soil with 10% natural organic matter content. These threshold concentrations must be adjusted for the particular natural organic matter content of the specific site. The natural organic matter content in soil may be determined using the Walkley and Black Method, AS 1289.D1.1–1977, *Determination of the Organic Matter Content of a Soil (Standard Method)*.

The threshold concentrations for ethyl benzene and xylenes to protect terrestrial organisms have been derived from aquatic toxicological data using equilibrium partitioning. Investigations have shown (Van Gestal & Ma 1993) that in the case of earthworms, toxicity is related to the pore water contaminant concentration. The LC_{50} pore water concentrations for several compounds have been favourably compared with LC_{50} aquatic toxicological data for fish.

Threshold Concentration for Sensitive Land Use – Soils Guidelines for Assessing Service Station Site (NSW EPA 1994) (cont.)

Explanatory notes for Table 3 (cont.)

The derivations of criteria adopted as threshold concentrations have not explicitly taken account of chemical mixtures. The potential impact of mixtures of chemicals should be assessed on a site-specific basis.

The potential for the generation of odours may mean that lower thresholds than those listed in Table 2 are required for volatile compounds.

b Total petroleum hydrocarbons

c Approximate range of petroleum hydrocarbon fractions: petrol C6–C9, kerosene C10–C18, diesel C12–C18 and lubricating oils above C18.

d The TPH C6–C9 threshold concentration, i.e. 65 mg/kg, applies to soil containing 10% natural organic matter. This concentration has been calculated assuming the following:

- that there has been a fresh spill of petrol
- that the aromatic content of the petrol is 30%
- that the resultant BTEX soils concentrations are at their lower thresholds.

TPH C6–C9 concentrations above the relevant threshold may indicate that BTEX concentrations are above their thresholds. This threshold concentration should be interpreted as only an approximate potential indicator of contamination.

e The TPH C10–C40 threshold concentration is based on a consideration both of the Netherlands Intervention Level for the TPH C10–C40 range and on commonly reported analytical detection limits. The Netherlands intervention value is 5,000 mg/kg dry weight.

f A lower benzene threshold concentration may be needed to protect groundwater.

g The toluene threshold concentration is the Netherlands MPC to protect terrestrial organisms in soil. This value was obtained by applying a US EPA assessment factor to terrestrial chronic No Observed Effect Concentration (NOEC) data. The MPC is an 'indicative' value (Van de Plassche *et al.* 1993; Van de Plassche & Bockting 1993).

h Human health and ecologically based protection level for toluene. The threshold concentration presented here is the Netherlands intervention value for the protection of terrestrial organisms. Other considerations such as odours and the protection of groundwater may require a lower remediation criterion.

i The ethyl benzene threshold concentration is the Netherlands MPC for the protection of terrestrial organisms in soil. No terrestrial ecotoxicological data could be found for use in the Netherlands criteria derivation. Therefore, equilibrium partitioning has been applied to the MPC for water to obtain estimates of the MPC for soil. The MPC for water has been derived from aquatic ecotoxicological data (Van de Plassche *et al.* 1993; Van de Plassche & Bockting 1993).

j Human health based protection level for ethyl benzene or total xylenes as shown. The threshold concentration presented here is the Netherlands intervention value. Other considerations such as odours and the protection of groundwater may require a lower remediation criterion

k The xylene threshold concentration is the Netherlands MPC for the protection of terrestrial organisms in soil. No terrestrial ecotoxicological data could be found for use in the Netherlands criteria derivation. Therefore, equilibrium partitioning has been applied to the MPC for water to obtain an estimate of the MPC for soil. The MPC for water has been derived from aquatic ecotoxicological data. The concentration shown applies to total xylenes and is based on the arithmetic average of the individual xylene MPCs (Van de Plassche *et al.* 1993; Van de Plassche & Bockting 1993).

l Phenol contamination is not expected to be significant at service station sites. Phenol has been included in the analyte list because it is a potential constituent of waste oil. The potential impact of phenol should be evaluated on a site-specific basis. Phenol may have a significant impact on waters.

m Polycyclic aromatic hydrocarbons

Trigger Values (TV) for Screening Fresh 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)	24/13	ANZECC (2000) 95% protection levels.
Cadmium – Cd	0.2	
Nickel – Ni	11	
Manganese	1900	ANZECC (2000) 95% protection levels (figure may not protect key test species from chronic toxicity)
Mercury – Hg	0.06	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Chromium – Cr (III/VI)	3.3/1.0	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000) for Cr (III)
Cobalt	2.8	
Copper – Cu	1.4	ANZECC (2000) 95% protection levels.
Lead – Pb	3.4	
Zinc – Zn	8.0	
Aromatic Hydrocarbons		
Benzene	950	Moderate reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Toluene	180	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
Ethylbenzene	80	
m-xylene	75	
o-xylene	350	Moderate reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
p-xylene	200	
Polycyclic Aromatic Hydrocarbons		
Naphthalene	16	ANZECC (2000) 95% 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	
Organochlorine Pesticides		

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
Cadmium – Cd	0.7	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Nickel – Ni	7	
Mercury – Hg	0.1	
Manganese	80	Low reliability trigger values (derived from the mollusc figure)
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
Anthracene	0.01	Low reliability trigger values from Volume 2 of ANZECC (2000)
Phenanthrene	0.6	
Fluroanthene	1	ANZECC (2000) 99% protection level due to potential for bio-accumulation or acute toxicity to particular species.
Benzo (a) pyrene	0.1	
Chlorinated Alkanes		
Tetrachloroethene - PCE	70	Low reliability trigger values (95% level of protection) from Volume 2 of ANZECC (2000)
1,1,2 Trichlorothene- TCE	330	
1,1,2 Trichlorothene- 1,1,2-TCE	330	
Vinyl chloride (chloroethene)	100	
1,1,1 Trichloroethane – 1,1,1-TCA (111-TCE)	270	
1,1 Dichloroethene	700	

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004)

Table 10.9 Guidelines for microbial quality - monitoring of E.coli (or thermotolerant coliforms)

Guideline	No sample of drinking water should contain any E. coli (or thermotolerant coliforms) (minimum sample 100 mL).
Action	If E. coli (or thermotolerant coliforms) are detected, then irrespective of the number of organisms, both the following steps should be taken immediately: 1) Another sample (a repeat sample) should be taken from the same site and from the immediate upstream treated sources of supply and tested for the presence of E. coli (or thermotolerant coliforms). – If the additional samples are negative for E. coli (or thermotolerant coliforms), then routine sampling can resume, but only after step 2 (below) has been completed. – If any additional sample is positive for E. coli (or thermotolerant coliforms), then increased disinfection and a full sanitary survey should be implemented immediately. The sanitary survey should include a review of the integrity of the system. AND 2) Disinfection should be increased and/or an investigation undertaken to determine possible sources of contamination. These might include a breakdown in disinfection, a mains break, interruption to the supply, surges in supply, or deliberate or accidental contamination of the system. The investigation may include a visual inspection of the system and associated service reservoirs by trained personnel. When found, the source of contamination should be eliminated.

Table 10.10 Guideline values for physical and chemical characteristics

Characteristic	Guideline values*		Comments
	Health	Aesthetic[a]	
Acrylamide	0.0002		Minor impurity of polyacrylamide, used sometimes as a flocculant aid.
Aluminium (acid-soluble)	[c]	0.2	Guideline value based on post-flocculation problems; < 0.1 mg/L desirable. Lower levels needed for renal dialysis. No health-based guideline value can be established currently.
Ammonia (as NH_3)	[c]	0.5	Presence may indicate sewage contamination and/or microbial activity. High levels may corrode copper pipes and fittings.
Antimony	0.003		Exposure may rise with increasing use of antimony-tin solder.
Arsenic	0.007		From natural sources and mining/industrial/agricultural wastes.
Asbestos	[c]		From dissolution of minerals/industrial waste, deterioration of asbestos-cement pipes in distribution systems. No evidence of cancer when ingested (unlike inhaled asbestos).
Barium	0.7		Primarily from natural sources.
Benzene	0.001		Could occur in drinking water from atmospheric deposition (motor vehicle emissions) and chemical plant effluent. Human carcinogen.
Beryllium	[c]		From weathering of rocks, atmospheric deposition (burning of fossil fuels) discharges.
Boron	4		From natural leaching of minerals and contamination. < 1 mg/L in uncontaminated sources; higher levels may be associated with seawater intrusion.
Bromate	0.02		Possible byproduct of disinfection using ozone, otherwise unlikely to be found in drinking water.
Cadmium	0.002		Indicates industrial or agricultural contamination; from impurities in galvanised (zinc) fittings, solders and brasses.
Carbon tetrachloride	0.003		Sometimes occurs as impurity in chlorine used for disinfection (it is not a disinfection byproduct).

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004) (cont.)

Table 10.10 Guideline values for physical and chemical characteristics (Continued)

Characteristic	Guideline values*		Comments
	Health	Aesthetic	
Dichloroethenes			Rarely found in drinking water; found occasionally in groundwater from wells heavily contaminated by solvents.
1,1-dichloroethene	0.03		
1,2-dichloroethene	0.06		
Dichloromethane (methylene chloride)	0.004		Widely used solvent, commonly found in ground and surface waters overseas. Volatilises from surface waters and biodegrades in the atmosphere
Dissolved oxygen	Not necessary	> 85%	Low concentrations allow growth of nuisance microorganisms (iron/manganese/sulfate/nitrate-reducing bacteria) causing taste and odour problems, staining, corrosion. Low oxygen concentrations are normal in groundwater supplies and the guideline value may not be achievable.
Epichlorohydrin	0.0005[4]		Used in manufacture of some resins used in water treatment.
Ethylbenzene	0.3	0.003	Natural component of petrol and petroleum products.
Ethylenediamine tetraacetic acid (EDTA)	0.25		Metal-complexing agent widely used in industry and agriculture, and as a drug in chelation therapy.
Fluoride	1.5		Occurs naturally in some water from fluoride-containing rocks. Often added at up to 1 mg/L to protect against dental caries. > 1.5 mg/L can cause dental fluorosis. > 4 mg/L can cause skeletal fluorosis.
Formaldehyde	0.5		Byproduct of ozonation.
Haloacetonitriles			Byproduct of chlorination.
dichloroacetonitrile	<		
trichloroacetonitrile	<		
dibromoacetonitrile	<		
bromochloroacetonitrile	<		
Hardness (as $CaCO_3$)	Not necessary	200	Caused by calcium and magnesium salts. Hard water is difficult to lather. < 60 mg/L $CaCO_3$ soft but possibly corrosive. 60-200 mg/L $CaCO_3$ good quality. 200-500 mg/L $CaCO_3$ increasing scaling problems. > 500 mg/L $CaCO_3$ severe scaling.
Hexachlorobutadiene	0.0007		Industrial solvent.
Hydrogen sulfide	<	0.05	Formed in water by sulfate-reducing microorganisms or hydrolysis of soluble sulfide under anoxic conditions. Obnoxious 'rotten egg' odour, threshold 0.05 mg/L.
Iodine	<		Can be used as an emergency water disinfectant. Taste threshold 0.15 mg/L.
Iodide	0.1		From mineral and salt deposits.
Iron	<	0.3	Occurs naturally in water, usually at < 1 mg/L, but up to 100 mg/L in oxygen-depleted groundwater. Taste threshold 0.3 mg/L. High concentrations stain laundry and fittings. Iron bacteria cause blockages, taste/odour, corrosion.
Lead	0.01		Occurs in water via dissolution from natural sources or household plumbing containing lead (e.g. pipes, solder).
Manganese	0.5	0.1	Occurs naturally in water; low in surface water, higher in oxygen-depleted water (e.g. groundwater at bottom of deep storages). > 0.1 mg/L causes taste, staining. < 0.05 mg/L desirable.
Mercury	0.001		From industrial emissions/spills. Very low concentrations occur naturally.

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004) (cont.)

Table 10.10 Guideline values for physical and chemical characteristics (Continued)

Characteristic	Guideline values*		Comments
	Health	Aesthetic[a]	
Molybdenum	0.05		Concentrations usually < 0.01 mg/L; higher concentrations from mining, agriculture, or fly-ash deposits from coal-fuelled power stations.
Monochloramine	3	0.5	Used as water disinfectant. Odour threshold 0.5 mg/L.
Nickel	0.02		Concentrations usually very low; but up to 0.5 mg/L reported after prolonged contact of water with nickel-plated fittings.
Nitrate (as nitrate)	50		Occurs naturally. Increasing in some waters (particularly groundwater) from intensive farming and sewage effluent. Guideline value will protect bottle-fed infants under 3 months from methaemoglobinaemia. Adults and children over 3 months can safely drink water with up to 100 mg/L nitrate.
Nitrite (as nitrite)	3		Rapidly oxidised to nitrate (see above).
Nitrilotriacetic acid	0.2		Chelating agent in laundry detergents (replacing phosphate). May enter water through sewage contamination.
Organotins			
dialkyltins	‹		
tributyltin oxide	0.001		Stabilisers in plastics, may leach from new poly vinyl chloride (PVC) pipes for a short time. Tributyltins are biocides used as antifouling agents on boats and in boiler waters.
Ozone			As ozone used for disinfection leaves no residual, no guideline value has been established.
pH	‹	pH 6.5-8.5	While extreme pH values (< 4 and > 11) may adversely affect health, there are insufficient data to set a health guideline value. < 6.5 may be corrosive. > 8 progressively decreases efficiency of chlorination. > 8.5 may cause scale and taste problems. New concrete tanks and cement-mortar lined pipes can significantly increase pH and a value up to 9.2 may be tolerated provided monitoring indicates no deterioration in microbial quality.
Plasticisers			
di(2-ethylhexyl) phthalate	0.01		Used in all flexible PVC products, and may leach from these over a long time. Could also occur in drinking water from spills.
di(2-ethylhexyl) adipate	‹		
Polycyclic aromatic hydrocarbons (PAHs)			
Benzo-(a)-pyrene	0.00001 (10 ng/L)		Widespread. Contamination can occur through atmospheric deposition, or leaching from bituminous linings in distribution systems.
Selenium	0.01		Generally very low concentrations in natural water.
Silver	0.1		Concentrations generally very low. Silver and silver salts occasionally used for disinfection.
Sodium	*	180	Natural component of water. Guideline value is taste threshold.
Styrene (vinylbenzene)	0.03	0.004	Could occur in drinking water from industrial contamination.
Sulfate	500	250	Natural component of water, and may be added via treatment chemicals. Guideline value is taste threshold. > 500 mg/L can have purgative effects.
Taste and odour	Not necessary	Acceptable to most people	May indicate undesirable contaminants, but usually indicate problems such as algal or biofilm growths.
Temperature	Not necessary	No value set	Generally impractical to control; rapid changes can bring complaints.

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004) (cont.)

Table 10.10 Guideline values for physical and chemical characteristics (Continued)

Characteristic	Guideline values*		Comments
	Health	Aesthetic	
Tetrachloroethene	0.05		Dry-cleaning solvent and metal degreaser. Could occur in drinking water from contamination or spills.
Tin	[a]		Concentrations in water very low; one of the least toxic metals.
Toluene	0.8	0.025	Occurs naturally in petrol and natural gas, forest-fire emissions. Could occur in drinking water from atmospheric deposition, industrial contamination, leaching from protective coatings in storage tanks.
Total dissolved solids	Not necessary	500	< 500 mg/L is regarded as good quality drinking water based on taste. 500-1000 mg/L is acceptable based on taste. > 1000 mg/L may be associated with excessive scaling, corrosion, and unsatisfactory taste.
Trichloroacetaldehyde (chloral hydrate)	0.02		Byproduct of chlorination.
Trichlorobenzenes (total)	0.03	0.005	Industrial chemical.
1,1,1-Trichloroethane	[c]		Could occur in drinking water from contamination/spills.
Trichloroethylene	[c]		Industrial solvent, cleaning fluid, metal degreaser. Could occur in drinking water from direct contamination or via atmospheric contamination of rainwater.
Trihalomethanes (THMs) (Total)	0.25		Byproduct of chlorination and chloramination
True Colour	Not necessary	15 HU	15 HU just noticeable in a glass. Up to 25 HU is acceptable if turbidity is low. If colour is high at time of disinfection, then the water should be checked for disinfection byproducts such as THMs.
Turbidity	[c]	5 NTU	5 NTU just noticeable in a glass. >1 NTU may shield some microorganisms from disinfection. <1 NTU desirable for effective disinfection.
Uranium	0.02		Occurs naturally, or from release from mine tailings, combustion of coal and phosphate fertilizers.
Vinyl chloride	0.0003		From chemical spills. Used in making PVC pipes. Human carcinogen.
Xylene	0.6	0.02	Could occur in drinking water as a pollutant, or from solvent used for bonding plastic fittings.
Zinc	[c]	3	Usually from corrosion of galvanised pipes/fittings and brasses. Natural concentrations generally < 0.01 mg/L. Taste problems > 3 mg/L.

* All values mg/L unless otherwise stated

HU = Hazen units; NTU = nephelometric turbidity units; THMs = trihalomethanes.

a – Aesthetic values are not listed if the compound does not cause aesthetic problems, or if the value determined from health considerations is the same or lower.

b – If present at all in Australian drinking waters, concentrations of all organic compounds other than disinfection byproducts are likely to be very low relative to the guideline value.

c – Insufficient data to set a guideline value based on health considerations.

d – The guideline value is below the limit of determination. Improved analytical procedures are required for this compound.

e – No health-based guideline value is considered necessary.

Note: All values are as 'total' unless otherwise stated.

Note: Routine monitoring for these compounds is not required unless there is potential for contamination of water supplies (e.g. accidental spillage).

Note: The concentration of all chlorination byproducts can be minimised by removing naturally occurring organic matter from the source water, reducing the amount of chlorine added, or using an alternative disinfectant (which may produce other byproducts). Action to reduce trihalomethanes and other byproducts is encouraged, but must not compromise disinfection.

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004) (cont.)

Table 10.11 Guideline values for pesticides

Pesticide	Guideline value[a] (mg/L)	Health value[b] (mg/L)
Acephate		0.01
Aldicarb	0.001	0.001
Aldrin[c] (and dieldrin)	0.00001	0.0003
Ametryn	0.005	0.05
Amitrole[c]	0.001	0.01
Asulam		0.05
Atrazine[c]	0.0001	0.04
Azinphos-methyl	0.002	0.003
Benomyl		0.1
Bentazone		0.03
Bioresmethrin		0.1
Bromacil	0.01	0.3
Bromophos-ethyl		0.01
Bromoxynil		0.03
Carbaryl	0.005	0.03
Carbendazim		0.1
Carbofuran	0.005	0.01
Carbophenothion		0.0005
Carboxin	0.002	0.3
Chlordane[c]	0.00001	0.001
Chlorfenvinphos		0.005
Chlorothalonil	0.0001	0.03
Chloroxuron		0.01
Chlorpyrifos[c]		0.01
Chlorsulfuron		0.1
Clopyralid[c]	1	1
2,4-D[c]	0.0001	0.03
DDT[c]	0.00006	0.02
Diazinon	0.001	0.003
Dicamba		0.1
Dichlobenil		0.01
Dichlorvos	0.001	0.001
Diclofop-methyl		0.005
Dicofol		0.003
Dieldrin[c] (see aldrin)	0.00001	0.0003
Difenzoquat		0.1
Dimethoate		0.05
Diuron[c]		0.03
DPA (2,2-DPA)		0.5
EDB	0.001	0.001
Endosulfan[c]	0.00005	0.03
Endothal	0.01	0.1
EPTC	0.001	0.03
Ethion		0.003
Ethoprophos	0.001	0.001
Etridiazole	0.0001	0.1
Fenamiphos		0.0003
Fenarimol	0.001	0.03
Fenchlorphos		0.03
Fenitrothion		0.01
Fenoprop		0.01
Fensulfothion	0.01	0.01
Fenvalerate		0.05
Flamprop-methyl		0.003
Fluometuron		0.05
Formothion		0.05
Fosamine[c]		0.03
Glyphosate	0.01	1
Heptachlor[c] (including its epoxide)	0.00005	0.0003
Hexaflurate		0.03
Hexazinone[c]	0.002	0.3
Lindane[c]	0.00005	0.02
Maldison		0.05
Methidathion		0.03
Methiocarb	0.005	0.005
Methomyl	0.005	0.03
Methoxychlor	0.0002	0.3
Metolachlor	0.002	0.3
Metribuzin	0.001	0.05
Metsulfuron-methyl		0.03
Mevinphos	0.005	0.005
Molinate[c]	0.0005	0.005
Monocrotophos		0.001

Trigger Values (TV) for Drinking Water Protection (µg/L) NHMRC and NRMMC (2004) (cont.)

Table 10.11 Guideline values for pesticides

Pesticide	Guideline value[a] (mg/L)	Health value[b] (mg/L)
Oryzalin		0.3
Oxamyl	0.005	0.1
Paraquat[c]	0.001	0.03
Parathion		0.01
Parathion methyl	0.0003	0.1
Pebulate	0.0005	0.03
Pendimethalin		0.3
Pentachlorophenol	0.00001	0.01
Permethrin	0.001	0.1
Picloram[c]		0.3
Piperonyl butoxide		0.1
Pirimicarb		0.005
Pirimiphos-ethyl		0.0005
Pirimiphos-methyl		0.05
Profenofos		0.0003
Promecarb		0.03
Propachlor	0.001	0.05
Propanil	0.0001	0.5
Propargite		0.05
Propazine	0.0005	0.05
Propiconazole[c]	0.0001	0.1

Pesticide	Guideline value[a] (mg/L)	Health value[b] (mg/L)
Propyzamide	0.002	0.3
Pyrazophos		0.03
Quintozene		0.03
Simazine	0.0005	0.02
Sulprofos		0.01
Silvex (see Fenoprop)		
2,4,5-T	0.00005	0.1
Temephos[c]	0.3	0.3
Terbacil	0.01	0.03
Terbufos	0.0005	0.0005
Terbutryn	0.001	0.3
Tetrachlorvinphos	0.002	0.1
Thiobencarb		0.03
Thiometon		0.003
Thiophanate		0.005
Thiram		0.003
Triadimefon	0.1	0.002
Trichlorfon		0.005
Triclopyr[c]		0.01
Trifluralin	0.0001	0.05
Vernolate	0.0005	0.03

a – These are generally based on the analytical limit of determination (the level at which the pesticide can be reliably detected using practicable, readily available and validated analytical methods). If a pesticide is detected at or above this value the source should be identified and action taken to prevent further contamination.

b – Based on 10% of acceptable daily intake (ADI).

c – These pesticides have either been detected on occasions in Australian drinking water or their likely use would indicate that they may occasionally be detected.

Note: Routine monitoring for pesticides is not required unless potential exists for contamination of water supplies. See also Section 6.3.3

Table 10.12 Guideline values for radiological quality of drinking water

Guideline value

The total estimated dose per year from all radionuclides in drinking water, excluding the dose from potassium-40, should not exceed 1.0 mSv.

If this guideline value is exceeded, the water provider, in conjunction with the relevant health authority, should evaluate possible remedial actions on a cost-benefit basis to assess what action can be justified to reduce the annual exposure.

Screening of water supplies

Compliance with the guideline for radiological quality of drinking water should be assessed, initially, by screening for gross alpha and gross beta activity concentrations. The recommended screening level for gross alpha activity is 0.5 Bq/L. The recommended screening level for gross beta activity is 0.5 Bq/L after subtraction of the contribution from potassium-40.

If either of these activity concentrations is exceeded, specific radionuclides should be identified and their activity concentrations determined. The concentration of both radium-226 and radium-228 should always be determined, as these are the most significant naturally occurring radionuclides in Australian water supplies. Other radionuclides should be identified if necessary to ensure all gross alpha and beta activity is accounted for, after taking into account the counting and other analytical uncertainties involved in the determination.

Trigger Values (TV) for Recreational Purposes (µg/L) (ANZECC 2000)

Table 5.2.3 Summary of water quality guidelines for recreational purposes: general chemicals

Parameter	Guideline values (µg/L, unless otherwise stated)
Inorganic:	
Arsenic	50
Asbestos	NR
Barium	1000
Boron	1000
Cadmium	5
Chromium	50
Cyanide	100
Lead	50
Mercury	1
Nickel	100
Nitrate-N	10 000
Nitrite-N	1000
Selenium	10
Silver	50
Organic:	
Benzene	10
Benzo(a)pyrene	0.01
Carbon tetrachloride	3
1,1-Dichloroethene	0.3
1,2-Dichloroethane	10
Pentachlorophenol	10
Polychlorinated biphenyls	0.1
Tetrachloroethene	10
2,3,4,6-Tetrachlorophenol	1
Trichloroethene	30
2,4,5-Trichlorophenol	1
2,4,6-Trichlorophenol	10
Radiological:	
Gross alpha activity	0.1 Bq/L
Gross beta activity (excluding activity of ^{40}K)	0.1 Bq/L
Other chemicals:	
Aluminium	200
Ammonia (as N)	10
Chloride	400 000
Copper	1000
Oxygen	>6.5 (>80% saturation)
Hardness (as $CaCO_3$)	500 000
Iron	300
Manganese	100
Organics (CCE & CAE)	200
pH	6.5–8.5
Phenolics	2
Sodium	300 000
Sulfate	400 000
Sulfide	50
Surfactant (MBAS)	200
Total dissolved solids	1 000 000
Zinc	5000

NR = No guideline recommended at this time; MBAS Methylene blue active substances

Trigger Values (TV) for Recreational Purposes (µg/L) (ANZECC 2000) (cont.)

Table 5.2.4 Summary of water quality guidelines for recreational purposes: pesticides

Compound	Maximum concentration (µg/L)	Compound	Maximum concentration (µg/L)
Acephate	20	Fenvalerate	40
Alachlor	3	Flamprop-methyl	6
Aldrin	1	Fluometuron	100
Amitrol	1	Formothion	100
Asulam	100	Fosamine (ammonium salt)	3000
Azinphos-methyl	10	Glyphosate	200
Barban	300	Heptachlor	3
Benomyl	200	Hexaflurate	60
Bentazone	400	Hexazinone	600
Bioresmethrin	60	Lindane	10
Bromazil	600	Maldison	100
Bromophos-ethyl	20	Methidathion	60
Bromoxynil	30	Methomyl	60
Carbaryl	60	Metolachlor	800
Carbendazim	200	Metribuzin	5
Carbofuran	30	Mevinphos	6
Carbophenothion	1	Molinate	1
Chlordane	6	Monocrotophos	2
Chlordimeform	20	Nabam	30
Chlorfenvinphos	10	Nitralin	1000
Chloroxuron	30	Omethoate	0.4
Chlorpyrifos	2	Oryzalin	60
Clopzralid	1000	Paraquat	40
Cyhexatin	200	Parathion	30
2,4-D	100	Parathion-methyl	6
DDT	3	Pendimethalin	600
Demeton	30	Perfluidone	20
Diazinon	10	Permethrin	300
Dicamba	300	Picloram	30
Dichlobenil	20	Piperonyl butoxide	200
3,6-Dichloropicolinic acid	1000	Pirimicarb	100
Dichlorvos	20	Pirimiphos-ethyl	1
Diclofop-methyl	3	Pirimiphos-methyl	60
Dicofol	100	Profenofos	0.6
Dieldrin	1	Promecarb	60
Difenzoquat	200	Propanil	1000
Dimethoate	100	Propargite	1000
Diquat	10	Propoxur	1000
Disulfoton	6	Pyrazophos	1000
Diuron	40	Quintozene	6
DPA	500	Sulprofos	20
Endosulfan	40	2,4,5-T	2
Endothal	600	Temephos	30
Endrin	1	Thiobencarb	40
EPTC	60	Thiometon	20
Ethion	6	Thiophanate	100
Ethoprophos	1	Thiram	30
Fenchlorphos	60	Trichlorofon	10
Fenitrothion	20	Triclopyr	20
Fenoprop	20	Trifluralin	500
Fensulfothion	20		

Sources: NHMRC & AWRC (1987), NHMRC (1989)

Trigger Values (TV) for Aquaculture Protection (mg/L) (ANZECC 2000)

Table 4.4.2 Physico-chemical stressor guidelines for the protection of aquaculture species

Measured parameter	Recommended guideline (mg/L)	
	Freshwater production	Saltwater production
Alkalinity	≥20[5]	>20[3]
Biochemical oxygen demand (BOD_6)	<15[1]	ND
Chemical oxygen demand (COD)	<40[1]	ND
Carbon dioxide	<10	<15
Colour and appearance of water	30–40[2] (Pt-Co units)	30–40[2] (Pt-Co units)
Dissolved oxygen	>5[3]	>5[3]
Gas supersaturation	<100%[6]	<100%[6]
Hardness ($CaCO_3$)	20–100[5]	NC[6]
pH	5.0–9.0	6.0-9.0
Salinity (total dissolved solids)	<3000[6]	33 000–37 000[6] (3000–35 000 Brackish)[6]
Suspended solids	<40	<10 (<75 Brackish)
Temperature	<2.0°C change over 1 hour[4]	<2.0°C change over 1 hour[4]

1 Schlotfeldt & Alderman (1995)

2 O'Connor pers. comm.

3 Meade (1989)

4 ANZECC (1992)

5 DWAF (1996)

6 Lawson (1995)

Others are based on professional judgements of the project team.

Trigger Values (TV) for Aquaculture Protection (µg/L) (ANZECC 2000) (cont.)

Table 4.4.3 Toxicant guidelines for the protection of aquaculture species

Measured parameter	Guideline (µg/L)	
	Freshwater production	Saltwater production
INORGANIC TOXICANTS (HEAVY METALS AND OTHERS)		
Aluminium	<30 (pH >6.5)[1] <10 (pH <6.5)	<10[1]
Ammonia (un-ionised)	<20 (pH >8.0) coldwater[2] <30 warmwater[2]	<100
Arsenic	<50[1,2]	<30[1,2]
Cadmium (varies with hardness)	<0.2–1.8[2]	<0.5–5[1]
Chlorine	<3[1]	<3[1]
Chromium	<20[2]	<20
Copper (varies with hardness)	<5[2]	<5[3]
Cyanide	<5[1]	<5[1]
Fluorides	<20[4]	ND
Hydrogen sulfide	<1[2]	<2
Iron	<10[1]	<10[1]
Lead (varies with hardness)	<1–7[4]	<1–7[4]
Magnesium	<15 000[1]	ND
Manganese	<10[1,5]	<10[1,5]
Mercury	<1	<1
Nickel	<100[1]	<100[1]
Nitrate (NO_3^-)	<50 000[6]	<100 000[3,7]
Nitrite (NO_2)	<100[1,7]	<100[1,7]
Phosphates	<100[2]	<50
Selenium	<10[1]	<10[1]
Silver	<3[1]	<3[1]
Tributyltin (TBT)	<0.026[1]	<0.01[1]
Total available nitrogen (TAN)	<1000[1]	<1000[1]
Vanadium	<100[1]	<100[1]
Zinc	<5[1]	<5[1]
ORGANIC TOXICANTS (NON-PESTICIDES)		
Detergents and surfactants	<0.1[8]	ND
Methane	<65 000[9,10]	<65 000[9,10]
Oils and greases (including petrochemicals)	<300[6]	ND
Phenols and chlorinated phenols	<0.6–1.7[6]	ND
Polychlorinated biphenyls (PCBs)	<2[1]	<2[1]
PESTICIDES		
2,4-dichlorophenol	<4.0[2]	ND
Aldrin	<0.01[2,3,8]	ND
Azinphos-methyl	<0.01[2]	ND
Chlordane	<0.01[11]	0.004[11]
Chlorpyrifos	<0.001[2]	ND
DDT (including DDD & DDE)	<0.0015[2]	ND
Demton	<0.01[11]	ND
Dieldrin	<0.005[2]	ND
Endosulfan	<0.003[2,11]	0.001[11]
Endrin	<0.002[2]	ND
Gunthion (see also Azinphos-methyl)	<0.01[11]	ND
Hexachlorobenzole	<0.00001[8]	ND
Heptachlor	<0.005[2]	ND
Lindane	<0.01[11]	0.004[11]
Malathion	<0.1[5,11]	ND
Methoxychlor	<0.03[11]	ND
Mirex	<0.001[2,11]	ND
Paraquat	ND	<0.01
Parathion	<0.04[11]	ND
Toxaphene	<0.002[2]	ND

ND: Not determined — insufficient information; NC: Not of concern; 1. Meade (1989); 2. DWAF (1996); 3. Pillay (1990); 4. Tebbutt (1972); 5. Zweig et al. (1999); 6. Schlotfeldt & Alderman (1995); 7. Coche (1981); 8. Langdon (1988); 9. McKee & Wolf (1963); 10. Boyd (1990); 11. Lannan et al. (1986). Others are based on professional judgements of the project team.

Trigger Values (TV) for Aquaculture Protection (mg/L) (ANZECC 2000) (cont.)

Table 4.4.5 Guidelines for chemical compounds in water found to cause tainting of fish flesh and other aquatic organisms

Parameter	Estimated threshold level in water (mg/L)
Acenaphthene	0.02
Acetophenone	0.5
Acrylonitrile	18.0
Copper	1.0
m-cresol	0.2
o-cresol	0.4
p-cresol	0.1
Cresylic acids (meta, para)	0.2
Chlorobenzene	0.02
n-butylmercaptan	0.06
o-sec. butylphenol	0.3
p-tert. butylphenol	0.03
o-chlorophenol	0.0001–0.015
p-chlorophenol	0.0001
2,3-dinitrophenol	0.08
2,4,6-trinitrophenol	0.002
2,4-dichlorophenol	0.0001–0.014
2,5-dichlorophenol	0.02
2,6-dichlorophenol	0.03
3,4-dichlorophenol	0.0003
2-methyl-4-chlorophenol	2.0
2-methyl-6-cholorophenol	0.003
3-methyl-4-chlorophenol	0.02–3.0
o-phenylphenol	1.0
Pentachlorophenol	0.03
Phenol	1.0–10.0
Phenols in polluted rivers	0.15–0.02
2,3,4,6-tetrachlorophenol	0.001
2,3,5-trichlorophenol	0.001
2,4,6-trichlorophenol	0.002
2,4-dimethylphenol	0.4
Dimethylamine	7.0
Diphenyloxide	0.05
B,B-dichlorodiethyl ether	0.09–1
o-dichlorobenzene	<0.25
Ethylbenzene	0.25
Ethanethiol	0.2
Ethylacrylate	0.6
Formaldehyde	95.0
Gasoline	0.005
Guaicol	0.08
Kerosene	0.1
Kerosene plus kaolin	1.0
Hexachlorocyclopentadiene	0.001
Isopropylbenzene	<0.25
Naphtha	0.1
Naphthalene	1.0
Naphthol	0.5
2-Naphthol	0.3
Nitrobenzene	0.03
a-methylstyrene	0.25
Oil, emulsifiable	>15.0
Pyridine	5–28
Pyrocatechol	0.8–5
Pyrogallol	20–30
Quinoline	0.5–1
p-quinone	0.5
Styrene	0.25
Toluene	0.25
Outboard motor fuel as exhaust	7.2
Zinc	5.0

Source: Reproduced from ANZECC (1992), an adaptation of NAS/NAE (1973)

Trigger Values (TV) for Irrigated Crop Protection (mg/L) (ANZECC 2000)

Table 4.2.10 Agricultural irrigation water long-term trigger value (LTV), short-term trigger value (STV) and soil cumulative contaminant loading limit (CCL) triggers for heavy metals and metalloids[a]

Element	Suggested soil CCL[b] (kg/ha)	LTV in irrigation water (long-term use — up to 100 yrs) (mg/L)	STV in irrigation water (short-term use — up to 20 yrs) (mg/L)
Aluminium	ND	5	20
Arsenic	20	0.1	2.0
Beryllium	ND	0.1	0.5
Boron	ND	0.5	Refer to table 9.2.18 (Volume 3)
Cadmium	2	0.01	0.05
Chromium	ND	0.1	1
Cobalt	ND	0.05	0.1
Copper	140	0.2	5
Fluoride	ND	1	2
Iron	ND	0.2	10
Lead	260	2	5
Lithium	ND	2.5 (0.075 Citrus crops)	2.5 (0.075 Citrus crops)
Manganese	ND	0.2	10
Mercury	2	0.002	0.002
Molybdenum	ND	0.01	0.05
Nickel	85	0.2	2
Selenium	10	0.02	0.05
Uranium	ND	0.01	0.1
Vanadium	ND	0.1	0.5
Zinc	300	2	5

a Trigger values should only be used in conjunction with information on each individual element and the potential for off-site transport of contaminants (Volume 3, Section 9.2.5)

b ND = Not determined; insufficient background data to calculate CCL

Table 4.2.6 Chloride concentrations (mg/L) causing foliar injury in crops of varying sensitivity[a]

Sensitive <175	Moderately sensitive 175–350	Moderately tolerant 350–700	Tolerant >700
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugar beet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sorghum	

a After Maas (1990)

Trigger Values (TV) for Irrigated Crop Protection (mg/L) (ANZECC 2000) (cont.)

Table 4.2.7 Risks of increasing cadmium concentrations in crops due to chloride in irrigation waters[a]

Irrigation water chloride concentration (mg/L)	Risk of increasing crop cadmium concentrations
0–350	Low
350–750	Medium
>750	High

a McLaughlin et al. (1999)

If high chloride concentrations are present in irrigation water, it is recommended that produce is tested for cadmium concentration in the edible portions (e.g. tubers for potatoes, leaves for leafy vegetables, grain for cereals, etc.).

Table 4.2.8 Sodium concentration (mg/L) causing foliar injury in crops of varying sensitivity[a]

Sensitive <115	**Moderately sensitive 115–230**	**Moderately tolerant 230–460**	**Tolerant >460**
Almond	Pepper	Barley	Cauliflower
Apricot	Potato	Maize	Cotton
Citrus	Tomato	Cucumber	Sugar beet
Plum		Lucerne	Sunflower
Grape		Safflower	
		Sesame	
		Sorghum	

a After Maas (1990)

Table 4.2.11 Agricultural irrigation water long-term trigger value (LTV) and short-term trigger value (STV) guidelines for nitrogen and phosphorus

Element	**LTV in irrigation water (long-term — up to 100 yrs)**	**STV in irrigation water (short-term — up to 20 yrs)**
	(mg/L)	**(mg/L)**
Nitrogen	5	25–125 [a]
Phosphorus	0.05 (To minimise bioclogging of irrigation equipment only)	0.8–12 [a]

a Requires site-specific assessment (see Section 9.2.6)

Trigger Values (TV) for Livestock Drinking Water Protection (mg/L) (ANZECC 2000)

Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).

Stock should tolerate concentrations of calcium in water up to 1000 mg/L, if calcium is the dominant cation and dietary phosphorus levels are adequate. In the presence of high concentrations of magnesium and sodium, or if calcium is added to feed as a dietary supplement, the level of calcium tolerable in drinking water may be less.

Insufficient information is available to set trigger values for magnesium in livestock drinking water.

Magnesium is an essential element for animal nutrition. In high doses magnesium can cause scouring and diarrhoea, lethargy, lameness, decreased feed intake and decreased performance. Drinking water containing magnesium at concentrations up to 2000 mg/L has been found to have no adverse effects on cattle.[a]

Nitrate concentrations less than 400 mg/L in livestock drinking water should not be harmful to animal health. Stock may tolerate higher nitrate concentrations in drinking water, provided nitrate concentrations in feed are not high. Water containing more than 1500 mg/L nitrate is likely to be toxic to animals and should be avoided.

Concentrations of nitrite exceeding 30 mg/L may be hazardous to animal health.

Both nitrate and nitrite can cause toxicity to animals, with nitrite being far more toxic than nitrate. Symptoms of acute poisoning include increased urination, restlessness and cyanosis, leading to vomiting, convulsions and death.

Confusion can arise concerning trigger values for nitrate and nitrite because concentrations are sometimes reported on the basis of their respective nitrogen (N) contents, i.e. as nitrate-N and nitrite-N. Note that trigger values in the present guidelines are expressed as nitrate and nitrite. The conversions are as follows:

1 mg/L nitrate-N = 4.43 mg/L nitrate, (4.3)

1 mg/L nitrite-N = 3.29 mg/L nitrite. (4.4)

No adverse effects to stock are expected if the concentration of sulfate in drinking water does not exceed 1000 mg/L. Adverse effects may occur at sulfate concentrations between 1000 and 2000 mg/L, especially in young or lactating animals or in dry, hot weather when water intake is high. These effects may be temporary and may cease once stock become accustomed to the water. Levels of sulfate greater than 2000 mg/L may cause chronic or acute health problems in stock.

Trigger Values (TV) for Livestock Drinking Water Protection (mg/L) (ANZECC 2000) (cont.)

Table 4.3.1 Tolerances of livestock to total dissolved solids (salinity) in drinking water[a]

Livestock	Total dissolved solids (mg/L)		
	No adverse effects on animals expected	Animals may have initial reluctance to drink or there may be some scouring, but stock should adapt without loss of production	Loss of production and a decline in animal condition and health would be expected. Stock may tolerate these levels for short periods if introduced gradually
Beef cattle	0–4000	4000–5000	5000–10 000
Dairy cattle	0–2500	2500–4000	4000–7000
Sheep	0–5000	5000–10 000	10 000–13 000[b]
Horses	0–4000	4000–6000	6000–7000
Pigs	0–4000	4000–6000	6000–8000
Poultry	0–2000	2000–3000	3000–4000

a From ANZECC (1992), adapted to incorporate more recent information

b Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production

Total dissolved solids (TDS) is a measure of all inorganic salts dissolved in water and is a guide to water quality. For convenience, TDS is often estimated from electrical conductivity (EC). An approximate conversion of EC to TDS is:

$$EC\ (dS/m) \times 670 = TDS\ (mg/L)\ or, \quad (4.5)$$

$$EC\ (\mu S/cm) \times 0.67 = TDS\ (mg/L) \quad (4.6)$$

Salinity is used as a convenient guide to the suitability of water for livestock watering. If a water has purgative or toxic effects, especially if the TDS concentration is above 2400 mg/L, the water should be analysed to determine the concentrations of specific ions.

Trigger Values (TV) for Livestock Drinking Water Protection (mg/L) (ANZECC 2000) (cont.)

Table 4.3.2 Recommended water quality trigger values (low risk) for heavy metals and metalloids in livestock drinking water [a]

Metal or metalloid	Trigger value (low risk)[a,b] (mg/L)
Aluminium	5
Arsenic	0.5 up to 5[c]
Beryllium	ND
Boron	5
Cadmium	0.01
Chromium	1
Cobalt	1
Copper	0.4 (sheep) 1 (cattle) 5 (pigs) 5 (poultry)
Fluoride	2
Iron	not sufficiently toxic
Lead	0.1
Manganese	not sufficiently toxic
Mercury	0.002
Molybdenum	0.15
Nickel	1
Selenium	0.02
Uranium	0.2
Vanadium	ND
Zinc	20

a Higher concentrations may be tolerated in some situations (details provided in Volume 3, Section 9.3.5)

b ND = not determined, insufficient background data to calculate

c May be tolerated if not provided as a food additive and natural levels in the diet are low

Trigger Values (TV) for Industrial Water Protection (mg/L) (ANZECC 2000)

To limit corrosion and fouling of pumping, irrigation and stock watering systems, pH should be maintained between 6 and 8.5 for groundwater systems and between 6 and 9 for surface water systems.

Trigger values for assessing the corrosiveness of water are given in table 4.2.14.

Table 4.2.14 Corrosion potential of waters on metal surfaces as indicated by pH, hardness, Langelier index, Ryznar index and the log of chloride:carbonate ratio

Parameter[a]	Value	Comments
pH	<5	High corrosion potential
	5 to 6	Likelihood of corrosion
	>6	Limited corrosion potential
Hardness	<60 mg/L CaCO3	Increased corrosion potential
Langelier Index	<-0.5	Increased corrosion potential
	-0.5 to 0.5	Limited corrosion potential
Ryznar Index	<6	Limited corrosion potential
	>7	Increased corrosion potential
Log of chloride to carbonate ratio	>2	Increased corrosion potential

a For further information on these parameters refer to Volume 3, Section 9.2.9.1

Table 4.2.15 Fouling potential of waters as indicated by pH, hardness, Langelier index, Ryznar index and the log of chloride:carbonate ratio

Parameter[a]	Value	Comments
pH	<7	Limited fouling potential
	7 to 8.5	Moderate fouling potential (groundwater)[b]
	>8.5	Increased fouling potential (groundwater)[c]
Hardness	>350 mg/L CaCO3	Increased fouling potential
Langelier Index	>0.5	Increased fouling potential
	-0.5 to 0.5	Limited fouling potential
Ryznar Index	<6	Increased fouling potential
	>7	Limited fouling potential
Log of chloride to carbonate ratio	<2	Increased fouling potential

a For further information on these parameters refer to Volume 3, Section 9.2.9.1
b For surface waters, pH range 7 to 9
c For surface waters, pH >9

Exposure Classification for Potential Impacts to Concrete Building Structures as per AS 2159 (1995) *Piling – Design and Installation*

Exposure Conditions				Exposure Classification	
Sulfates (expressed as SO_3)*		*pH*	*Chlorides in water (ppm)*	*Soil Conditions - A (saturated high permeability soils)*	*Soil Conditions - B (low permeability saturated soils or all soils above groundwater)*
In soil (%)	*In groundwater (ppm)*				
<0.2	<300	>6.5	<200	Non-aggressive	Non-aggressive
0.2-0.5	300-1000	5-6.5	2000-6000	Mild	Non-aggressive
0.5-1.0	1,000 - 2,500	4.5-5	6000-12000	Moderate	Mild
1.0-2.0	2,500 – 5,000	4-4.5	12000-30000	Severe	Moderate
>2.0	>5,000	<4	>30000	Very severe	Severe

* Assuming approximately 100ppm SO_4 = 80ppm SO_3.

Exposure Classification for Potential Impacts to Steel Building Structures as per AS 2159 (1995) *Piling – Design and Installation*

Exposure Conditions				Exposure Classification	
Chlorides		*pH*	*Resistivity (ohm.cm)*	*Soil Conditions – A (saturated high permeability soils)*	*Soil Conditions - B (low permeability saturated soils or all soils above groundwater)*
In soil (%)	*In groundwater (ppm)*				
<0.5	<1,000	>5	>5,000	Non-aggressive	Non-aggressive
0.5 - 2	2,000 - 5,000	4-5	2,000 – 5,000	Mild	Non-aggressive
2 - 5	1,000 - 2,000	3-4	1,000 – 2000	Moderate	Mild
>5	>20,000	<3	<1,000	Severe	Moderate

Notes: Sulphate levels >1000ppm may indicate sulfate-reducing bacteria may be present and active, sometimes leading to microbiologically induced corrosion. In such cases, classify as 'mild' for low permeability soils and 'moderate for high permeability soils.

Threshold Concentrations for Landfill Gases

Landfill Gas	Trigger Level	Basis for Trigger Level
Carbon Dioxide (CO_2)	5,000ppm	Hazardous Substance Information System data provided on the Australian Safety and Compensation Council website (http://hsis.ascc.gov.au) indicates that Time Weighted Average exposure standard for CO_2 is 5,000ppm and the Short Term Exposure Limit for CO_2 is 30,000ppm.
Carbon Monoxide (CO)	30ppm	CO is potentially toxic to humans, trigger level based on Hazardous Substance Information System data provided on the Australian Safety and Compensation Council website (http://hsis.ascc.gov.au) – Time Weighted Average exposure standard = 30ppm.
Hydrogen (H)	1%v/v	No atmospheric toxicity data available for H. H is potentially explosive, trigger level based on the Lower Explosive Limit of H (1%v/v) with a factor of safety of 4. H displaces oxygen and accordingly is classed as an asphyxiant. This should be taken into account when reviewing landfill gas data.
Hydrogen Sulphide (H_2S)	10ppm	H_2S is potentially toxic to humans, trigger level based on Hazardous Substance Information System data provided on the Australian Safety and Compensation Council website (http://hsis.ascc.gov.au) – Time Weighted Average exposure standard =10ppm, Short Term Exposure Limit = 15ppm.
Methane (CH_4)	1.25%v/v	No atmospheric toxicity data available for CH_4. CH_4 is potentially explosive, trigger level based on on the Lower Explosive Limit of CH_4 (5%v/v) with a factor of safety of 4, as per NSW EPA (1996) *Environmental Guidelines: Solid Waste Landfills*. CH_4 displaces oxygen and accordingly is classed as an asphyxiant. This should be taken into account when reviewing landfill gas data.
Nitrogen (N)	NA	No atmospheric toxicity data available for N. N displaces oxygen and accordingly is classed as an asphyxiant. This should be taken into account when reviewing landfill gas data.