Contaminated Sites Management Series

Assessment Levels for Soil, Sediment and Water

Draft for Public Comment

Version 3
November 2003

PREFACE

This draft version of the *Assessment Levels for Soil, Sediment and Water* guideline has been prepared by the Department of Environment (DoE) to provide consultants, local government authorities, industry and other interested parties with a document which outlines the criteria utilised by the DoE in assessing site contamination and determining the requirements for further investigation, or assessment of risk to determine if any further action is required.

This guideline is an amended version of the Assessment Levels for Soil, Sediment and Water (DEP, 2001) guideline. Any comments on this guideline should be forwarded to the Land and Water Quality Branch of the DoE by 28 February 2004.

Written comments on the guideline should be forwarded to:

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ACKNOWLEDGMENTS

The DoE acknowledges the Department of Health Western Australia (DOH) and CSIRO Land and Water, South Australia for their assistance in the preparation of this guideline.

LIMITATIONS

This guideline applies only to persons investigating contaminated sites. The contents herein provide guidance only and do not purport to provide a methodology for the assessment of sites. Competent persons should be engaged to provide specific advice in relation to the assessment of contaminated sites.

This guideline should be used in conjunction with the texts referenced herein, and any other appropriate references.

DISCLAIMER

This guideline has been prepared by the Department of Environment in good faith, exercising all due care and attention. No representation or warranty, expressed or implied, is made as to the relevance, accuracy, completeness or fitness for purposes of this document in respect of any particular user's circumstances. Users of this document should satisfy themselves concerning its application to their situation, and where necessary seek expert advice.

CONTAMINATED SITES MANAGEMENT SERIES

This guideline forms part of a management series developed by the DoE to provide guidance on the assessment and management of contaminated sites in Western Australia.

The Contaminated Site Management Series will contain the following guidelines:

- Assessment Levels for Soil, Sediment and Water
- Bioremediation of Hydrocarbon Contaminated Soils in Western Australia
- Certificate of Contamination Audit Scheme
- Community Consultation
- Contaminated Site Auditor Accreditation Scheme
- Disclosure Statements
- Development of Sampling and Analysis Programs
- Potentially Contaminating Activities, Industries, and Landuses
- Reporting of Known or Suspected Contaminated Sites
- Reporting on Site Assessments
- Site Classification Scheme
- Use of Monitored Natural Attenuation for Groundwater Remediation

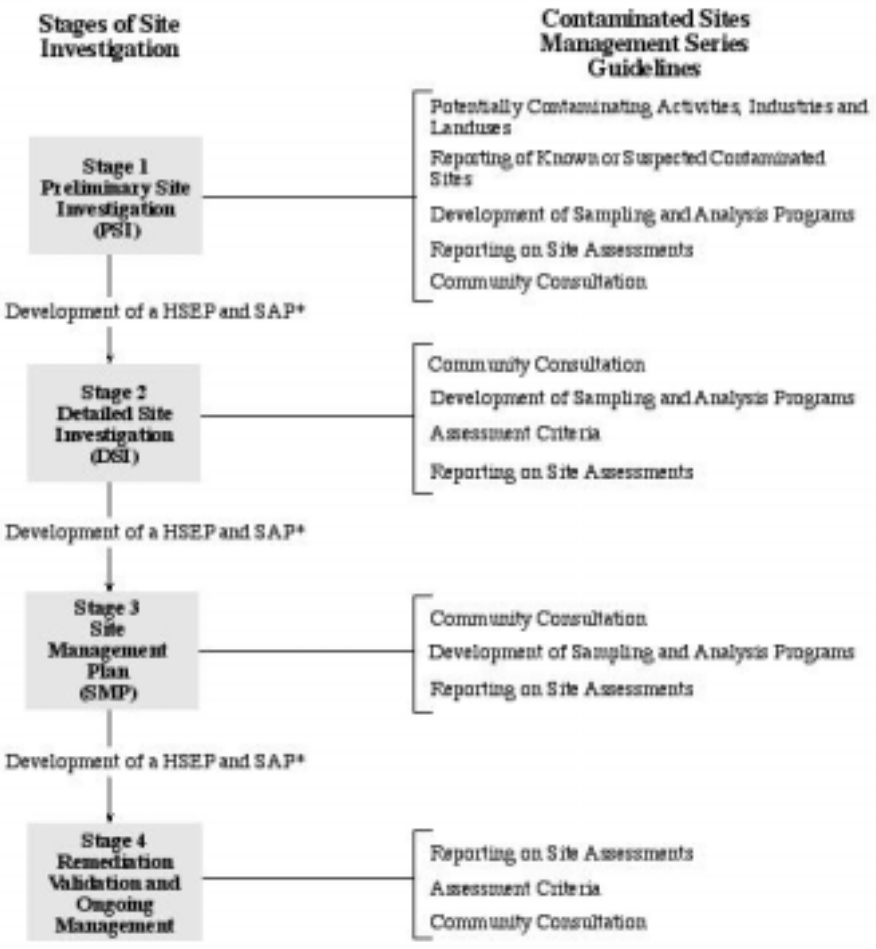
Reference to these guidelines should ensure that the minimum requirements of the DOE are satisfied.

Copies of these guidelines are available from the DoE's library located at Westralia Square, Level 8, 141 St George's Terrace, Perth, or from the DoE's website at www.environ.wa.gov.au.

STAGED APPROACH TO SITE INVESTIGATIONS

The Contaminated Sites Management Series of guidelines has been developed by the DoE to encourage a consistent approach to contaminated site assessment and management. One of the main focuses of the series is the **staged approach to site investigation.**

The purpose of this flow-chart, which appears in the preface of each of the Contaminated Sites Management Series guidelines, is to highlight to the reader the appropriate reference guideline(s) during each of stages of site investigation.



*Where samples are to be collected a Health, Safety and Environment Plan (HSEP), and Sampling and Analysis Plan (SAP) should be prepared.

TABLE OF CONTENTS

LIST OF TABLES

1. INTRODUCTION

The purpose of this document is to compile the assessment levels adopted by the Department of Environment (DoE), which are from a number of sources, into one document, and to provide explanatory text on how the DoE recommends that the assessment levels be used to determine whether a site is potentially contaminated and whether further investigation is required.

The assessment levels in this document should be used as a "first pass" assessment of analytical results to determine if substances are present at a site at concentrations which may present a risk to either human health or the environment. Where a substance is present above the assessment level, further investigation, including risk assessment, is required to determine whether a site is contaminated.

The document contains assessment levels for the main substances investigated at sites only. Where no assessment levels are provided in this document for a substance of concern at a site, they should be sourced from other documents e.g. guidelines from other jurisdictions/organisations, or site specific criteria developed.

Key messages in the document are highlighted in bold text, contained within boxes.

1.1 SOURCE OF ASSESSMENT LEVELS

This document provides the assessment levels adopted by the Department of Environment (DoE) for the assessment of soil, water and sediment quality. The assessment levels listed herein have been amalgamated from published guidelines developed within Australia and internationally. The assessment levels can be used for comparative purposes when assessing the occurrence of contaminants at a site. Application of the assessment levels is based upon the environmental value of the site (where the environmental value is defined as the beneficial use or the ecosystem health condition) and/or the current or potential landuse(s) of the site. The assessment levels have been developed using ecological and/or health risk assessments to compile a list of contaminant concentrations in water, soil and sediment. The DoE has adopted assessment levels from the following sources:

1.1.1 Soil

- National Environment Protection Council (NEPC) (1999) *National Environment Protection (Assessment of Site Contamination) Measure; Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater*.
- Australian and New Zealand Environment and Conservation Council (ANZECC) and National Health and Medical Research Council (NHMRC) (1992) *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.*
- Moen, J.E.T., Cornet, J.P and Evers, C.W.A (1986) Soil protection and remedial actions: criteria for decision making and standardisation of requirements, in Assink, J.W and van den Brink, W.M (1986) *Contaminated Soils, First International TNO Conference on Contaminated Soil, 11-15 November 1985.*

- Victorian Environment Protection Authority (Vic EPA) (1990) *Acceptance Criteria in the Clean-up Notice for the Bayside Site, Port Melbourne.*
- US Environmental Protection Agency (EPA) National Center for Environmental Assessment (NCEA) Superfund Technical Support Center (2000) *Region 9 Preliminary Remediation Goals.*

1.1.2 Sediment

- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.*
- Australian and New Zealand Environment and Conservation Council (ANZECC) (1998) *Interim Ocean Disposal Guidelines.*

1.1.3 Water

- National Environment Protection Council (NEPC) *(1999) National Environment Protection (Assessment of Site Contamination) Measure; Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater.*
- Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) *Australian Water Quality Guidelines for Fresh and Marine Waters*.
- National Health and Medical Research Council (NHMRC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (1996) *Australian Drinking Water Guidelines.*

The assessment levels utilised by the DoE, as extracted from these sources, are presented in Table 1 (Soil), Table 2 (Sediment), and Table 3 (Water) of this document.

These tables present the most frequently used parameters and do not present the full suite of parameters available from the source documents, or which may be present at a site. Analyses should be chosen based upon the known or potential contaminants at a site.

1.2 ALTERNATIVE ASSESSMENT LEVELS

The assessment levels presented in Tables 1 to 3 of this document should be used to assess whether a substance is present at a site for which further investigation, including risk assessment is required. However, where substances are present at a site for which assessment levels are not included in these tables, then alternative assessment levels may be presented (some useful references are listed below). Where other assessment levels are used, the applicability of those guidelines to the study site must be considered and documented, ie. whether the assumptions made in developing the guidelines are relevant to the site.

1.2.1 Suggested Reference Documents

Generic guidance on the development of site-specific criteria can be obtained from the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) Schedules 4 to 6 (NEPC, 1999) and *Environmental Health Risks, Guidelines for assessing human health risks from environmental hazards* (enHealth, 2002).

Ecological Risk

The following sources of information have been provided by CSIRO as useful references for information for ecological risk assessment:

- Australasian Journal of Ecotoxicology http://www.ecotox.org.au/AJE/AJEtocV7.html
- Canadian Council of Ministers of the Environment - http://www.ccme.ca
- Canadian Network of Toxicology Centres - http://www.uoguelph.ca/cntc/
- Oakridge National Laboratory, Environmental Sciences Division, USA - http://www.esd.ornl.gov/programs/ecorisk/ecorisk.html
- USA Environmental Protection Agency:
    - http://www.epa.gov/superfund/programs/nrd/era.htm
    - http://www.epa.gov/ecotox

Human Health Risk

Other sources of information on obtaining and using default values, standards and guidelines relating to the assessment of human health risk are as follows:

Australian Jurisdictions (alphabetical order)

- Food Standards Australia New Zealand - http://www.nicnas.gov.au/australia/fsanz.htm
- Australian Pesticides and Veterinary Medicines Authority - http://www.nicnas.gov.au/australia/NRA.htm or http://www.apvma.gov.au
- Department of Health and Aging - http://www.health.gov.au/
- enHealth Council - http://enhealth.nphp.gov.au/
- Environment Protection and Heritage Council – http://www.ephc.gov.au
- National Environment Protection Council – http://www.ephc.gov.au
- National Health and Medical Research Council - http://www.health.gov.au/nhmrc/
- State and Territories health and environment jurisdictions
- Worksafe Australia - http://www.worksafe.gov.au/

International Jurisdictions (in order of acceptability to Department of Health)

- World Health Organisation (http://www.who.int/en/) standards and guidelines including from the following (no specific order):
    - Concise International Chemical Assessment Documents
    - Environmental Health Criteria
    - International Agency for Research on Cancer
    - International Programme on Chemical safety
    - Joint Expert Committee on Food Additives
    - Joint pesticide meeting on pesticide residues
- United Kingdom Department of Health - http://www.doh.gov.uk/

- Netherlands National Institute of Public Health and the Environment (RVIM) - http://www.rivm.nl/
- Health Canada - http://www.hc-sc.gc.ca/
- Agency for Toxic Substances Disease Registry - http://www.atsdr.cdc.gov/
- United States Environmental Protection Authority - http://www.epa.gov/

1.3 SITE SPECIFIC ASSESSMENT AND CLEAN-UP LEVELS

The assessment levels contained in this document have been compiled from a number of sources, which are themselves compiled from a number of methodologies and studies. They are therefore generic and provide guidance only.

Assessment Levels

Where no assessment levels are available for a specified substance, or suite of substances of interest at a site, then site-specific assessment levels should be developed.

Site-specific assessment levels, and the risk assessment information upon which they are based, will need to be reviewed by the DoE and other relevant government agencies (e.g Department of Health) to ensure that they are acceptable.

Clean-up/Response Levels

Where a site is found to be contaminated, the DoE, in accordance with the NEPM, supports the derivation of site-specific response/clean-up levels using sound and accurate field and analytical results and appropriate ecological and/or health risk assessment.

Site-specific response levels and the site contamination and risk assessment information upon which they are based will need to be reviewed by the DoE and other relevant government agencies (e.g Department of Health) to ensure that they are acceptable.

Where the assessment criteria listed in Tables 1 to 3 of this document are proposed to be adopted as cleanup/response levels for a site, justification on the applicability of their use versus the development of site-specific criteria is required. Justification will need to be based upon risk assessment ie. include reference to the receptors and exposure pathways at a site(both ecological and human)and the relevance of the assessment levels (including the assumptions made during their derivation), for each relevant substance in protecting the identified receptors.

1.4 USE OF NATA ACCREDITED LABORATORIES

All results submitted for assessment to the DoE should be obtained from laboratories that hold NATA accreditation for the particular substances and methodologies required.

Laboratory results should be NATA endorsed and include:

- the results of the analysis;
- sample numbers;

- laboratory numbers;
- a statement about the condition of the samples when they were received (eg. on ice, cold, at ambient temperature etc.);
- date and time of receipt;
- date and time of any sample preparation undertaken and of chemical analysis;
- quality control results;
- a report on sampling and extraction holding times; and
- laboratory methodology used for analysis.

Further information on the presentation of laboratory information to the DoE is presented within the *Reporting on Site Assessments* (DoE, 2001) guideline.

1.5 LABORATORY LIMITS OF REPORTING/LIMITS OF DETECTION

In some situations, the assessment criteria for substances will be below the Limits of Reporting (LORs) which can be achieved by commercial, NATA-accredited chemical laboratories undertaking chemical analysis of samples. In particular, this may be a problem where the 99% trigger values are used as assessment levels for fresh and marine waters (refer to Table 3).

In these situations, the DoE will accept the use of LORs as assessment levels provided that the chemical analysis has been undertaken using the most sensitive NATA-accredited technique available, and that a risk assessment is completed to set the exposure scene. Alternatively, non-NATA accredited techniques can be adopted to undertake the chemical analysis to the required Limit of Reporting (ie at least 50% of the appropriate assessment criterion), provided that appropriate QA/QC is undertaken to confirm the applicability of the analysis. Any such acceptance will be provisional until laboratories implement NATA – accredited techniques that will achieve the assessment levels.

2. ASSESSMENT LEVELS FOR SOIL

Contaminated soils can arise from a number of sources including accidental spillage of chemicals, leaching of contaminants from inappropriate landfills, and leakage from drums, tanks, pipework and drains. Contamination of soil is generally the most common form of contamination at a site.

Contaminated soils can pose a threat to human health and the environment through contributing to groundwater contamination via the leaching of substances through the soil profile, through the release of hazardous dusts and vapours during reworking of the soils, e.g. redevelopment of a site, and through direct contact with the skin and ingestion.

Table 1 presents the soil assessment levels adopted by the DoE for determining if soil is contaminated.

It should be noted that Table 1 does not present assessment levels for every known substance. Where substances not listed in this table are being investigated, assessment levels published in other relevant documents may be applicable (refer to section 1.2).

Table 1 is divided into two sections, Ecological Investigation Levels (EILs), and Health Investigation Levels (HILs).

It should be noted that the EILs and HILs as presented in Table 1 are to be used for the identification of contamination. These criteria have not been developed as cleanup or response levels, nor are they desirable soil quality criteria. They are intended to prompt an appropriate site-specific assessment when they are exceeded, and the development of appropriate cleanup/response levels where required. The level to which such assessments are conducted will depend on site-specific conditions.

In addition, appropriate assessment levels may need to be developed where:

- assessment values are not available for substances of concern and/or data are not available to enable the derivation of criteria;
- site conditions, receptors and/or exposure pathways differ significantly from those assumed in the derivations of the EILs or HILs; or
- there are significant ecological concerns (eg. critical or sensitive habitats, threatened or endangered species, parklands and nature reserves).

Unless site-specific response levels, risk assessment or further investigation has been conducted, as a worst case scenario the DoE will classify sites where substances exceed documented EILs/HILs as "contaminated" in accordance with the draft *Site Classification Scheme* (DEP, 2001) guideline.

Sites should always be assessed against the EILs to determine the potential for environmental impact. Where no environmental impact is occurring or likely to occur, e.g. no leaching of substances into groundwater or surface water sources, or where no impact will occur with the soil remaining *in situ*, then reference may be made to the HILs only (refer to section 2.2). In these circumstances the reasons for this approach must be documented with justification for use of the HILs only.

As some sites have potential human receptors, dependant on the landuse here results are reported, they should always be assessed against both the EILs and the relevant HIL.

Where the EILs and HILs are proposed to be adopted as cleanup/response levels for a site, justification on the applicability of their use versus the development of site-specific criteria is required. Justification will need to be based upon risk assessment i.e. include reference to the receptors and exposure pathways at a site (both ecological and human) and the relevance of the assessment levels (including the assumptions made during their derivation), for each relevant substance in protecting the identified receptors.

2.1 ECOLOGICAL INVESTIGATION LEVELS

The EILs are primarily based on the Environmental Investigation Levels provided in the *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites* (ANZECC/NHMRC, 1992), which are based on threshold levels for phytotoxicity and uptake of contaminants which may result in impairment of plant growth or reproduction or unacceptable residue levels. Where the ANZECC/NHMRC guidelines are lacking, the Dutch B guidelines (Moen et. al 1986) and the Victorian EPA Bayside criteria (1990) have been adopted.

The EILs are utilised by the DoE as an initial screening tool to determine whether concentrations of substances in soil at a site pose a risk to the environment under certain exposure scenarios.

It should be noted that the EILs presented in Table 1 of this document vary slightly from the EILs presented in the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) (NEPC, 1999). These variations relate to chromium (total), copper, lead, barium, phosphorus, sulphur and vanadium. In the NEPM, these values are based on considerations of phytotoxicity and background soil survey data from four Australian cities (all outside Western Australia). The development of the NEPM investigation levels did not address contamination of groundwater or surface water. In order to protect the sensitive water

resources of Western Australia, the more conservative ANZECC/NHMRC B and Dutch B levels have been retained where appropriate:

- for chromium (total), copper and lead, the DoE has retained the values as presented in the ANZECC/NHMRC 1992 document;
- for barium the DoE has retained the levels as presented in Moen et. al (1986) (Dutch B).

The EILs presented in Table 1 of this document also include guideline values for antimony, molybdenum, tin and total phenols additional to the EILs presented in the NEPM (NEPC, 1999). The criteria presented for these parameters are derived from ANZECC/NHMRC (1992) or Moen et. al (1986) (Dutch B).

In some circumstances higher EIL values may be acceptable for arsenic, cobalt, chromium, copper, nickel, lead and zinc in areas where soils naturally have high background concentrations of these substances. Hamon et al (2003) have found that natural background levels for these substances in Australian soils are strongly related to the iron content of the soil. The DoE is proposing to coordinate research between iron and trace metal concentrations for WA soils.

Soil EIL values obtained from Table 1 are not meant to be pass-fail criteria for contaminants in soils. However, contaminant values in excess of EIL figures should trigger further risk-based investigations to determine whether there is likely to be a significant impact on the environment, including groundwater if contaminated soil is not treated and remains on the site.

2.1.1 Ecological Investigation Level Review Process

The assessment levels used by the DoE are dynamic and will change as new information on substance impact to the environment and human health is determined. The DoE is currently undertaking a review of the EILs to ensure that assessment criteria adopted by the DoE ensure that the WA environment is protected, particularly groundwater. Any revision to the EILs will be undertaken through the nationally agreed National Environmental Protection Measure (NEPM) process.

2.2 HEALTH INVESTIGATION LEVELS

The Health Investigation Levels (HILs) adopted by the DoE and Department of Health are primarily based on the Health-based Soil Investigation Levels presented in the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPM) (NEPC, 1999). The NEPM investigation levels have been developed through the enHealth Council and are based on the concept of a tolerable daily intake (TDI). A TDI is a dose that humans may be exposed to every day throughout life without appreciable risk, and incorporates assumptions about the general population exposure and the exposure scenario.

Where the NEPM guidelines are lacking, Preliminary Remediation Goals (PRGs) derived by the United States Environmental Protection Agency (US EPA, 2000) have been adopted as interim HILs.

The use of Preliminary Remediation Goals (PRGs) for HILs is an interim approach until these substances have been scrutinised through the enHealth Council process for determining Australian health-based soil investigation levels.

Where there are no HILs established, site-specific criteria will need to be developed and submitted to the DoE for review (refer section 1.2). The DoE will then refer all relevant documentation to the Environmental Health Branch, Department of Health for review and comment. The HILs listed in this document have been provided by the Department of Health.

The HILs should be used to assess the need for further investigation of soil impact where:

- there is no adverse impact (risk), or little potential for any adverse impact, to the environment, or the environmental value of an environmental receptor; and therefore
- the potential for adverse impact arising from contamination at a site are to human health only.

Where it is concluded that there is no actual or potential adverse impact to the environment, full justification of the use of HILs only as assessment criteria should be provided which addresses such things as:

- site location and zoning;
- surrounding land use and zoning;
- environmental value (beneficial use) of the site (including groundwater beneath and in the vicinity of the site)and surrounding land;
- description of any receptors or migration pathways;
- groundwater depth, flow direction, aquifer characteristics and discharge location;
- soil type beneath the site;
- location of any surface water bodies at, or in the vicinity of, the site;
- type and extent of soil contamination (lateral and vertical); and
- leaching characteristics of the contamination (if applicable).

It should be noted that where insufficient information is provided to demonstrate the appropriateness of the use of the HILs only, it is not unreasonable for the DoE to protect environmental values by adopting assessment levels which may be seen as conservative at the time of the assessment, e.g. EILs.

It should also be noted that where no value is presented for HIL "A" (standard residential) in Table 1, and in the absence of the determination of site-specific criteria, the DoE may accept the use of EILs as health investigation levels.

2.2.1 Health Investigation Levels for Total Petroleum Hydrocarbons

Separate HILs for the aliphatic and aromatic hydrocarbon fractions ($>C_{16}$) were developed through enHealth Council (NEPC, 1999) and are presented in Table 1. The enHealth Council

is undertaking further work to derive HILs for the TPH fractions $<C_{16}$ that exhibit more complex environmental behaviours and/or are carcinogenic.

Separate hydrocarbon fractions are often determined by an analytical method which measures combined aliphatic and aromatic constituents. With regard to HILs for fractions C_{15}-C_{28} and C_{29}-C_{36}, the reference level that should be used is the HIL presented for the C_{16}-C_{35} *aromatic* fraction (enHealth Council, 2001). Where TPH concentrations are found to exceed the relevant *aromatic* HIL, further analysis is required to determine the aromatic and aliphatic components, which can then be compared to the separate HILs.

Summary

Where soils are potentially impacted with petroleum hydrocarbons then:

1. **Analyse soil samples for appropriate substances (ie. TPH, BTEX, PAHs and any additional compounds required for a particular site);**
2. **Compare concentrations to the relevant HILs (Table 1) or site-specific criteria; and**
3. **Combine concentrations of fractions within the C_{16}-C_{35} range, e.g. C_{15}-C_{28} and C_{29}-C_{36} and compare to the relevant HIL for the C_{16}-C_{35} aromatic fraction – where this level is exceeded, further analysis is required to separate aromatic and aliphatic components.**

2.3 ADJUSTING ASSESSMENT LEVELS FOR COMPOSITE SAMPLES

Where composite sampling is used during site investigations, the assessment level requires modification.

It is possible for a sub-sample containing a high concentration of a substance (representing a hot spot) to remain undetected due its dilution in the compositing process. To overcome this, it is recommended that the appropriate assessment level (selected from Table 1 or site-specific level) be divided by the number of sub-samples making up the composite. Applying this procedure assumes the worst-case scenario in that one sub-sample has a high concentration while other sub-samples all have a zero concentration. If the concentration of the composited sample exceeds the adjusted acceptable level, then all sub-samples should be analysed individually.

This method of adjusting assessment levels is adopted from the *New South Wales Environment Protection Authority Sampling Design Guidelines* (NSW, 1995).

Further information on composite sampling can be obtained from the DoE's guideline *Development of Sampling and Analysis Programs* (DEP, 2001).

The use of composite sampling may be appropriate for a preliminary Site Assessment (PSI), but is not appropriate for validation of a site nor for any analysis which will be used as part of an ecological or health risk assessment.

TABLE 1. ASSESSMENT LEVELS FOR SOIL

Parameter	Ecological Investigation Levels[1] (mg/kg)	Health Investigation Levels (mg/kg)					
		A	B[2]	C[3]	D	E	F
Total Petroleum Hydrocarbons (TPH)							
C_6-C_9	100[4]	-	-	-	-	-	-
C_{10}-C_{14}	500[4]	-	-	-	-	-	-
C_{15}-C_{28}	1000[4]	-	-	-	-	-	-
>C_{16}-C_{35} (Aromatics)	-	90[5]	-	-	360[5]	180[5]	450[5]
>C_{16}-C_{35} (Aliphatics)	-	5600[5]	-	-	22400[5]	11200[5]	28000[5]
>C_{35} (Aliphatics)	-	56000[5]	-	-	224000[5]	112000[5]	280000[5]
Monocyclic Aromatic Hydrocarbons (MAHs)							
Benzene	1[7]	1[8]	-	-	-	-	1.5[8]
Toluene	3[6]	520[8]	-	-	-	-	520[8]
Ethylbenzene	5[6]	230[8]	-	-	-	-	230[8]
Xylenes	5[6]	210[8]	-	-	-	-	210[8]
Metals/Metalloids							
Antimony, Sb	20[7]	30[8]	-	-	-	-	820[8]
Arsenic, As	20[7]	100[5]	-	-	400[5]	200[5]	500[5]
Barium, Ba	400[6]	5370[8]	-	-	-	-	100000[8]
Beryllium, Be	-	20[5]	-	-	80[5]	40[5]	100[5]
Cadmium, Cd	3[7]	20[5]	-	-	80[5]	40[5]	100[5]
Chromium (III)	-	12%[5]	-	-	48%[5]	24%[5]	60%[5]
Chromium (VI)	-	100[5]	-	-	400[5]	200[5]	500[5]
Chromium (Total), Cr	50[7]	210[8]	-	-	-	-	-
Cobalt, Co	50[6]	100[5]	-	-	400[5]	200[5]	500[5]
Copper, Cu	60[7]	1000[5]	-	-	4000[5]	2000[5]	5000[5]
Lead, Pb	300[7]	300[5]	-	-	1200[5]	600[5]	1500[5]
Manganese, Mn	500[7]	1500[5]	-	-	6000[5]	3000[5]	7500[5]
Methyl mercury	-	10[5]	-	-	40[5]	20[5]	50[5]
Mercury, Hg	1[7]	15[5]	-	-	60[5]	30[5]	75[5]
Molybdenum, Mo	40[6]	390[8]	-	-	-	-	10220[8]
Nickel, Ni	60[7]	600[5]	-	-	2400[5]	600[5]	3000[5]
Tin, Sn	50[7]	46900[8]	-	-	-	-	100000[8]
Zinc, Zn	200[7]	7000[5]	-	-	28000[5]	14000[5]	35000[5]
Phenols							
Phenol	-	8500[5]	-	-	34000[5]	17000[5]	42500[5]
Total Phenols	1[6]	-	-	-	-	-	10[8]
Pesticides							
Individual Organochlorine Pesticides eg. Aldrin	0.5[6]	-	-	-	-	-	-
Total Organochlorine Pesticides	1[6]	-	-	-	-	-	-
Individual Non-Chlorinated Pesticides	1[6]	-	-	-	-	-	-
Total Non-Chlorinated Pesticides	2[6]	-	-	-	-	-	-
Dieldrin	0.2[7]	-	-	-	-	-	-
Aldrin + Dieldrin	-	10[5]	-	-	40[5]	20[5]	50[5]
Chlordane	0.5[6]	50[5]	-	-	200[5]	100[5]	250[5]
DDT + DDD + DDE	1[6]	200[5]	-	-	800[5]	400[5]	1000[5]
Heptachlor	0.5[6]	10[5]	-	-	40[5]	20[5]	50[5]

Parameter	Ecological Investigation Levels[1] (mg/kg)	Health Investigation Levels (mg/kg)					
		A	B[2]	C[3]	D	E	F
Polychlorinated Biphenyls (PCBs)							
Total PCBs	1[7]	10[5]	-	-	40[5]	20[5]	50[5]
Polycyclic Aromatic Hydrocarbons (PAHs)							
Total PAHs	20[6]	20[5]	-	-	80[5]	40[5]	100[5]
Anthracene	10[6]	21900[8]	-	-	-	-	100000[8]
Benzo[a]pyrene	1[6]	1[5]	-	-	4[5]	2[5]	5[5]
Fluoranthene	10[6]	2290[8]	-	-	-	-	30100[8]
Naphthalene	5[6]	60[8]	-	-	-	-	190[8]
Phenanthrene	10[6]	-	-	-	-	-	100[8]
Pyrene	10[6]	2310[8]	-	-	-	-	54220[8]
Other							
Boron, B	-	3000[5]	-	-	12000[5]	6000[5]	15000[5]
Cyanides (Complexed)	50[6]	500[5]	-	-	2000[5]	1000[5]	2500[5]
Cyanides (Free)	10[6]	250[5]	-	-	1000[5]	500[5]	1250[5]
Sulphate[9]	2000[7]	-	-	-	-	-	-

Notes:

A. Standard residential with garden/accessible soil (home grown produce contributing less than 10% of vegetable and fruit intake; no poultry); this category includes children's daycare centres, kindergartens, pre-schools and primary schools.

B. Residential with substantial vegetable garden (contributing 10% or more of vegetable and fruit intake) and/or poultry providing any egg or poultry meat dietary intake.

C. Residential with substantial vegetable garden (contributing 10% or more of vegetable and fruit intake); poultry excluded.

D. Residential with minimal opportunities for soil access: includes dwellings with fully or permanently paved yard space such as high-rise apartments and flats.

E. Parks, recreational open space and playing fields, includes secondary schools.

F. Commercial/Industrial, includes premises such as shops and offices as well as factories and industrial sites

Adopted from the *National Environment Protection (Assessment of Site Contamination) Measure (NEPC 1999)*

– No level available.

1. The EILs presented in this table vary slightly to the EILs presented in NEPM (NEPC, 1999). These variations relate to chromium (total), copper, lead, barium, phosphorus and sulphur. In the NEPM, these values are based on considerations of phytotoxicity and background soil survey data from four Australian cities (all outside Western Australia). For chromium (total), copper, and lead, the DoE has retained the values as presented in the ANZECC/NHMRC 1992 document. For barium, the DoE has retained the value as presented in Moen et. al. (1986) (Dutch B).
2. Site and contaminant specific: on-site sampling is the preferred approach for estimating poultry and plant uptake. Exposure estimates may then be compared to relevant Acceptable Daily Intakes (ADIs), Provisional Tolerable Weekly Intake (PTWIs) and Guideline Doses (GDs).
3. Site and contaminant specific: on-site sampling is the preferred approach for estimating plant uptake. Exposure estimates may then be compared to relevant ADIs, PTWIs and GDs.
4. Victorian EPA (1990) Acceptance Criteria in the Clean-up Notice for the Bayside Site, Port Melbourne.
5. Health Investigation Levels, *National Environment Protection (Assessment of Site Contamination) Measure* (NEPC, 1999).
6. Dutch B (Indicative value for further investigation) from Moen, J.E.T., Cornet, J.P and Evers, C.W.A (1986) Soil protection and remedial actions: criteria for decision making and standardisation of requirements, in Assink, J.W and van den Brink, W.M (1986) *Contaminated Soils, First International TNO Conference on Contaminated Soil 11-15 November 1985.*
7. ANZECC B (Environmental Investigation Levels) from ANZECC/NHMRC (1992) *Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites*.
8. US EPA 2000 Region 9 Preliminary Remediation Goals (PRGs) EPA National Center for Environmental Assessment (NCEA) Superfund Technical Support Center (Internet link: http://www.epa.gov/region09/waste/sfund/prg/intro.htm). **The use of PRG levels for HILs is an interim approach until these substances have been scrutinised through the enHealth Council process for determining health-based soil investigation levels.**
9. For protection of built structures (as presented in the NEPM, NEPC 1999).

3. ASSESSMENT LEVELS FOR SEDIMENT

Contaminated sediments are soils, sand, organic matter, or minerals that accumulate on the bottom of a water body and contain substances that may adversely affect human health or the environment. They may result from discharges, wash from land, be deposited from the air, erode from river banks or beds, or form from underwater breakdown or build-up of minerals. The important role of sediments as both a source and sink of dissolved contaminants has been recognised for some time. In addition to their influence on surface water quality, sediments represent a source of bioavailable contaminants to benthic biota, and hence potentially to the aquatic food chain. Contaminated sediments can therefore impact aquatic ecology integrity, and impact human health e.g. where exposure occurs through consumption of impacted aquatic organisms.

The sediment assessment levels adopted by the DoE as presented in Table 2, have been extracted from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). It is emphasised that the levels presented should not be used on a pass/fail basis, but are trigger (assessment) values that, if exceeded, prompt further investigation.

The ANZECC/ARMCANZ guidelines recommend a hierarchical approach to the assessment of sediments, with a focus on issue identification and the protection necessary to manage these issues. This hierarchical approach is based upon an initial assessment of total contaminant concentrations against the ISQG (Interim Sediment Quality Guideline), presented in Table 2, followed by further investigations/analysis to determine bioavailability and toxicity of contaminants:

- where total concentrations or dilute acid soluble metal analysis are less than ISQG-Low, no action is required;
- where total concentrations or dilute acid soluble metal analysis exceed the ISQG-Low, but are below the ISQG-High, then an assessment against background concentrations should be made;
- where the measured contaminant concentrations are found to exceed either the ISQG-High or both the ISQG Low and background concentrations, then an assessment of the bioavailability of the contaminants should be completed;
- where the bioavailable concentrations are found to be less then the ISQG-Low, then no further action is required;
- where the bioavailable concentrations are found to exceed the ISQG-Low, then toxicity testing is required, and contaminants found to be toxic will require remediation.

Where aquatic ecosystems are considered to be pristine and of high environmental value such as marine parks and sanctuary areas, a precautionary approach to assessment is recommended. In these ecosystems, there should be no detectable changes from natural variation.

This guideline only provides a brief summary of the assessment of sediments. It is therefore strongly recommended that prior to the assessment of sediments at a site, guidance be sought from the references provided herein, and from appropriately qualified persons to ensure that the correct methodologies are employed.

Important factors to consider when assessing sediments are:

- when analysing for metals, the dilute-acid-soluble metal concentration is seen as a more meaningful measure than the total value;
- non-available forms might include mineralised contaminants that require strong acid dissolution;
- measured as acid volatile sulphides (AVS) can be an important factor in reducing metal bioavailability, as it is able to bind released metals in non-bioavailable forms; and
- changes in redox potential and pH have effects on the availability of metals and other contaminants.

It should be noted that when assessing sediments, it is important to consider both sediment particles and sediment pore waters as contaminant sources. The importance of these sources will vary for different sediment dwelling organisms.

Where no assessment level has been developed for a specified contaminant of interest, this generally reflects the absence of an adequate data set for that contaminant. The ANZECC/ARMCANZ document suggests that an indicative value can be derived based on natural background concentrations multiplied by an appropriate factor (factor of 2, but in highly disturbed ecosystems, a larger factor may be more appropriate (but no larger than a factor of 3). Alternatively, site-specific assessment/response levels can be determined through appropriate risk assessment. Refer to Schedule 6 (Guideline on Ecological Risk Assessment) of the *National Environment Protection (Assessment of Site Contamination) Measure* (NEPC, 1999).

Where sediments are located within estuarine and marine waters, and are being assessed for dredging and ocean disposal, then the criteria presented in the *Interim Ocean Disposal Guidelines* (Table 4, Action List Preliminary Recommendation for Screening and Maximum Levels) (ANZECC, 1998) should be utilised. These assessment criteria have not been included in this document as there are a number of specific requirements for the assessment of material to be disposed at sea, and reference should be made to the original document.

TABLE 2. ASSESSMENT LEVELS FOR SEDIMENT[1]

Parameter	ISQG-Low[2] (Trigger value)	ISQG-High[3]
Metals/Metalloids (mg/kg dry wt)		
Antimony, Sb	2	25
Arsenic, As	20	70
Cadmium, Cd	1.5	10
Chromium, Cr	80	370
Copper, Cu	65	270
Lead, Pb	50	220
Mercury, Hg	0.15	1
Nickel, Ni	21	52
Silver, Ag	1.0	3.7
Zinc, Zn	200	410
Organometallics		
Tributyltin (µg Sn/kg dry wt)	5	70
Organics (µg/kg dry wt)[4]		
Acenapthene	16	500
Acenaphthalene	44	640
Anthracene	85	1100
Fluorene	19	540
Naphthalene	160	2100
Phenanthrene	240	1500
Low Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs)[5]	552	3160
Benzo(a)anthracene	261	1600
Benzo(a)pyrene	430	1600
Dibenzo(a,h)anthracene	63	260
Chrysene	384	2800
Fluoranthene	600	5100
Pyrene	665	2600
High Molecular Weight Polycyclic Aromatic Hydrocarbons (PAHs)[6]	1700	9600
Total Polycyclic Aromatic Hydrocarbons (PAHs)	4000	45000
Total DDT	1.6	46
P,p'-DDE	2.2	27
o,p'- + p,p'-DDD	2	20
Chlordane	0.5	6
Dieldrin	0.02	8
Endrin	0.02	8
Lindane	0.32	1.0
Total Polychlorinated Biphenyls (PCBs)	23	-

Notes:

1. Extracted from Australian and New Zealand (ANZECC)/Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.
2. Interim Sediment Quality Guidelines - Low: Probable effects concentrations below which biological effects would rarely occur.
3. Interim Sediment Quality Guidelines - High: Probable effects concentrations below which biological effects would possibly occur. Concentrations above these values represent a probable-effects range within which effects would be expected to frequently occur.
4. Normalised to 1% organic carbon. If the sediment organic carbon is markedly higher than 1%, the guideline value should be reduced accordingly, since additional carbon binding sites reduce the contaminant bioavailability.
5. Low molecular weight PAHs are the sum of acenaphthalene, anthracene, fluorene, 2-methylnaphthalene, naphthalene and phenanthrene.
6. High molecular weight PAHs are the sum of benzo(a)anthracene, benzo(a)pyrene, chrysene, Dibenzo(a,h)anthracene, fluoranthene and pyrene.

Values are expressed as concentrations on a dry weight basis. This does not imply that samples should be dried before analysis resulting in potential loss of some analytes, but that results should be corrected for moisture content.

4. ASSESSMENT LEVELS FOR WATER

Table 3 presents the levels adopted by the DoE for the assessment of surface water and groundwater quality in Western Australia. These assessment levels are from the *Australian Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000), and the *Australian Drinking Water Guidelines* (NHMRC/ARMCANZ, 1996).

The use of the assessment levels should be based on the beneficial use and management objectives of the water resource, e.g. aquatic ecosystem, public drinking water supply, or domestic irrigation. Where groundwater is being assessed/monitored, the most appropriate groundwater quality assessment level is dependent upon the discharge location and beneficial use of the groundwater resource. For example, where contamination is present in shallow groundwater (such as in the superficial aquifer in Perth), and the site is located adjacent to a wetland that is the discharge point for the shallow contaminated groundwater, then the guidelines for the protection of fresh water aquatic ecosystems (ANZECC, 2000) would be the most appropriate assessment levels. Similarly, where a site is located within an area where groundwater is abstracted for domestic irrigation, then the irrigation guidelines would be most applicable. Depending upon the location of a site, assessment against more than one criteria may be required.

Aquatic Ecosystem (Fresh and Marine) Guidelines
When assessing surface water bodies, or groundwater which discharges to surface water bodies, then unless otherwise specified in Table 3, the values to ensure 95% of aquatic species are protected should be used as assessment values.

For environments with a high conservation value, such as Ramsar wetlands, the DoE may require that 99% trigger values are used instead of the 95% values.

Where surface waters are highly modified, less conservative assessment levels may be appropriate. Justification for using less conservative levels must be provided to the DoE where they are used.

Exceedance of these criteria does NOT necessarily mean that a substance will cause ecological harm, but that a proponent will be required to carry out further investigations involving risk assessment to demonstrate that there will be no harmful effects in situations where the 95% trigger value is exceeded.

Drinking and Irrigation Guidelines
Application of the drinking and irrigation guidelines relate to human consumption/contact with surface and groundwater.

These guidelines should be applied as assessment levels at the point of monitoring, and as response levels at the point of use (i.e abstraction).

Where contamination occurs in an area where groundwater is extracted for drinking water purposes, or where background groundwater quality has a potential to be used as a drinking water resource, even where it is not currently being used, then the *Australian Drinking Water*

Guidelines (NHMRC/ARMCANZ, 1996) would be the most appropriate assessment levels to ensure protection of groundwater resources into the future.

Where a site is located up hydraulic gradient of any domestic bores which may be influenced by contaminated groundwater, then a determination as to whether the water is used for recreational purposes (eg. filling swimming pools, bathing), drinking or irrigation purposes should be made and the water quality assessed against the appropriate assessment levels (eg drinking water, irrigation water)

Where groundwater is used for irrigation purposes only (including domestic irrigation), then the irrigation guidelines presented in Table 3 can be utilised. Where no irrigation levels exist, site-specific criteria should be developed, or the drinking water guidelines used.

Where background groundwater quality has reduced beneficial uses (eg. hypersaline groundwater), then the DoE may allow less stringent assessment levels, based on site-specific characteristics and the nature and extent of contamination.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) contain guidelines for "recreational use". These guidelines have not wholly been adopted by the DoE based upon advice from the DoH. A number of substances listed in the recreational guidelines are at guideline levels which are more conservative than the currently published drinking water guidelines (ANZECC, 1996). Therefore water may be deemed not to pose a risk to any person drinking the water, but may pose a risk if a person was to have contact with the water during any recreational activity such as swimming, fishing etc. The recreational guidelines can be used for the assessment of sites, but should be accompanied by a site-specific risk assessment looking at exposure pathways.

Where groundwater contains levels of substances above the appropriate assessment levels, then further investigation should be carried out to determine the source/s and extent of contamination, and any risks posed to the environment or human health.

It is the site investigator's responsibility to recommend appropriate water quality assessment levels based on an assessment of the beneficial use of the groundwater resource and receiving environment. However, where a site investigator fails to recommend water quality assessment levels within an assessment report, or where the DoE considers that the adopted water quality assessment levels are not appropriate, the DoE may revert to drinking water levels or other levels for assessment purposes.

In some situations, the assessment criteria for some chemical substances will be below Limits of Reporting (LORs) which can be achieved by commercial, NATA-accredited chemical laboratories undertaking chemical analysis, in particular where the 99% trigger values are being used as assessment criteria (refer to section 1.4).

4.1 WATER QUALITY GUIDELINES REVIEW PROCESS

It should be noted that the guidelines presented in the *Australian Drinking Water Guidelines* (NHMRC/ARMCANZ, 1996) and referenced in Table 3 are subject to an ongoing review process. As a result, drinking water guidelines may be revised as new scientific information becomes available.

TABLE 3. ASSESSMENT LEVELS FOR WATER

	Marine Waters[1] (μg/L)	Fresh Waters[1] (μg/L)	Drinking Water[2] Health* Aesthetic# (mg/L)	Long-Term Irrigation Water[3] (mg/L)
Monocyclic Aromatic Hydrocarbons (MAHs)				
Benzene	500	950	0.001	-
Chlorinated benzenes[4,5]	20 (for 1,2,4 trichloro-)	3-260[5]	-	-
Chlorinated phenols[4,5]	11 (for pentachloro-)	3-340[5]	0.02-0.3*,[6] (0.0001-0.002#)[6]	-
Toluene	-	300	0.8* (0.025#)	-
Ethylbenzene	-	-	0.3* (0.003#)	-
Xylenes	-	350 (as o-xylene), 200 (as p-xylene)	0.6* (0.02#)	-
Metals/Metalloids				
Aluminium, Al	-	55 (pH>6.5)	(0.2#)	5.0
Arsenic, As	50	24 (as AsIII) 13 (as AsV)	0.007	0.1
Barium, Ba	-	-	0.7	-
Beryllium, Be	-	4	-	0.1
Boron, B	-	370	0.3	0.5
Cadmium, Cd	0.7	0.2	0.002	0.01
Chromium (Total), Cr	50	10	-	0.1
Chromium (VI)	4.4	1.0	0.05	-
Cobalt, Co	1	-	-	0.05
Copper, Cu	1.3	1.4	2.0 (1.0#)	0.2
Iron, Fe	-	-	(0.3#)	0.2
Lead, Pb	4.4	3.4	0.01	2.0
Lithium, Li	-	-	-	2.5 (0.075 for citrus crops)
Manganese, Mn	-	1900	0.5 (0.1#)	0.2
Mercury (Total), Hg	0.1	0.06	0.001	0.002
Molybdenum, Mo	-	-	0.05	0.01
Nickel, Ni	7	11	0.02	0.2
Selenium (Total), Se	70	5.0	0.01	0.02
Silver, Ag	1.4	0.05	0.1	-
Tributyl tin	0.002	-	-	-
Uranium, U	-	-	0.009[7]	0.01
Vanadium, V	100	-	-	0.1
Zinc, Zn	15	8	(3.0#)	2.0

	Marine Waters[1] (µg/L)	Fresh Waters[1] (µg/L)	Drinking Water[2] Health Aesthetic[#] (mg/L)	Long-Term Irrigation Water[3] (mg/L)
Pesticides				
Organochlorine Pesticides[4,6,10]				
Aldrin	0.01	0.01	(and Dieldrin) 0.0003	-
Chlordane	0.004	0.03	0.001	-
DDT	0.001	0.006	0.02	-
Dieldrin	0.002	0.002	(and Aldrin) 0.0003	-
Chlorpyrifos	0.009	0.01	0.01	-
Diazinon	-	0.01	0.003	-
Dimethoate	-	0.15	0.05	-
Fenitrothion	-	0.20	0.01	-
Malathion	-	0.05	-	-
Parathion	-	0.004	0.01	-
Herbicides & Fungicides[10]				
Diquat	-	1.4	0.005	-
2,4-D	-	280	0.03	-
2,4,5-T	-	36	0.1	-
Molinate	-	3.4	0.005	-
Thiobencarb	-	2.8	0.03	-
Thiram	-	0.01	0.003	-
Atrazine	-	13	0.02	-
Simazine	-	3.2	0.02	-
Tebuthiuron	-	2.2	-	-
Glyphosate	-	370	1	-
Trifluralin	-	2.6	0.05	-
Phthalate esters				
di-n-butylphthalate	-	9.9	-	-
di (2-ethylhexyl) phthalate	-	0.6	-	-
Other phthalate esters		0.2		
Polycyclic Aromatic Hydrocarbons (PAHs)				
Naphthalene	50	16	-	-
Benzo[a]pyrene	-	-	0.00001	-
Total PAHs	3.0	3.0		
Polychlorinated Biphenyls (PCBs)				
Aroclor 1242	-	0.3	-	-
Aroclor 1254	-	0.01	-	-
Total PCBs	0.004	0.004		
Phenols				
Phenol	400	320	-	-

	MarineWaters[1] (µg/L)	Fresh Waters[1] (µg/L)	Drinking Water[2] Health* Aesthetic# (mg/L)	Long-Term Irrigation Water[3] (mg/L)
Other Organics				
Styrene (vinylbenzene)	-	-	0.03* (0.004#)	-
Tetrachloroethene	-	-	0.05	-
Trichlorobenzenes (Total)	-	3 (as 1,2,3-trichloro-) 85 (as 1,2,4-trichloro-)	0.03* (0.005#)	-
Vinyl chloride	-	-	0.0003	-
1,2-dichloroethane	-	-	0.003	-
Carbon tetrachloride	-	-	0.003	-
Chlorobenzene	-	-	0.3* (0.01#)	-
Dichloromethane (Methylene chloride)	-	-	0.004	-
Ethylenediamine tetraacetic acid (EDTA)	-	-	0.25	-
Hexachlorobutadiene	-	-	0.0007	-
Others				
Calcium	-	-	-	-
Chloride	-	-	(250.0#)	40[9]
Cyanide	4	7	0.08	-
Fluoride	-	-	1.5	1.0
Nitrate	-	700	50.0	-
Nitrite	-	-	3.0	-
Nitrate-N	-	3100	-	-
Nitrite-N	-	-	-	-
Hydrogen sulfide	-	1.0	0.05	
Other Parameters				
Colour and clarity	<10% change in euphotic depth	<10% change in euphotic depth	-	-
Hardness as $CaCO_3$	-	-	(200#)	-
pH	8.0-8.4	6.5 – 8.5	(6.5 – 8.5#)	-

Notes:

This list is not exhaustive, and additional water quality guidelines exist for further chemicals and environmental conditions. Reference should be made to the *Australian Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) for guidance on how to assess additional parameters and site-specific conditions.

- No level available. This does not necessarily imply that no assessment can be made; site specific details may be required – refer to Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) *Australian Water Quality Guidelines for Fresh and Marine Water Quality*.

1. Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) *Australian Water Quality Guidelines for Fresh and Marine Water Quality* – Trigger Values for slightly-moderately disturbed ecosystems.
2. National Health and Medical Research Council (NHMRC)/Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (1996) *Australian Drinking Water Guidelines.*
3. Long-term irrigation refers to the application of irrigation water up to 100 years. For irrigation water that will not be used for this length of time, short-term irrigation guidelines may appropriate – refer to Table Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) *Australian Water Quality Guidelines for Fresh and Marine Water Quality.*
4. For additional compounds in fresh and marine waters, refer to Table 3.4.1 of *Australian Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000).
5. The guideline refers to a range of "threshold levels" for a group of compounds. Should the measured value exceed the lower range, speciation should be conducted and compared against more specific guidelines (e.g. ANZECC 2000).
6. Value is as presented in *Australian Drinking Water Guidelines* (NHMRC/ARMCANZ, 1996), which differs from that presented in the NEPM (NEPC, 1999).
7. For additional pesticides for drinking water quality refer to the Australian Drinking Water Guidelines (NHMRC, 1996).
8. Provisional health guideline for uranium is from the World Health Organisation (1993) Guidelines for Drinking Water Quality, available at web site http://www.who.int/water_sanitation_health/GDWQ/. This document may be used to provide drinking water criteria in situations where there is not a relevant Australian criterion.
9. Guideline refers to the minimum crop tolerance of Chloride; the individual crop sensitivity should determine the acceptable Chloride concentration.

10. Whilst the guideline refers to health-based levels, any level of pesticide in drinking water that is above the appropriate detectable limit may be hazardous. Further reference should be made to *Australian Drinking Water Guidelines* (NHMRC/ARMCANZ, 1996) for acceptable detection limits.

5. GLOSSARY

Analyte	Refers to any chemical compound, element or other parameter as a subject for analysis.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Aquifer	Rock or sediment in a geological formation, or group of formations, or part of a formation which is capable of being permeated permanently or intermittently and can thereby transmit water.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
Assessment Levels	Guideline concentrations of contaminants adopted by the DoE to use as a comparison against which to assess the presence and severity of contamination at a site.
Background Concentrations	Naturally occurring ambient concentrations in the local areas of a site.
Beneficial Use	The use of the environment, or of any portion thereof, which is – (a) conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment and which requires protection from the effects of emissions or of activities referred to in paragraph (a) or b) of the definition of "environmental harm" in Section3A(2) of the *Environmental Protection Act 1986* (as amended); or (b) identified and declared under Section 35(2) of the *Environmental Protection Act 1986* (as amended) to be a beneficial use to be protected under an approved policy.
Bioavailability	Availability of contaminants in a form in which organisms or biota can assimilate contaminants e.g. contaminants being in a dissolved state or capable of being solubilised once ingested.
Bore	A hole drilled into an aquifer for the purpose of monitoring or extracting groundwater. Another common term is 'well'.
BTEX	Benzene, Toluene, Ethylbenzene, Xylene.

Clean Fill	Material that will have no harmful effects on the environment and which consists of rocks or soil arising from the excavation of undisturbed material. For material not from a "clean excavation", it must be validated to have contaminants below EILs.
Competent Professional	Possessing the skills, knowledge, experience, and judgement to perform the assigned tasks or activities satisfactorily.
Composite Sample	The bulking and thorough mixing of equal quantities of soil samples collected from more than one sample location to form a single soil sample for chemical analysis.
Contaminant	A substance which has the potential to present a risk of harm to human health or any environmental value.
Contaminant Rebound	Occurs when residual non-aqueous phase liquid (NAPL), sorbed or otherwise, immobilised contaminants, are re-dissolved into the groundwater.
Contaminated	In relation to land or underground water, means that a substance is present in, on or under that land or in that underground water, at a concentration that presents, or has the potential to present, a risk of harm to human health or any environmental value.
Data Quality Objective (DQO)	Qualitative and quantitative statements which specify the quality of the data required.
Dense Non-Aqueous Phase Liquid (DNAPL)	Non-aqueous substances which have an average density greater than water (specific gravity greater than 1) and therefore generally sink in water.
DoE	Department of Environment
Detailed Site Investigation (DSI)	An investigation which confirms and delineates potential or actual contamination through a comprehensive sampling program.
Development (of bores)	The removal of fines (including drilling mud) from the aquifer immediately surrounding the bore and creating a filter zone around the bore that prevents further movement of aquifer particles into the bore.

Diffuse Source	Widespread sources of contamination such as the contents of landfill sites, residential areas or large industrial complexes containing a number of point sources.
DOIR	Department of Industry Resources
Ecosystem	Unit including a community of organisms, the physical and chemical environment of that community, and all the interactions among those organisms and between the organisms and their environment.
EIL_{soil}	Ecological Investigation Level. EILs for soil are the concentration of a contaminant below which adverse impacts upon site-specific ecological values are unlikely to occur.
Environmental Harm	Means direct or indirect – (a) harm to the environment involving removal or destruction of, or damage to – (i) native vegetation; or (ii) the habitat of native vegetation or indigenous aquatic or terrestrial animals; (b) alteration of the environment to its detriment or degradation or potential detriment or degradation; (c) alteration of the environment to the detriment or potential detriment of an environmental value; or (d) alteration of the environment of a prescribed kind.
Environmental Value	Means - (a) beneficial use; or (b) an ecosystem health condition.
FID	Flame Ionisation Detector.
Groundwater (also Underground Water)	All waters occurring below the land surface.
HIL_{soil}	Health Investigation Levels. HILs are utilised to assess contamination where: (a) there is no adverse impact, or little potential for any adverse impact, to the environment, or the environmental value or beneficial use of an environmental receptor; and therefore (b) the adverse impacts arising from contamination at a site are to human health only.

Hydraulic Gradient	The change in the static head (of groundwater) per unit of distance in a given direction.
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Interim Sediment Quality Guidelines-Low (ISQG-Low)	Probable-effects concentrations below which biological effects would rarely occur.
Interim Sediment Quality Guidelines-High (ISQG-High)	Probable-effects concentrations below which biological effects would possibly occur. Concentrations at or above the ISQG-High represent a probable-effects range within which effects would be expected to frequently occur.
Investigation Levels	The concentration of a contaminant above which further investigation, evaluation and possibly remediation will be required.
Landfill	In relation to the legal disposal of contaminated material, landfill means a site used for disposal of solid material by burial in the ground that is licensed as a landfill under the *Environmental Protection Act 1986.*
Light Non-Aqueous Phase Liquid (LNAPL)	Non-aqueous substances which have an average density less than water (specific gravity of less than 1) and therefore generally float on water, e.g. petrol.
NATA	National Association of Testing Authorities.
Natural Attenuation	Reliance on natural processes, including various physical, chemical, or biological processes, that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil, sediment or groundwater. These *in situ* processes include biodegradation, dispersion, dilution, sorption, volatilisation, chemical or biological stabilisation, transformation, or destruction of contaminants.
NEPC	National Environment Protection Council.
NEPM	National Environment Protection Measure.
NHMRC	National Health and Medical Research Council.
PID	Photoionisation Detector.
Point Source	Localised source of contamination such as storage tanks,

	pumps and drums.
Practitioners	Suitably qualified professionals with experience in environmental investigations and management.
Preliminary Site Investigation (PSI)	An investigation consisting of a desktop study, a detailed site inspection and, where appropriate, limited sampling. The preliminary site investigation should be of such scope as to be sufficient to indicate whether contamination is present or likely to be present and to determine whether a detailed site investigation should be conducted. Also to provide information for designing a DSI.
Public Drinking Water Source Area (PDWSA)	An area allocated for the collection/abstraction of water for public drinking water supply.
Receptor	The entity that may be adversely affected by contact with or exposure to a contaminant of concern.
Remediation	Action taken to eliminate, limit, correct, counteract, mitigate or remove any contaminant or the negative effects on the environment or human health of any contaminant.
Residual/Remaining Soil/Groundwater	Soil/groundwater remaining after contaminated soil/groundwater has been removed.
Response Level	Concentration of a contaminant at a specific site based on a site assessment for which some form of response is required, to provide an adequate margin of safety to protect public health and/or the environment.
Risk Assessment	Process of estimating the potential impact of a chemical, biological or physical agent on humans, plants, animals and the ecology.
Sample Pattern	The location of sampling points within a sampling area.
SAP	Sampling and Analysis Program.
Saturated Zone	The zone within an aquifer in which all the pores and rock fractures are filled with water.
Sediment	Loose particles of sand, clay, silt and other substances that settle at the bottom of a body of water. Sediment can derive from the erosion of soil or from the decomposition of plants and animals.
Separate Phase Hydrocarbons (also referred to as Phase-	Differences in the physical and chemical properties of water and Non-Aqueous Phase Liquids (NAPLs) results in a

Separated Hydrocarbons)	physical interface between the liquids, which prevents the liquids from mixing.
Site	An area of land or underground water.
Underground Storage Tank (UST)	A tank that: a) is currently, or has historically been used for the storage of environmentally hazardous substances such as, but not limited to, petroleum products, acids and alkalis; and b) is fully or partially buried.
Underground Water Pollution Control Area (UWPCA)	An area gazetted under the *Metropolitan Water Supply and Drainage Act 1909* to protect groundwater resources used for public drinking water supply. Within these areas restrictions apply to activities which may pollute the groundwater.
Validation	The process of demonstrating that a site has been remediated successfully. Involves the collection and analysis of samples to demonstrate that contaminant concentrations are below acceptable limits and do not pose a risk to human health or the environment.
Watertable	The surface of an unconfined aquifer or confining bed at which the pore water pressure is atmospheric. It can be measured by installing groundwater bores into the zone of saturation and measuring the water level in those bores.
Water Reserve	An area gazetted under the *Country Areas Water Supply Act 1947* to protect groundwater resources used for public drinking water supply. Within these areas restrictions apply to activities which may pollute the groundwater.
Well	Refer to Bore.

6. REFERENCES

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