Government of **Western Australia**
Department of **Water and Environmental Regulation**

Guideline

Assessment and management of contaminated sites

Activities regulated under the:

Contaminated Sites Act 2003

Contaminated Sites Regulations 2006

National Environment Protection (Assessment of Site Contamination) Measure 1999

November 2021

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November 2021

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Acknowledgments

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1. Purpose

The purpose of this document is to provide guidance on the assessment and management of contaminated sites in Western Australia (WA) within the legislative framework provided by the Contaminated Sites Act 2003 (CS Act), the Contaminated Sites Regulations 2006 (CS Regulations) and the revised national site assessment framework provided in the National Environment Protection (Assessment of Site Contamination) Measure 1999 (ASC NEPM).

This document includes guidance on:

- how to assess and manage contaminated sites
- how to assess risks to human health, the environment and environmental values
- how to apply the generic assessment levels specific to WA
- how to apply the ASC NEPM assessment levels in WA
- what information you should include when reporting on the various stages of contaminated site assessment and management.

This guideline may also be useful for other purposes such as due diligence assessments.

However, it may also be necessary to discuss site-specific circumstances with the Department of Water and Environmental Regulation (the department), refer directly to the CS Act and CS Regulations, and/or seek specific legal advice.

2. Introduction

The department has prepared this guideline to support environmental practitioners, land owners and other industry stakeholders to understand:

- how to investigate, assess, remediate and manage contaminated sites
- what reports they must submit to the department and accredited contaminated site auditors under the CS Act and the CS Regulations[1].

In WA, we regulate contaminated sites through the CS Act and CS Regulations (available from the WA State Law Publisher at www.legislation.wa.gov.au). We also work with the Department of Health (DoH) in relation to public health issues at contaminated sites.

The ASC NEPM guides the assessment of site contamination. When you refer to the ASC NEPM, you should also consult the NEPC website for *errata* and additional information provided in the ASC NEPM Toolbox. The *National Environment Protection Council Act 1994* limits the scope of the ASC NEPM to site assessment and therefore it does not include guidance on remediation of contaminated sites.

We provide additional guidance specific to WA within the *Contaminated sites guidelines* (CSG), which include this guideline. DoH provides information and guidance on contaminated land.

You should refer to our guidance, as well as that of the ASC NEPM and DoH, when conducting site assessments. You must keep up-to-date with the current versions of guidance documents referred to herein and published *errata*.

Note the CSG replace the guidelines within the *Contaminated sites management series* (see below).

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[1] From here, this guideline will refer to the Department of Water and Environmental Regulation as 'we/us' and to the environmental practitioners, land owners and other industry stakeholders to whom this guideline is addressed as 'you'.

Contaminated sites guidelines	***Contaminated sites management series* (superseded)**
Assessment and management of contaminated sites (2014, 2021)	*Development of sampling and analysis plans* (2001) *Community consultation* (2006) *Potentially contaminating activities, industries and land uses* (2004) *Assessment levels for soil, sediment and water* (2010) *Bioremediation of hydrocarbon contaminated soils in Western Australia* (2004) *Interim guideline on the assessment and management of per- and polyfluoroalkyl substances* (2018) *The use of risk assessment in contaminated site assessment* (2006) *Reporting on site assessments* (2001)
Identification, reporting and classification of contaminated sites in Western Australia (2017)	*Reporting of known and suspected contaminated sites* (2006) *Site classification scheme* (2006) *Certificate of contamination audit scheme* (2000)
Use of monitored natural attenuation (MNA) for groundwater clean-up (2021)	*Use of monitored natural attenuation for groundwater remediation* (2004)
The Western Australian contaminated sites auditor scheme (2016) *Requirements for mandatory auditors' reports* (2016) *Accreditation of contaminated sites auditors* (2016)	*Contaminated sites auditors – guidelines for accreditation, conduct and reporting* (2009)
Guidelines for the Assessment, Remediation and Management of Asbestos Contaminated Sites in Western Australia (joint publication DWER and DoH) (2021)	*Assessment, remediation and management of asbestos-contaminated sites in Western Australia* (joint publication DER and DoH) (2009)

3. Health safety and emergency response

3.1 Occupational health and safety

The assessment and management of site contamination can present risks to site personnel, the public and the environment.

Detailed guidance on the occupational health and safety aspects of working on contaminated sites is outside the scope of this guideline. This chapter briefly discusses appropriate consideration of these issues when you are planning work at known or suspected contaminated sites. See Section 13.1 for site management strategies for the general protection of human health and the environment during site assessment and remediation.

Information on worker safety

Guidance note — Occupational safety and health management and contaminated sites work (Commission for Occupational Safety and Health 2005)

You should consider occupational health and safety issues for all sites and manage them according to national and state legislative requirements. The *Occupational Safety and Health Act 1984* and Occupational Health and Safety Regulations 1996 (WA) provide the requirements for ensuring the health, safety and welfare of people in the workplace. Refer to WorkSafe and the Commission for Occupational Safety and Health for further information.

Before you visit a site, whether it is to conduct a non-intrusive site inspection, comprehensive sampling program or remedial work, you should prepare a health, safety and environment plan (HSEP) to address the anticipated site conditions, including the potential contaminants and contaminated media.

An HSEP identifies appropriate measures to protect health, safety and the environment. Depending on the site-specific circumstances, workers may require additional training before they work at the site and/or may need to participate in a health monitoring program.

You must ensure ‘adequate communication’ with all site personnel about the HSEP before they start work, and keep documentation of all training, inductions and meetings.

We are not responsible for assessing HSEP documentation and it is not necessary to include a copy of the HSEP and associated documentation in reports you send us.

3.2 Pollution incidents and emergency response

Guidance on the appropriate response for the management of acute health risks, emergencies and pollution incidents such as from the effects of explosion, bushfires, floods or recent spills is not within the scope of this document. You should address these issues immediately in consultation with the relevant authorities such as the Department of Fire and Emergency Services and our Pollution Response team.

Pollution incidents with the potential to cause contamination, such as spills and leaks, should be cleaned up as soon as possible after the original incident or as directed by the relevant authorities. If a spill or pollution incident is not resolved through an immediate clean-up response, the site may need to be reported to us as a known or suspected contaminated site.

For guidance on reporting obligations, including statutory timeframes, see *Identification, reporting and classification of contaminated sites in Western Australia* (DER 2017).

4. Environmental practitioners

4.1 Environmental consultants

The assessment and remediation of contamination is a specialised field that requires knowledge and expertise in a variety of scientific disciplines. We recommend you only engage suitably qualified and experienced consultants to carry out this type of work. Schedule B9 of the ASC NEPM provides guidance on the necessary competencies and experience required by practitioners (environmental consultants and auditors) involved in contaminated site assessment.

The Certified Environmental Practitioners Scheme, as of 1 January 2018, has replaced the previous schemes run by the Environment Institute of Australia and New Zealand and Site Contamination Practitioners Australia. We do not accredit or register environmental consultants to work in WA. See the *Contaminated sites fact sheet 3 — Seeking help from contaminated sites experts* for guidance on selecting and appointing an environmental consultant.

Asbestos

DoH considers that environmental consultants employed to investigate, remediate and manage asbestos contamination should be supervised by a lead consultant with appropriate asbestos qualifications and experience. The lead consultant should normally have a minimum of three years' continuous experience with asbestos soil contamination and relevant tertiary qualifications in environmental science, science or engineering.

For more information, including lead consultant requirements, refer to the *Guidelines for the assessment, remediation and management of asbestos-contaminated sites in Western Australia* (DoH 2021).

4.2 Accredited contaminated site auditors

Mandatory audits

Contaminated sites auditors are expert contaminated-land professionals that we accredit under the CS Act to conduct audits in WA. Auditors provide an independent review of the investigations, assessments, monitoring and remedial works undertaken by environmental consultants. The auditor's findings are documented in an audit report.

For detailed guidance on the operation of the contaminated sites auditor scheme, refer to *The Western Australian contaminated sites auditor scheme* (DER 2016a) and *Requirements for mandatory auditors' reports* (DER 2016b) on our *Contaminated sites guidelines* webpage.

Regulation 31 of the CS Regulations and s. 44 of the CS Act set out when a mandatory auditor's report (MAR) must accompany reports submitted to us.

CS Regulations r.31 when mandatory auditor's reports are required

(1) A mandatory auditor's report is to be provided to the CEO –

- (a) in accordance with regulation 29(2)(d), when a request for a certificate of contamination audit is made in respect of land; or
- (b) with every report provided to the CEO containing information as to, or which will be relevant to, the investigation, assessment, monitoring or remediation of a source site; or
- (c) with every report containing information as to, or which will be relevant to, the investigation, assessment, monitoring or remediation of a site provided to the CEO for the purposes of—
  - (i) complying, or attempting to comply, with another written law; or
  - (ii) a requirement or condition (by whatever name called) imposed under another written law[1];
  - (iii) or taking a necessary step towards doing so; or
- (d) at the written request of the CEO, in respect of a site –
  - (iv) which, in the opinion of the CEO, presents particularly complex technical issues; or
  - (v) in respect of which, in the opinion of the CEO, inadequate information or reports have been provided; or
  - (vi) in respect of which, in the opinion of the CEO, a mandatory auditor's report is required to enable the site to be properly dealt with for the purposes of the Act.

CS Act s.44 Auditor's report in relation to notice

A notice is to require a person on whom the notice is binding to engage an auditor to report on the actions taken to comply with the requirements of the notice.

[1] For example, a planning or Ministerial condition or similar statutory requirement

We do not have the power to waive a requirement to provide a MAR if one is prescribed under regulation 31.

Unless the MAR is being prepared to report on work undertaken in response to a notice, you may submit a MAR at any stage of a project as appropriate, or as agreed in consultation with us. See Section 2.4 of *Requirements for mandatory auditors' reports* (DER 2016) for further information.

Non-statutory auditor advice

You may wish to consider obtaining technical advice from an auditor when:

- you anticipate planning (or similar) conditions
- you want a greater level of confidence in the adequacy of the contamination assessment and/or remediation, and/or

- the site assessment is very complex and requires an auditor's technical oversight to coordinate site investigations, assessment and remediation.

Non-statutory auditor advice sent to us for a site assessment under the *Contaminated Sites Act 2003* is known as a voluntary auditor's report (VAR).

We recommend that the general format and content of a VAR should follow that of a MAR; however, the statutory forms and notification requirements do not apply until a statutory requirement for the MAR is triggered.

5. Key terms

5.1 Definitions relating to 'site'

Site

Section 3 of the CS Act provides the following definition of a site:

CS Act s.3 — definition of 'site'

'**site**' means an area of land and includes –

(a) underground water under that land; and

(b) surface water on that land

You must identify a site using the boundaries given in the relevant certificate(s) of title. This enables us to use the state land administration system to identify and record known and suspected contaminated sites on the Contaminated Sites Register and to lodge memorials under the CS Act.

You may need to distinguish between the contaminated and uncontaminated parts of a land parcel so that we can apply the site classification and any memorial to the relevant portion of the site. You can do this by registering a Deposited Plan for Interest Purposes Only (DP-IPO) with Landgate (see DER 2017).

Source and affected sites

A site may comprise several land parcels or a single land parcel where the contaminating activities occurred. The CS Act differentiates between sites where contamination has originated, and sites that have become contaminated because of the movement or migration of contamination from another site; that is, the offsite movement of gases in a soil profile, contaminated groundwater, surface water or the movement of contaminated soil by natural processes such as erosion. Section 3 of the CS Act defines these types of sites as source sites and affected sites.

CS Act s.3 — definition of ‘source site’ and ‘affected site’

‘**source site**’ means a site –

(a) on which contamination; or

(b) on which a substance

has originated and from which it has migrated to another site (the ‘**affected site**’) causing, or contributing to, contamination on that other site

‘**affected site**’ means a site on which contamination is caused, or contributed to –

(a) by contamination; or

(b) by a substance,

which has migrated to that site from another site (the ‘**source site**’).

5.2 Definitions of ‘contaminated’

Contaminated

Section 4(1) of the CS Act provides the following definition of ‘contaminated’:

CS Act s.4(1) — definition of ‘contaminated’

‘**contaminated**’, in relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value.

Contamination can be present in the soil, groundwater and/or surface water of a site. It may be present in the solid, liquid or gaseous phases (e.g. soil or groundwater contamination giving rise to contaminant vapours in soil pore spaces). Where substances are present at above background concentrations, further assessment of those substances is required to assess the risk of harm to human health, the environment and environmental values.

Section 4(2) of the CS Act provides for exemptions from the definition of contaminated, which are prescribed in r.5 of the CS Regulations. See DER (2016a) for further information.

Substances that can present a risk of harm

The term ‘substance’ is used in the definition of contaminated in the CS Act. We may also refer to a substance as a contaminant or potential contaminant. A range of substances may be considered contaminants when present at above background concentrations. A contaminant may be:

- inorganic (e.g. metals, asbestos fibres) or organic (e.g. petroleum hydrocarbons)

- man-made (anthropogenic) (e.g. pesticides and herbicides)
- radioactive (e.g. uranium, thorium, radon)
- microbiological (e.g. pathogens).

A contaminant can be present in the soil, groundwater and/or surface water of a site. It may be present as a solid, liquid, vapour and/or gas (e.g. contaminant vapours in soil pore spaces or ambient air).

The potential for a contaminant to cause harm depends on its toxicity, concentration, and rate of emission, as well as the extent over which it occurs. For example, metals such as cadmium and mercury have a higher toxicity and may pose a risk at much lower concentrations (and over smaller areas) than less toxic metals such as iron and aluminium. In addition, the presence of more than one contaminant may have an additive or synergistic toxic effect.

Disturbance of naturally occurring substances

Some naturally occurring substances can present a risk of harm when they are disturbed. This may result in a site being considered contaminated. Examples include naturally occurring acid sulfate soils, radioactive minerals, asbestiform minerals and metals and metalloids in mineralised areas.

Naturally occurring substances that are disturbed and result in site contamination require risk-based assessment and management to protect human health and the environment in the same way as other sources of contamination. See DER (2016a) for guidance on reporting known or suspected contamination in accordance with the CS Act and contact us on the Contaminated Sites information line 1300 762 982 for advice in relation to specific site conditions .

Background concentrations

The meaning of ‘background concentration’ is not defined in the CS Act or Regulations. The ASC NEPM, however, defines background concentrations.

ASC NEPM — definition of ‘background concentrations’

‘**Background concentration**’ means the naturally occurring, ambient concentrations of a substance in the local area of a site.

Ambient background concentration (ABC) is discussed in section 2.5.7 of Schedule B1 of the ASC NEPM. The ABC of a contaminant is the soil concentration in a specified locality that is the sum of the naturally occurring background level and the contaminant levels that have been introduced from diffuse (non-point) sources by general anthropogenic activity not attributed to industrial, commercial or agricultural activities (e.g. motor vehicle emissions).

Go to section 11.3 for an outline of the methods to determine background concentration in soil. Refer to section 3.3 of Schedule B6 of the ASC NEPM for a discussion of background groundwater quality.

To determine whether a substance has the potential to pose a risk of harm, its concentration on a site is generally compared with generic assessment levels and in the context of background concentrations. See sections 10 and 11 for more information.

Note that the risk profile of a substance may be affected by changes in the physical condition of a material (e.g. increased leachability following disturbance of soil or crushing/grinding of rock) such that the substance may have the potential to pose a risk of harm, even when it is present at the natural background concentration.

Risk and risk of harm

The meaning of 'risk' is not defined in the CS Act or Regulations. Risk is defined in the ASC NEPM as:

ASC NEPM – definition of 'risk'
The probability in a certain timeframe that an adverse outcome will occur in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a chemical substance, that is, it depends on both the level of toxicity of the chemical substance and the level of exposure*.

* The original definition of risk referred to 'hazardous agents' rather than 'chemical substance'. The change to 'chemical substance' was made in the May 2013 amendment to the ASC NEPM to clarify the meaning of the term.

Environmental values

Section 3(2) of the CS Act provides for the use of definitions in the EP Act to apply to the CS Act, unless otherwise stated. The term 'environmental value' is included in the definition of contaminated in the CS Act and is defined in the EP Act as:

EP Act s.3 – definitions relevant to 'environmental value'
'**environmental value**' means— (a) a beneficial use; or (b) an ecosystem health condition; '**beneficial use**' means a 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 section 3A(2); or (b) identified and declared under section 35(2) to be a beneficial use to be protected under an approved policy. '**ecosystem health condition**' means a condition of the ecosystem which is—

(a) relevant to the maintenance of ecological structure, ecological function or ecological process 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 section 3A(2); or

(b) identified and declared under section 35(2) to be an ecosystem health condition to be protected under an approved policy

EP Act s.3A — definitions of 'environmental harm'

(2) In this Act —

'**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;

or

(b) alteration of the environment to its detriment or degradation or potential detriment or degradation; or

(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 values may relate to land or water. Within the ASC NEPM, the environmental values of land are referred to in land use categories, such as urban residential/public open space, commercial/industrial and areas of ecological significance. The ASC NEPM defines an area of ecological significance as one where the planning provisions or land use designation is for the primary intention of conserving and protecting the natural environment (s.2.5.3 Schedule B1).

Schedule B6 of the ASC NEPM defines environmental values in relation to groundwater, as values or uses of the environment that are conducive to public benefit, welfare, safety or health that require protection from the effects of pollution, waste discharge and deposits and include uses of water – for drinking, recreation and agriculture (such as for stock water supply or irrigation) and protecting aquatic ecosystems.

Consistent with the ASC NEPM, the environmental values of water relevant to the assessment of site contamination in WA include:

- groundwater-dependent ecosystems (such as the protection of stygofauna, phreatophytic vegetation and groundwater-dependent wetlands)
- aquatic ecosystems (fresh, marine and estuarine waters)
- drinking water (e.g. direct consumption but also applicable to bathing, filling swimming pools, food preparation or cooking)
- non-potable use of water (e.g. irrigation of gardens or parks and reserves, washing cars and clothes, flushing toilets)

- recreational use (e.g. water sports, swimming)
- agricultural use (e.g. stock water and commercial irrigation), and/or
- industrial use (e.g. process water).

You should take into account the current and potential[2] uses of water when considering whether a particular environmental value of water is relevant to a site. See section 11.7 for detailed guidance on the environmental values of groundwater and surface water and the application of Tier 1 assessment levels. See Appendix D for the Tier 1 assessment levels for water.

Definition of remediation

The CS Act provides the following definition of ‘remediation’:

CS Act s.3 — definitions of ‘remediation’

‘remediation’ in respect of a site that is contaminated includes—

(a) the attempted restoration of the site to the state it was before the contamination occurred;

(b) the restriction, or prohibition, of access to, or use of, the site;

(c) the removal, destruction, reduction, containment or dispersal of the substance, causing the contamination, or the reduction or mitigation of the effect of the substance;

(d) the protection of human health, the environment or any environmental value from the contamination.

Although the CS Act definition of remediation includes measures to manage contamination, such as by restricting access or use of the site, the term ‘remediation’ is commonly used in the literature to refer to active clean-up measures such as treating, removing or containing contamination (by engineered means). The terms ‘remediation’ and ‘management’ are also used interchangeably in the literature.

In this guideline, we use the term ‘clean-up’ when specifically referring to active and passive (e.g. monitored natural attenuation) forms of remediation and ‘remediation’ when we wish to convey the broader definition (under s. 3 of the CS Act).

See sections 11 and 12 for details about the clean-up and management of contaminated sites.

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[2] (realistic future uses)

6. Overview of site assessment and management

6.1 Triggers for site assessment

A site assessment seeks to determine whether there are any substances at above background concentrations that present, or have the potential to present a risk of harm to human health, the environment or any environmental values.

The assessment of site contamination may be required under the CS Act or the *Planning and Development Act 2005*. It may also be carried out voluntarily.

Triggers for site assessment and/or clean-up

Regulatory triggers:

- Classification under the CS Act. Action is required to assess contamination at sites classified as *possibly contaminated – investigation required* and to remediate or manage contamination at sites classified as *contaminated – remediation required*. In some circumstances, action may be required for sites classified *contaminated – restricted use* and *remediated for restricted use*.
- Regulatory notice (investigation, clean-up or hazard abatement notice).

Planning and development conditions:

- Action is required to assess potential contamination at sites where a condition has been applied by a planning authority for approval of rezoning, subdivision or development to ensure that the site is suitable for the proposed land use.
- Ministerial conditions applied under Part IV of the EP Act.

Other triggers:

- Action may be taken voluntarily by site owners, occupiers or other interested persons as part of a due diligence process; for example, establishing the contamination status of land prior to purchase or lease, or for insurance or financial purposes.

6.2 Prescribed premises under the EP Act

Certain industrial premises with the potential to cause emissions and discharges to air, land or water are regulated under Part V of the EP Act. See Schedule 1 of the EP Regulations for a list of the prescribed premises categories.

Under s.52 of the EP Act, an occupier who changes a premises to become, or to become capable of being, a prescribed premises, commits an offence unless it is done in accordance with a works approval. Under s.56 of the EP Act, occupiers of prescribed premises must be licensed for emissions. A works approval and licence may include conditions in accordance with s.62A of the EP Act; for example, a requirement to carry out regular groundwater sampling and analysis to monitor the effectiveness of management measures used to prevent emissions and discharges to the environment.

However, a licence does not negate reporting requirements or other statutory obligations arising under the CS Act. Some prescribed activities, by their very nature, will result in legacy contamination being present when the activity has ceased, with landfills and tailings storage facilities at mine sites being the most common examples.

If emissions or discharges at a prescribed premises cause contamination, the site should be reported to us as a known or suspected contaminated site under the CS Act (see DER 2017). Contamination issues at the site may be regulated under the CS Act, while all other matters will continue to be regulated under the EP Act. However, while a site is operational and regulated under Part V of the EP Act, the site's licence will, in most instances, be the primary regulatory instrument for the management of contamination issues.

Information obtained for the purpose of licence compliance, such as groundwater monitoring results, may be sent to our Contaminated Sites branch if it is relevant to the site's contamination status (see section 6.5 on report presentation). Note that our reporting requirements in relation to contaminated sites are generally more exacting than those associated with licence compliance.

In addition to the data you collect to comply with licence conditions, you may need to undertake further monitoring and investigation to delineate and characterise contamination and assess the risk to potential receptors.

Go to www.der.wa.gov.au/our-work/licences-and-works-approvals for further information on prescribed premises, including contact details for our regulatory services.

6.3 ASC NEPM framework for site assessment

The ASC NEPM provides a national framework for the assessment of site contamination and recommends you investigate contaminated sites in stages. This approach means the information you obtain during each stage may be used to inform and update the conceptual site model (CSM) and plan the subsequent scope of work. The staged approach means you can focus on the site's most critical issues in a prioritised and defensible manner to address unacceptable risks. You may carry out risk assessment at more than one stage of the site assessment and management process.

The ASC NEPM has a policy framework supported by two schedules (see Figure 1):

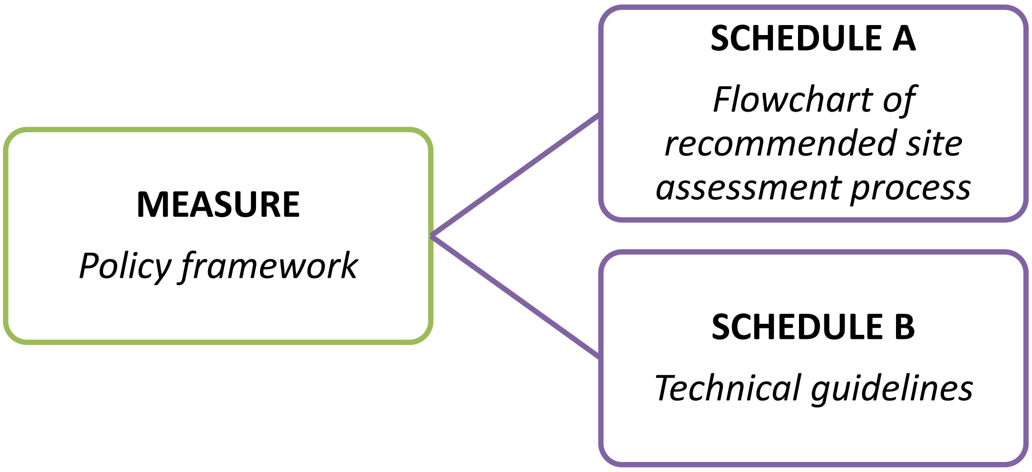

Figure 1: Structure of the ASC NEPM

Schedule B of the ASC NEPM is comprised of general guidelines for the assessment of site contamination, which are listed below. Supporting information to the ASC NEPM includes frequently asked questions (FAQs), *errata* and the ASC NEPM toolbox. This supporting material is periodically updated.

Guidelines that form Schedule B of the ASC NEPM	
Schedule B1	*Guideline on investigation levels for soil and groundwater*
Schedule B2	*Guideline on site characterisation*
Schedule B3	*Guideline on laboratory analysis of potentially contaminated soils*
Schedule B4	*Guideline on site-specific health risk assessment methodology*
Schedule B5a	*Guideline on ecological risk assessment*
Schedule B5b	*Guideline on methodology to derive ecological investigation levels in contaminated soils*
Schedule B5c	*Guideline on ecological investigation levels for arsenic, chromium (III), copper, DDT, lead, naphthalene, nickel and zinc*
Schedule B6	*Guideline on the framework for risk-based assessment of groundwater contamination*
Schedule B7	*Guideline on derivation of health-based investigation levels*
Schedule B8	*Guideline on community engagement and risk communication*
Schedule B9	*Guideline on competencies and acceptance of environmental auditors and related professionals*

Although the ASC NEPM does not provide guidance on the clean-up or management of contaminated sites, it does provide a preferred hierarchy of options for site clean-up and/or management in principle 16 of the site contamination policy framework, which is discussed in section 12.4.

6.4 Reporting framework

Reporting of site contamination works is generally undertaken according to the framework below.

Site contamination reporting framework

Preliminary site investigation (PSI) consists of a desktop study, a detailed site inspection and interviews with relevant personnel. A PSI may also include limited sampling and analysis. The information is used to develop an initial CSM. If contamination or sources of contamination (potential areas of concern) are identified, further detailed site investigation is necessary.

Detailed site investigation (DSI) assesses potential or actual contamination through an appropriate sampling and analysis program. Several phases of investigation (including risk assessment) may be required to adequately characterise the site, particularly for complex sites. The CSM is refined on an iterative basis until there is sufficient information and understanding of the site to devise risk-based strategies to manage the identified risks.

Remedial action plan (RAP) documents the type and extent of remediation required to ensure that the site is suitable for its current or intended future use, and to protect the surrounding environment and land uses. The plan details the clean-up techniques proposed to achieve the remedial objectives and criteria for assessing the effectiveness of the clean-up in the site validation process.

Site remediation and validation (SRV) is the process of cleaning up the site (remediation) and evaluating the effectiveness of the clean-up (validation). Where the remedial objectives are not met, further work may be required such as further remediation, risk assessment or ongoing site management.

Site management plan (SMP) documents ongoing management of the site if this is required, such as long-term monitoring and assessment of residual contamination. The SMP may require periodic revision and updating to ensure it remains relevant over time. A relevant stakeholder, such as the land owner or body corporate, must assume responsibility for maintaining and implementing the SMP.

You should consult the guidance in the ASC NEPM when determining the issues relevant to your particular site.

Appendix A has a checklist of information you should consider when planning, implementing and reporting on site assessment, clean-up and management. The checklist is not exhaustive as you should consider site location, physical characteristics, contaminants and potential risks on a site-specific basis. As such, you may determine additional site-specific factors for consideration when you develop the scope of work and subsequent reporting.

For sites comprising more than one land parcel, you should consider what information you need to address the site classification of each land parcel.

Site monitoring over time – such as groundwater, surface water or vapour monitoring – is often a necessary part of contamination assessment and management. For example, you may need to do this to assess trends in contaminant behaviour or confirm the successful remediation or containment of contamination. To obtain representative data, you should ensure the monitoring events are carried out in a consistent and comparable manner that considers issues that may affect the interpretation of longer-term trends, such as diurnal, seasonal or climatic effects. Monitoring may be done as part of a detailed site investigation, site remediation and validation program, or ongoing site management.

6.5 Report presentation

General report requirements

This section outlines our general requirements for presenting information when reporting on site contamination. You can find further guidance on report and data presentation in section 14 and Appendix D of Schedule B2 of the ASC NEPM.

Your report title must identify the site, the type of report (e.g. PSI, DSI, RAP) and the month and year the work was carried out. The title should at least include the legal lot number, street name and locality and remain consistent if you are producing multiple reports (and/or versions) for one site. The report should state the date of issue, the author, the person reviewing/approving the report and the version number if relevant. You should make clear whether the report is ‘draft’ or ‘final’, noting we will only accept a ‘final’ version of a report for review.

You should include our site classification reference number (DMO number) if you have it. You should also number your pages and present your information in a logical sequence with appropriate subject headings to guide the reader through the document.

Your diagrams and tabulated data should be clearly legible. As a guide, the main text, tables and figures should be at least font size 11. This requirement applies to both tabulated data in the main body of the report and all appendices, including laboratory data.

Graphics and data presentation

Your report should present and discuss all of the available information to accurately describe the site and surrounding land, and the work that has been carried out.

We encourage you to include site plans (including geological and aquifer cross-sections). These are a valuable tool to summarise complex information obtained during site assessment and remediation. Any graphics (e.g. site plans, cross-sections and CSM), site photographs and aerial photographs should be of a suitable scale, colour and quality to clearly display the relevant information. Site photographs should be accompanied by a location and aspect plan and aerial photographs should clearly identify the site boundaries.

You may wish to use an aerial photograph (if it is contemporary) as the basis for your site plan and to overlay other features and labels. Your graphics should make use of colour and shading to highlight different features such as current and former infrastructure, sample types, results and exceedences of assessment criteria.

Your report should also include tables and site plans that present field and laboratory results accompanied by clear and concise descriptive text. Where more than one land parcel is involved, you should give the identity/location of the land parcels (current cadastral parcels) in the tabulations and site plans.

It is important that you differentiate between raw data and interpreted or inferred information. Site plans with contours interpreted from groundwater elevations or contaminant concentrations should have labelled contour intervals which are appropriate for the quantity and quality of data available. You should include copies of laboratory analytical reports, including quality assurance/quality control (QA/QC) compliance and chain of custody forms as received from the laboratory, generally as an appendix to the main body of the report.

Data interpretation

You should tabulate and interpret the analytical results, noting that we require parcel-specific information on the nature and extent of site contamination for the purposes of site classification.

If the site comprises more than one land parcel, you should summarise the contamination affecting each individual land parcel.

You should discuss trends in groundwater conditions, such as differences in groundwater flow direction, or reducing or increasing contaminant concentrations between monitoring events.

Statistical analysis may be necessary to determine whether trends are significant. You should not refer to a decrease in the concentration of a contaminant between two consecutive groundwater monitoring events (in isolation) as a reducing trend because you would not have enough information to support this statement. You should discuss the application, data limitations and outcomes of statistical analysis in the report and provide the raw data, formulas and calculations in an appendix.

Schedule B2 of the ASC NEPM (section 8.3.4) provides a general discussion of the attenuation of groundwater contaminants. See our *MNA guideline* (2021) for detailed guidance on assessing trends from groundwater monitoring data and attenuation of groundwater contamination.

Conclusions and recommendations

Your report should include a clear and concise summary of the assessment/work carried out, the conclusions you have drawn from that assessment/work and any recommendations for further assessment or remediation (see Appendix A). Where the site comprises more than one land parcel, your summary, conclusions and recommendations must be parcel-specific.

6.6 Report submission

You must provide enough information to demonstrate that the site assessment and remediation has been carried out in accordance with our guidelines and the ASC NEPM. You should document your rationale for decision-making and put all the relevant supporting information in the report (see the report checklist in Appendix A). It is essential that we can relate the information you give to the current cadastre/certificates of title for the site.

You should send your report to us and/or the auditor for assessment at the completion of each stage. This supports the timely development of site investigation and remediation objectives before the next stage of work begins. This staged submission can reduce delays in the final assessment and clearance of sites. It also allows us to periodically update the site classification, which ensures accurate and timely information is available to relevant decision-making bodies and other stakeholders, including the public.

In prescribed circumstances, your report must have an accompanying mandatory auditor’s report (MAR) – see section 4.2. Go to DER (2016b) for further information on submitting a MAR.

In general, you must send your report to us in electronic format, either as an attachment to an email, or saved onto a portable storage device.

We will refer sites that require a human health risk assessment to DoH for advice, including:

- reports on asbestos investigations, remediation, validation and/or management, and/or
- a detailed or site-specific human health risk assessment.

We may also refer sites that require a radiation assessment to the Radiological Council of Western Australia (RCWA) for advice.

You should address your report to the Senior Manager, Contaminated Sites, and email it to info@dwer.wa.gov.au.

We may return reports without assessment if they are inconsistent with this guideline in either content or format, or if they contain graphics or data that have significant errors, or are illegible because of poor quality image resolution or inappropriate font size.

7. Conceptual site model

7.1 Overview

A conceptual site model (CSM) is a critical element of any site assessment. The CSM describes the environmental setting, identifies contaminant sources (potential areas of concern and associated contaminants), modes of contaminant movement (migration pathways), the person/ecosystem components/environmental values that the contamination may affect (potential receptors) and how exposure may occur (exposure routes).

Creating a CSM is an iterative process: the initial CSM is developed in the first stage of site assessment and revised as more detailed information on the site and the nature of contamination becomes available. The CSM is used to identify risks to human health, the environment and environmental values, as well as uncertainties or critical gaps in information that need to be addressed in subsequent stages.

For exposure to occur, a complete pathway must exist between the source of contamination and the receptor (i.e. complete source-pathway-receptor linkage). Where the exposure pathway is incomplete, exposure cannot occur and hence no risk is present via that pathway under the existing site-specific circumstances. However, the potential for new exposure pathways to be created or completed (e.g. by a proposed change of land use) should be considered in the CSM.

An exposure pathway typically consists of the following elements:

- a source of contamination (e.g. a spill or leak)
- a release mechanism (e.g. migration in soil, leaching to water, emission to air)
- retention in the transport medium (e.g. soil, groundwater, surface water, air)
- an exposure point (e.g. where a person comes into contact with contaminated dust or soil or contaminated groundwater from a bore, or in a building overlying volatile contamination)
- an exposure route (e.g. inhalation, ingestion, absorption through the skin).

The presence of contamination may give rise to a number of issues. For example, soil contamination may pose a risk to human health through direct ingestion of soil particles or, if volatile, through volatilisation and entry into buildings as vapours. If the contamination is leachable, it may pose a risk through migration via groundwater and exposure where the groundwater is used for drinking or garden irrigation or supports a groundwater-dependent ecosystem.

Your CSM should include discussion of the following elements:

- the location of known and suspected sources of contamination and the potential contaminants of concern

- contaminant migration pathways in air, surface water, groundwater, sediments, soil and dust (you may need to do a separate report for detailed fate and transport assessments)
- potential receptors and exposure routes
- uncertainties or limitations of the assessment (e.g. conclusions of the data evaluation or areas that could not be sampled because of the presence of infrastructure).

You should discuss the above information in appropriate detail and use a table to clearly identify source-pathway-receptor linkages and risks that require further assessment or management. You can also use a graphic (see Figure 2 for an example) to illustrate the linkages.

See section 4 of Schedule B2 of the ASC NEPM for further guidance on developing CSMs.

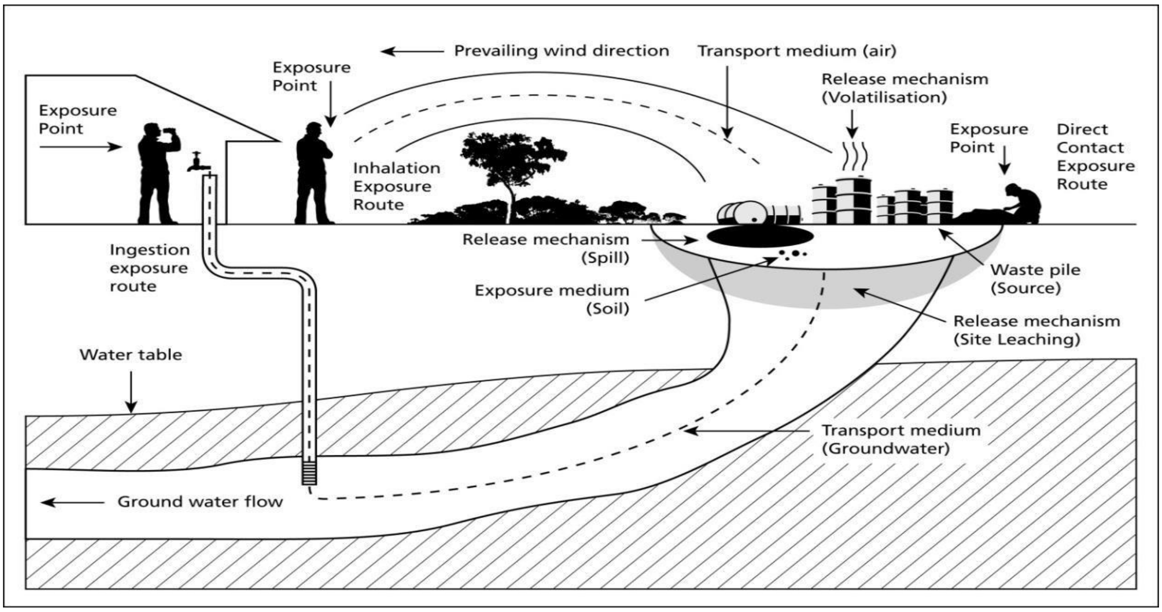

Figure 2: An example of a simple CSM illustrating potential source-pathway-receptor linkages

7.2 Aesthetics

Materials that may present an aesthetic concern include:

- inert materials such as construction and demolition waste (e.g. concrete, bricks, scrap metal, timber and plastics)
- trivial amounts of bonded asbestos-containing materials in good condition
- substances that cause soil or water discolouration or odour.

These materials do not pose an unacceptable risk to human health, the environment or environmental values from a contamination point of view; however, they may be undesirable in the context of the site-specific land use or the surrounding land uses depending on their sensitivity (e.g. community expectations are generally higher for residential land use compared with industrial land uses).

You should use caution in concluding that some materials have aesthetic effects only; rather, you should consider the risk of contamination in the context of the site’s history and the origin of the materials.

Section 3.6 of Schedule B1 of the ASC NEPM gives further guidance on aesthetic issues. You should assess sites with asbestos-containing materials in accordance with DoH (2021). The assessment levels for water in Table D1 of Appendix D include aesthetic criteria for some substances.

If a site is only affected by aesthetic issues, and this is the only factor or issue of concern, then you do not need to report the site to us as a known or suspected contaminated site (see DER 2017 for further information on reporting). However, it may be necessary for the site to be managed under other legislation. Contact us for advice on the Contaminated Sites information line 1300 762 982.

8. Preliminary site investigation

8.1 Introduction

The purpose of a preliminary site investigation (PSI) is to identify the potential sources of contamination and contaminants of concern, the receptors that may be exposed to contamination and the relevant exposure pathways. In a PSI, your scope of work should be enough to provide an initial indication of the site's contamination status, the nature and location of likely sources and receptors, and to determine whether a detailed site investigation (DSI) is warranted.

A PSI generally comprises:

- a desktop study (records and published information relevant to the environmental setting and site history)
- detailed site inspection(s)
- interviews with site representatives (managers, owners, former employees, neighbours etc.)
- data evaluation
- development of an initial CSM
- identification of potential risks and any uncertainties or limitations.

We generally do not recommend you undertake sampling as part of a PSI, as insufficient information may be available at this stage to inform the HSEP. However, you may wish to conduct opportunistic sampling to inform the sampling and analysis quality plan (SAQP) for the DSI.

Your initial CSM, developed from the findings of the PSI, forms the basis of further site investigations. We recommend that you obtain as much information on the site as possible in this phase of investigation. You should assess the accuracy of the information and identify any significant data gaps. A poor-quality PSI will result in a lack of confidence in the findings of any subsequent site investigations. For example, a PSI report that does not specifically comment on the presence or absence of bonded asbestos-containing materials on the land surface, where fences on the site were once composed of asbestos, may lead to additional work later on in the assessment.

Reporting under s.11 of the CS Act

Where information obtained during a PSI suggests potential contamination, the site may require reporting as a known or suspected contaminated site in accordance with s.11 of the CS Act (see DER 2017). It may be necessary for you to conduct a detailed site investigation (DSI) to ascertain whether contamination exists, and whether it poses a risk to human health, the environment or environmental values.

You should conduct your PSI following the guidance in section 3 of Schedule B2 of the ASC NEPM. See below for a discussion of the elements of a PSI and Appendix A for a checklist of information you should include in a PSI report.

See section 9.2 of this document for guidance on preparing an SAQP, which you may need to include with the PSI report, if relevant. Depending on the circumstances, your SAQP may need to be part of your PSI or a separate document.

8.2 Potentially contaminating activities

Your PSI should consider whether the activities at your site have the potential to cause contamination. See Appendix B for a list of potentially contaminating activities. The list is not exhaustive (e.g. contaminants of emerging concern may not be included) and you may need to consider whether other activities at your site could cause or contribute to contamination. You may also need to consider potentially contaminating activities on surrounding land if these have the potential to affect your site.

Note that a site is not necessarily contaminated solely because an activity listed in this guideline has occurred on the site. You should take a weight-of-evidence approach and assess all available sources of information.

Some sites may have been host to more than one potentially contaminating activity during their history and you should consider all such activities for assessment purposes. For example, ‘work depots’ may have had components of fuel storage, asphalt manufacturing/storage, pesticide mixing and vehicle maintenance.

You should use information about the site’s history, such as manifests and inventories, to identify the potential contaminants of concern. This may include the chemicals listed in Appendix B. Some chemicals specifically named in Appendix B (e.g. persistent organic pollutants) are recognised as causing adverse effects on humans and the ecosystem under the Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention 2004). Note that some of these substances may not have been used in Australia, or may not be currently registered for use in Australia. The site history and the CSM should tell you whether you need to consider these when planning site investigations.

8.3 Site history

You should be able to find valuable information on the nature and extent of potential contamination and pathways for contaminant migration using the site’s history. Keep a log of your information sources and in your report include details of all the documents you review. You should update your log as and when you find further information.

You should develop a chronology or timeline of the relevant events to support interpretation (e.g. Table 1 and Figure 1 in Schedule B2 of the ASC NEPM). Section 3.3 of Schedule B2 of the ASC NEPM discusses site history information that is relevant to a PSI.

8.4 Environmental setting

The environmental setting includes the surrounding land uses, geology and hydrogeology, surface waters, wetlands, tidal regime, seasonal or climatic conditions or any other feature of the environment that may be relevant to the assessment.

The purpose of describing the environmental setting is to identify potential receptors, understand how contaminants may behave in the environment and identify potential offsite sources of contamination. You should determine the area for assessment based on the likely distances that potential contaminants could migrate (site-specific and contaminant-specific considerations apply). You might assume a 500-metre radius around the site in initial assessments, but the data you gather during the DSI phase might cause you to further refine (or extend) the assessment area. You should consider the adequacy of the investigation area during the iterative development of the CSM.

8.5 Site inspection

Your site inspection should seek to identify potential sources of contamination, pathways and receptors; confirm the layout of the site; and identify constraints to site access for sampling. Use your site inspection to describe the current condition of the site and validate plans or other information from the desktop investigation. Take photographs for future reference. Where possible, you should undertake the site inspection in the company of a person familiar with the site, such as the site manager or a knowledgeable employee.

Note any areas of the site that could not be accessed during the site inspection. Record your observations at the time of the inspection and include these as descriptive text within the main body of your report, together with a plan of the site's features and photographs (accompanied by a location and aspect plan). Depending on the nature of the site, it may also be relevant to note the absence of potential contaminants (e.g. asbestos on the site surface) or indicators of contamination.

8.6 Information sources

Section 3.3 of Schedule B2 of the ASC NEPM has a list of information sources you should consider when compiling a PSI. Other sources of information relevant to assessments in WA include:

- the department:
    - our register of known or suspected contaminated sites, including the publicly available Contaminated Sites Database
    - a basic or detailed summary of records (BSR or DSR) (submit a Form 2 to us with the prescribed fee (see DER 2017)
    - our information on acid sulfate soils

  - our information on current environmental licences and works approvals (additional information may be accessed by applying under the *Freedom of Information Act 1992*)[3]
  - our information on registered bores, the *Perth groundwater atlas* (DoW 2014b) and drinking water source protection reports.
- Landgate – certificates of title, aerial photographs, property interest report.
- WA Planning Commission – land use and water management strategies.
- Water Corporation **Error! Hyperlink reference not valid.**– annual reports and 10-year plan for Western Australia (Water Corporation 2012).
- State Library of WA – for site history information.
- Bureau of Meteorology 2015 – *Atlas of groundwater dependent ecosystems*
- Department of Biodiversity, Conservation and Attractions – Naturemap: Mapping Western Australia's biodiversity.
- Dial Before You Dig service (www.1100.com.au or phone 1100) – for the location of underground services before you undertake any subsurface investigations.
- Department of Mines, Industry Regulation and Safety (DMIRS):
  - for information on dangerous goods licence records, licensees, location and types of USTs, inspections, licence compliance etc.
  - geological and geochemical information.
- Australian Soil Resource Information System (ASRIS)– an online, map-based resource for information on soil types.
- Local government authorities – for zoning details, service infrastructure and planning approvals and complaints.
- DoH – Asbestos in contaminated sites.

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[3] For the purpose of informing a PSI, we recommend that your application under the *Freedom of Information Act 1992* (FOI Act) should only include the documents that may be relevant to the site's potential contamination, such as old licences, complaints, incidents and spills. A broad application will only delay the process and in some cases, we may refuse to deal with it (s.20 of the FOI Act).

9. Detailed site investigation

9.1 Introduction

A detailed site investigation (DSI) involves the collection and evaluation of site-specific data. You must design the sampling and analysis of environmental media (soil, soil gas, surface water, groundwater, sediment) to characterise the site and the nature and extent of contamination. Use the information you obtain to refine the CSM and identify potential or actual risks to human health, the environment or environmental values that require further assessment, and/or remediation. See section 10 for more details on risk assessment.

We acknowledge that at some sites, only targeted site investigations may be necessary – without the need to complete a comprehensive PSI (e.g. when investigating a spill or leak, or for due diligence investigations where an existing potentially contaminating land use will continue). Note that at least some of the information you would usually obtain in a PSI (see section 8) will be necessary for planning a targeted investigation. In some circumstances you will need to compile a comprehensive PSI at a later date to ensure all possible sources of contamination have been considered and addressed.

A DSI generally involves:

- development of data quality objectives (DQO), which includes the formulation of project objectives
- planning and implementing an SAQP to meet the DQOs
- data evaluation
- refining the CSM
- identifying risks and any uncertainties or limitations.

In circumstances where you identify a risk, you will need to undertake further risk-based assessment and/or remediation, which may involve further desktop investigation, site investigation and/or risk assessment.

Site classification under the CS Act

Reported sites that require investigation will usually be classified *possibly contaminated – investigation required* under the CS Act (see DER 2017 for more information on site classifications).

You should compile a DSI following Schedule B2 of the ASC NEPM. See below for a discussion about the elements of a DSI and the checklist in Appendix A for examples of information you should include in a DSI report (if it is relevant to your site).

The detailed investigation of some types of contamination may require you to consider issues that the ASC NEPM does not specifically discuss. See below for some additional sources of information.

Issue	Reference
Assessment of surface waters and sediments	*Australian and New Zealand guidelines for fresh and marine water quality [online] (Water Quality Australia, 2019).*
Clandestine drug labs	*Clandestine drug laboratory remediation guidelines* (Attorney-General's Department 2011).
Service stations and other fuel storage sites	*Technical note: Investigation of service station sites* (NSW EPA 2014b).
Radiological contamination	Contact the Radiological Council of Western Australia (RCWA) and the department.
Per- and polyfluoroalkyl substances (PFAS)	*PFAS National environmental management plan* (HEPA, 2020).

For all matters relating to risk associated with radiological contaminants, we rely on the RCWA's technical advice.

Neither this guideline nor the ASC NEPM specifically address radionuclide contamination risks. We therefore recommend that if you need to assess radiation risk, you ask a recognised radiation health professional to do so, in consultation with RCWA. We expect that risks associated with radionuclide contamination will be assessed with reference to guidelines issued by WA and Australian regulatory authorities, such as DMIRS and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

We also recommend that you consult authoritative international guidance to address any issues that are not included in WA or other Australian guidelines.

Site assessment in acidic landscapes

When you conduct soil and groundwater sampling in acid sulfate soils (ASS) or acidic landscapes in Western Australia, special considerations apply. See DER (2015a) and DER (2015b) for detailed guidance on how to identify, assess and manage ASS, as well as our acid sulfate soils guidelines.

In ASS landscapes, the oxidative state of soils and groundwater will vary in response to seasonal conditions in the zone of watertable fluctuation. When planning a site investigation in these areas, you must take specific measures to obtain representative site data and representative background data, such as:

- collecting samples over different seasons, and at different depths within the range of groundwater fluctuation, to assess the range of conditions

- considering whether trends are present in historical data and whether the most-recent data available represent current conditions
- conducting field tests for soil and groundwater pH
- using field oxidation tests as an indicator of oxidation potential
- using laboratory analysis to characterise the nature of ASS
- using appropriate sampling and handling techniques to minimise oxidation of samples between collection and laboratory analysis.

Disturbance of ASS, which can result from human activities such as excavation or dewatering, or from watertable fluctuations in response to climate change, can lead to the formation of acidity, a drop in groundwater pH and the mobilisation of metals and metalloids.

If soil pH at a site in an ASS landscape is less than 4, this indicates that ASS has been disturbed and oxidised. If this is the case, you will need to investigate and manage the site following DER (2015a) and DER (2015b). You will also need to revise your CSM to determine the likely risk to human health or the environment; for example, through direct contact with soils or leaching to groundwater or surface water. If you identify a potential risk to human health or the environment, contact us on the Contaminated Sites Information line 1300 762 982. We will consider what may be needed for management, monitoring and/or clean-up on a site-specific basis.

Development or remediation-related disturbance of ASS that leads to degradation of groundwater quality (e.g. due to dewatering without appropriate management) may lead to sites being classified under the CS Act. Whether a particular site is classified will depend on the severity and extent of groundwater impacts and this will be assessed on a site-specific basis.

9.2 Sampling and analysis quality plans

Systematic planning is essential to ensure the data you collect meets the objectives of the investigation stage and the overall objectives for the site. You should prepare a sampling and analysis quality plan (SAQP) to ensure that the data you collect are representative and sufficient to address critical gaps and uncertainties in your CSM. This will help ensure the information you obtain provides a reliable basis for making site management decisions. This includes the collection of statistically robust data where your assessment includes comparison with investigation/screening/assessment/clean-up levels.

You should develop your SAQP in accordance with the ASC NEPM before you collect any samples on a site. Include your SAQP in your site assessment report. The scope and detail of your SAQP will depend on the complexity of contamination issues relevant to the site.

Section 5 and Appendix B of Schedule B2 of the ASC NEPM describe the process of developing DQO and an SAQP, including what you should consider when you determine the appropriate field quality assurance and quality control (QA/QC) procedures for a site (section 5.4 and Appendix C). Section 3 of Schedule B3 of the ASC NEPM has guidance on laboratory QA/QC procedures.

Your SAQP should demonstrate your rationale for sample locations and data to be collected by linking the areas of concern in your CSM with the sampling program. Show your areas of concern on a site plan that also shows the sampling locations. Summarise your sampling program in a table that lists each area of concern and details of the sampling and analysis to be carried out in each area. This approach is particularly useful for large and/or complex sites with multiple potential sources of contamination.

You should decide on the sample naming protocols before you compile the SAQP. These should:

- be logical so the reader can easily recognise the different types of samples (e.g. surface soil SS, soil bore SB, monitoring bore MB, test pit TP, soil validation SV)
- be consistent in report text, site plans, tables, chain of custody forms and laboratory analytical certificates
- include the depth from which they were obtained for soil samples (e.g. SB1-0.5, TP1-0.75) or multi-depth groundwater samples (e.g. shallow MB1s, middle MB1m, deep MB1d) so the reader does not need to cross-reference this information
- be consistent and numbered sequentially throughout multiple stages of work at a site.

9.3 Sampling design

Overview

To select an appropriate sampling design, you must use professional judgement and have a sound understanding of the sampling program's objectives. Collecting data of a suitable type and quality will minimise the need to collect more data at a later date. You should also consider the type of information you need to carry out a rigorous and meaningful risk assessment.

Judgmental sampling may be the most appropriate sampling design where comprehensive knowledge of potential sources of contamination exist. Probability-based designs such as grid-based sampling may be useful where there is limited information on the site's historical use, or where a large area may potentially be contaminated (e.g. the cultivated area at a market garden site). You may adopt a combination of both judgmental and probability-based sampling programs, as this means you can target the contamination based on expert knowledge, as well as make quantitative statements about contamination at a site.

You must justify the sampling designs you choose with reference to the CSM and DQOs. See section 6 of Schedule B2 of the ASC NEPM for detailed guidance on sampling designs and their applications.

Minimum number of samples

There is no minimum number of sampling points recommended for a given size of site as you will determine this by considering the site-specific characteristics (CSM) and the DQOs for the assessment. You should collect enough statistically robust and representative data to enable meaningful comparison with the relevant investigation/ screening and/or assessment levels for the site.

Regardless of the sampling design you adopt, your SAQP should include the rationale for your decision and comment on the robustness of the data.

Composite sampling

Composite sampling involves combining several soil samples from adjoining locations into a single sample for analysis. You should prepare composite samples from field-moist samples in a laboratory environment and not in the field to ensure well-mixed samples. Although composite sampling has limitations it may be suitable where it can meet the DQOs for the site.

We do not accept the use of composite sampling under the following circumstances:

- sampling of groundwater
- sampling of clay or silt soils – which are unable to be adequately homogenised when field-moist
- assessment of pH, semi-volatile or volatile substances – which includes some organochlorine (OC) and organophosphate (OP) pesticides, as well as low molecular weight polycyclic aromatic hydrocarbons (PAHs).

See section 6.2.6 of Schedule B2 of the ASC NEPM and Appendix B of AS4482.1-2005 for general guidance on composite sampling.

When comparing analytical results for composite samples with assessment levels, you should divide the relevant assessment levels by the number of subsamples making up the sample for analysis. For example, if you have prepared a composite sample from four soil subsamples, divide the relevant assessment level by four, and compare the analytical result with the adjusted assessment level.

You should explicitly address the use of composite sampling in the DQOs for the site (with appropriate justification for their use) and discuss the uncertainties.

You should also give field descriptions for each sample and document the compositing methodology in the report.

9.4 Data evaluation

Your DSI report should evaluate the data against the investigation objectives as incorporated in the DQOs and discuss the data’s precision, accuracy or bias, representativeness, completeness and comparability, and the implications for decision-making.

See section 13 and Appendix C of Schedule B2 of the ASC NEPM for detailed guidance on the assessment of data quality.

9.5 Soil assessment

Overview

See section 7 of Schedule B2 of the ASC NEPM for detailed guidance on soil assessment, including for the collection of soil samples and field screening techniques. Schedule B3 has guidance on the laboratory analysis of potentially contaminated soils.

Schedule B1 of the ASC NEPM and section 9.1 of this report have guidance on how to apply screening criteria to assess risks from soil contamination. See below for more information on some specific kinds of soil assessment.

Asbestos in soils

The primary source of guidance when you need to assess potential asbestos contamination and asbestos-contaminated sites in WA is the *Guidelines for the assessment, remediation and management of asbestos-contaminated sites in Western Australia* (DoH 2021).

DoH also provides additional information on its website. See section 11 of Schedule B2 of the ASC NEPM for a summary of the assessment requirements.

Stockpile characterisation

You may need to characterise stockpiled soil to determine its suitability for re-use or disposal requirements. Your characterisation methodology should be consistent with the approach in section 7.5 of Schedule B2 of the ASC NEPM. See section 13.1 of this report for more information on stockpiles.

In WA, you should characterise material that is intended for disposal to landfill following section 7.5 of Schedule B2 of the ASC NEPM and classify it using the criteria in *Landfill Waste Classification and Waste Definitions 1996 (amended 2019)* (DWER 2019) to determine the appropriate type or class of landfill and where it can be accepted. The beneficial re-use of excavated soil is discussed in section 12.9.

9.6 Groundwater assessment

Overview

Groundwater is a valuable resource in WA, with shallow groundwater being particularly vulnerable to impacts from surface and near-surface sources of contamination. All WA contaminated site assessments should consider the potential for groundwater impacts.

You should organise an initial hydrogeological assessment in the first stage of site assessment to determine whether a risk to groundwater quality exists. You will need to conduct further investigations where a risk of harm to any current or potential future environmental values of groundwater is found, or where groundwater could create a potential exposure pathway that might cause a risk to human health or the environment. Schedule B6 of the ASC NEPM provides a risk-based framework for the assessment of groundwater contamination.

Triggers for groundwater investigations include the presence of:

- potential primary sources of groundwater contamination, such as sumps, drains, pipework or storage tanks
- soil contamination which potentially extends to the zone of watertable fluctuation
- soil contamination above the watertable which has the potential to leach or may have already leached
- potential preferential pathways.

Your groundwater investigations must be designed and undertaken by appropriately qualified and experienced groundwater professionals (see schedules B6 and B9 of the ASC NEPM for further information).

See section 8 of Schedule B2 of the ASC NEPM for detailed guidance on the characterisation of groundwater contamination, groundwater monitoring and the application of contaminant fate and transport modelling. See section 11.7 of this guideline for how to select and apply appropriate assessment levels for groundwater in WA. See section 9.1 for what to consider when assessing groundwater in acidic landscapes.

You should conduct a desktop investigation before you develop a groundwater sampling program. See Appendix A of this guideline for examples of what you should consider when compiling a desktop assessment of groundwater and/or reporting on a groundwater investigation.

Refer to the following sources of information for desktop assessment of regional groundwater conditions:

- the department:
  - database of registered groundwater bores throughout the state (as registration of domestic groundwater bores is not compulsory you should not rely on the database to identify all potential receptors)
  - *Perth groundwater atlas,* which indicates the quality, depth and flow direction of local groundwater in the Perth area
  - proclaimed area maps
  - public drinking water source area mapping tool, which displays protection zones that protect the immediate areas around where drinking water is abstracted.

- The Department of Primary Industry and Regional Development (DPIRD):
  - interactive groundwater and salinity map for the south-west agricultural region, which provides information on regional and local groundwater trends and dryland groundwater salinity in the state's south-west.

You should not rule out a groundwater investigation based on the absence of current abstraction bores where bores may reasonably be installed in the future (i.e. you must consider the inherent value and potential uses of groundwater).

Groundwater sampling methods

When you develop an SAQP that includes groundwater sampling, you should consider what sampling methods are suitable for the aquifer conditions and contaminants of concern. Section 8.2.4 of Schedule B2 of the ASC NEPM provides detailed guidance relevant to planning and implementing a groundwater sampling program. In particular, the use of bailers or high speed pumps is not recommended because of their limitations in obtaining representative groundwater samples. These methods are prone to agitating groundwater, which can cause increased turbidity and aeration, resulting in chemical alteration of the sample (e.g. partial or total loss of volatile or semi-volatile contaminants or changes in metal speciation). See section 9.1 for a discussion about groundwater sampling in ASS landscapes.

Biodegradation and secondary groundwater contaminants

When assessing groundwater, you should consider the possible effects of geochemical changes arising from the biodegradation of organic contaminants. Geochemical changes can cause naturally occurring substances, such as arsenic and metals, which are adsorbed to the soil by iron oxyhydroxides, to be released into groundwater. For example, the biodegradation of petroleum hydrocarbons can involve the reduction of electron acceptors such as ferric iron (Fe3+). Naturally occurring arsenic adsorbed to the soil is mobilised during ferric iron reduction, which can result in a significant increase in dissolved arsenic concentrations. You should consider the release of secondary contaminants during the degradation process for the CSM, and assess them for the SAQP as relevant for the site-specific circumstances. See the *MNA guideline* (DWER 2021) for further information on assessing the natural attenuation of contaminants.

9.7 Vapour assessment

Overview

Contaminated soil and groundwater may emit vapours or ground gases derived from the contaminating substances or the breakdown of substances. These have the potential to be explosive, flammable, toxic or behave as an asphyxiant. Volatile substances include, but are not limited to, methane, carbon dioxide, carbon monoxide, hydrogen sulfide, radon and other (non-methane) volatile organic compounds. These gases may be referred to as soil vapour, soil gas or ground gas depending on the context, and may be present within the ground, outdoor and indoor air and accumulate in confined spaces such as service conduits or buildings. See US EPA (2012) for an informative discussion about the differences between petroleum hydrocarbons and chlorinated hydrocarbons and their potential for vapour intrusion.

In WA, you are most likely to need to do a vapour assessment in association with the presence of landfills, petroleum products and/or organic solvents. However, volatile contaminants may also be encountered in other circumstances such as at sewage disposal sites, fill or made ground and human or animal burial grounds (CIRIA 2007). Hydrogen sulfide can also be released during the disturbance of ASS materials (see section 2.4.1 of DER 2015b) and from the decomposition of vegetation (CIRIA 2007).

See schedules B2, B4 and B7 of the ASC NEPM for guidance on the assessment of vapour intrusion (VI).

The US EPA has prepared several technical documents and tools to support guidance development:

- *Background indoor air concentrations of volatile organic compounds in North American residences (1990 – 2005): A compilation of statistics for assessing vapor intrusion*
- *EPA's vapor intrusion database: Evaluation and characterization of attenuation factors for chlorinated volatile organic compounds and residential buildings*
- *Conceptual model scenarios for the vapor intrusion pathway*
- *Indoor air vapor intrusion mitigation approaches*
- *Petroleum hydrocarbons and chlorinated hydrocarbons differ in their potential for vapor intrusion*.

The US EPA CLU-IN (Clean-Up Information) website is a useful source of guidance on various VI-related issues including sampling and analysis, predictive modelling, building design, forensic approaches and site investigation case studies.

The Interstate Technology & Regulatory Council (ITRC) has also published a number of guidance documents on VI and related fields including:

- *Vapour intrusion pathway: A practical guideline* (ITRC 2007a)
- *Vapour intrusion pathway: Investigative approaches for typical scenarios* (IRTC 2007b)
- *Integrated DNAPL site strategy* (ITRC 2011).

The science informing VI assessment continues to develop. You should understand the limitations outlined in the ASC NEPM and other technical guidance documents when undertaking vapour assessments.

Where NAPLs and/or significant dissolved concentrations of volatile substances are present, you will need to show multiple lines of evidence, using a weight-of-evidence approach, to demonstrate that the vapour intrusion/emission pathways are unlikely to be complete or to present a significant risk.

Assessment of vapour risk is a specialist area and should only be undertaken by qualified and experienced professionals.

The assessment of petroleum hydrocarbon vapour, chlorinated hydrocarbon vapour and landfill gas are discussed below.

Petroleum hydrocarbon vapour assessment

See Schedule B1 of the ASC NEPM for the health screening levels (HSLs) to assess the VI risks from petroleum hydrocarbons, and sections 2.4 and 3.3 for guidance on their application. See section 11.4 of this guideline for additional information on their application.

Technical report 23 – Petroleum hydrocarbon vapour intrusion assessment: Australian guidance (CRC CARE 2013) has detailed guidance on the assessment of petroleum vapour intrusion (PVI), including the use of screening PVI assessments to identify sites requiring further assessment of risk from VI. This report also has guidance on the procedures to follow when the HSLs are not applicable (e.g. shallow groundwater) or where exceedences of the HSLs occur and how to conduct a detailed PVI assessment. The report also has detailed guidance on installing soil vapour probes/wells and field sampling procedures.

Chlorinated hydrocarbon vapour assessment

The ASC NEPM (schedules B2, B4 and B7) outlines the fundamental framework for undertaking VI assessment in Australia.

Schedule B1 of the ASC NEPM provides interim health investigation levels for volatile organic chlorinated compounds in soil (see section 2.3 for guidance on their application).

The guidance in CRC CARE (2013) is specific to assessing PVI. You should not apply it indiscriminately to the assessment of chlorinated hydrocarbon vapours.

Consistent with the ASC NEPM, you should apply a tiered risk-based approach, using multiple lines of evidence for the assessment of chlorinated hydrocarbon vapour intrusion (CVI).

In May 2020, DoH consulted contaminated sites auditors to gauge their opinion on current volatile organic chlorinated compounds (VOCC) assessment practice. The auditors and DoH agreed that:

- There is no basis or justification to deviate from the published default ‘soil vapour to indoor air’ vapour attenuation factors (VAF) used to derive interim HILs for VOCCs, as set out in ASC NEPM (Schedule B1, section 2.3).
- NEPM interim HILs are only to be used as a screening level to trigger further site-specific vapour intrusion assessment; and should not be used as a definitive ‘safe level’ or clean-up standard.
- DoH will accept interim HILs based on VAF of 0.1 (10%) as an appropriate and suitable precautionary screening level to trigger further site-specific assessment based on ‘multiple lines of site’ and ‘building specific evidence’.

- DoH supports the ‘multiple lines of site’ or ‘building specific evidence’ approaches promoted in ASC NEPM. This includes both indoor air quality monitoring where practicable and appropriate (i.e. for existing buildings), and quantitative vapour intrusion modelling based on robust, contemporary and representative soil vapour monitoring data (i.e. for proposed buildings).

Ground gas assessment

Ground gases such as methane, carbon dioxide, carbon monoxide, hydrogen sulfide and hydrogen cyanide are typically formed from the biodegradation of organic carbon (or sulfurous compounds) present in the ground and groundwater. The type and quantity of ground gas production primarily depends on the amount of organic carbon, oxygen, moisture and other nutrients available to sustain the population of bacteria producing the gas.

Ground gases move through the soil primarily through advection (high to low pressure) and diffusion (high to low concentration). Movement is influenced by changes in atmospheric pressure, wind-speed, temperature, rainfall, soil permeability, building design and the presence of preferential pathways such as service lines, trenches, pile foundations and abstraction bores. Ground gases are soluble in the underlying groundwater and may move significant distances offsite within groundwater flows.

The ASC NEPM does not provide specific guidance on the assessment of ground gases. For ground gas assessments in WA, you should follow the same broad approach outlined in the ASC NEPM and this guideline, including the development of an SAQP, data evaluation and CSM. Your assessment should adequately characterise the nature and extent of contamination, including site-specific ‘worst-case scenario conditions’, so that current and future gas generation trends, migration and accumulation can be reasonably predicted, assessed and managed.

The following documents have detailed guidance on assessing ground gases:

- *Assessment and management of hazardous ground gases: Contaminated land guidelines* (NSW EPA 2020).
- *Assessing risks posed by hazardous ground gases to buildings* (CIRIA 2007) – includes assessment levels for ground or soil gases such as methane and carbon dioxide at landfill sites and additional information necessary for their correct application.

You may need to conduct a detailed human health risk assessment for your site if a ground gas investigation identifies that non-methane volatile organic compounds are present which may pose chronic risks to human health via inhalation.

9.8 Sediment assessment

Although the ASC NEPM does not cover the assessment of sediments in detail, the underlying principles and general approach for the assessment of site contamination outlined in Schedule B2 are applicable.

Sediments comprise soils, sand, organic matter or minerals that accumulate on the bottom of a waterbody. Sediments may represent a source and/or a sink of dissolved contaminants, influence surface water quality, and/or represent a source of bio-available contaminants to benthic biota (and hence potentially to the aquatic food chain). Impacts from contaminated sediments can therefore degrade aquatic ecosystems and pose a threat to human health via bioaccumulation in edible aquatic organisms.

You may need to conduct a sediment investigation where:

- wetlands/rivers/streams form part of a site, or are located near it
- an aquatic environment such as a harbour, estuary or river bed forms the whole or part of a site
- sediment must be dredged as part of port/harbour construction/expansion works or development in a riverine or marine environment.

Your assessment of contamination in sediments should:

- consider the relationship between sediment, sediment pore water and water quality, including the potential for mobilisation of contaminants into the water column and/or aquatic food chain
- identify and enable protection of uncontaminated sediments
- identify where contamination is likely to result in adverse impacts to sediment ecological health.

See Appendix C for general guidance on sediment sampling design. More detailed guidance on sediment quality assessment is provided in:

- *Sediment quality assessment – a practical guide* (Simpson & Batley 2016)
- *Australian and New Zealand guidelines for fresh and marine water quality* (Water Quality Australia, 2019)
- AS/NZS 5667.12:1999 Sampling of bottom sediments.

If you are assessing sediments for dredging and ocean disposal, refer to the *National assessment guidelines for dredging* (Commonwealth of Australia 2009).

You should seek expert advice from suitably qualified and experienced professionals to ensure the appropriate sediment assessment methodologies are employed.

9.9 Assessment of perfluoroalkyl and polyfluoroalkyl substances (PFAS)

Refer to the *PFAS national environmental management plan* (PFAS NEMP) (HEPA, 2020) for detailed guidance on the environmental management of per- and poly-fluoroalkyl substances (PFAS). The PFAS NEMP was developed to provide nationally-consistent guidance on the management of PFAS in the environment, including the assessment of PFAS impacts, prevention of environmental harm from PFAS, and the management and remediation of PFAS contamination.

The PFAS NEMP focuses on perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), and perfluorohexane sulfonate (PFHxS), and their direct and indirect precursors, as these are the most widely studied PFAS. The PFAS NEMP includes health and environmental screening levels for these three PFAS, some of which have been referenced in Appendix D of this guideline. However, PFAS assessment criteria are undergoing review, and these criteria may be revised as and when new data are published.

Guidance in the PFAS NEMP has superseded information provided in the now-rescinded document *Interim guideline on the assessment and management of perfluoroalkyl and polyfluoroalkyl substances* (PFAS) (DER, 2017).

The PFAS 'family' has more than 4,000 known chemical compounds and scientific knowledge on the environmental fate and risk assessment of PFAS is evolving rapidly. PFOS, PFOA, and PFHxS are often primary indicators that a broader range of PFAS compounds are present, including other short- and long-chain perfluoroalkyl acids (PFAAs) and precursors. In general, PFAS compounds are characterised as being bioavailable, bioaccumulative, persistent and mobile in the environment, although these properties differ to some extent between various PFAS compounds. Assessment and management of PFAS-impacted sites can sometimes be complex due to the potential presence of compounds for which there are no screening levels, limited information on environmental toxicity, and high levels of public concern.

In situations where regulatory guidance and specific screening criteria are limited or unavailable, assessment and management should be guided by available scientific approaches, and a general precautionary approach to risk evaluation.

9.10 Collection and disposal of contaminated materials

Test pitting and the advancement of boreholes is likely to generate excavation spoil. Test pit and borehole waste may contain contaminating substances that require special management and disposal.

In addition, test pitting and borehole installation may disturb natural soils and rocks which, when brought to the surface, represent a hazard. These may include potential ASS, natural mineralised rocks (e.g. lead and arsenic ores, asbestos minerals) or radiation emitted from granitic rocks and mineral sands. Deep rotary drilling operations often involve the injection of drilling fluids (i.e. muds) which contain hazardous chemicals. In addition, test pits and boreholes may introduce preferential pathways for the movement of contaminated groundwater between aquifers, and cause hazardous ground gases or vapours to come to the surface.

You can return spoil from test pits to the pit, as long as it is free from contamination. You should not return contaminated materials, such as excavated spoil and unused samples, to a pit or bore to prevent the contamination of unaffected strata or groundwater. Backfill sample pits and boreholes as soon as possible after sampling to prevent potentially contaminated water from accumulating in open pits and boreholes.

Take care to ensure that potentially or visually contaminated excavated spoil is not spread across an otherwise uncontaminated surface. Make sure you temporarily place the excavated material on an impervious surface or into appropriate containers (such as a lined skip or drums) for offsite disposal. If the excavated material is not physically contained, you should consider placing a bund around the material to prevent potential surface runoff.

You may collect fragments of potential asbestos-containing materials (PACM) following DoH guidance (DoH, 2021) for the purpose of laboratory analysis or to remove isolated, sparsely distributed fibre-cement fragments from the surface. Carefully collect and secure your PACM fragments in a labelled, heavy duty plastic bag or wrap them in heavy duty plastic (minimum of 0.2 mm thickness) for transport to a laboratory or disposal to a licensed waste facility.

You should dispose of purged borehole water appropriately to avoid spreading contamination across the site. Collect gross liquid contamination – such as from purged borehole water or from the recovery of non-aqueous phase liquids – in appropriate containers for offsite disposal.

You should ensure the materials to be collected for offsite disposal are subject to laboratory analysis to determine the appropriate disposal method. Store drums and skips in a secure location until collection, and clearly label them with contact details and drum contents.

In some instances, soil and groundwater may be determined as controlled waste in accordance with the Environmental Protection (Controlled Waste) Regulations 2004 (Controlled Waste Regulations). See section 13.1 for information about the transportation of contaminated materials and controlled wastes, and the associated documentation to be retained. You must dispose of material containing asbestos at a licensed asbestos facility in accordance with Controlled Waste Regulations. Inform the facility operator that the waste contains asbestos on arrival.

10. Risk assessment framework

10.1 Introduction

Risk-based assessment is fundamental to the assessment and management of contaminated sites in WA: the concept of risk of harm is part of the definition of contamination in the CS Act.

The ASC NEPM is the primary guidance for conducting health and ecological risk assessments in WA. The DoH (2006) guideline, *Health risk assessment in Western Australia,* provides an introduction to the topic of health risk assessments and an overview of their potential uses and limitations .

Depending on the scope of your risk assessment, it may be preferable to present the results in a separate report. You should document and justify all the assumptions, input data and calculations in the report. See Appendix A for a checklist of information you should include.

When you need a risk assessment for contaminated land, you must engage suitably qualified and experienced professionals as this work requires a high degree of objectivity and scientific skill.

10.2 Objectives of risk assessment

In contaminated site assessment, risk assessment considers the likelihood of exposure to potential contaminants of concern and the severity of the effect of such exposure. It formalises the process of identifying the key issues that need further consideration. Risk assessment provides the basis for determining an appropriate management response to eliminate or mitigate the identified unacceptable risks in an appropriate timeframe (see section 10.9).

10.3 Staged approach to risk assessment

Schedule A of the ASC NEPM provides a flow chart that depicts the decision-making process for assessing site contamination and shows the relationship between the tiered approach to risk assessment and the staged approach to investigation.

A risk assessment is required for all known and suspected contaminated sites reported to the department. When you need to do so, the level of your risk assessment should be appropriate to the problem and the level of detail in the CSM. It is not appropriate to carry out a detailed quantitative risk assessment if you have only conducted limited site characterisation.

You may undertake more than one phase of risk assessment at a site. This is because you should revise the risk assessment as more information becomes available or if conditions change. There are three levels or tiers of risk assessment:

- Tier 1 (screening) risk assessment
- Tier 2 risk assessment

- Tier 3 risk assessment.

Using the tiered approach, you apply simple conservative assumptions in the initial assessment to identify which issues are likely to present the greatest risk, allowing more detailed, site-specific risk assessment to focus on these issues. This allows you to prioritise resources on the most critical issues associated with the site in a defensible manner.

Most contaminated site assessments begin with a Tier 1 screening risk assessment and progress to a site-specific Tier 2 or Tier 3 risk assessment, if necessary. As the level of site characterisation increases with each stage of investigation, uncertainties in the CSM decrease, which enables the risk assessment to consider more of the site-specific conditions.

Throughout the site assessment process, options exist to carry out more detailed assessment, or proceed directly to risk management. Figure 3 shows the decision--making process (after site assessment has been triggered), assuming that potentially unacceptable risks are identified in the CSM. You should consider the following to reach a management decision:

- the uncertainties in the data and risk assessment outcomes - Have the risks been adequately characterised?
- the potential costs and benefits of undertaking more detailed investigation and risk assessment compared with making potentially more conservative management decisions based on the available information.

10.4 Tier 1 screening risk assessment

Schedule B1 of the ASC NEPM is the primary guidance for carrying out a Tier 1 screening assessment.

At this level, you compare site data with generic assessment levels. You may also need to obtain data on background levels relevant to the site. If you identify unacceptable risks, or find that significant uncertainties exist, you must conduct a Tier 2 or 3 risk assessment after your Tier 1 risk assessment. An alternative may be to implement an appropriate management strategy.

Refer to section 11 of this guideline for additional assessment levels and issues for consideration in WA.

Before you apply the generic assessment levels, you need to consider whether the assessment levels are suitable for the site, including the site setting and the exposure assumptions (see section 11). The assessment levels have been developed based on various generic exposure scenarios. If the site conditions are significantly different from the assumptions, then you may need to make some adjustments (see Tier 2 assessments below).

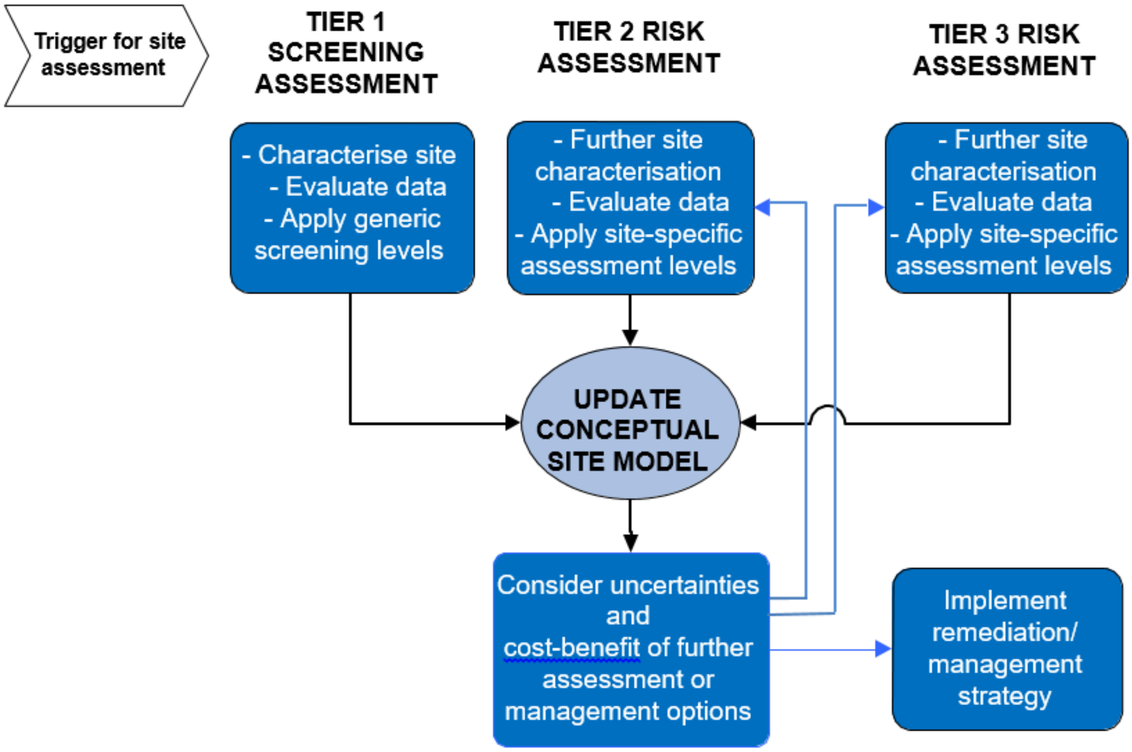

Figure 3: Decision-making framework for risk assessment

Example of a Tier 1 screening risk assessment

A site proposed for a residential development contains elevated concentrations of metals (lead and copper) in surface soil.

To determine if the soil contamination might adversely affect the site’s suitability for residential purposes or nearby ecological receptors, detailed sampling is carried out on the site and at a reference site to establish ambient background concentrations. A screening assessment is then carried out comparing the measured concentrations of metals in the soil with the relevant ecological investigation levels and health-based investigation levels.

The concentrations are below the ecological investigation levels and health-based investigation levels, suggesting no further action is required with respect to these substances in soil to protect human health and terrestrial ecosystems.

The assessment also needs to consider what impacts there may be if the soil were left in place (see box below).

A Tier 1 screening risk assessment also needs to consider if other factors may be relevant to the nature and extent of contamination which require further assessment:

Examples of issues you should consider in a Tier 1 screening risk assessment

- The presence of substances that are above background concentrations and may pose a risk and no generic assessment levels are available.
- The combination of contaminants that have similar toxicological effect mechanisms (additive or synergistic effects may require Tier 2 or 3 assessment).
- Leachability of contaminants – giving rise to groundwater contamination.
- Erodibility of contaminated materials, such as erosion of metal-impacted soil following rain, leading to contamination of adjacent properties or waterways.
- Odour (see section 7.2 on aesthetic impacts).
- Emission of volatiles that could enter buildings or service conduits and accumulate (vapour intrusion), adversely affecting the health of residents or occupants (see section 9.7 on vapour assessment).

10.5 Tier 2 risk assessment

You may need to conduct a Tier 2 risk assessment if:

- one or more contaminants exceed the generic assessment levels
- assessment levels are not relevant to the exposure scenario
- there are uncertainties that limit the reliability of the Tier 1 assessment.

If the site setting and exposure scenario differ significantly from the assumptions that underlie the generic assessment levels, you may be able to develop site-specific criteria by adjusting the assessment levels to reflect the exposure scenario more closely.

Use caution when modifying Tier 1 assessment levels, because some of the underlying assumptions reflect policy positions that should not ordinarily be changed (e.g. consumption of two litres of water per day in the *Australian drinking water guidelines*). It may still be appropriate to apply the unmodified generic criteria for the assessment of contaminant concentrations at offsite locations (e.g. contaminant concentrations in groundwater at a sensitive receptor).

You must justify and clearly document any modification of the generic assessment levels. The exposure scenario should adequately represent the site land use and potential offsite impacts with a reasonable degree of conservativeness.

You should submit any modified generic investigation levels/site response for review by the auditor and/or the department (and DoH for health-related assessments) to ensure they are acceptable before you implement a remedial action plan that is based on those levels.

Example of a simple Tier 2 risk assessment

A site proposed for high-density residential development is found to have metals (e.g. lead and copper) in soil at concentrations that exceed health-based assessment levels for residential development with minimal opportunities for soil access (HIL B). In this case the screening assessment has found that further investigation and possibly clean-up is required.

As the soil contamination is located where the building footprint is proposed to be, the contamination could be effectively contained under the building floor slab and direct contact with the contamination would be prevented. This assessment recognises that the soil assessment levels are based on effects arising from ingestion of soil, absorption through the skin, and inhalation of soil particulates (dust).

In this specific exposure scenario, it may be acceptable to permit soils with contaminant concentrations in excess of the generic assessment levels (HIL B) to remain onsite. However, before this proposal could be accepted, the developer must consider several factors:

- The works associated with the building's construction should not result in the redistribution of contaminated soil elsewhere on the site where subsequent exposure could occur. A suitable site management plan may be required to address this issue.
- The building works should be carried out so as not to pose an unacceptable level of risk to the occupational health of workers (consider application of relevant WorkSafe standards).
- How to manage future works or maintenance that would involve excavation and exposure of soil under the building, which may occur if new utilities or services were to be provided, or existing services required maintenance. If such works were anticipated, then a site management plan would be required to describe appropriate measures for managing the disturbance of contaminated soil. If all building works were subject to control through a management body, such as a body corporate, then it might be reasonable to assume that the site management plan would be implemented.
- Making sure the contamination is not volatile such that volatile contaminants could migrate through the sub-base or building floor or along service conduits or trenches (unlikely if the contamination only involves metals).
- Whether the contamination is above the seasonal high watertable (if the contamination were below the watertable it could give rise to groundwater contamination) and will not leach into groundwater.
- The presence of contamination may be indicated by the site's classification (such as *contaminated – restricted use* or *remediated for restricted use*) and a memorial on the relevant certificates of title. The development of a site management plan (see section 13.2) may be necessary to ensure the transfer of information on contamination at the site if it were sold or redeveloped.

10.6 Tier 3 risk assessment

You must conduct a Tier 3 risk assessment when a Tier 1 screening risk assessment and/or a Tier 2 risk assessment (which are based on generic assessment levels) do not, or cannot, adequately assess the level of risks present at the site; for example, if soil assessment levels are not available for the contaminants of concern, or the proposed use of the site does not match any of the land use scenarios for which soil assessment levels have been defined (e.g. agricultural land).

A Tier 3 risk assessment usually focuses on the risk-driving contaminants and exposure pathways to identify unacceptable risks that require clean-up or management. It may include specialised contaminant fate and transport modelling and/or a toxicity assessment of particular contaminants. It usually involves deriving hazard indices or increased lifetime cancer risks for the contaminant concentrations observed at a site to determine the acceptability of risks or developing site-specific investigation or response levels for contaminants.

If you do a Tier 3 risk assessment, you may adopt less conservative exposure assumptions because you are using site-specific information, reflecting a greater understanding of the site and consequently reduced levels of uncertainty. These more realistic assumptions may result in site-specific risk-based criteria that correspond to higher concentrations of contaminants than the generic assessment levels used for screening purposes, but which are nevertheless protective of human health, the environment and environmental values. You should ask the department and/or the auditor (and DoH for health-related levels) to review your site-specific response levels and the site information on which they are based to ensure they are acceptable before you implement a remedial action plan based on those levels.

For example, soil contamination may be acceptable in a Tier 1 screening risk assessment with regard to human health and ecological risk, but you may find uncertainty about the migration of contaminants in groundwater to a nearby waterbody and risks to the health of recreational users and the aquatic ecosystem. Your Tier 3 risk assessment would then concentrate on evaluating the risks associated with groundwater contamination and the requirements for managing those risks.

If it is clear that a serious problem exists and immediate action is required, you must direct your available resources to manage the risks. Such management may include immediate mitigation measures followed by an assessment of the residual risks. If it is clear from the subsequent assessment that the contamination no longer poses an unacceptable risk, you would not need to take further action.

A Tier 3 risk assessment may not be necessary where the issues are self-evident and the Tier 1 screening risk assessment or Tier 2 risk assessment process will provide enough information to determine a suitable risk management strategy.

Example of where a Tier 3 risk assessment may be required

In the previous example of a Tier 2 risk assessment, it was suggested that it might be acceptable for high levels of metals in soil to remain onsite if the contaminated soils were contained beneath a building slab.

However, this may not be the case if the contamination was found to be present throughout the soil profile (e.g. the contamination was associated with deep fill) and found to extend to the zone of seasonal watertable fluctuations. Contamination may leach into groundwater despite the presence of overlaying buildings that would prevent leaching through rainfall infiltration.

For example, consider the case where groundwater is of potable quality, an extraction bore exists on the downgradient neighbouring property, and analysis of a groundwater sample from an onsite bore near the contamination indicates that the relevant assessment levels for both potable and non-potable uses of water are exceeded. The soil was deposited at the site one year ago to level the site for development.

Further investigation shows that the groundwater impact extends beyond the zone of fill to within 100 metres of the neighbour’s bore and soil leachate testing has identified that the contamination has a high potential for ongoing leaching of metals. The neighbour’s bore is used to irrigate the garden, which includes some edible produce.

Although initial testing of the neighbour’s borewater does not find elevated concentrations of metals, this scenario indicates a potential risk to the neighbour from the contamination leaching from the soil and migrating via the groundwater to their bore.

In this example a decision is made to further characterise the risk, rather than carry out clean-up based on the available information (based on a simple cost-benefit analysis). A Tier 3 risk assessment is carried out to assess the risk to the neighbour, inform the extent of clean-up necessary (if any) and the urgency with which it should be carried out. Contaminant fate and transport modelling is used to evaluate the potential migration of the contamination in groundwater, while a toxicity and exposure assessment is used to characterise the risk to bore users and devise risk-based management strategies.

10.7 Contaminant fate and transport modelling

In some circumstances, you may need to model the fate and transport of contaminants to adequately assess the risk posed to receptors. Several modelling tools are available with various functions and limitations. Section 10 of Schedule B2 of the ASC NEPM provides guidance on contaminant fate and transport modelling. The UK Environment Agency has prepared detailed guidance on evaluating the validity of contaminant fate and transport modelling (McMahon et al. 2001).

Your report on contaminant fate and transport modelling should document all assumptions, input data and calculations. The checklist in Appendix A has general information for reporting on fate and transport models. The UK Environmental Agency guideline has detailed checklists for assessing the quality and validity of model predictions.

10.8 Material change in site condition

Your risk assessment should take into account all information relevant to the site. You must revise the risk assessment if conditions materially change at the site or new information become available after it has been completed (e.g. change of land use and/or site layout, or new contamination is identified that was not accounted for in the risk assessment). The outcomes of the revised risk assessment may result in changes to the recommended risk management strategy.

Example of a material change in site conditions when we must be notified

A groundwater plume has been laterally and vertically delineated, and a Tier 3 risk assessment has been undertaken with contaminant fate and transport modelling. The site has been assessed following the department's *MNA guidance* (2021) and found suitable for remediation via monitored natural attenuation (MNA).

An SMP was developed that established an extensive groundwater monitoring program to assess the progress of natural attenuation in reducing groundwater contamination. However, after three years of monitoring it became evident that the levels of contamination were not decreasing as predicted, and that trigger levels were likely to be exceeded. It was not appropriate to wait until trigger levels had been exceeded before implementing contingency measures.

The custodian of the SMP had to notify us and implement contingency measures. Contingency actions included active clean-up to some extent, followed by revision of the risk assessment and implementation of a new management strategy.

10.9 Risk management

Risk management involves evaluating options for the management of unacceptable risks identified through a risk assessment. The main objective of risk management is to ensure that the risks associated with a contaminated site are appropriately and proportionately managed.

Selecting the most appropriate risk management option involves value judgements that take into account the results of the human health and/or ecological risk assessment, the relative costs of different options, regulatory requirements and community expectations. The process of risk management also includes any necessary monitoring and evaluation of the outcome of risk management actions, and community engagement.

AS/NZS ISO 31000 describes the principles, framework and process for managing risk effectively. It provides general guidance that you can apply to decision-making for contaminated sites when considering the likelihood that a situation or consequence will arise, the severity of that situation or consequence, and prioritising action(s) to be undertaken. Risks are defined as 'event driven' and ranked in terms of probability of occurrence or frequency (i.e. likelihood) and severity (i.e.

consequence). The likelihood and consequence is ranked on a simple basis (e.g. 1–5) and the resulting estimate of risk is qualitative or semi-quantitative.

Standards Australia handbook *HB203:2012 Managing environment-related risk* illustrates how to implement AS/NZS ISO 31000.

Example of a situation where the approach in AS/NZS ISO 31000 may be useful

A decision needs to be made if contamination present at depth poses such a high risk that it requires remediation. The contamination is at depth (e.g. more than 5 metres below surface) and exposure is very unlikely to occur in the course of normal activities that would take place on the site. If the contamination is minor and exposure is unlikely to give rise to serious health effects or affect groundwater, then it may be concluded from **an assessment of likelihood and consequence that the overall risk is low** and that it might be acceptable to leave the contamination in place.

However, if the depth of contamination is relatively shallow (e.g. less than 2 m below surface), it is possible that maintenance works (e.g. re-laying or repairing service trenches) could result in contaminated soil being exposed. If significant levels of contamination are present that could adversely affect human health if the soil were to be exposed, it may be concluded from **the assessment of likelihood and consequence that the risk is unacceptable** and some form of remediation or management is required.

11. Tier 1 assessment levels

11.1 Introduction

You should use generic assessment levels in the context of a Tier 1 screening risk assessment (see section 10.4) to determine whether substances at a site potentially present a risk to human health, the environment or environmental values. Where a substance is present above the relevant assessment level and/or background concentrations, you must conduct further investigations to determine whether the site is contaminated such that it poses a risk to human health, the environment or environmental values.

Before applying generic assessment levels, you should always consider the quality and relevance of the data in the context of the CSM and the SAQP by:

- evaluating the data against the DQOs to determine whether they are acceptable and adequate for the purpose of the assessment (see section 9.4 of this guideline and sections 5.6, 13.1 and Appendix B of Schedule B2 of the ASC NEPM)
- understanding the effect of uncertainties in the CSM
- identifying appropriate assessment level(s) for the site based on the receptors, migration pathways and exposure routes identified in the CSM
- understanding the limitations associated with the relevant assessment levels.

Sources of assessment levels to be used in WA for soil, soil gas, water and sediment are listed in the next section. The assessment levels provided are the most relevant available at the time of publication.

It is your responsibility to check whether the assessment levels or guidance on their application have been updated in the relevant source documents, such as through publication of *errata,* or whether new assessment levels have been published.

You can contact us on the Contaminated Sites information line 1300 762 982 for advice if necessary.

11.2 Sources of assessment levels

Tables 1 to 6 below list the documents that contain the Tier 1 assessment levels to be used in WA. Schedule B1 of the ASC NEPM is the primary reference for assessment levels and has detailed guidance on the correct methods for their application. You should also refer to the additional sources of information for the application of assessment levels in WA (specified in tables 1 to 6). Section 3 of Schedule B1 and section 13.2 of Schedule B2 of the ASC NEPM provide guidance on the appropriate use of summary statistics for data analysis and assessing the significance of exceedences of Tier 1 assessment levels.

If you cannot find relevant assessment levels in the sources listed below, you may need to develop alternative assessment levels on a site-specific basis using the methods in the ASC NEPM or sources contained therein. Where you adopt assessment levels other than those listed or referenced in this guideline or in the ASC NEPM (e.g. alternative assessment levels from other states of Australia or international jurisdictions), you must be able to justify that the derivation methodology and exposure scenarios are relevant to the site. You should consult the department, the auditor and/or DoH before you apply alternative assessment levels. Where appropriate generic assessment levels cannot be sourced, you may need to adopt a site-specific approach, as discussed in section 10 (risk assessment).

Note that occupational exposure limits such as time weighted averages (TWAs) are relevant to assessing exposure as a result of occupational use of a substance in the workplace. You should not apply TWAs as public health criteria when assessing environmental exposures in contamination scenarios. For example, the TWA for toluene in indoor air is not a relevant screening level for assessing human health risks to workers in a workplace that does not store or use products that contain toluene. You should consult Safework Australia guidance when considering occupational exposures in a human health risk assessment.

Table 1: Ecological assessment levels for soil

Environmental receptor	Contaminants	Assessment level	Reference	Application in WA
Terrestrial ecosystems	Arsenic (aged contamination >2yrs)	Ecological investigation level (EIL)	ASC NEPM B1 Table 1B(5)	section 11.3
Terrestrial ecosystems	Arsenic (fresh contamination <2yrs)	EIL	ASC NEPM B5b Table 34*	s. 11.3
Terrestrial ecosystems	Zinc, copper, lead, nickel, chromium III (aged contamination >2yrs)	EIL (ambient background concentration ABC + added contaminant limit	ASC NEPM B1 Zn Table 1B(1) Cu Table 1B(2) Ni Table 1B(3) Cr Table 1B(3) Pb Table 1B(4)	s. 11.3
Terrestrial ecosystems	Zinc, copper, lead, nickel, chromium III (fresh contamination <2yrs)	EIL (ABC + ACL)	ASC NEPM B5c Zn Table 19 Cu Table 55 Pb Table 65* Ni Table 77* Cr Table 85*	s. 11.3
Terrestrial ecosystems	Naphthalene, DDT (fresh contamination <2yrs)	EIL	ASC NEPM B1 Table 1B(5)	s. 11.3

Environmental receptor	Contaminants	Assessment level	Reference	Application in WA
Terrestrial ecosystems	Petroleum hydrocarbons	Soil ecological screening levels (ESLs)	ASC NEPM B1 s. 2.6	No specific considerations
Terrestrial ecosystems	Per- and polyfluoroalkyl substances (PFAS)	Soil ecological guideline values for direct and indirect exposure	PFAS NEMP 2.0	No specific considerations
Terrestrial ecosystems	All other contaminants	Site-specific EILs	ASC NEPM B5b	No specific considerations
Aquatic ecosystems (leaching)	All contaminants	Site-specific EILS and/or aquatic ecosystems protection guidelines	ASC NEPM B3 and B5b; Australian and New Zealand guidelines for fresh and marine water quality (online)	s. 11.3

* LOEC & EC30 data has been adopted in the ASC NEPM for the derivation of EILs and are the relevant data from these tables to be used as ACLs and EILs.

Table 2: Human health assessment levels for soil

Exposure pathway	Contaminants	Assessment level	Reference	Application in WA
All exposure routes (chronic risk)	Metals and organic substances	Health investigation levels (HILs)	ASC NEPM B1 s. 2.2 and B7	No specific considerations
Inhalation of vapours (chronic risk)	Petroleum hydrocarbons	Soil HSLs for vapour intrusion	ASC NEPM B1 s. 2.4	s. 11.4
Direct contact (ingestion, dermal contact)	Petroleum hydrocarbons	HSLs for direct contact	Friebel and Nadebaum (2011)	s. 11.4
Inhalation	Asbestos	HSLs for asbestos in soil	DoH 2021; ASC NEPM B1 s4	DoH (2021)

Exposure pathway	Contaminants	Assessment level	Reference	Application in WA
Aesthetics, fire/ explosion risk, effects on buried infrastructure	Petroleum hydrocarbons	Management limits	ASC NEPM B1 s2.9	s. 3.2 and 7.2
Interim screening level to identify the presence of methyl tertiary-butyl ether	MTBE	Interim screening level for MTBE	Adopted by the department in consultation with DoH	s. 11.5
All exposure routes (chronic risk)	Per- and PFAS	HILs	PFAS NEMP 2.0	No specific considerations

Table 3: Human health assessment levels for soil vapour

Exposure pathway	Contaminant(s)	Assessment level	Reference	Application in WA
Inhalation (long-term/chronic risk)	Selected VOCCs	Interim soil vapour health investigation levels (interim HILs)	ASC NEPM B1 s. 2.3 ASC NEPM B4 and B7	No specific WA considerations
Inhalation (long-term/chronic risk)	Petroleum hydrocarbons	Soil vapour HSLs for vapour intrusion	ASC NEPM B1 s. 2.4	s. 11.4
Inhalation	Petroleum hydrocarbons	Screening distances (minimum clean soil thickness for biodegradation)	CRC CARE (2013)	s. 11.4
Explosion or short-term/acute risks	Landfill gas (LFG) (methane and carbon dioxide)	Gas screening values	CIRIA (2007)	s. 3.2

Table 4: Human health assessment levels for groundwater (petroleum hydrocarbon vapour intrusion)

Exposure pathway	Contaminant(s)	Assessment level	Reference	Application in WA
Inhalation of vapours	Petroleum hydrocarbons	Groundwater HSLs for vapour intrusion	ASC NEPM B1 s. 2.4	s. 11.4

Table 5: Ecological and human health assessment levels for groundwater and surface water

Environmental value to be protected	Assessment levels	Reference	Application in WA
Fresh, estuarine or marine aquatic ecosystems	Fresh and/or marine water aquatic ecosystem protection guidelines	Australian and New Zealand guidelines for fresh and marine water quality (online)	s. 11.7 and Table D3 in Appendix D
Drinking water source	Australian drinking water guidelines (ADWG) Microbiological assessment levels (MALs)	NHMRC & ARMCANZ 2011	s. 11.6 and 11.7; tables D1 and D2 in Appendix D
Non-potable use	Non-potable use guidelines (NPUG) Interim screening level for MTBE	DoH 2014	s. 11.5 and 11.7; Table D1 in Appendix D
Recreational use	NPUG MALs	DoH 2011; DoH 2014; NHMRC 2008; EPHC 2006	s. 11.6 and 11.7; tables D1 and D2 in Appendix D
Agricultural or industrial use	Irrigation water guidelines (short-term and long-term use) MALs Primary industries – livestock drinking water guidance	ANZECC & ARMCANZ 2000 Australian and New Zealand guidelines for fresh and marine water quality (online)	s. 11.6 and 11.7; tables D1 and D2 in Appendix D

Table 6: Ecological assessment levels for sediment

Environmental value to be protected	Assessment levels	Reference	Application in WA
Sediment quality in fresh, estuarine or marine aquatic ecosystems	Sediment quality guidelines	Australian and New Zealand guidelines for fresh and marine water quality (online)	s. 11.8
Sediment pore water quality	Fresh and/or marine water aquatic ecosystem protection guidelines	Australian and New Zealand guidelines for fresh and marine water quality (online); Simpson et al. 2013	s. 11.7 and 11.8

11.3 Ecological assessment levels for soil

Overview

The ecological investigation levels (EILs) in the ASC NEPM are to assess risks to terrestrial ecosystems and apply to the root zone and habitation zone of many species (generally the top two metres of soil but may be extended to three metres in arid areas).

Schedules B1 and B5c of the ASC NEPM provide EILs for selected metals and metalloids (zinc, copper, chromium III, nickel, lead and arsenic), DDT and naphthalene. Schedule B5b provides the methodology for deriving EILs for other substances and additional guidance on deriving EILs for protecting aquatic ecosystems and incorporating the bioavailability of contaminants.

The ASC NEPM methodology uses a combination of lowest observed effect (LOEC) and 30% effect (EC30) data to derive EILs.

The EIL methodology assumes that ecosystems are adapted to the ambient background concentration (ABC) and that it is only adding contaminants over and above this background concentration, referred to as the added contaminant limit (ACL), which has a potential adverse effect on the environment.

ASC NEPM schedules B1 and B5b present ACL values for selected metals and metalloids that should be added to the ABC to derive the EIL. ACLs are not provided for arsenic, DDT and naphthalene, as there was insufficient data available and generic EILs are provided for these substances instead of ACLS. The ABC should not be added to the EIL for these substances.

Depending on the characteristics of the contaminant, knowledge of certain soil physicochemical properties (pH, cation exchange capacity and clay content) and the land use scenario is required to determine the ACL (see ASC NEPM schedules B1 and B5b and B5c). Consideration of background concentrations is only relevant for the calculation of EILs when assessing metals or metalloids as the background concentration of most organic compounds of anthropogenic origin should be zero.

The ASC NEPM toolbox has a spreadsheet for calculating site-specific EILs.

Fresh and aged contamination

As metals age in soils they generally decrease in bioavailability due to the action of soil attenuation processes. However, the ageing process may be partially reversed by changes in environmental conditions (e.g. pH decreases). Where contaminated soil undergoes redox changes (e.g. as a result of fluctuating water table or biodegradation of organic contaminants) that could result in the complete or partial remobilisation of bound contaminants, through reduction or oxidation processes, then the contamination should be considered as fresh.

Most of the EILs in Schedule B1 of the ASC NEPM apply to aged contamination, defined as contamination that has been present in the soil for at least two years. The EILs for fresh contamination (that which has been present for less than two years) are in ASC NEPM Schedule B5c. The relevant tables for fresh contamination in ASC NEPM Schedule B5c are listed in Table 1.

EILs, acid sulfate soils and acid drainage

The EILs are relevant to certain soil conditions likely to occur at many sites in WA. However, the EILs have more limited application where the soils have been affected by the oxidation of iron sulfides and/or other sulfidic minerals, resulting in low pH (generally pH<4). This includes sites affected by acid sulfate soils (ASS) and sites affected by acid and metalliferous mine drainage (see also section 11.3).

ASS are widespread around coastal regions of WA and are also locally associated with freshwater wetlands and saline, sulfate-rich groundwater in some agricultural areas. In developing the CSM for your site, you should consider whether ASS or potential ASS may be present. Soil field pH provides a quick indication of the likely presence and severity of actual ASS. If the soil pH at your site is 4 or lower, this is an indicator that metal sulfide minerals may have been disturbed and oxidised. You should also consider the possibility that actual ASS are present if the soil pH is in the range pH 4–5. See DER (2015b) for detailed information and methodology.

Particular areas of concern for the occurrence of acid sulfate soils (DER 2015b)

- Peaty wetlands in the Perth metropolitan area (e.g. Stirling, Gwelup, Bayswater and Ashford).
- Estuarine, floodplain, damp land and seasonal wetland areas between Perth and Dunsborough, including the Peel-Harvey, Leschenault and Vasse-Wonnerup estuarine systems.
- Tidal, intertidal and supratidal flats along the northern coastline including the Pilbara and Kimberley coasts.
- Swan coastal plain (including iron-cemented and/or organic-rich ‘coffee rock’ sands in Bassendean Sands).
- Scott coastal plain.
- Parts of the Wheatbelt where secondary land salinisation has occurred.

If necessary, you should revise your CSM to determine whether there is likely to be a risk to human health or the environment; for example, via direct contact with soils or leaching to groundwater or surface water. If you identify a potential risk to human health or the environment, you should contact us for advice on the Contaminated Sites information line 1300 762 982. We will consider the requirement for management, monitoring and/or clean-up on a site-specific basis.

Figure 4 summarises the process for applying the EILs in WA. You should consider each relevant soil unit in the soil profile separately.

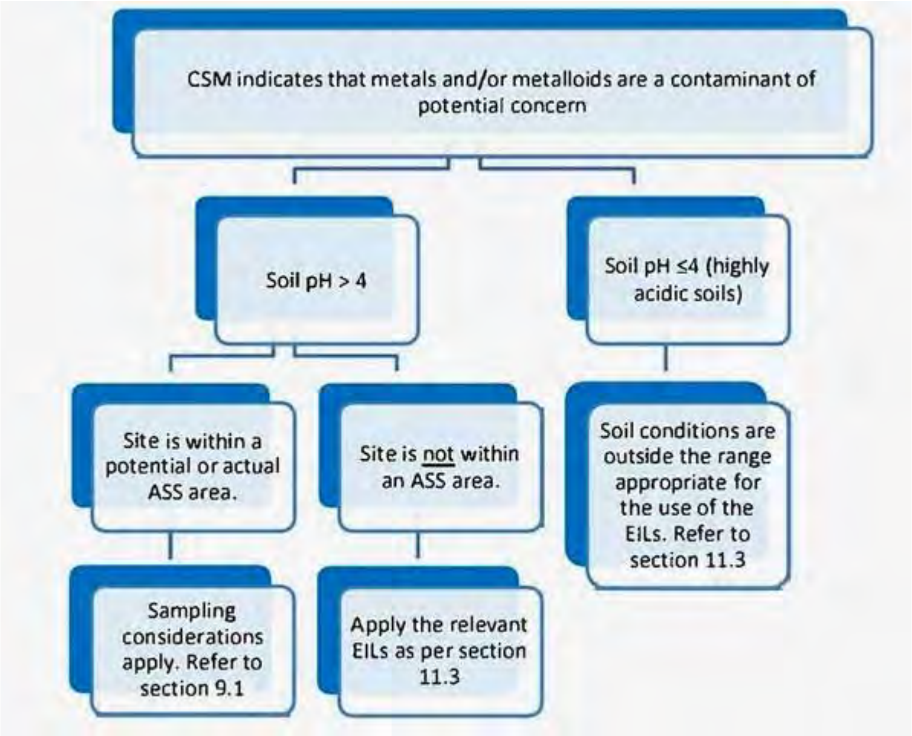

Figure 4: Procedure for applying EILs in WA

Determining ambient background concentrations

The ambient background concentration (ABC) is only relevant when considering metals or metalloids, as the background concentration for organic compounds of anthropogenic origin should normally be zero[4]. ABC methods may not be appropriate for the assessment of fill material that has originated from another location because of likely differences in soil characteristics.

Schedule B5b of the ASC NEPM presents three approaches for determining the ABC for metals or metalloid compounds (see Schedule B1 for a summary). See Figure 5 and the discussion below for a hierarchy of options to determine ambient background concentration for soils in WA, when applying the EILs.

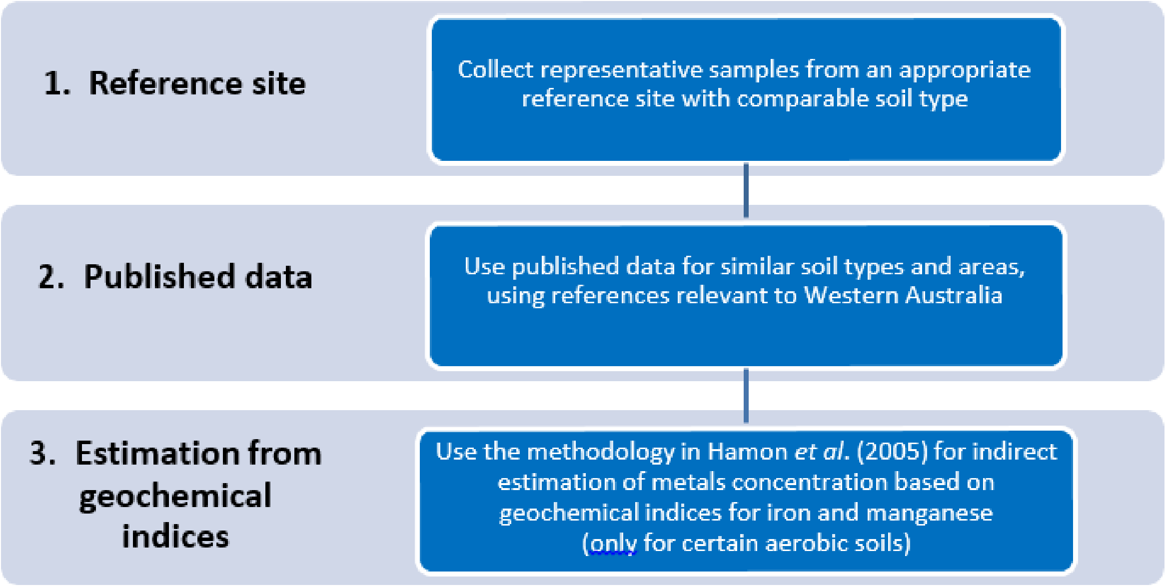

Figure 5: Hierarchy of options for determining ABC for soils in WA

1. Reference site (preferred approach)

Consistent with the ASC NEPM, our preferred method for determining the ABC is to characterise it at an appropriate reference site, analysing enough samples to obtain representative values (see section 2.5.7 in Schedule B1 of the ASC NEPM). This approach is essential in areas where there is a high naturally occurring background level, such as mineralised areas. Sometimes you may not be able to find a non-impacted area on the site being assessed and, if possible, you should obtain offsite reference samples.

Whether onsite or offsite, the reference site should:

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[4] Diffuse and/or multiple non-point sources may give rise to background levels of anthropogenic organic compounds (e.g. dioxins, PFAS, phthalate esters) in developed urban areas, depending on historical uses of the compounds and their chemical properties. Assessment of appropriate regional reference locations or use of published data may be a means to characterise background in such circumstances.

- be located as close as possible to the site being investigated
- be up-gradient of the site to minimise the risk that surface runoff or shallow groundwater flow will have transported contaminated material to the reference site
- not be contaminated (you should provide sufficient historical information to show that the background site has not been affected by land uses carried out on the investigation site or preferably any other potentially contaminating activity (see sections 5.2 and 8.2)
- be a site with a comparable soil type (different soil units should be sampled separately).

You may need to select more than one reference site to address the range of sources and associated contaminants. Collect soil samples from reference sites using the same sampling equipment and sample collection and handling methods as the investigation site. Make sure you collect samples from comparable depths and soil horizons.

2. Published data

Where an appropriate reference site is not available, you may use published data on background metal or metalloid concentrations for the relevant soil unit. The data on background metal concentrations presented in Schedule B5b of the ASC NEPM from Olszowy et al. (1995) does not include data from WA. However, Olszowy et al. (1995) does provide limited data from a site in Canning Vale obtained before metropolitan development.

Other sources of published data relevant to WA conditions include:

- Australian Soil Resource Information System (ASRIS) (CSIRO, ACLEP & DAFF 2013).
- *Mineralogy and chemistry of sandy acid sulfate soils in the Perth metropolitan area of the Swan coastal plain* (DEC & UWA 2011).
- *Soil guide: A handbook for understanding and managing agricultural soils* (Moore 1998).
- *Geomorphology, soils and landuse in the Swan coastal plain in relation to contaminant leaching* (Salama et al. 2001).
- *Reference soils of south-western Australia* (McArthur 2004).
- *Soil groups of Western Australia* (Schoknecht & Pathan 2013).
- Soil data collected during the department’s acid sulfate soil risk mapping project, available online (Landgate 2014).
- Review of the uncontaminated fill thresholds in Table 6 of the *Landfill Waste Classification and Waste Definitions 1996 (as amended 2019).*

Published data may not be adequate for estimating ABC or soil parameters in ASS landscapes, particularly for complex sites.

3. Geochemical indices (least preferred approach)

Estimating background concentrations of metals and metalloids from geochemical indices is not our preferred method due to its limitations.

In certain circumstances, you can estimate background metal and metalloid concentrations based on the concept of geochemical indices. For example, the method published by Hamon et al. (2004) assumes a relationship between the concentration of iron (as iron oxyhydroxide minerals) present in soil and the quantity of metal and metalloids bound to the soil. There are limitations to this method; in particular, the relationship is less strong for soils with very low concentrations of iron. You should only consider this method where iron is present in a chemically stable form.

The use of geochemical indices is not suitable where:

- soils are affected by seasonal waterlogging (fluctuating watertable or surface flooding)
- anoxic conditions are present (e.g. oxygen is depleted through the decay of organic matter)
- the soil profile is highly leached (minerals are leached from the surface horizons and accumulate deeper in the soil profile (where well-cemented, known as ‘coffee rock’).

Anoxic conditions result in chemical reduction and partial dissolution of iron oxyhydroxide minerals, known as ‘gleying’, and affected soils are typically grey, green or mottled orange or red and grey/green. This process is likely to cause the release of adsorbed metals and metalloids into soil pore water on a seasonal basis.

The Hamon et al. (2004) method may be used for soils developed on deep, iron-rich weathered profiles. It should not be used for iron-poor sandy soils, including the Safety Bay Sand and Tamala Limestone on the Swan coastal plain, or where soils are seasonally waterlogged and/or anoxic.

Mine sites and mineralised areas

Background levels for metals and metalloids in soil profiles in metalliferous areas are likely to be naturally high. However, you should not assume that comparable metal and metalloid levels in soils contaminated by mine wastes (e.g. waste rock and tailings) indicate a negligible environmental risk from these materials. This is because metals and metalloids are likely to be in a more bioavailable and/or leachable form in a disturbed soil profile or in soils affected by acid drainage compared with the undisturbed materials. Therefore, you may not be able apply EILs at sites that have been extensively disturbed by mining activities.

You should consider the geochemical processes relevant to the site-specific contaminants of concern. For example, metals and metalloids that form stable oxyanions in solution such as chromium, uranium, arsenic and selenium may be leached from waste rock under neutral or alkaline conditions. Other metals and metalloids such as aluminium, cadmium, lead and copper will be more available in soils affected by acid drainage. Arsenic and uranium may also be mobilised under acidic conditions.

If the EILs in the ASC NEPM do not apply to the site conditions, you should undertake a site-specific assessment that considers contaminant leachability, bioavailability and bioaccumulation and the potential risk to ecological receptors and environmental values.

See Schedule B5b of the ASC NEPM for information on assessing bioavailability and accounting for bioaccumulation when deriving site-specific EILs, and Schedule B3 for a discussion of bioavailability and leachability testing. See also the ecological risk assessment framework in Schedule B5b.

Leaching of soil contamination and protection of environmental values of water

The EILs and ESLs in the ASC NEPM do not take into account the potential for soil contamination to leach and contaminate groundwater or affect aquatic ecosystems. Where necessary, you may develop site-specific EILs that protect groundwater quality and aquatic ecosystems using the method in Appendix B of Schedule B5b of the ASC NEPM. However, this method requires an understanding of the local groundwater catchment, as well as information on the soil-water partition coefficient for the contaminant. See Schedule B5c for example calculations for zinc and arsenic.

An alternative approach is to consider the extent of and potential for contaminant leaching. When you develop and refine your CSM, you should consider the physicochemical properties of the contaminants, the likely age of contamination and the duration of the potentially contaminating activity in evaluating whether contamination has the potential to be leached or to have already impacted groundwater. You should also consider potential changes in hydrogeological conditions; for example, the oxidation of iron oxyhydroxides on a seasonal basis resulting in the mobilisation of previously bound metals and metalloids.

You can assess the potential for contaminated soils to leach contaminants with soil leaching tests. See Schedule B2 (section 7.6) and Schedule B3 (sections 2.7 and 11) of the ASC NEPM for guidance on leachability tests for soil. Select your samples to be tested for leachability with reference to the CSM and ensure they represent the impacted materials. We also recommend analysis of appropriate background samples, consistent with Schedule B2 of the ASC NEPM and advice in this guideline on Determining ambient background concentrations.

You should select the suitable assessment levels for comparing concentrations of substances within soil leachate based on the potential receptors identified in the CSM. If groundwater is a potential receptor, you should consider the environmental values of groundwater and the applicable assessment levels discussed in section 11.7.

For inorganic substances, leachability is affected by soil pH, contaminant solubility and redox conditions. When you are assessing leachability in WA, you should consider whether the site is within an ASS or acidic landscape, and how that may affect contaminant mobility (see EILs, acid sulfate soils and acid drainage).

11.4 Health screening levels for petroleum hydrocarbons

Health screening levels for vapour intrusion

Schedule B1 of the ASC NEPM has the health screening levels (HSLs) for assessing health risks related to petroleum vapour intrusion. HSLs are included for petroleum hydrocarbons in soils, groundwater and for direct measurements of soil vapour. They depend on specific soil physicochemical properties, land use scenarios, and the characteristics of building structures. The HSLs were developed for the assessment of commercial petroleum hydrocarbon sites and are not directly applicable to complex mixtures of contaminants, pure solvents or large-scale leaks at refinery sites. In these cases, a site-specific risk assessment may be necessary, including an assessment of the cumulative effects of substances present.

You must ensure the assumptions underlying the HSLs apply to your site. Completion of the HSL application checklist (Friebel & Nadebaum 2011) will help you identify whether the HSLs apply to your site or whether the site circumstances mean you will need to do a more detailed, site-specific assessment. You should include a copy of the completed checklist in any related assessment report you submit to us.

Health screening levels for direct contact with soil

HSLs for the direct contact exposure pathway via incidental oral ingestion, dermal contact and dust inhalation of petroleum hydrocarbon contaminated soils are available in Friebel & Nadebaum (2011).

You should apply the direct contact criteria with caution, as surface soils with concentrations equal to the levels of the relevant HSLs may give rise to odour concerns and potentially headaches, nausea and eye/respiratory irritation in people exposed. Consider the direct contact HSLs in combination with odours/aesthetics in sensitive locations such as residential and parks/public open space land uses (see section 7.2).

Screening **distances for ‘clean’ biologically active aerobic soil**

CRC CARE (2013) provides an assessment approach for certain petroleum hydrocarbon sites. It uses screening distances to screen out sites that do not pose a risk to human health via vapour intrusion. The screening distance is the minimum thickness (vertical) of soil with a high potential for bioattenuation that is sufficient to effectively attenuate petroleum vapours such that they do not pose a risk to human health (i.e. the potential for PVI is considered negligible) and no further assessment of PVI is required.

Limitations apply, and you must ensure that the selected approach applies to your site. These screening distances are relevant to sites with a high potential for bioattenuation of petroleum hydrocarbon vapours and do not apply to:

- large contaminant plumes with a significant area of light non-aqueous phase liquids (LNAPL) – such as leaks associated with major pipelines or refinery/bulk terminal sites
- LNAPL sources below large slabs/buildings (≥7.5 m minimum distance from the centre to the edge of a continuous sealed slab)
- ASS landscapes (these typically have reducing anaerobic conditions).

In these circumstances a detailed PVI assessment is more appropriate – as discussed in CRC CARE (2013).

Ethanol-containing fuels

In March 2013, two types of ethanol-blended fuels were introduced into Western Australia:

- E10 containing 10% ethanol and 90% unleaded petrol
- E85 containing 85% ethanol and 15% unleaded petrol.

The presence of ethanol (or other biofuels) in a leak or a spill will have implications for the effectiveness of natural attenuation processes in mitigating risks to receptors. It may also significantly increase the size of the benzene groundwater plume. Research by Ziegler et al. (2015) found that mixed ethanol and petroleum-based fuels increased the rate by which arsenic and other natural trace elements were released from aquifer sediments to groundwater when compared with petroleum-based fuels alone. The research highlighted the importance of monitoring trace elements at natural and enhanced attenuation sites.

11.5 Interim screening levels for MTBE

An interim screening level of 0.5 mg/kg has been adopted for methyl tertiary-butyl ether (MTBE) in soil to identify the presence of MTBE, given its high solubility and potential for impacting groundwater.

An interim screening level of 0.02 mg/L has been adopted for MBTE in water, based on odour and taint of water supplies.

You should notify us if you detect MTBE in soil at concentrations above the interim screening level as soon as practicable. We will consider reporting requirements under the CS Act on a site-specific basis. You should identify and discuss any exceedences of the screening levels in the assessment report. DoH should be consulted (through the department) where the interim screening level is exceeded – preparation of a detailed human health risk assessment may only be necessary at concentrations much greater than these screening levels.

11.6 Microbiological assessment levels

Potential sources of microbiological contamination include septic tanks, sewage sludge or biosolids, 'night soil', landfills, animal and bird manures, buried animal carcasses, wastewater systems, wastewater treatment plants, sewers, cesspools, landfills and livestock operations (animal manures and animal carcasses). The ASC NEPM does not provide specific guidance on the assessment of microbiological contamination of soil or water.

Generally you would not need to assess microbiological risks via soil exposure unless you are proposing a change to a more sensitive land use and the previous land uses were:

- sewage treatment (excluding domestic systems)
- intensive livestock operations or waste disposal (particularly large-scale disposal of manure or animal carcasses)
- an activity that involved the historical application of biosolids.

Where the CSM indicates that human exposure to microbiological contamination in surface water or groundwater may have occurred, your initial assessment should include screening for *E. coli* (thermotolerant coliforms) as an indicator of faecal contamination and a comparison with the relevant microbiological assessment levels (MALs) in Table D2.

You can find further information about the assessment of microbiological risks from pathogenic organisms in EPHC et al. (2006), EPHC et al. (2008), Pedley et al. (2006), CRC for Water Quality and Treatment (2004) and DoH (2011).

In the first instance, generally the department and DoH will manage the public health risks related to wastewater overflows as an immediate pollution response issue in accordance with *Wastewater overflow response procedures 2013* (DoH et al. 2013). Emergency response (such as for floods) is outside the scope of this guideline, as stated in section 3.2.

11.7 Assessment levels for surface water and groundwater

Groundwater and surface water contamination assessment in WA is risk-based, consistent with the framework in Schedule B6 of the ASC NEPM. The site assessment should consider background water quality – the sum of both ambient and natural sources in the site’s local area. Background water quality is relevant when considering pH, nutrients, metals and metalloids, but you should normally assume that organic compounds of anthropogenic origin have zero concentration. See section 3.3 of Schedule B6 of the ASC NEPM for more information.

In WA, you should consider the assessment levels discussed below for both groundwater and surface water when you are seeking to

- identify human health and environmental receptors (including risks to environmental values)
- develop your CSM.

The *Australian guidelines for fresh and marine water quality* (Water Quality Australia, 2019) is the primary source of assessment levels for fresh and marine water quality. The guidelines are being regularly updated and published on the Water Quality Australia website. Where specific guidelines are not yet available through the Water Quality Australia website, you should refer to previous guidance provided in ANZECC and ARMCANZ (2000).

Aquatic ecosystems

Freshwater aquatic ecosystems include lakes, reservoirs, wetlands, rivers and streams and marine water aquatic ecosystems include estuarine, coastal and marine environments (Water Quality Australia 2019). They also include groundwater-dependent ecosystems (discussed below). The *Australian and New Zealand guidelines for fresh and marine water quality* do not provide assessment levels for inland salt lakes and thus you may need to conduct a site-specific assessment (if relevant). In the absence of site-specific information, you may use default marine water quality criteria (Water Quality Australia 2019) for specific toxicants (Batley et al. 2003).

You should apply assessment levels for fresh or marine aquatic ecosystems to substances in the relevant surface waterbody or to groundwater where it discharges to an aquatic ecosystem. When you assess estuarine systems you may need to consider both fresh and marine assessment levels on a site-by-site basis.

The *Australian and New Zealand guidelines for fresh and marine water quality* (Water Quality Australia 2019) lists default guideline values for toxicants at three different protection levels:

- *high conservation/ecological value ecosystems* – effectively unmodified or other highly-valued ecosystems, typically (but not always) occurring in national parks, conservation reserves or in remote and/or inaccessible locations
- *slightly–moderately disturbed ecosystems* – aquatic biodiversity may have been adversely affected to a relatively small but measurable degree by human activity, such as rural streams receiving runoff from land disturbed by grazing or pastoralism, or marine ecosystems adjacent to metropolitan areas
- *highly disturbed ecosystems* – measurably degraded ecosystems of lower ecological value, such as shipping ports and harbours serving coastal cities, urban drains receiving road and stormwater runoff, or rural streams receiving runoff from intensive agriculture/horticulture.

See the *Australian and New Zealand guidelines for fresh and marine water quality* and the ASC NEPM for more information on applying these assessment levels.

Technical guidance – Protecting the quality of Western Australia’s marine environment (Environmental Protection Authority 2016) provides detailed information on the application of assessment levels and appropriate levels of protection for marine waters in Western Australia.

See section 3.3 of ANZECC and ARMCANZ (2000) for the default guideline values for a range of physical and chemical stressors (such as nutrients, dissolved oxygen and pH). See Appendix D of this guideline for the trigger values relevant to WA.

In some instances, the protection level of a waterbody, catchment or aquatic ecosystem may be specified in a management strategy published by an agency or local authority responsible for its management. You should consult such guidance where appropriate to ensure your adopted assessment levels are consistent with the goals of any local management strategies for aquatic ecosystems.

Groundwater-dependent ecosystems

Consistent with Schedule B6 of the ASC NEPM, groundwater environmental values should include ‘ecosystem protection’, which refers to aquatic ecosystems partly or fully dependent on groundwater to maintain ecosystem health (groundwater-dependent ecosystems). This includes wetlands and rivers that rely on groundwater base flow, some estuarine and nearshore marine systems, cave ecosystems and subterranean fauna.

Subterranean fauna include stygofauna (aquatic organisms living in groundwater) and troglofauna (air-breathing organisms living in caves and voids). WA’s subterranean fauna is recognised as globally significant because of its high species richness and high levels of endemism, with particularly high biodiversity occurring in Cape Range, Barrow Island, and the Yilgarn and Pilbara regions (EPA 2013). If subterranean fauna are likely to be present, you should consider this a relevant groundwater environmental value.

Where you identify a groundwater-dependent ecosystem as a relevant receptor, you should consider whether to apply the fresh or marine guidelines on a site-specific basis, based on the CSM.

Drinking (potable) water

See Appendix D for the drinking water assessment levels, noting these are derived from NHMRC and NRMMC (2011). For microbial drinking water quality standards, refer directly to NHMRC and NRMMC (2011).

Drinking (potable) water is defined as water intended primarily for human consumption, either directly as supplied from the tap or indirectly in beverages, ice or foods prepared with water. Some domestic uses of water, such as bathing and showering, are also considered potable uses because they involve a high potential for dermal absorption and incidental ingestion of substances in water (NHMRC & ARMCANZ 2011).

The public drinking water supply in WA is sourced from a combination of surface water (freshwater dams), groundwater and desalination of seawater. Public drinking water source areas are proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* or the *Country Areas Water Supply Act 1947* as a water reserve, a catchment area or an underground water pollution control area.

When to apply the Australian drinking water guidelines (ADWG)

You should consider drinking water as a relevant environmental value and use the ADWG to assess concentrations of substances in groundwater or surface water if:

- a public drinking water source area is a potential receptor
- scheme water is not available (in this situation it is reasonable to assume that groundwater or surface water may be used for potable purposes)
- there is a reasonable expectation that the groundwater or surface water could be used as a drinking water resource, even where it is not currently being used for that purpose.

Factors relevant to whether the use of water as a drinking water resource is feasible include background water quality, yield or flow, hydrogeology or hydrology, the potential for saline intrusion into aquifers and/or impact on groundwater-dependent ecosystems. Saline groundwater is desalinised for potable use in many Mid-West and Goldfields towns.

In accordance with DoH (2014) advice, domestic bore water should not be used for drinking, bathing, filling swimming and paddling pools, food preparation or cooking unless it has been appropriately tested and treated.

You can find information on public drinking water sources in WA in the department's drinking water source protection reports, the Western Australian Planning Commission's land use and water management strategies and various Water Corporation publications, including its 10-year plan for WA (Water Corporation 2012).

Non-potable use of water

Refer to Appendix D for the assessment levels for non-potable water use. These are derived from DoH (2014).

DoH has developed guidelines for non-potable use (NPUG) to protect the public from contaminated groundwater exposure in a non-potable setting (DoH 2014). The guidelines have been derived using a method consistent with the National Health and Medical Research Council's *Guidelines for managing risks in recreational water* (NHMRC 2008), which also applies to recreational waters (see the next section).

The NPUG apply to surface water and groundwater that may be used for watering gardens (including growing edible produce), irrigating parks and reserves, washing cars and clothes, and flushing toilets. The NPUG apply to groundwater before abstraction (noting they should be applied at the point of monitoring in the first instance). Exceedences of the NPUG at the point of use; for example, in water abstracted from a domestic bore, may require immediate action to mitigate risks to the relevant receptors.

The DoH (2014) guideline value is generally a factor of 10 times the corresponding ADWG health value (or equal to the aesthetic value where there is no health value), except for certain odorous substances where the aesthetic value is retained. Guideline values for pesticides not listed in the ADWG have been derived using the same methods as for the NPUG (DoH 2014).

Note that application of NPUG levels for PFAS requires a more detailed consideration of potential exposure pathways than for other contaminants. This is because of the properties of PFAS as a group and the variation in the persistence, transfer rates and bioaccumulation of the different PFAS compounds.

For PFAS, you should adopt drinking water guideline values as Tier 1 screening levels for non-potable uses (such as watering gardens) in situations where consumption of home-grown produce is a viable/plausible exposure pathway. In such cases, a Tier 2 assessment of home-grown produce is recommended. Direct testing of home-grown fruit and vegetables and specific consumption data, where available, is most appropriate for health risk assessment. However, where residential block sizes or local land use significantly limits the potential cultivation of home-grown produce, such as in the inner suburbs or on urban industrial land, 10x ADWG may be an appropriate Tier 1 screening level.

When to apply the NPUG

You should consider 'non-potable use' as an environmental value and use the NPUG to assess concentrations of substances in groundwater or surface water if:

- the water source is currently used for that purpose (e.g. a groundwater bore is present on the site)
- the site is up-hydraulic gradient of an area where water is used for that purpose (e.g. nearby groundwater bores) which may be impacted by contamination
- there is a reasonable expectation that water could be used for non-potable purposes in the future (e.g. owners or occupiers could install a new groundwater bore).

The department has published maps of areas considered suitable and unsuitable for the development of groundwater bores within the Perth superficial aquifer (see the Perth groundwater map for details. We may consider areas unsuitable for domestic garden bores due to:

- the groundwater salinity
- the potential for saline intrusion
- the proximity to conservation wetlands or groundwater-dependent ecosystems
- the unreliable yield (e.g. Guildford clay)
- the presence of ASS
- abstraction adversely affecting an underlying confined aquifer
- the area already being over-allocated to existing users.

In unsuitable areas we do not support the establishment of new domestic garden bores. However, there is generally no requirement to obtain a licence to install a groundwater bore into superficial aquifers for low abstraction volumes (such as for garden bores) and registration of bores is not compulsory.

Therefore if contamination is present in the superficial aquifer, you should consider the potential for current and future non-potable use of water when developing your CSM. We may consider that clean-up or management is necessary to protect human health or the environmental values of groundwater at a site in an ‘unsuitable’ area or where no bores are registered with us.

Recreational use

Consistent with the ASC NEPM, if a CSM indicates the possibility of public exposure to contaminants in surface water (or in groundwater where it discharges to a river, lake or estuary), through recreational activities such as water sports and swimming, the *Guidelines for managing risks in recreational water* (NHMRC 2008) apply.

Consistent with NHMRC (2008), DoH (2014) has specified that the NPUG applies for the screening assessment of chemical substances in recreational waters, or groundwater that discharges to recreational waters. The recreational water guidelines are under review – when complete they will underpin the refinement of the NPUG to assess recreational exposures.

Agricultural or industrial use

See Table D1 in Appendix D of this guideline for the assessment levels for water used in agricultural or commercial irrigation – derived from ANZECC & ARMCANZ (2000).

The short- and long-term irrigation water guidelines apply to commercial and agricultural applications. It is important to note that these guidelines do not usually apply to an urban setting. These guidelines were developed to minimise the build-up of contaminants in surface soils during irrigation and to prevent the direct toxicity of contaminants in irrigation waters to standing crops. Short-term irrigation water guidelines apply for up to 20 years of irrigation and long-term irrigation water guidelines apply for up to 100 years.

For some substances Table D1 states ‘refer to guideline’ if the assessment level is considered ‘low reliability’ because it was derived using a limited quantity of data (ANZECC & ARMCANZ 2000). See ANZECC & ARMCANZ (2000) for additional assessment levels and guidance on their application to aquaculture or stock watering.

Pesticides

The term ‘pesticide’ includes agricultural chemicals such as insecticides, herbicides, nematicides, rodenticides and miticides. The use of pesticides in WA is subject to regulation. When used correctly and following the label and material safety data sheet directions, leaching of pesticides to groundwater is not likely. The detection of pesticides in groundwater suggests inappropriate use (such as repeated application at concentrations unsuitable for the environmental setting) or illegal disposal, spills or dumping.

You should notify the DoH Environmental Health Directorate if you detect pesticides in surface water or groundwater, even if the concentrations do not exceed the assessment levels in Appendix D. Whenever pesticides are detected, the DoH may require an investigation to ensure appropriate controls are in place.

11.8 Assessment levels for sediment

The *Australian and New Zealand guidelines for fresh and marine water quality* (Water Quality Australia 2019) have default guideline values (DGVs) for toxicants in sediment. The DGVs have limitations relating to the availability of appropriate ecotoxicology data and the small number of species on which they are based. The quality of sediment pore water should be assessed against the criteria relevant to the adjacent waterbody (see section 11.7).

The recommended DGVs for sediment quality contain two concentrations: the DGV (or trigger value) and the GV-High concentration. The DGV trigger value is a threshold concentration – below this the frequency of adverse effects is expected to be very low. The GV-High concentration is intended to represent a concentration above which adverse biological effects are expected to occur more frequently. You should only use GV-High as an indicator of potential high-level toxicity problems, not as a guideline value to ensure the protection of ecosystems.

Where aquatic ecosystems are considered to be pristine and therefore of high environmental value, such as in marine parks and marine sanctuary areas, you should take a precautionary approach to assessment. In these ecosystems, no detectable change from natural background conditions is permitted (Water Quality Australia 2019).

For more information about applying the sediment quality guidelines, go to the Water Quality Australia website.

Where the investigation site is within an acid sulfate or acidic landscape, disturbance of sediments could cause acidity to form, a drop in pH and the mobilisation of metals from sediments. In that circumstance, the sediment DGVs may not be directly relevant and you should undertake a site-specific assessment. Further information on the assessment and management of ASS and acidic landscapes is available in DER (2015a and 2015b) – see www.der.wa.gov.au/ass and sections 9.111.3 and 11.3.

You should consult the *National assessment guidelines for dredging* (DEWHA 2009) when you are assessing sediments within marine waters and dredging and ocean disposal are involved. Note that these guidelines are not appropriate for assessing disposal of dredged sediment to land. This would require characterisation of the material and assessment of its compatibility with the receiving environment and associated land uses on a site-specific basis (following the guidance in Schedule B2 of the ASC NEPM).

12. Remediation

12.1 Introduction

The assessment process outlined in this guideline recommends assessment of site contamination to the extent necessary to provide enough information to enable risk-based decision-making. If the risk assessment process identifies unacceptable risks to human health, the environment and/or environmental values, some form of remediation (clean-up and/or management) will be required to mitigate those risks.

Site classification under the CS Act

Sites that require remediation are classified *contaminated–remediation required* under the CS Act (see DER 2017 for further information on when a site is likely to be classified as *contaminated–remediation required)*.

You must submit an appropriate site remediation and validation (SRV) report for assessment (see Appendix A for a report checklist) in order for the department to reclassify a site that has been remediated. If residual contamination is present, you may also need to submit a site management plan (SMP).

The revised site classification will be *decontaminated, contaminated – restricted use* or *remediated for restricted use* depending on the extent of remediation carried out.

If poorly selected, designed and/or implemented, remediation (clean-up) has the potential to cause greater impacts than the contamination it seeks to address. We therefore support consideration of sustainability issues:

- at the planning stage for a project (as the remediation solution may influence the project design and vice versa)
- when evaluating and selecting the remedial strategy/option.

Sustainable remediation

'a remedial solution selected through the use of a balanced decision-making process that demonstrates, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than any adverse effects'

A framework for assessing the sustainability of soil and groundwater remediation, Sustainable Remediation Forum (SuRF) Australia (2011).

The remediation of contaminated sites includes three distinct stages:

- development of a remedial action plan (RAP) – planning the active remedial work and how its success will be evaluated (validated)
- implementation of the RAP and validation
- if necessary, management of residual contamination via a site management plan (SMP) – see section 13.2.

You need to prepare a remedial action plan (RAP) when remediation (clean-up) is required. Your RAP must define the purpose and specific objectives of the remediation, document the evaluation of remedial options, and specify how the remediation will be carried out and how it will be validated.

You should document the remedial activities and the validation of the remedial works in a site remediation and validation (SRV) report. Appendix A has a checklist of the information to include in RAP and SRV reports.

You must ensure the remediation is planned and undertaken by suitably experienced and qualified consultants and/or contractors.

CRC CARE, in consultation with regulators (including the department), industry and other interested parties, has developed a National Remediation Framework (NRF). The NRF has practical general guidance on remediation (clean-up) and management of contaminated sites. The guidance comprises modules and guidelines to develop and implement RAPs, and considers post-remediation matters. The Heads of EPAs Australia and New Zealand (HEPA) has endorsed the NRF as best practice.

Currently the NRF provides guidance on the following matters:

National Remediation Framework		
Development of remediation plans	*Implementation of remediation plans*	*Post-remediation considerations*
A1 Guidance on regulatory considerations	B1 Guideline on health and safety	C1 Guideline for validation and closure
A2 Guideline on establishing remediation objectives	B2 Guideline on stakeholder engagement	C2 Guideline on implementing long-term monitoring
A3 Guideline on performing remediation options assessment	B3 Guideline on documentation record keeping and reporting	C3 Guideline for role of auditing
A4 Technology guides (soil) – consisting of seven guides		C4 Guideline for institutional controls
A4 Technology guides (groundwater) – consisting of six guides		
A5.1 Guideline on performing cost-benefit and sustainability analysis of remediation options		
A5.2 Cost-benefit and sustainability analysis tool		

For further information, go to the NRF website. See section 12.4 for a list of guidance documents relating to specific clean-up technologies/management options.

12.2 Remediation objectives

You should plan, design, implement and validate remediation with a view to remove or mitigate risk to an acceptable level. An RAP must include high-level knowledge of the nature and extent of the contaminating substances and their associated risk, an appraisal of the available contamination remediation options and timeframes, stakeholder and community consultation, a robust validation and verification program and a contingency plan in the event that the chosen remediation option proves ineffective.

Defining the remediation objectives is an important first step in developing the RAP. The issues you should consider include, but are not limited to:

- the risks to be mitigated and the desired outcomes
- the timeframe available to carry out the remedial works (see section 12.3)
- the sensitivity of the current or proposed land use and the site's environmental values
- the views of stakeholders, particularly owners of affected sites
- the acceptability of post-remediation institutional controls such as ongoing site management or a memorial on the certificate of title (see section 13.2).

You may need a remedial strategy to prioritise actions to be undertaken (addressing the highest risks to human health and the environment first), depending on funding and other constraints.

An RAP should detail the remedial objectives, including the specific remedial targets to be achieved, and the rationale and method by which they were derived. You may derive your remedial targets by adjusting the generic assessment levels suitable for the site conditions (see section 10.5) and/or by doing a site-specific risk assessment. When you develop site-specific remedial targets, you should consult the auditor or the department (and DoH for health-related criteria) by submitting the relevant report(s) for review – detailing the risk assessment and how you derived the site-specific remedial targets – before you finalise the RAP.

Remediation of source and affected sites

When you are responsible for the remediation of source sites, you must consider the land use and environmental values of affected sites when developing your RAP. You should seek the views of the owners and occupiers of affected sites; for example, about your remediation objectives and timeframe for completion. See Schedule B8 of the ASC NEPM and section 14 of this guideline for guidance on engaging with stakeholders.

Our default position when assessing an RAP's acceptability is that the clean-up will restore and protect the environmental values of affected sites, such as rendering groundwater suitable for domestic irrigation and enabling restrictions on land use to be removed.

Remediation of a source site to the extent that it achieves a restricted use classification for affected sites (i.e. remediated for restricted use) may be acceptable. This would be when the negotiated remediation outcome and likely classification under the CS Act are acceptable to the affected parties, as long as human health and the ecological receptors are protected. If this applies to you, ensure you document the negotiated outcomes with stakeholders and include copies of the relevant agreements in your RAP.

12.3 Timeframe for remediation

We expect that the timeframes you propose in the RAP are reasonable and appropriate to the level of risk the contamination poses and the sensitivity of the receptors. You should link the timeframes to the remedial objectives and site-specific factors, such as the remediation necessary to prevent contamination migrating offsite and affecting additional properties and sensitive environmental receptors.

The issues you should consider include, but are not limited to:

- the degree of risk posed to human health, the environment and environmental values and whether actual or potential harm is occurring
- the nature and extent of contamination and the potential for further contaminant migration (e.g. Is a groundwater plume increasing, stable or contracting in extent?)
- the results and reliability of contaminant fate and transport modelling
- the acceptability of timeframes to stakeholders, particularly the owners of affected sites
- intergenerational equity (remediation should be completed in a timeframe that ensures the polluter bears the cost rather than future generations).

12.4 Evaluation of remedial options

Your RAP should document the process you have undertaken to select the proposed remediation approach and demonstrate you have considered the issues relevant to the site. For large-scale projects, you should develop a standalone RAP, whereas for small-scale projects, a chapter within your DSI report should be adequate to address the requirements for a RAP.

In your evaluation of remedial options, you should consider the preferred hierarchy for site clean-up and/or management as described in principle 16 of the ASC NEPM:

Principle 16 of the ASC NEPM – Hierarchy of options for remediation

…the preferred hierarchy of options for site clean-up and/or management which is outlined as follows:

- onsite treatment of the contamination so that it is destroyed or the associated risk is reduced to an acceptable level, and
- offsite treatment of excavated soil, so that the contamination is destroyed or the associated risk is reduced to an acceptable level, after which soil is returned to the site; or,

if the above options are not practicable:

- consolidation and isolation of the soil onsite by containment with a properly designed barrier, and
- removal of contaminated material to an approved site or facility, followed, where necessary, by replacement with appropriate material, or
- where the assessment indicates remediation would have no net environmental benefit or would have a net adverse environmental effect, implementation of an appropriate management strategy.

When deciding which option to choose, the sustainability (environmental, economic and social) of each option should be considered, in terms of achieving an appropriate balance between the benefits and effects of undertaking the option.

In cases where no readily available or economically feasible method is available for remediation, it may be possible to adopt appropriate regulatory controls or develop other forms of remediation.

Your remediation approach must consider the views of relevant stakeholders. An onerous or long-term restriction or prohibition on access to or use of land, particularly when that land is owned or occupied by a third party, can give rise to significant anxiety and distress, which may result in psychological and/or physical harm. It is therefore critical that you negotiate with affected stakeholders and communities on all the remediation options, including management.

See section 14 and ASC NEPM Schedule B8 for guidance on community engagement.

When you evaluate the remedial options, you should consider the constraints that apply to the site itself as well as the environmental setting and surrounding land uses. The issues you should consider include, but are not limited to:

- technical constraints (technical ability to remove, destroy or reduce (treat), contain or manage the substance(s) causing contamination and restore the relevant environmental values)
- logistical constraints (such as site access, availability of materials and infrastructure and waste disposal)

- site management issues that may arise from the preferred method(s) (see section 13.1)
- acceptability of preferred method(s) to stakeholders, particularly owners of affected sites and neighbours
- sustainability, including waste minimisation.

Appendix A provides guidance on the information to consider when evaluating remedial options and compiling the RAP report.

You can find information relevant to evaluating remedial options and specific clean-up technologies on the following websites:

- CRC CARE National Remediation Framework guidance https://www.remediationframework.com.au/
  - CRC CARE National Remediation Framework – A2 guideline on establishing remediation objectives (CRC CARE, August 2019)
  - CRC CARE National Remediation Framework – A3 guideline on performing remediation options assessment (CRC CARE, August 2019)
- US EPA CLU-IN www.clu-in.org/
- ITRC www.itrcweb.org/Guidance
- CL:AIRE www.claire.co.uk/
- SuRF ANZ www.surfanz.com.au/

CRC CARE, NSW EPA and the department have published guidance on specific clean-up technologies:

Soil

- *Best practice note: Landfarming* (NSW EPA 2014a).
- National Remediation Framework – A4 technology guides (soil) (CRC CARE, August 2019). Technology guides covering:
  - containment
  - chemical immobilisation and stabilisation
  - bioremediation
  - soil washing
  - thermal desorption
  - excavation
  - soil vapour remediation.

Groundwater

- The use of monitored natural attenuation for groundwater clean-up (DWER MNA guideline 2021).

- National Remediation Framework – A4 technology guides (groundwater) (CRC CARE, August 2019). Technology guides covering:
    - in situ air sparging
    - in situ chemical oxidation
    - skimming
    - barrier systems
    - pump and treat
- *The role of natural source zone depletion in the management of LNAPL contaminated sites*, Technical Report no. 46 (CRC CARE 2020)
- *Flux-based groundwater assessment and management*, Technical Report no. 37 (CRC CARE 2016)

12.5 Requirements for a works approval, licence or licence amendment under the EP Act

In some cases you may be required under the *Environmental Protection Act 1986* (EP Act) to obtain a works approval, pollution prevention licence or licence amendment for clean-up activities for the site on which contamination has originated.

Clean-up methods carried out offsite may result in the offsite location being considered a prescribed premises under Part V Division 3 of the EP Act (see section 6.2 of this guideline), which would trigger the requirement for a works approval.

Offsite soil treatment facilities that would be considered to be prescribed premises

An offsite bioremediation facility would be considered a Category 61A Premises (solid waste facility) if 1,000 tonnes or more per year of solid waste would be stored, reprocessed, treated or discharged onto land. This might also trigger Category 67A Premises (compost manufacturing and soil blending), in which case Part V Division 3 of the EP Act would apply and a works approval before construction began and a licence to operate would be required.

Clean-up/remediation technologies (e.g. soil vapour extraction) carried out on a prescribed premises may require an amendment to an existing licence. Go to www.der.wa.gov.au/our-work/licences-and-works-approvals for more information.

12.6 Validation

Validation enables clean-up performance, in the context of the remediation objectives and remedial targets, to be evaluated. You should validate and document all clean-up activities otherwise we cannot provide ‘sign-off’ for a planning condition or confirm in the site classification that you have successfully remediated the site.

You can validate clean-up by implementing an SAQP that has been designed to characterise the site's post-remediation condition and provides results that can be assessed against your remediation objectives and remedial targets. The SAQP should consider the potential for contaminant rebound and other site-specific factors such as seasonal effects.

Although the ASC NEPM does not specifically discuss validation, Schedule B2 has guidance relevant to developing the SAQP and implementing the sampling program and data evaluation to characterise (i.e. validate) a site after clean-up.

Site classification under the CS Act

You must submit an appropriate site remediation and validation (SRV) report so that we can reclassify a site that has been cleaned up. If you do not submit a satisfactory SRV, we cannot issue an 'endpoint' classification such as *decontaminated* or *remediated for restricted use*.

You should document the remedial activities and the validation results in a site remediation and validation (SRV) report. The checklist in Appendix A of this guideline lists issues for consideration in an SRV report.

12.7 Management of remediation by-products

If relevant, your RAP should document the by-products you expect to be generated from the selected remediation method, and include details of the waste type, expected discharge volumes and the associated management measures proposed for any by-products. You should consider the management measures for remediating by-products in the context of the technical guidance in the NRF.

12.8 Bioremediation of soils

Bioremediation, when appropriately managed, can be an environmentally sound and cost-effective method to treat contaminated soils containing certain organic compounds. Successful bioremediation may enable the re-use of treated soils and minimise disposal of soil to landfill.

There are numerous types of bioremediation methods that include both in situ and ex situ methods for treating soil and groundwater.

Meaning of 'bioremediation'

Bioremediation means an accelerated process using micro-organisms (indigenous or introduced) and other processes to degrade and detoxify organic substances to become less toxic compounds, such as carbon dioxide and water, in a controlled environment.

Bioremediation, in the context of soil treatment, includes bio piles (also known as bio cells, bio heaps and bio mounds). These are aboveground engineered systems that use oxygen to stimulate the growth and reproduction of aerobic bacteria, which in turn, degrade the contaminants adsorbed onto soil. Bio piles are aerated by forcing air to move by injection or extraction through slotted or perforated piping placed through the pile. Landfarms are similar to bio piles but are usually aerated by tilling.

The ex situ treatment of soils is generally done in contained and managed bio piles or, subject to limitations, by landfarming either onsite, or at an approved offsite location. Depending on the scale of the operations, a bioremediation facility may be considered a prescribed premises (see sections 6.2 and 12.5).

The design requirements for bioremediation facilities are site-specific and are outside the scope of this guideline.

You should carefully consider the location and construction of bioremediation facilities to avoid negatively impacting the surrounding environment and the community. Refer to the *Best practice note: Landfarming* (NSW EPA 2014) for guidance on site selection and other considerations for establishing and managing a bioremediation facility.

Bioremediation facilities

Bioremediation facilities should incorporate contemporary emission and control systems.

We expect you to undertake effective stakeholder engagement before you construct a bioremediation facility.

It is generally not advisable to construct bioremediation facilities near sensitive land uses such as residential areas, child care centres, schools or public open spaces or sensitive environmental receptors.

Depending on the nature of the facility, you may need to conduct surface and groundwater monitoring for the duration of the bioremediation operation and for a period post-completion, to evaluate the performance of the emission control measures.

See schedules B2 and B6 of the ASC NEPM for groundwater monitoring guidance.

See DEC (2011a) for guidance on monitoring air quality. Note that some ambient air standards are prescribed in the *National environment protection measures for ambient air* (NEPC 2008) and air toxics (NEPC 2004).

See section 13.1 for site management considerations.

12.9 Re-use of excavated soil

Soil excavated (and treated) as part of a remediation program may be suitable for use as fill material onsite, or at an offsite location, provided you have appropriately characterised the soil to ensure it is suitable for the current or proposed land use at the re-use location.

When considering the suitability, and potential requirements for analytical testing, of soil being used as fill, you should first consider whether the soil meets the definition of waste (see Factsheet – Assessing whether material is waste).

The Environmental Protection Regulations 1987 (EP Regulations) were amended in 2018 to allow for the use of certain types of waste fill without the need for a landfill premises licence or payment of the waste levy. The amendments were supported by changes to the *Landfill Waste Classification and Waste Definitions 1996 (amended 2019)* (DWER 2019) (Waste Definitions) which provide definitions for the waste types 'clean fill' and 'uncontaminated fill' (see Factsheet – Amendments to the Environmental Protection Regulations 1987 – clean fill and uncontaminated fill).

Essentially, 'clean fill' is waste material which, by virtue of the history of the site from which it originates, is *unlikely* to contain contamination of any type. There are no laboratory testing requirements for 'clean fill'. Soil imported to a site that has been excavated from an offsite location with no history of potentially contaminating activity may meet the definition of clean fill.

'Uncontaminated fill' originates from sites where the history indicates contamination may be present. Testing is therefore required to confirm that material from such sites is not contaminated (that is, meets the specifications in Table 6 of the Waste Definitions guideline) before it can be considered 'uncontaminated fill'. Where the history indicates a contaminant may be present that is not listed in Table 6, the material is not suitable for classification as 'uncontaminated fill'.

The definitions of both 'clean fill' and 'uncontaminated fill' only have practical effect for sites which accept waste for burial and would otherwise meet the description of a category 63 (inert) landfill premises in the EP Regulations. The requirements for 'clean fill' and 'uncontaminated fill' do not apply to soil excavated from a site that is re-used on the same site, such as may occur during a remediation program.

Material imported to site during remediation or development

You should 'assess' any material imported to site, such as for reinstating excavation voids, or for land development purposes, to ensure it is environmentally suitable for the purpose for which it is being used.

The definitions of 'clean fill' and 'uncontaminated fill' in the Waste Definitions only apply to material that meets the definition of waste. Basic raw materials extracted from quarries (as part of extractive industries' operations) and sold as products do not have to meet the 'clean fill' or 'uncontaminated fill' definitions. We do not support the indiscriminate use of the uncontaminated fill thresholds in Table 6 of the Waste Definitions for assessing material that is not consistent with the definition of waste.

13. Site management

13.1 Site management during assessment and remediation

Introduction

You must carefully plan and implement the site management measures during the assessment and remediation phases, together with appropriate community engagement, to ensure that disturbance of contamination does not result in a risk to human health, the environment or environmental values, or cause concern or nuisance to the surrounding community. The measures you adopt should protect public and worker health and safety, the environment and address aesthetic issues. Work, health and safety are discussed briefly in section 3.1.

You should document the site management measures you adopt in the SAQP, the RAP or in a standalone site management plan (SMP), as appropriate for the scale of the operation. This type of SMP documents transient measures to be adopted as opposed to that required for ongoing site management (see section 13.2).

The EP Act provides for the prevention, control and abatement of pollution and environmental harm. Part V of the *Environmental Protection Act 1986* places a clear obligation on persons to prevent pollution and specifies pollution and environmental harm offences and notices, orders and directions that can be enforced to address pollution and environmental harm.

Section 15 of Schedule B2 of the ASC NEPM provides guidance on the protection of human health and the environment during site assessment, which is also relevant to site management during remediation. Some elements of site management are discussed below and additional sources of information provided. You should consult Schedule B8 of the ASC NEPM and section 14 of this guideline for guidance on community engagement and risk communication.

Dust and odours

You must manage any dust and odours generated during the excavation and/or disturbance of soils at their source. Odours may impact the local community because they cause nuisance, but also because of concerns about potential risks to human health and the environment.

Odour management should include the use of contemporary odour mitigation measures which may include the use of odour suppressants, foggers and biodegradable foams. You should undertake monitoring at the site boundary if the risk of potential emissions is significant.

The DoH (2021) asbestos guidelines include guidance on air quality monitoring and principles and methods relevant to the management of nuisance dust, as well as potential asbestos contamination issues.

DEC (2011a) and NEPC (2004 and 2008) has additional information on managing dust and nuisance/noxious odours.

Water management

You should consider water management, including appropriate controls, during the planning stage of site assessment and remediation. Water must be managed to ensure that potential runoff, leachate or wastewater generated at the site does not result in the movement of contaminated soils or water to uncontaminated portions of the site or offsite. A discharge of contaminated soil and/or water to the environment (including stormwater drains) may be considered an offence under the Environmental Protection (Unauthorised Discharge) Regulations 2004 and result in a reporting obligation under the CS Act.

Recycling water for dust suppression of stockpiles is acceptable where you can demonstrate that it will not cause unacceptable risks to the environment, human health or environmental values.

If all other mitigation measures have been exhausted, you might consider the following options for the disposal of wastewater:

- onsite treatment
- disposal to the wastewater system – either a trade waste permit or 'one-off discharge of trade waste' permit is required – go to the Water Corporation website for details www.watercorporation.com.au/home/business/trade-waste/trade-waste-in-your-business/requirements-for-one-off-discharge-of-industrial-waste
- disposal to main drains – the Water Corporation considers applications for a one-off discharge of industrial wastewater to main drains (further information is available at www.watercorporation.com.au/home/business/trade-waste)
- offsite treatment and/or disposal (see Transportation).

You need the approval of the relevant authority (such as the Department of Biodiversity, Conservation and Attractions, local government authority or the department) for water to enter wetlands or waterways, either directly or indirectly, via the stormwater or the associated drainage system. See section 3.3 of DER (2015a) for more information.

Additional information on water management

Wastewater lagoon construction (EPA South Australia 2019) https://www.epa.sa.gov.au/files/4771372_guide_lagoon.pdf

Water quality protection note 26: Liners for containing pollutants, using synthetic membranes (DoW 2013) https://www.water.wa.gov.au/__data/assets/pdf_file/0012/4062/84590.pdf

Australian and New Zealand guidelines for fresh and marine water quality (Water Quality Australia 2019) www.waterquality.gov.au/anz-guidelines

Noise

Noise generated at a site can pose a potential health risk to workers and a nuisance to occupants of neighbouring properties. Potential sources of noise (and vibration) include earthmoving equipment, trucks and other mobile plant and drilling activities and fixed plant such as pumps and generator sets.

You should address noise issues following the Environmental (Noise) Regulations 1997 (Noise Regulations). These are regulated by the local government authority, unless the site is a prescribed premises, in which case it is regulated by the department.

Reversing beepers on mobile plant are not exempt from the Noise Regulations. You should consider the use of broad-band beepers or non-acoustic warning systems.

For further information, contact your local government authority www.dlg.wa.gov.au/content/directory/default.aspx or the department www.der.wa.gov.au/your-environment/noise.

Stockpiling

You may need to stockpile contaminated soil while waiting on the results of laboratory analysis for its characterisation, or before transport to another site for re-use, treatment or disposal. To prevent potential re-contamination of the site or adverse impacts to the surrounding environment, stockpiled soils should remain onsite for the shortest practical time after being excavated. You should not put uncovered stockpiles near sensitive receptors such as residential properties, child care centres, schools or public open spaces.

See section 9.5 of this guideline and section 7.5 of Schedule B2 of the ASC NEPM for guidance on characterising stockpiled materials. You should consider:

- maintaining a log of stockpile locations, their origins, relevant sample locations and results and transport details offsite
- using an effective liner or sealed surface in combination with bunding to prevent runoff or soil erosion
- restricting the maximum height of a stockpile to be generally less than 3 metres and/or lower than boundary fence heights
- avoiding locating stockpiles adjacent to, or near site boundaries
- maintaining an effective dust and/or odour mitigation cover
- maintaining appropriate soil moisture content to reduce dust emissions (particularly during handling).

Additional information on stockpile management

Guideline for stockpile management: Waste and waste-derived products for recycling and re-use (SA EPA 2010)

Treatment and management of soils and water in acid sulfate soil landscapes (DER 2015a)

Unexpected finds

It is a common practice to put management contingencies in RAPs and SMPs to deal with the possibility that unexpected contamination sources may be disturbed or exposed during site excavations. Such contingencies should consider potential health risks to workers and occupants of neighbouring properties and may include a requirement to stop work until risk can be fully assessed. You should make every effort to anticipate, investigate and assess all potential contamination onsite.

You should only apply the terminology 'unexpected find' to those finds that arise due to knowledge gaps in the site history. When you identify substances as contaminants of potential concern during the PSI stage of investigations, these are not considered to be unexpected finds.

Unexpected finds

An unexpected find is contamination that is unlikely to occur at a site and cannot reasonably be anticipated, investigated or assessed in accordance with regulatory requirements.

Transportation

You may need to transport contaminated materials to move them around a site or offsite for treatment, re-use or disposal. Whatever level of contamination is present, you should transport materials offsite in a manner that ensures no spillage from the vehicle occurs. Take care when moving contaminated material within the boundaries of your site to ensure you do not spread contamination to previously unaffected areas.

If your contaminated material requires transport by road and has been determined as controlled waste in accordance with the Environmental Protection (Controlled Waste) Regulations 2004 (Controlled Waste Regulations), you (the person who possesses or controls the controlled waste) have statutory obligations under the Controlled Waste Regulations. See www.der.wa.gov.au/controlledwaste for more information.

You should include documentation of the volumes taken offsite, the nature of the materials, licences (such as a controlled waste licence) and acceptance receipts from the receiving facility in the relevant assessment/remediation report.

13.2 Ongoing site management

Overview

You may need to adopt a site management approach based on preventing exposure to contamination where it is not possible/desirable or viable to remediate a site to a standard suitable for all land uses. For ongoing site management, you may need to implement control measures to mitigate risks by restricting or prohibiting access to or use of a site, and/or containing contamination in such a way that protects receptors from exposure.

For this to be an acceptable approach, you must adequately characterise the contamination risks and ensure the proposed management measures are:

- suitable to mitigate the risks to human health, the environment and environmental values
- acceptable to stakeholders, particularly the owners of affected sites.

The site classification scheme provides a framework for the management of contaminated sites. It places restrictions on the use of certain sites and enables the transfer of information about contamination when the site is proposed for a new land use, redeveloped, leased or sold.

You may decide to take measures to manage contamination onsite including:

- construct a purpose-built containment cell
- maintain a cover of clean soil or buildings over a contaminated layer
- develop an SMP that details how you will manage contamination at the site.

Site classification under the CS Act

We will classify contaminated sites as *contaminated – restricted use* or *remediated for restricted use* where the risks to human health, the environment and environmental values have been adequately characterised and where current and potential future receptors can be protected through restrictions on use of the site.

The classification will specify the restrictions relevant to the site, for example:

- the site is suitable for commercial/industrial land use (excluding sensitive uses such as child care centres, schools and residential)
- contaminated soil that is safely contained at a site is not to be disturbed
- the abstraction of contaminated groundwater is prohibited as it is not suitable for non-potable uses such as garden irrigation.

We will require further contamination assessment or remediation when activities are proposed that are not in accordance with the restrictions on use or if there is a change in site use.

You may need to undertake periodic monitoring of soil, groundwater and/or air to monitor the effectiveness of the implemented measures; for example, groundwater monitoring around an engineered containment system or vapour monitoring in connection with a building that has a vapour control system. Monitoring requirements will depend on the nature of the remediation carried out. For example, you may need to conduct groundwater monitoring on a quarterly basis for a number of years to evaluate seasonal variation. This might decrease to annual monitoring once the variation is understood.

Site management plans

When to prepare an SMP

In some cases, when we specify restrictions in the site classification, we may still not consider they provide adequate controls in relation to the site's long-term use. We would then require a site-specific SMP to document the necessary site management procedures, such as periodic maintenance and monitoring, and those to be followed when carrying out intrusive works.

See below for some examples of instances when we may require an SMP (these assume you have carried out appropriate risk assessment and site management provides effective mitigation of the risks).

SMP necessary	**SMP not generally necessary**
Contaminated soil is buried beneath a warning barrier and one metre of clean soil at a commercial site. Activities at the site are likely to include the installation and maintenance of underground services. An SMP is necessary to ensure the correct thickness (elevation) of clean cover is maintained over the contaminated material, to detail the requirements for protecting workers and to prevent the material being brought to the surface during subsurface activities.	Contaminated soil is contained beneath a warning barrier, two metres of clean soil and a permanent building. The site classification includes a restriction on disturbing soils beneath the clean soil layer. An SMP is not generally necessary as the material is unlikely to be disturbed unless there is a significant change in use of the site. This is likely to involve planning authorities who would be alerted to the presence of contamination by the memorial on title and, as such, the planning authority would be required to seek advice from the department under s. 58(6) of the CS Act.

A site has been remediated by placing contaminated soil into an engineered containment cell. However, if the containment cell were to fail, the material could pose a risk to groundwater and groundwater users. Periodic groundwater monitoring is required to assess performance of the containment cell. An SMP is necessary to formalise the monitoring plan – who is responsible, details of the monitoring to be carried out, who the information is to be provided to, relevant trigger levels and contingency actions if these are breached.	Soil at a residential development site has been remediated by removal and offsite disposal, however the groundwater is contaminated and unsuitable for non-potable uses such as garden irrigation. Monitoring has demonstrated that substances are naturally attenuating and further monitoring is not considered necessary. The site classification (*remediated for restricted use*) includes a restriction on the installation of bores and use of groundwater. An SMP would not generally be necessary as the new owners must be notified by the vendor of the presence of contamination under s. 68 of the CS Act.

Purpose and objectives

An SMP defines how you will manage or monitor the site to ensure the risks from contamination remain at an acceptable level. You should consider including the following in your SMP:

- a summary of the contamination issues at the site including the CSM
- the purpose and objectives of site management
- the specific risks to be mitigated as identified in the CSM
- the timeframe for which site management is necessary (potentially in perpetuity for a containment cell)
- details of how site activities are to be managed, or the monitoring and maintenance actions required, such as groundwater monitoring or minimum elevation/thickness of clean soil cover to be maintained
- reporting framework
- contingency measures to be taken in the event that any action criteria/trigger levels are exceeded
- contact details for the person or body corporate responsible for implementing the SMP
- timeframe for the SMP to be reviewed and revised.

An SMP may be required for a finite period, and may be attached to a site in perpetuity or until further remedial work is carried out. The checklist in Appendix A of this guideline has examples of information you should consider for inclusion in an SMP report.

Stakeholder statement

We can only endorse an SMP if it includes a statement from each of the key stakeholders (e.g. local government authority, owners, occupiers, infrastructure owners, affected site owners) that they are aware of the SMP, agree to its content and agree to abide by it.

You can find examples of department-endorsed management plans at https://www.der.wa.gov.au/your-environment/contaminated-sites/74-site-management-plans.

Contingency measures

Your SMP should specify the circumstances that would constitute a material change in conditions requiring action, the actions you would take and their timeframe. A material change in conditions may comprise, but not be limited to:

- the minimum thickness/elevation of clean soil to be maintained over a contaminated layer
- the integrity of sealed surfaces, buildings or fencing
- concentrations or extent of contaminants that are monitored
- a change in land use or certain activities at a site
- the identification of new contamination that has not been considered in the SMP
- the period of time that the SMP remains relevant to the site.

Your SMP should have clear instructions for the actions to be carried out and timeframe for action in the event that a trigger level or other management measure is exceeded. Actions may include, but not be limited to:

- reinstating the cover of clean soil, or repairing sealed surfaces or fencing
- increased monitoring or further site characterisation
- active clean-up and/or risk assessment
- decommissioning groundwater bores, treatment of water at the point of use or provision of an alternative water source
- revision of the SMP
- re-reporting the site to the department if new contamination is known or suspected
- community engagement to inform stakeholders and engage them in the process of evaluating further actions, such as remediation and revision of the SMP.

Monitoring

If periodic reporting of results or conditions is required, your SMP should specify the format and frequency of reporting, and who the report(s) will be sent to. If monitoring of the site includes sampling and analysis of environmental media, then you should include a detailed SAQP in the SMP to ensure consistency in sampling and analysis over time. Reports detailing the results of periodic sampling and analysis should meet the equivalent requirements to those for a DSI report.

You should periodically review and update the SAQP to ensure the monitoring regime is appropriate for the site conditions.

14. Community engagement

14.1 Introduction

Community engagement is an integral part of contaminated site assessment and remediation and should be considered in the planning and implementation of all stages of such work in Western Australia.

Schedule B8 of the ASC NEPM provides guidance on developing community engagement programs and sets out the benefits and key principles of community engagement and risk communication. It includes a suggested step-by-step procedure, useful engagement techniques and Australian case studies of well-planned and successful community engagement strategies.

You should engage suitably qualified and experienced professionals to conduct the community engagement for your site.

14.2 Identifying stakeholders

You should consider that members of the community who live in, work in or visit the area near the contaminated site are relevant stakeholders that may be directly or indirectly affected by investigation and remediation activities at the site. They may be affected by:

- potential health risks
- potential impacts to the environmental values of their property such as contaminated groundwater that has migrated from a source site to their property, or close to their property
- loss of amenity
- short-term nuisance, such as noise generated during site investigations and clean-up.

You must carry out more extensive community engagement if your site poses a significant risk to human health, the environment or environmental values; affects adjacent land (source and affected sites); or has contamination with the potential to migrate offsite or affect sensitive offsite receptors (e.g. residential properties, day care centres, wetlands).

The scope and detail of community engagement will depend on the project’s size and the level of community interest or concern. The level of community engagement required varies from site to site and is influenced by a number of factors.

What level of community engagement is appropriate?

Is the site high profile or controversial within the community because of the industry, contaminants involved or proposed land development?

How much involvement does the community want?

How long will the site assessment, clean-up work or ongoing management take?

Are there issues related to the management of works at the site that could cause concern in the local community? (See section 13.1.)

The extent of community engagement will also vary, depending on the sensitivity of adjacent land uses. For example, removing underground storage tanks at a disused service station site and backfilling with clean soil might only require a letter drop to neighbouring properties if the works are planned and managed appropriately (see section 13.1 and section 15 of Schedule B2 of the ASC NEPM). However, remediating a former gasworks located alongside the Swan River and close to a residential suburb, a primary school and a child care centre, may be of interest and concern to a broader part of the community and would require more extensive consultation and engagement.

When discussing site contamination, you should use plain language and avoid jargon. Visual aids such as diagrams and aerial photos of the site are helpful. Take care to ensure your information is accessible to all, including people with disabilities and those for whom English is a second language.

The level of community interest and stakeholders who should be involved will vary on a site-by-site basis. Consider including the following people:

Who should be engaged?

Landowners and occupiers affected by contamination moving offsite

Local member of Parliament

Community groups (e.g. rate payers' associations)

Industry and professional associations

Media

Residents living near the site

Local businesses

Indigenous custodians

Local schools

Unions

Local government authorities

State government agencies

Environmental action groups

Public

Public utilities/service providers, e.g. Western Power, Water Corporation

14.3 Timing of community engagement

You should start your community engagement as early as possible in the contaminated site assessment process, particularly for contentious sites. It is important to maintain open communication at all times and to ensure that the community can access information throughout the process by providing appropriate contact details to the relevant stakeholders.

Site assessment and management stage	Community engagement
Preliminary site investigation (PSI)	Generally only necessary for contentious sites.
Detailed site investigation (DSI)	Let the relevant stakeholders know there is known or suspected contamination at the site that requires investigation, and what the likely or actual contaminants are. Tell people what to expect – hours of operation at the site, drilling, traffic management, noise and/or dust management, who will be carrying out the work and contact details. If appropriate, give people an opportunity to comment on the proposed investigation and articulate any specific concerns they may have. Communicate the DSI findings and provide information on future work, e.g. further investigations or potential remedial work.
Site remediation planning	Discuss the preferred clean-up options with stakeholders. Involve them in the decision-making process on remedial objectives and the evaluation of remedial options (methods). This is particularly important for the owners and occupiers of affected sites. Signatures from the parties concerned may be required to formalise and endorse the remediation decisions.
Clean-up, validation and ongoing management	Communicate remediation and monitoring results to meet any commitments made to the community and provide closure for participants. If monitoring is continuing, update the community as results are known.

14.4 Reporting on community engagement

You should properly document your community engagement process and include a rationale for how you determined the extent and timing of consultation and identified the relevant stakeholders. You may need to carry out several stages of community engagement relating to the different stages of the site assessment and remediation process. The engagement process will generally comprise three phases:

- planning – identifying stakeholders and the appropriate level of engagement, planning how stakeholders will be engaged and how the information obtained will be used
- implementation – engaging with stakeholders, gathering and disseminating information and involving stakeholders in the decision-making process
- feedback and evaluation – seeking feedback from all involved and evaluating the success of community engagement.

You should document all three phases of community engagement in the relevant assessment and/or remediation reports. For large or contentious projects, you may need to prepare standalone reports on the community engagement for each stage. For smaller sites, you can report this information in the relevant DSI, RAP or SRV report.

An auditor appointed to review the investigation and clean-up of a site is also responsible for reviewing your community engagement.

Your reporting should include, but not be limited to:

- stakeholders (individuals and groups) who were identified and invited to participate
- how stakeholders were contacted (e.g. newspaper advertisements, letter drops)
- number of community members who participated
- where and when events took place
- information provided to the community
- the community's input and comments
- how the community's input was considered and included in the decision-making process
- an evaluation of the effectiveness of the community engagement carried out.

Shortened forms

ABC	Ambient background concentration
ACL	Added contaminant limit
ADWG	Australian drinking water guidelines
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AS/NZS	Australian / New Zealand Standard
ASRIS	Australian Soil Resource Information System
ASS	Acid sulfate soils
AWQG	Australian water quality guidelines
BSR	Basic summary of records
CIRIA	Construction Industry Research and Information Association
CRC CARE	Cooperative Research Centre for Contamination Assessment and Remediation of the Environment
CS Act	*Contaminated Sites Act 2003*
CS Regulations	*Contaminated Sites Regulations 2006*
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSM	Conceptual site model
CVI	Chlorinated hydrocarbon vapour intrusion
DBCA	Department of Biodiversity Conservation and Attractions
DEC	Department of Environment and Conservation (predecessor of DWER and DER)
DER	Department of Environment Regulation (predecessor of DWER)

DMIRS	Department of Mines, Industry Regulation and Safety (Western Australia)
DNAPL	Dense non-aqueous phase liquid
DoH	Department of Health (Western Australia)
DoW	Department of Water (predecessor of DWER)
DQO	Data quality objective
DSI	Detailed site investigation
DSR	Detailed summary of records
DWER	Department of Water and Environmental Regulation
EIL	Ecological investigation level
EPA	Environmental Protection Authority (Western Australia)
EPHC	Environment Protection and Heritage Council
ESL	Ecological screening level
GIL	Groundwater investigation level
GMRRW	Guidelines for managing risk in recreational waters
HIL	Health investigation level
HSEP	Health, safety and environment plan
HSL	Health screening level
ISQG	Interim sediment quality guideline
LNAPL	Light non-aqueous phase liquid
LOR	Limit of reporting
MAR	Mandatory auditor’s report
MNA	Monitored natural attenuation
MTBE	Methyl tertiary-butyl ether
NAPL	Non-aqueous phase liquid

ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure 1999
NHMRC	National Health and Medical Research Council
NPUG	Non-potable use guidelines
NSW EPA	New South Wales Environmental Protection Authority
PQL	Practical quantification limits
PSI	Preliminary site investigation
PVI	Petroleum hydrocarbon vapour intrusion
QA/QC	Quality assurance / quality control
RAP	Remediation action plan
RCWA	Radiological Council of Western Australia
SAQP	Sampling and analysis quality plan
SMP	Site management plan
SRT	Swan River Trust
SRV	Site remediation and validation
TWA	Time weighted average
US EPA	United States Environmental Protection Agency
VAR	Voluntary auditor’s report
VI	Vapour intrusion

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Appendices

Appendix A – Reporting checklists

Table A1 – Reporting checklist for preliminary site investigation reports and detailed site investigation reports

Table A1 has a comprehensive checklist of items that may be included in PSI and DSI reports.

Use this table to mark when you have completed the item (✓). If it does not apply to the scope of your assessment, write N/A.

The table corresponds with information included NEPM schedules B1 to B9 and the NEPM field checklist (NEPM Toolbox). Footnotes are provided at the end of Table A2.

1. Document control	**PSI**	**DSI**
Date of report		
Report revision number and status of report (e.g. final version)		
Report reference number		
Department of Water and Environmental Regulation DMO reference number (if known)		
2. Executive summary	**PSI**	**DSI**
Site location		
Study area (lots/ land parcels that comprise the site)		
Current land use		
Name of party commissioning the report		

Reasons for commissioning the report		
Classification status of the site under the Contaminated Sites Act (list land parcels)		
Contaminated site auditor details (if a mandatory auditor’s report is required)		
Objectives of investigation and/or remediation		
Summary of work undertaken including site walkover/ fieldwork dates		
Summary of the conceptual site model and risks to human health, the environment and environmental values		
Summary of outstanding data gaps		
Summary of conclusions and recommendations		
3. Introduction	**PSI**	**DSI**
Summary of project understanding – typically providing an overview of site location, study area (lots/ land parcels that comprise the site), current land use, name of party commissioning the report, reasons for commissioning the report, classification status of the site under the Contaminated Sites Act (list land parcels), Contaminated site auditor details (if a mandatory auditor’s report is required) and licence details (if licensed as a prescribed premises under the EP Act).		
Summary of site progress to date (where applicable) – typically providing an overview of historical investigations and outstanding data gaps.		
4. Objectives	**PSI**	**DSI**
Project objectives for the current scope of work (with reference to previously identified data gaps if applicable)		
Site classification objectives (if applicable)		
5. Scope of works	**PSI**	**DSI**

List of tasks carried out to develop this report		
Dates of site inspection and/ or fieldwork activities carried out as part of this report		
6. Site identification	**PSI**	**DSI**
Site name or description (can be common name of site such as local business or landmark)		
Street address (street number name, suburb/town/city)		
Legal property description for each parcel of land comprising the site (i.e. lot/ plan/ parcel reference) – include copies of current certificates of title in Appendix		
Latitude and longitude (centre of site or site corners for regular shapes) – geographic coordinates using GDA94 / MGA		
Name of current owner(s)		
Name of current occupier(s) (if known)		
Proposed ownership changes		
Site area and dimensions (for each parcel of land)		
Local government authority		
Current zoning (as per Town Planning Scheme)		
Trigger for assessment (e.g. change in land use)		
State or local government statutory controls assigned to the site		
Legal permission to access site required/ obtained		

Consent of adjoining landowners and/or occupiers to access land (if required)		
LOCALITY MAP[1] – showing site location, site boundary, cadastral boundary or boundaries, surrounding area and any key nearby features (e.g. surface water features, ocean, sites classified under the Contaminated Sites Act where relevant)		
7. Site condition and surrounding environment	**PSI**	**DSI**[1]
Site inspection (date, by whom)		
Topography of site in relation to surrounding land		
Elevation		
Position of site on slope (e.g. crest, upper slope, mid slope, lower slope, flat), including direction		
Quantification of slope as percentage slope (if required)		
Summary of local meteorology and climatic conditions – survey of climatic information from nearby weather stations (e.g. annual range in monthly temperature, precipitation, seasonal variations)		
Current land use		
Surrounding land uses (north, south, east, west) noting apparent condition		
Density of residential use in surrounding area		
Site boundary conditions		
Location and conditions of all visible features, including current buildings and surface structures, roads, foundations, positions of former buildings, tanks, pits, wells, drains and bores		

Site building information (if applicable) including: • occupancy and use of buildings • age of buildings • construction of buildings including materials (e.g. wood frame), openings (e.g. windows, doors), and height (e.g. one storey, multistorey) • number of storeys • height of storeys • foundation type (e.g. basement, crawlspace, slab on ground), if combination then percentage • depth below grade to base of foundation • foundation construction for both floor and subsurface walls (e.g. poured concrete, concrete block, brick, timber) • general condition of foundation (cracks, openings) • elevator shafts • sub-slab ventilation systems or moisture vapour barriers below buildings • sumps or drains or wells inside buildings • attached garage • below building parking • chemical use and storage • type of cooling and heating systems (e.g. natural gas, oil, radiant, steam, electrical) • equipment location (e.g. basement, crawl space, roof) • air intake and exhaust units • source of return air (e.g. inside air, outside air, combination) • system design consideration relation to indoor air pressure (e.g. positive pressure is often the case for commercial buildings)		

Condition and type of surface cover e.g. bare ground, asphalt, concrete, gravel etc and estimate of percentage of site occupied by buildings, landscaped areas, paved or non-paved areas		
Chemical storage and transfer areas, including the presence of waste or chemical containers		
Details of above ground and underground storage systems and associated infrastructure (number, location, capacities, contents, age, construction, condition, bunding and spill control)		
Underground storage tanks (USTs) – product stored, volume, direct or remote fill points, dispenser bowsers, contained or uncontained fill points, underground piping and ventilation points, dip stick volume gauge, age of tank, records of spills or stock loss		
Above ground storage tanks (ASTs) – product stored, volume, remote fill, bunded or unbunded containment area, staining within bund, staining outside bund, bund plug in place, staining around bund plug, nearby drains, record of spills or stock losses		
Evidence of debris, waste disposal, lagoons, drums, chemical storage or other indicators of potential contamination sources		
Locations of settlement ponds		
Description and location of services and utilities including onsite septic systems		
Identification of electrical transformers/substation/capacitors		
Odours		
Visible signs of contamination such as discolouration or staining on the surface of soil or water, bare soil patches – onsite and at site boundaries		
Presence of any stockpiled material, imported soil or fill material as well as any signs of settlement, subsidence or disturbed ground		
Vegetation type and extent of cover (e.g. scattered, sparse, dense, absent, invasive, native)		
Condition of vegetation (noting visibly distressed, disturbed or dead vegetation)		

Assessment of soil loss or deposition that has occurred in the past and evaluation of the future erosion potential		
Visible signs of erosion (on and offsite)		
Surface water bodies (e.g. lakes, rivers, streams, wetlands), fresh/marine and distance from site		
Surface water drainage (e.g. drainage bores, soak wells, sumps) and runoff and identification of ponding areas (and potential for flooding)		
Direction of flow of water runoff from the site and adjacent properties		
Depth of any standing water, the direction and rate of flow of rivers, streams or canals, together with their flood levels and any tidal inundations		
Surface water and groundwater use on site including rate and location of abstractions (current and historical)		
Evidence of possible naturally occurring contaminants		
Identification of environmentally sensitive or significant features or habitats		
Evidence chemical substances have migrated or are likely to have migrated to a neighbouring site and is or is likely to be causing contamination of the neighbouring property		
Inspection/ walkover limitations (e.g. acknowledgment of areas that are inaccessible and reasons why)		
PHOTOGRAPHS – Photographs showing significant site features, nature of surface, existing structures etc. including the date taken, location and direction photo was taken from		
CURRENT SITE LAYOUT PLAN[1] – showing current site features, buildings, infrastructure (labelled), location accompanying site photographs were taken from (if relevant)		
8. Site history	**PSI**	**DSI**[1]

Historical property title search (with copies of historical certificates of title provided in Appendix)		
Identification of previous and present owners, occupiers, managers and users of the site where relevant		
Interviews with owner/occupier/staff/neighbours (present and former) who have a historical knowledge of the site		
Review of historical aerial photographs and site photography (can include as cropped images in main report or include in an Appendix where possible)		
Chronological list and summary of land use activities including information gaps, uncertainties and unoccupied periods		
Description of manufacturing processes, raw materials, chemicals and fuels associated with site use		
Products (including intermediate products) discharged during batch or continuous production processes, listed by common, systematic and trade names where possible		
Identification and location of chemical storage and transfer areas		
Wastes (including failed batched) discharged during batch or continuous production processes, listed by common, systematic and trade names where possible including their chemical characteristics, volume and method of treatment		
Disposal locations (on and offsite) of the wastes from previous and present industries and uses, identifying solid waste and liquid waste lagoons, settling tanks and sumps		
Discharges to land, water and air (authorised and unauthorised)		
Product spills, losses, incidents and accidents, including fires, with an indication of the chemicals spilled, frequency, estimates of quantity, extent of fire damage and structures affected		
Plans of sewer and underground service locations identifying active and abandoned services		
Location and size of previous or existing storage tanks (both above ground and underground) and infrastructure and details of integrity testing		

Location of onsite and nearby wells and groundwater monitoring wells		
Location of transfer lines and notation of whether they are above or below ground		
Locations of dispensing or fill points		
Spill control systems e.g. bund (noting construction details)		
Earthmoving activities carried out onsite		
Current and previous land uses of adjacent land taking into account relevant features listed above as appropriate		
Complaint history – regulatory actions, legal actions		
State and local government planning records including historical zoning and land uses		
Details of permits, licences, approvals and trade waste agreements with records of compliance		
State and local government environmental records including licensing conditions, regulatory notices, inspection records, complaints, licence breaches		
State or local government dangerous goods records including licensing requirements, goods licensed to store, storage licences, inspection records, complaints, licence breaches		
State and local government records on contamination for site and surrounding areas		
Historical site photographs (labelled and dated)		
Summary of literature relating to the site (including newspaper articles where available)		
Consideration of cultural heritage (Indigenous heritage and State heritage)		

Potential sources of site contamination and potential offsite impacts		
Potential chemical substances associated with activities		
Verification of information sources (assessment of the integrity and accuracy of the information)		
Differences between current site condition and site history		
HISTORICAL SITE LAYOUT PLAN[1] – showing locations of key historical infrastructure/storage areas/waste disposal areas etc, preferably overlain against a plan/aerial of the current site layout		
9. Site investigation history	**PSI**	**DSI**
Document all existing environmental reports (environmental investigations, risk assessments, remediation) including: • report title, author, date of report • a brief summary of each report		
List of previous site contamination audit reports (if contaminated sites auditor engaged)		
10. Regional and local geology, hydrogeology and hydrology	**PSI**[3]	**DSI**
Description of regional and site-specific local geology records		
Geophysical data		
Drilling/test pit logs which clearly identify imported and locally derived fill (including refuse) and natural stratum		
Well logs including strata, casing or construction details and water level, quality and pump/discharge rate information		
Aquifers (unconfined, semi-confined, confined) and aquitards/ aquicludes present		

Direction and rate of groundwater flow		
Values for soil bulk density and porosity		
Storativity or storage		
Soil organic matter content		
Cation exchange capacity		
Soil pH		
Redox potential measured in situ		
Regional and site-specific hydrogeologic information, including groundwater quality		
Hydraulic and piezometric heads and hydraulic gradients		
Basic assessment of hydraulic conductivity and porosities		
Transmissivity		
Reported depths to groundwater in unconfined and confined aquifers		
Regional groundwater flow direction		
Rate and direction of groundwater flow		
Current usage/resource potential		
Existing monitoring wells and records of registered production wells/ survey of surrounding landholders to determine existence of wells where the resource may		

potentially be used in the vicinity of the site		
Identify beneficial use of aquifers		
Details of any future realistic use		
Details of any relevant environmental beneficial uses		
Searches of databases and other sources of information for receptor surface water bodies such as wetlands, streams, rivers, open drains and oceans		
Flow paths for surface runoff		
Identifying recharge sources, discharge points and other hydraulic boundaries		
Identification of acid sulfate soil risk areas		
GEOLOGICAL CROSS-SECTION – showing stratigraphy and aquifers	■	
11. Meteorological data	**PSI**	**DSI**
Air temperature	■	
Wind direction	■	
Humidity	■	
Barometric pressure	■	
Rainfall (date/amount)	■	
12. Contaminant characteristics and migration	**PSI**	**DSI**

Review of previous environmental, geotechnical or other site investigations with summary of results (to characterise key issues)		
Contaminants of potential concern		
Contaminant sources		
Contaminant variability in time and space		
Contaminant fate and transport		
Preferential pathways		
Building characteristics (e.g. basement, crawl space)		
Meteorology (e.g. heavy rainfall events, etc which may cross-reference to Section 11)		
Contaminant susceptibility to various treatment or destruction options		
Data gaps and uncertainties		
13. Preliminary conceptual site model	**PSI**	**DSI**
The initial CSM is based on desktop information supplemented with information gathered from site inspections and interviews, which is refined with the results of site-specific investigation and assessment		
Known and potential sources of contamination (areas of concern, potential contaminants, toxicity, mobility, volatility, potential for degradation, potential media affected)		
Potential and complete contaminant migration pathways (including preferential migration pathways) and exposure routes		
Potential receptors (human, ecological and environmental values)		

Data gaps and uncertainties		■
Tabulation of potential source-pathway-receptor linkages		■
PRELIMINARY CONCEPTUAL SITE MODEL GRAPHIC – showing schematic geology, hydrogeology and potential sources, receptors and pathways		■
14. Assessment levels	**PSI[4]**	**DSI**
Identification and rationale for the assessment levels selected (discuss assumptions and limitations in the context of the site)	■	
Table(s) listing all assessment levels and reference to origin of assessment criteria (e.g. NEPM)	■	
15. Sampling analysis and quality plan (documented in a separate report if appropriate)	**PSI[4]**	**DSI**
Sampling and analysis data quality objectives, indicators and targets	■	
Statement of intended duplicate and blank frequency	■	
Rationale for selection of sampling pattern, locations and depths	■	
Rationale for selection of sampling density, including estimated size of residual hotspots that may remain undetected and statistical confidence in the estimate	■	
Media selection (soil, water, sediment, vapour)	■	
Detailed description of the sampling methods including: • sampling devices and equipment type • sampling containers and the type of seal used • sample preservation methods and reference to recognised protocols (Schedule B3) • sample handling procedures	■	

• equipment decontamination procedures		
Details of sampling team		
Standardised field checklists and purge sheets		
Standardised field sampling forms		
Detailed description of any field-screening protocols, methods and equipment and their calibration		
Field instrument inspection and maintenance requirements		
Decontamination procedures		
Justification for investigation levels		
Rationale for analyte selection		
Justification for analytical methods and detection limits		
Rationale for selection of samples for analyses and which not analysed		
Coordination with analysing laboratories to determine any specific requirements		
Specialised training required by field staff (if required)		
Holding times		
Transport of samples		
Selection of appropriate sample handling procedures and to ensure prepared for receipt and analysis of samples		

Standardised chain of custody procedures and forms, including as a minimum: • name of person transferring the samples • time and date samples are taken • time and date samples are received e.g. at the laboratory • nature and contact details of client • nature of the sample • sample preservation methods • analytes to be determined • where the use of composite samples is required, the set of samples to be composited • other specific instructions • where high levels of contamination are expected		
Analytical testing turn-around time		
Procedures for data transfer from the analytical laboratory		
Methods for analysing and interpreting data		
Documentation and record keeping		
PROPOSED SITE INVESTIGATION PLAN[1] – aerial site plan showing site boundary, proposed locations of monitoring wells, boreholes and/or pits, key site infrastructure.		
16. Fieldwork methodology	**PSI**[4]	**DSI**
Fieldwork activities		

Laboratory analysis: • laboratory selection • analytical suites		
SITE INVESTIGATION PLAN[1] – aerial site plan showing site boundary, actual installed locations of monitoring wells, boreholes and/or pits, and historical investigation locations (and dates installed) where appropriate		
17. Field QA/QC procedures		
Standardised field sampling forms (include in Appendix) including: • sample logs (primary samples, trip and field blanks, rinsate samples, replicate samples, decontamination procedures etc.) • bore logs (soil bore, groundwater bore / vapour probe installation logs, documenting fill, lithology, grain size, clay content, odours, staining etc.) using Unified Soil Classification System (USCS) • sampling logs (field screening results, depths to water/LNAPL, purging details, observations etc.) • field instrument calibration records • field instrument detection limits • chain of custody form identifying (for each sample) the sampler, media, collection date and time, sample preservation method, analyses to be performed, sender signature and departure date and time		
a) Summary of field QA/QC outcomes		
18. Laboratory QA/QC	**PSI**[4]	**DSI**
Signed laboratory receipt of signed chain of custody form identifying date/time of receipt, identity of samples included in shipment and condition of samples (e.g. chilled, warm, damaged, missing etc.) (include in Appendix)		
Laboratory analytical certificates (include in Appendix)		

Laboratory QA/QC report (include in Appendix) • analytical methods and laboratory accreditation for methods used • holding and extraction times for each analysis/sample • sample splitting techniques • surrogates, spikes and recoveries • instrument/method detection limits and matrix/practical quantification limits • standard and reference solution results • certified reference material results • laboratory duplicate and blanks results		
Relative per cent differences for inter- and intra-laboratory duplicates • field duplicate samples • split samples • rinsate blanks		
Summary of laboratory QA/QC outcomes		
19. Field and laboratory QA/QC data evaluation	**PSI**[4]	**DSI**
Deviations from the SAQP with reasons		
Acceptability of field QA/QC sample results		
Acceptability of laboratory QA/QC results		
Evaluation of factors which may materially affect the results (such as the collection and analysis of samples by different personnel, different methodologies,		

spatial and temporal variations)		
Implications for decision-making – precision, accuracy, representativeness, completeness and comparability of the data		
20. Field data interpretation	**PSI[4]**	**DSI**
Description of stratigraphy including soil/ fill and physical and chemical characteristics		
Location and extent of any imported fill		
Visual or olfactory observations of contamination		
Depth to groundwater, seasonal water table fluctuations and seasonal flow direction changes (hydraulic gradient), presence of any perched aquifers		
21. Analytical results	**PSI[4]**	**DSI**
Tabulation of field and laboratory results including sample identification, sampling dates and times, depths (if applicable), laboratory detection limits, relevant assessment criteria and results above the assessment criteria (incorporate previous results as appropriate)		
Summary of contaminant trends/ descriptive statistics/ potential migration characteristics (e.g. stable, increasing, decreasing) for the distribution of contaminants		
Summary of the vertical and lateral extent of contaminated areas		
Review of background concentrations (if relevant)		
Tables of historical analytical results to support discussion of temporal trends – raw data and calculations used in graphs or statistical analysis should be included in the report		
Tables of current analytical results		
22. Tier 1 and/or 2 risk assessment (human health and ecological)[4]	**PSI[4]**	**DSI**

Objectives and scope of the risk assessment with reference to the CSM		
Identification of exposure risks that cannot be assessed by a Tier 1 assessment (e.g. no generic criteria)		
Comparison with generic/ adjusted assessment levels including: • identifying any adjustments and the rationale for each receptor • the nature of any results above assessment criteria in the context of the descriptive statistics and more detailed statistical analysis as appropriate		
Risk characterisation such as consideration of (where relevant): • site characteristics (e.g. background concentrations, depth to source area, groundwater plume characteristics, preferential flow pathways etc.) • possible influence of naturally occurring chemical substances • persistence of chemical substances • physical−chemical and biochemical transformations which occur as chemical substances migrate through subsurface to groundwater to point of extraction • preferential surface and subsurface migration pathways for the contaminants of concern in addition to groundwater flow direction • preferential flow pathways • surface and subsurface hydrogeological processes affecting the redistribution of contaminants across the site • uncertainties (data gaps) • material changes in conditions that would alter the reliability of the risk assessment undertaken		
Revised CSM: • contamination sources, contaminant migration pathways, receptors and exposure mechanisms • conclusions regarding risks requiring management or further assessment		
Include supporting risk assessment tools in an appendix – e.g. HSLs checklist (Friebel & Nadebaum, 2011)		
REVISED CONCEPTUAL SITE MODEL GRAPHIC – showing schematic geology, hydrogeology and potential sources, receptors and pathways		
23. Tier 3 risk assessment (human health and ecological) (documented in a separate report if appropriate)[5]	**PSI**	**DSI[5]**
Objectives and scope of the risk assessment		

Exposure assessment		
Toxicity assessment		
Sensitivity analysis		
Limitations, assumptions and uncertainties (data gaps, changes in conditions that would alter risk scenarios)		
Risk characterisation with regard to each receptor evaluated		
Revised CSM and conclusions/recommendations regarding risks requiring management or further assessment		
24. Fate and transport modelling (documented in a separate report if appropriate)[6]	**PSI**	**DSI[6]**
Uncertainties in the CSM and the objectives for contaminant fate and transport modelling		
Scope of work and rationale for model selection		
Model validation and model results		
Evaluation of modelling results and sensitivity analysis including the limitations, assumptions and uncertainties		
Revision of the CSM and conclusions/recommendations regarding risks requiring management or further assessment		
25. Community engagement (documented in a separate report if appropriate)[7]	**PSI[7]**	**DSI[7]**
Key details: • stakeholders (individuals and groups) invited to participate (personal contact details not required) • details of how stakeholders were contacted • where and when engagement events took place		

• summary of information provided to stakeholders (provide copies of flyers, letters etc. in an appendix)		
Outcomes of community engagement: • summary of input and comments received • number of stakeholders/community members who participated • how stakeholder input was taken into account • document agreements reached and their effect on further investigation and/or remediation to be carried out		
26. Conclusions and recommendations	**PSI**	**DSI**
Conclusions arising from the site assessment and the implications for decision-making with regards to the management of unacceptable and/or potentially unacceptable risks		
Outstanding data gaps		
Recommendation on whether the site (including additional parcels of land) requires reporting to the department as a known or suspected contaminated site under s11 of the CS Act		
Recommendations on any limitations and constraints on the use of the site as relevant		
Recommendations for further investigation, risk assessment, remediation, validation and/or management as relevant		

Table A2 – Reporting checklist for remediation action plans, site remediation and validation reports and site management plans

Table A2 has a comprehensive checklist of items that may be included in PSI and DSI reports.

Use this table to mark when you have completed the item (✓). If it does not apply to the scope of your assessment, write N/A.

1. **Document control**	**RAP**	**SRV**	**SMP**
Date of report			
Report revision number and status of report (e.g. final version)			
Report reference number			
Department of Water and Environmental Regulation DMO reference number (if known)			
2. **Executive summary**	**RAP**	**SRV**	**SMP**
Site location			
Study area (lots/ land parcels that comprise the site)			
Current land use			
Name of party commissioning the report			
Reasons for commissioning the report			
Classification status of the site under the Contaminated Sites Act (list land parcels)			
Contaminated site auditor details (if a mandatory auditor’s report is required)			

Remediation objectives and remedial targets to be achieved			
Brief summary of the conceptual site model and risks to human health, the environment and environmental values			
Summary of remedial works undertaken including fieldwork dates	■		
Summary of conclusions and recommendations			
3. Introduction	**RAP**	**SRV**	**SMP**
Background including identification of the client and the reasons the report was commissioned			
Objectives of the scope of work and clear statement regarding the scope of work undertaken			
Site identification and general information (as for assessment)			
Confirmation of when the site (list land parcels) was reported to the department as a known or suspected contaminated site and the current classification under the CS Act			
Contaminated site auditor details if a mandatory auditor’s report was required			
Summary of previous work, the CSM and risks to human health, the environment and environmental values			
Extent of remediation/management required – summary of the risks to be mitigated, stakeholder views and time frame available to achieve the desired outcomes			
4. Remediation objectives	**RAP**	**SRV**	**SMP**
Remediation objectives and remedial targets to be achieved			
Documentation of discussions with stakeholders and copies of relevant agreements (e.g. regarding remediation objectives/remedial targets)			

Table of remedial targets and derivation details (reference to site-specific risk assessment report or other document(s) detailing their derivation)			
5. Remedial options	**RAP**	**SRV**	**SMP**
Identify potential remedial options that could achieve the remediation objectives within the available timeframe		■	■
Discuss the results of case studies or pilot studies/trials undertaken that support or do not support particular remedial options		■	■
Evaluate viable remedial options with reference to the preferred remediation hierarchy		■	■
Summarise the rationale for the selected remediation approach: • active remediation and/or • management measures		■	■
6. Remedial action plan	**RAP**	**SRV**	**SMP**
Description of remedial method including design and construction details			■
Discussion of limitations associated with the proposed remedial approach and the potential for additional clean-up and/or long-term site management			■
Identification of regulatory compliance requirements such as licences and approvals (local and state government)			■
Documentation of discussions with stakeholders and copies of relevant agreements (e.g. regarding remediation objectives/remedial targets)			■
Site preparation requirements (fencing, erection of warning signs, stormwater diversion)			■
Operational phase site management plan, including management of stormwater, stockpiles, waste soil, sediment and water, excavations, noise, dust, odour, decontamination procedures, site security, incidents, chemical/equipment storage			■
Detailed SAQP for any sampling required during or after remediation[8]			■

Key personnel and contact details as applicable (HSEP should be prepared but is not required to be presented in the report)			■
Remediation schedule and hours of operation			■
Location/source of any fill material to be used, validation requirements			■
Details of decommissioning and infrastructure removal when remediation objectives/remedial targets are achieved (as applicable)			■
Details of the contingency plan in the event remediation is ineffective			■
PROPOSED REMEDIATION PLAN[1] – aerial plan showing the proposed location of the remediation works (such as location of excavations, installation locations for extraction points etc.)			■
7. **Site remediation and validation**	**RAP**	**SRV**	**SMP**
Document remediation work undertaken	■		■
Evaluate validation results and compare with the remedial objectives and remedial targets	■		■
Discussion of the revised CSM and any uncertainties in the remediation outcomes	■		■
Provide recommendations for any further site clean-up or management and any restrictions on the use of the site	■		■
Document offsite disposal of all wastes e.g. transport dockets, landfill or treatment facility receipts	■		■
Document sources and quality of fill imported to the site	■		■
Document approvals and licences obtained from regulatory authorities	■		■
REMEDIATION PLAN – aerial plan showing the location of the remediation works (such as location of excavations, installation locations for extraction points etc.)	■		■

8. **Site management plan (documented in a separate report)**[9]	**RAP**	**SRV**	**SMP**
Time frame for site management e.g. 1 year, 5 years, in perpetuity	■	■	
Identification of the relevant stakeholders who have specific interests, roles and responsibilities in relation to the ongoing management of the site	■	■	
Documentation of stakeholder agreement to management roles and responsibilities	■	■	
Details of maintenance and/or monitoring requirements including trigger levels and an SAQP if applicable	■	■	
Contingency actions (e.g. repeat sampling, increased monitoring frequency, revision of the SMP, risk assessment) that will be carried out if trigger levels are exceeded	■	■	
Notification procedures if trigger levels are exceeded	■	■	
Format and frequency of reporting, and who will be provided with copies of the reports	■	■	
9. **Community engagement (documented in a separate report if appropriate)**[7]	**RAP**[7]	**SRV**[7]	**SMP**[7]
Key details: • documentation of discussions with stakeholders and copies of relevant agreements (e.g. regarding remediation objectives/remedial targets) • stakeholders (individuals and groups) invited to participate (personal contact details not required) • details of how stakeholders were contacted • where and when engagement events took place • summary of information provided to stakeholders (provide copies of flyers, letters etc. in an appendix)			
Outcomes of community engagement: • summary of input and comments received			

• number of stakeholders/community members who participated • how stakeholder input was taken into account • document agreements reached and their effect on further investigation and/or remediation to be carried out			

Footnotes

1 Site plans must include as a minimum a north arrow, scale and ratio bar, legend/ site feature labels and a defined site boundary.

2 A summary in the DSI is acceptable, providing that this section is detailed fully in the PSI.

3 Include desk-based information in PSI, where available.

4 Not commonly relevant to a PSI, unless opportunistic sampling has been undertaken during the preliminary investigation process.

5 Include in a DSI (or stand-alone report) if the findings of a Tier 1/Tier 2 risk assessment indicate that a Tier 3 risk assessment is required.

6 Include in a DSI (or stand-alone report) if fate and transport modelling is deemed necessary.

7 Include community engagement at all stages where appropriate (a community engagement plan can be provided as stand-alone report if preferable).

8 Refer to the requirements of a SAQP (which are detailed in Table A1).

9 A stand-alone report is preferential for a site management plan.

Appendix B - Potentially contaminating industries, activities and land uses

The list provided is indicative only. Proponents/site owners/persons responsible (as relevant) and their environmental consultants must consider, on a site-specific basis, whether the contaminants listed could be present at the site as well as the potential for other contaminants, including contaminant degradation products and/or emerging contaminants of concern.

In addition to the listed industries, activities and land uses, proponents should be aware of the potential contamination that may arise from unregulated or unreported leaks, spills, infilling and fly-tipping, demolition practices, emissions and poor practices. In addition to a review of land use history the proponent should conduct extensive stakeholder and community consultation to complete their enquiries.

Table B1: Potentially contaminating industries, activities and land uses

Industry, activity or land use	Common contaminant types
Abattoirs and animal processing works*	Also refer to tannery and associated trades Nutrients (e.g. nitrogen, phosphorus) Biological oxygen demand total suspended solids Oil and grease Pesticides and metals (by-products of rendering)
Abrasive blasting	Metals (e.g. iron, lead) (dependent on material being removed) Tributyltin (boat yards/boat maintenance) Radioactive minerals (garnet sand etc.)
Acid/alkali plant, formulation and bulk storage	Metals (e.g. mercury) Acids (e.g. hydrochloric, nitric, sulfuric sodium) Alkalis (e.g. sodium and calcium hydroxide)
Agriculture, intensive	*Refer intensive agriculture*
Airports, airstrips, aviation facilities	Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylene) Metals (e.g. aluminium, chromium, lead, magnesium) Solvents (e.g. trichloroethene) Flame retardants (e.g. PBDEs)

	Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams)
Analysts, analytical laboratory sites (e.g. research, commercial, mine site)	Solvents (e.g. trichloroethene, brominated solvents for heavy mineral separation) Acids Metals
Asbestos products, manufacture, use or disposal	ACM Asbestos fibres
Asphalt or bitumen manufacture or bulk storage*	Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Polycyclic aromatic hydrocarbons (e.g. creosote) Metals (e.g. chromium, lead)
Automotive repair, engine works and spray painting	Solvents (e.g. trichloroethene) Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. toluene, xylenes, white spirit) Phenol Chloroflurocarbons (CFCs) Metals (e.g. copper, chromium, lead, zinc) Alkalis Acids (e.g. sulfuric, phosphoric) Flame retardants (PBDEs)
Battery manufacturing, recycling, disposal	Metals (e.g. antimony, cadmium, cobalt, lead, lithium, manganese, nickel, mercury, silver, zinc) Acids (e.g. sulfuric, hydrochloric)
Biosolids application, muck spreading, organic fertiliser application	Nutrients (e.g. nitrogen, phosphorus) Metals (aluminium, arsenic, cadmium, chromium, cobalt, lead, nickel, potassium, zinc) Phenols Pathogens (e.g. *E. coli*, Enterococci) Per- and polyfluorinated alkyl substances (PFAS)

Boat building and maintenance*	Also refer to Automotive repair Metals (e.g. copper, chromium, lead, mercury, zinc) Antifouling paints (e.g. organotin, tributyltin)
Brake lining manufacturer	Asbestos Copper
Breweries/distilleries*	Alcohol (e.g. ethanol, methanol, esters) Nutrients (e.g. nitrogen, phosphorus) Biological oxygen demand (BOD)
Brickworks*	Metals (e.g. arsenic, cadmium, mercury, lead) Polycyclic aromatic hydrocarbons (e.g. coke, tars)
Cement/concrete/lime manufacturing or batching*	Lime, calcium hydroxide, alkalis Hydrocarbons Asbestos Metals (e.g. nickel, zinc)
Cemeteries	Nitrates Heavy metals, lead Formaldehyde
Chemical manufacturing, blending, mixing, handling or storage*	
Acid/alkali	Metals (e.g. mercury) Acids (sulfuric, hydrochloric, nitric) Sodium and calcium hydroxides
Adhesive/resins/fibreglass	Polyvinyl acetate (e.g. adhesives) Phenol Formaldehyde (e.g. resins) Phthalate esters Polychlorinated biphenyls Solvents (e.g. trichloroethene)

Dyes/inks/solvents/coatings	Metals (e.g. cadmium, chromium, cobalt, lead, titanium, zinc) Solvents (e.g. trichloroethene) Cresols Chlorinated hydrocarbon (e.g. 1,1,1-trichloroethane, cis1, 2-dichloroethene) Flame retardants (PBDEs)
Fertilisers	Metals (e.g. boron, cadmium, cobalt, copper, magnesium, molybdenum, zinc) Calcium phosphate, calcium sulfate, nitrates, ammonium sulfate, carbonates, potassium Pentachlorophenol
Flocculants	Aluminium Xanthates
Foam (e.g. polyurethane)	Urethane Formaldehyde Styrene
Fungicides	Metals (e.g. chromium, copper chloride/sulfate, zinc) Carbamates Organochlorine pesticides (e.g. Pentachlorophenol) Chlorinated hydrocarbons (e.g. trichloroethene)
Herbicides	Ammonium thiocyanate 2,4,5-T and 2,4-D Dioxins *(refer to Schedule B2 of the NEPM for specific guidance on the occurrence of dioxins and guidance on circumstances where analysis is recommended)* Herbicides (e.g. triazine, atrazine, MCPA, bipyridyls, sulfonyl ureas, chlorophenoxys) Metals (e.g. arsenic, mercury)

Paints	Metals (e.g. arsenic, barium, cadmium, chromium, cobalt, lead, manganese, mercury, selenium, titanium, zinc) Boron Solvents (e.g. toluene) Resins Chlorinated hydrocarbons Polychlorinated biphenyls
Pesticides	Wide range of insecticides, herbicides, rodenticides and fungicides Metals (e.g. arsenic, lead, mercury, tin, chromium) Organochlorine pesticides Organophosphate pesticides Carbamates Solvents (e.g. xylenes, kerosene) Chlorinated hydrocarbons Polychlorinated biphenyls Synthetic pyrethroids Acid herbicides
Pharmaceutical/cosmetics	Solvents (e.g. acetone, ethyl acetate, butyl acetate, methanol, ethanol, isopropanol, butanol) Carbamates Metals (e.g. selenium)
Photographic and photo-imaging facilities	Potassium bromide Metals (e.g. chromium, selenium, silver) Thiocyanate Ammonium compounds Sulfur compounds Phosphate Ethanol

Plastics	Formaldehyde Per- and polyfluorinated alkyl substances (PFAS) Metals (e.g. cadmium) Carbonates Solvents (e.g. trichloroethene) Styrene Sulfates Phthalate esters Chlorinated hydrocarbons (e.g. 1,1,1 - Trichloroethane) Polychlorinated biphenyls Polybrominated diphenyl ethers
Rubber manufacturing and processing	Metals (e.g. lead, zinc) Sulfur compounds Reactive monomers (e.g. isoprene, isobutylene) Acid (e.g. sulfuric, hydrochloric) Monocyclic aromatic hydrocarbons (e.g. xylenes, toluene) Solvents (e.g. trichloroethene) Hexachlorobenzene Chlorinated hydrocarbons (e.g. mirex, cis 1,2-dichloroethene)
Soap/detergents	Potassium compounds Phosphates Ammonia Alcohols Esters Sodium hydroxide Surfactants Silicate compounds Acids (e.g. sulfuric, stearic) Oils

Solvents	Ammonia Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Chlorinated organics (e.g. carbon tetrachloride, trichloroethane) Natural oils (e.g. eucalyptus, pine, tea tree, palm oils)
Chemical treatment/destruction facilities	*Consider substances being treated and potential degradation products* Polycyclic biphenyls (PCBs) Dioxins *(refer to Schedule B2 of the NEPM for specific guidance on the occurrence of dioxins and guidance on circumstances where analysis is recommended)* Per- and polyfluorinated alkyl substances (PFAS)
Clandestine drug manufacture/laboratories	Drug residues (various) Acids (e.g. hydrochloric, hydriodic, sulfuric) Metals (mercury, lithium, aluminium, nickel) Solvents (e.g. methanol, acetone, diethyl ether, methylated spirits) Anhydrous ammonia Nitrates Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes)
Compost manufacturing*	Nutrients (e.g. phosphorus, nitrogen) Metals (e.g. aluminium, iron, potassium, zinc) Per- and polyfluorinated alkyl substances (PFAS) (depending on source materials)
Defence works and defence establishments	Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Metals (e.g. aluminium, beryllium, copper, lead, mercury, silver) Explosives (e.g. TNT, 2,4, DNT, 2,6 DNT, RDX) Petroleum hydrocarbons Solvents (e.g. trichloroethene)

Demolition and salvage	Asbestos
Drilling	Drilling fluid additives – barite, surfactants Asbestos (dependent on historical timeframe) Petroleum hydrocarbons
Drum or tank re-conditioning or recycling facility	*Depends on contents of drums (consider original and re-purposed uses)* Solvents (e.g. methylene chloride, ortho-dichlorobenzene) Per- and polyfluorinated alkyl substances (PFAS) Pesticides and herbicides Petroleum hydrocarbons
Dry cleaners and laundries	Solvents (e.g. trichloroethylene (TCE), ethane, 1,1,1-trichloroethane, carbon tetrachloride, perchlorethylene (PCE), vinyl chloride) Volatile organic compounds (VOCs)
Electrical substations/transformers	Metals Polychlorinated biphenyls Solvents (e.g. trichloroethene)
Electricity generation/power stations*	Asbestos Contaminants associated with fly ash and bottom ash (e.g. sulfates, metals, total dissolved solids, selenium, actinide elements (U, Th)) Metals (e.g. copper, lead) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Petroleum hydrocarbons Polycyclic aromatic hydrocarbons (e.g. tars, benzo(a)pyrene) Polychlorinated biphenyls (PCBs)
Explosives production/bulk storage pyrotechnics	Acids (e.g. acetone, nitric, ammonium nitrate, sulfuric) Ammonia

	Chlorinated hydrocarbons Explosives (e.g. TNT, 2,4 DNT, 2,6 DNT, RDX) Hexachlorobenzene Metals (e.g. aluminium, copper, lead, manganese, mercury, silver) Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Perchlorate Petroleum hydrocarbons (fuel) Solvents (e.g. methanol, PCP)
Fertiliser manufacture or storage	Also refer Chemical manufacturing – fertiliser Calcium phosphate, calcium sulfate, copper chloride Sulfur, sulfuric acid Metals (e.g. boron, cadmium, cobalt, copper, magnesium, molybdenum, potassium, selenium) Nitrates, ammonia
Fibreglass reinforced plastic manufacturing*	Solvents (e.g. trichloroethene) Resins Styrene Boron
Fill material/ fill importation	*Consider potentially contaminating land use, industry or activity of source site (if known) and other activities conducted at the destination site.* Asbestos Metals Petroleum hydrocarbons Organochlorine pesticides
Firefighting and training (use of foams)	Solvents (e.g. glycol ethers) Surfactants (hydrocarbon and fluorinated) Per- and polyfluorinated alkyl substances (PFAS) (e.g. PFOS, PFOA, PFHxS and fluorotelomers) *Refer to the PFAS National environmental management plan (PFAS NEMP) for guidance on analysis for PFAS*

Foundry operations	Metals and chlorides/fluorides/sulfates of metals (e.g. iron, aluminium, cadmium, chromium and oxides, copper, lead, magnesium, tin, nickel, zinc) Acids (e.g. sulfuric and phosphoric) Polycyclic aromatic hydrocarbons (e.g. coke residues) Petroleum hydrocarbons (e.g. fuel oil)
Furniture restoration	Per- and polyfluorinated alkyl substances (PFAS) i.e. stain and water-resistant coatings. PBDEs Solvents (e.g. trichloroethene) Waxes
Gasworks	Cyanide (complexed and free) Ammonia, nitrate Sulfide/sulfate Metals (e.g. aluminium, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, zinc) Boron Thiocyanates Petroleum hydrocarbons Polycyclic aromatic hydrocarbons (e.g. in coal tar and creosote) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Phenols
Glass manufacturing	Metals (e.g. cobalt, lead)
Iron and steel works	*Also refer Gasworks* Metals (e.g. cadmium, chromium VI, cobalt, copper, lead, magnesium, manganese, nickel, selenium, zinc) Acids (e.g. sulfuric, hydrochloric) and alkalis Mineral oils Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes)

	Polycyclic aromatic hydrocarbons (e.g. coke residues) Solvents
Intensive agriculture* (including feedlots and saleyards)	Carbamates Organochlorine pesticides (e.g. Aldrin, Dieldrin, Endrin, Methoxychlor, Pentachlorophenol) Organophosphate pesticides Herbicides (e.g. Triazine, Atrazine, 2,4,5-T 2,4-D, MCPA, Picloram) Insecticides DDT, DDE and DDD, Bifenthrin Nitrates Salinity Metals (e.g. aluminium, arsenic, cadmium, copper, iron, lead, magnesium, potassium) Nutrients (e.g. nitrogen, phosphorus) Toxaphene
Landfill sites* and waste disposal sites	*Dependent on landfill type and disposed wastes* Polychlorinated biphenyls Sulfides Metals Asbestos Organic acids Nutrients (e.g. nitrogen, phosphorus) Petroleum hydrocarbons Polycyclic aromatic hydrocarbons Phthalate esters Flame retardants (PBDEs) Ammonia Landfill gases (e.g. methane) Total dissolved solids (TDS) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Per- and polyfluorinated alkyl substances (PFAS) Phenols

Livestock dips and spray races	Metals (e.g. arsenic) Carbamates Organochlorine pesticides Organophosphate pesticides Herbicides Synthetic pyrethroids
Market gardens, orchards, poly-tunnels, plant nurseries and viticulture	Metals (e.g. aluminium, arsenic, cadmium, copper, lead, mercury, magnesium, iron) Organochlorine pesticides (e.g. DDT, Dieldrin, Endosulfan) Organophosphate pesticides (e.g. Azinphos ethyl, Diazinon, Fenthion) Carbamates Petroleum hydrocarbon (fuel) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes)
Metal finishing and treatments (e.g. electroplating/carburising baths, anodising, galvanising, pickling, powder coating, enamelling, spray painting etc.*)	Metals (e.g. aluminium, barium, cadmium, chromium, copper, lead, nickel, tin, zinc) Acids (e.g. sulfuric, hydrochloric, nitric, phosphoric) Paint residues Perchlorate (rare earths processing) Per- and polyfluorinated alkyl substances (PFAS) (used as a mist suppressant in electroplating) Alkalis Solvents (e.g. 1,1,1-trichloroethane, tetrachloroethylene) Plating salts Monocyclic aromatic hydrocarbons (e.g. benzene, toluene) Cyanide
Metal smelting/forging or refining*	Metals (e.g. aluminium, copper, gold, lead, mercury, selenium, silver, tin) and their chlorides, fluorides and oxides Fluoride (from use of HF)

Mineral processing and extractive industries*, including mining, screening, crushing and tailing dams or storage facilities, but not voids where no other potentially contaminating activity has occurred	Acids, alkalis Total dissolved solids (TDS) Organic flocculants (e.g. xanthates, sulfate, cyanide) Ferrous and non-ferrous metals (e.g. aluminium, arsenic, chromium, cobalt, copper, iron, lead, manganese, mercury, tellurium, thallium, tin, zinc) – *metals should be determined through assessment of deposit composition and known impurities* Perchlorate (rare earths processing) Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Radioactive materials Polycyclic aromatic hydrocarbons asbestos pesticides Solvents (e.g. trichloroethene)
Motor vehicle manufacture, workshops, facilities, race venues	Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Solvents (e.g. trichloroethene) Resins Heavy metals Polycyclic aromatic hydrocarbons

Oil/gas exploration, production, refining and storage*	Petroleum hydrocarbon Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Acids (e.g. sulfuric) Alkalis Insulation lagging (e.g. asbestos) Metals (informed by crude oil composition and potential impurities such as arsenic, barium, cadmium, chromium, cobalt, copper, mercury, nickel and vanadium) Methyl tertiary-butyl ether Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Cyanides Drilling fluid additives
Pest control depots	*Refer Pesticides*
Print shops and print works	*Also refer to Photography* Acids Alkalis Solvents (e.g. trichloroethene) Metals (e.g. chromium)
Port/wharf/dock activities (including dredge spoil)	Metals (e.g. copper, tin, chromium, lead, mercury, zinc) Antifouling paints (e.g. organotin, tributyltin) Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Polycyclic aromatic hydrocarbons *Consider commodity-specific contaminants based on materials being handled and stored at the facility*.

Railway yards/marshalling yards and transport corridors	Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Phenolics (creosote) Metals (e.g. arsenic, cadmium, chromium, iron, lead, zinc) Nutrients (e.g. nitrates, ammonia) Per- and polyfluorinated alkyl substances (PFAS) – also refer firefighting/training (use of foams) Pesticides Asbestos Additional contaminants according to what has been transported by rail Consider additional contaminants as indicated by site history
Recycling (construction and building materials)	Asbestos Metals (e.g. lead, zinc)
Recycling (plastics, electronics and appliances)	Metals (e.g. copper, chromium, cobalt, lead, zinc) Flame retardants (PBDEs) Phthalate esters Solvents
Rifle ranges and pistol clubs	Metals (e.g. lead) Polycyclic aromatic hydrocarbons
Salvage and demolition yards	Asbestos Metals (e.g. lead, zinc)
Scrap metal recovery/recyclers, salvage yards and wreckers yards	Asbestos Metals (e.g. cadmium, lead, magnesium) Solvents Polychlorinated biphenyls Oil and grease Petroleum hydrocarbons Monocyclic aromatic hydrocarbons

	(e.g. benzene, toluene, ethylbenzene and xylenes) Polycyclic aromatic hydrocarbons
Service stations, roadhouses and fuel storage facilities/depots	Petroleum hydrocarbons Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Polycyclic aromatic hydrocarbons Methyl tertiary-butyl ether and other oxygenates Metals (e.g. barium, cadmium, copper, lead, nickel, zinc) Oil and grease Per- and polyfluorinated alkyl substances (PFAS) – *where firefighting foam deluge systems have been installed.* Solvents (e.g. trichloroethylene)
Sewage/wastewater treatment plant*	Nutrients (e.g. nitrogen, phosphorus) Metals (e.g. aluminium, arsenic, cadmium, chromium, cobalt, lead, manganese, nickel, potassium, zinc) Per- and polyfluorinated alkyl substances (PFAS) Phenols Pathogens (e.g. *E. coli*, Enterococci)
Tannery (and associated trades)*	Acids (e.g. hydrochloric) Metals (e.g. aluminium, chromium, copper, manganese) Formaldehyde Phenols Salts Solvents (e.g. trichloroethene) Petroleum hydrocarbons Oil and grease Cyanide Ammonia
Textile operations (e.g. carpet, leather, clothing, soft furniture upholsterers)*	Metals (e.g. aluminium, cadmium, chromium, titanium, tin, zinc) Carbon Acid (e.g. sulfuric)

	Alkalis (e.g. caustic soda) Salts Solvents (e.g. perchloroethylene) Monocyclic aromatic hydrocarbons (e.g. benzene, toluene, ethylbenzene and xylenes) Organochlorine pesticides (e.g. Dieldrin, Aldrin) Per- and polyfluorinated alkyl substances (PFAS) – *used in fabric protectors* Dyestuff residues Sodium hypochlorite Phenols
Timber preserving/storage/saw mills wood product manufacturing*	Solvents (e.g. trichloroethene) Polycyclic aromatic hydrocarbons (e.g. creosote, naphthalene) Organochlorine pesticides (e.g. chlordane, endosulfan, pentachlorophenol) Aldrin and dieldrin Anti-sapstain fungicides (e.g. chlorothananil) Metals (e.g. arsenic, copper, chromium VI, zinc) Boron Ammonia Cresols
Wool scouring*	Nutrients (e.g. phosphorus, nitrogen) Total dissolved solids Oil and grease Detergents (e.g. diazinon) Pesticides Solvents Bleaching agents (e.g. hydrogen peroxide)

*Prescribed premises under the Environmental Protection Regulations 1987

References

Standards Australia 2005, Guide to the investigation and sampling of sites with potentially contaminated soil, Part 1: Non-volatile and semi-volatile compounds, Table J1 AS4482.1.

National Environment Protection (Assessment of Site Contamination) Measure 1999, Schedule B2, Appendix A: Possible analytes for soil contamination, National Environment Protection Council. https://www.legislation.gov.au/Details/F2013C00288

Appendix C – Sediment sampling design

Inland sediments

As with soil sampling programs, the number of samples required is dependent upon the site history, distribution of contaminant sources and migration pathways of contamination. Where contaminated sediments are located along a stream or riverbed, the depth and downstream extent of contamination should be identified. Where water flow may have carried contamination downstream, samples should be collected progressively downstream, at regular intervals, from the contamination source and in areas where sediments are likely to settle (e.g. deep pools) until the extent of contamination is determined.

Marine sediments

Where sampling of marine sediments is being undertaken such as in a harbour, marina, port or estuary, the number of samples will depend upon the geography of the sampling location:

- where sediments are located at a site which is relatively uniform (e.g. in the centre of a large, flat-bottomed or gently sloping bay) and the site is distant from pollution sources (e.g. the centre of a large bay), then a minimum number of samples can be collected to adequately characterise the contamination status

  whereas

- where sediments are near the shore in a geographically complex embayment, with significant changes in depth, shoreline configuration and many potential pollution point sources (e.g. Cockburn Sound) then a larger number of samples will be required.

Sampling design

As with soils, where detailed information is available for the site in terms of physical characteristics, potential contaminants and potential sources of contamination, then judgemental sampling can be used to investigate contamination. Where there is little or no data in relation to the potential contamination of the site, then a systematic (grid) sampling pattern should be adopted. Sampling types may be combined such as a systematic (grid) pattern, with judgemental sampling at locations where more information is available.

Refer to Schedule B2 of the ASC NEPM for further information on various sampling patterns. Where large sites are being assessed, such as bays, harbours and marinas, where little information on contamination is available, it is recommended that:

- the site be divided into subareas and then random samples collected from within each block. Subarea size can be varied to increase sampling density in locations with greatest probability of high contamination levels, and areas can be increased if evidence indicates contaminant concentrations are unlikely to vary much across the site; or

- a pilot (or screening) study should be completed comprising 10–20% of the locations anticipated for the full-scale study. Pilot samples should be analysed for the full range of chemical parameters anticipated to be present.

When determining a sampling pattern the following should be taken into consideration:

- findings of the PSI
- objectives of the SAQP
- current and historical usage of the site
- known and potential contaminants (and their distribution)
- nature of contaminants
- beneficial uses of the site and adjacent sites
- potential/proposed site use(s)
- climatological conditions:
  - seasonal variability of temperature, wind direction and wind force (e.g. wave movements may restrict sampling location access, storm conditions may disturb sediments to be sampled)
- hydrographical conditions:
  - mobility of sediments (dynamic zones can result in sediment mobilisation enhancing contaminant release, sediment deposition and sorting of grain sizes)
  - tidal areas (e.g. variations in water depth, current speeds and directions)
  - rivers (e.g. flow rates, presence of riffles and pools)
  - standing bodies (e.g. lakes and harbour areas may have negligible current to cause sediment disturbance)
  - sediment conditions (e.g. nature and composition of sediment layer, sorting of sediments, sediment depth)
  - influence of stream mixing; and mixing through the profile from wave action
- nautical conditions (e.g. some sample points may need to be avoided due to marine traffic)
- sampling constraints:
  - physical constraints (e.g. boat size, water depth)
  - safety of sample collection (e.g. presence of soft mud, quicksand, deep holes, swift currents and dangerous marine life)
- contaminant characteristics:
  - solubility, density, persistence and type of contaminants

  - proximity of sampling location to outfalls and sources of contamination
- ecological considerations:
  - plant growth (e.g. disturbance of plant growth and restrictions on access to plant growth [algae on surface of waterbody, and riverbank vegetation]); and possible impacts on aquatic organisms (e.g. dispersion of contaminated sediments, disturbance of breeding grounds [timing of site access])
  - potential risks to human health and the environment.

Sampling depth

Determination of the depth of sampling should take into consideration:

- findings of the PSI
- objectives of the SAQP
- site history and possible depth of contamination through deposition
- sediment geology (natural confining layers, preferential pathways)
- nature of contaminants (mobility, persistence)
- known or assumed maximum depth of contamination
- field observations and identification of contamination (e.g. stained sediments)
- diffuse or point source contamination sources (diffuse contamination within a harbour, or point source contamination at depth from a pipe discharge)
- potential for mixing down the sediment profile
- human health and ecological risks.

Number of samples

Determination of the number of samples to be collected should take into consideration:

- findings of the PSI
- SAQP objectives
- size of the area to be sampled
- sampling pattern applied
- nature, complexity and distribution of known contaminants
- sediment lithology and variability
- potential remediation and management options
- small-scale variability in contaminant concentration.

Control points should be set up/identified to act as a reference point in determining the levels of contamination against 'background'.

Frequency of samples

There is often some form of mobility of sediments, and therefore more than one sampling event may be required to build up a picture of temporal changes in sediment quality. Determination of sampling frequency should take into consideration:

- objectives of the SAQP
- seasonal and diurnal changes in sediments due to tidal influences etc.
- sediment geology and stratification
- characteristics of particular contaminants (e.g. mobility, partitioning etc.).

Appendix D - Assessment levels for water

Table D1: Selected assessment levels for water, relevant to beneficial use

Refer to section 11.7 of this guideline for information on the correct application of these assessment levels. Cells shaded yellow are derived from 10x the ADWG health value, cells shaded orange are equal to the ADWG aesthetic value.

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Metals/metalloids					
Aluminium, Al	-	0.2	0.2	20	5
Antimony, At	0.003	-	0.03	-	-
Arsenic, As	0.01	-	0.1	2	0.1
Barium, Ba	2	-	20	-	-
Beryllium, Be	0.06	-	0.6	0.5	0.1
Boron, B	4	-	40	Refer to guideline	0.5
Cadmium, Cd	0.002	-	0.02	0.05	0.01
Chromium(unspeciated) Cr	-	-	-	1	0.1
Chromium, Cr(III)	-	-	-	-	-
Chromium, Cr(VI)	0.05	-	0.5	-	-
Cobalt, Co	0.05	-	0.5	-	-
Copper, Cu	2	1	1	0.1	0.05
Iron, (Total) Fe	-	0.3	0.3	10	0.2
Lanthanum La	0.002		0.02	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Lead, Pb	0.01		0.1	5	2
Lithium, Li	-	-	-	2.5 (0.075 for citrus crops)	2.5 (0.075 for citrus crops)
Manganese, Mn	0.5	0.1	5	10	0.2
Mercury (Total), Hg	0.001	-	0.01	0.002	0.002
Molybdenum, Mo	0.05	-	0.5	0.05	0.01
Nickel, Ni	0.02	-	0.2	2	0.2
Selenium (Total), Se	0.01	-	0.1	0.05	0.02
Silver, Ag	0.1	-	1	-	-
Sodium	-	180			
Uranium, U	0.017	-	0.17	0.1	0.01
Vanadium, V	-	-	-	0.5	0.1
Zinc, Zn	-	3	3	5	2
Other inorganics					
Ammonia as NH_3	-	0.5	0.5	-	-
Bromate, BrO_3	0.02	-	0.2	-	
Chloride, Cl^-	-	250	250	refer to guideline	refer to guideline
Cyanide (as un-ionised Cn)	0.08	-	0.8	-	-
Fluoride, F^-	1.5	-	15	2	1

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Hydrogen sulfide[5]	-	0.05	0.05	-	-
Iodide, I^-	0.5	-	5	-	-
Nitrate (as NO_3)[6]	50	-	500	-	-
Nitrite (as NO_2)[6]	3	-	30	-	-
Nitrogen (total N)	-	-	-	refer to guideline	5
Phosphorus (as P)	-	-	-	refer to guideline	0.05
Sulfate (as SO_4)	500	250	1000[7]	-	-
Tributyl tin oxide (TBT)	0.001	-	0.01	-	-
Organic compounds					
Acrylamide	0.0002	-	0.002	-	-
Ethylenediamine tetra acetic acid (EDTA)	0.25	-	2.5	-	-
Formaldehyde	0.5	-	5	-	-
Nitrilotriacetic acid	0.2	-	2	-	-
Methyl tertiary butyl ether (MTBE)	-	-	0.02[2]	-	-
Chlorinated alkanes					
Dichloromethane (DCM) (methylene chloride)	0.004	-	0.04	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Trihalomethanes (total, including chloroform)	0.25	-	2.5	-	-
Tetrachloromethane (carbon tetrachloride)	0.003	-	0.03	-	-
1,2-dichloroethane	0.003	-	0.03	-	-
Chlorinated alkenes					
Chloroethene (vinyl chloride)	0.0003	-	0.003	-	-
1,1-Dichloroethene	0.03	-	0.3	-	-
1,2-Dichoroethene	0.06	-	0.6	-	-
Perchloroethylene (PCE) also known as tetrachloroethene	0.05	-	0.5	-	-
Hexachlorobutadiene	0.0007	-	0.007	-	-
Chlorinated benzenes					
Chlorobenzene	0.3	0.01	0.01	-	-
1,2- Dichlorobenzene	1.5	0.001	0.001	-	-
1,3- Dichlorobenzene	-	0.02	0.02	-	-
1,4- Dichlorobenzene	0.04	0.0003	0.0003	-	-
1,2,3- Trichlorobenzene	0.03	0.005	0.005	-	-
Other chlorinated compounds					

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Epichlorohydrin	0.1	-	1	-	-
Hexachlorobutadiene	0.0007	-	0.007	-	-
Monochloramine	3	0.5	0.5	-	-
Monocyclic aromatic hydrocarbons					
Benzene	0.001	-	0.01	-	-
Toluene	0.8	0.025	0.025	-	-
Ethylbenzene	0.3	0.003	0.003	-	-
Xylenes	0.6	0.02	0.02	refer to guideline	refer to guideline
Styrene (vinyl benzene)	0.03	0.004	0.004	-	-
Polycyclic aromatic hydrocarbons (PAHs)					
Benzo[a]pyrene	0.00001	-	0.0001	-	-
Per- and polyfluoroalkyl substances (PFAS)[8]					
Perfluorooctane sulfonate and Perfluorohexane sulfonate (PFOS + PFHxS)	0.00007	-	refer to footnote 8	-	-
Perfluorooctanoic acid (PFOA)	0.00056	-	refer to footnote 8	-	-
Phenols					
Phenol	-	-	-	-	-
2-Chlorophenol	0.3	0.0001	3	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
4-Chlorophenol	-	-	-	-	-
2,4-Dichlorophenol	0.2	0.0003	2	-	-
2,4,6-Trichlorophenol	0.02	0.002	0.2	-	-
2,3,4,6-Tetrachlorophenol	-	-	-	-	-
Pentachlorophenol	-	-	-	-	-
2,4-Dinitrophenol	-	-	-	-	-
Phthalates					
Di(2-ethylhexyl) phthalate	0.01	-	0.1	-	-
Pesticides and herbicides					
Acephate	0.008	-	0.08	-	-
Acrolein	-	-	-	refer to guideline	refer to guideline
Aldicarb	0.004	-	0.04	-	-
Aldrin plus Dieldrin	0.0003	-	0.003	-	-
Ametryn	0.07	-	0.7	-	-
Amitraz	0.009	-	0.09	-	-
Amitrole	0.0009	-	0.009	refer to guideline	refer to guideline
Asulam	0.07	-	0.7	-	-
Atrazine	0.02	-	0.2	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Azinphos-methyl	0.03	-	0.3	-	-
Benomyl	0.09	-	0.9	-	-
Bentazone	0.4	-	4	-	-
Bifenthrin[2]	-	-	0.35[2]	-	-
Bioresmethrin	0.1	-	1	-	-
Bromacil	0.4	-	4	-	-
Bromoxynil	0.01	-	0.1	-	-
Captan	0.4	-	4	-	-
Carbaryl	0.03	-	0.3	-	-
Carbendazim (Thiophanate-methyl)	0.09	-	0.9	-	-
Carbophenothion	0.0005		0.005		
Carbofuran	0.01	-	0.1	-	-
Carboxin	0.3	-	3	-	-
Carfentrazone-ethyl	0.1	-	1	-	-
Chlorantraniliprole	6	-	60	-	-
Chlordane	0.002	-	0.02	-	-
Chlorfenvinphos	0.002	-	0.02	-	-
Chlorothalonil	0.05	-	0.5	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Chloroxuron	0.01	-	0.1	-	-
Chlorpyrifos	0.01	-	0.1	-	-
Chlorsulfuron	0.2	-	2	-	-
Clopyralid	2	-	20	-	-
Cyfluthrin, Beta-cyfluthrin	0.05	-	0.5	-	-
Cypermethrin isomers	0.2	-	2	-	-
Cyprodinil	0.09	-	0.9	-	-
1,3-Dichloropropene	0.1	-	1	-	-
2,2-DPA	0.5	-	5	refer to guideline	refer to guideline
2,4-D [2,4-dichlorophenoxy acetic acid]	0.03	-	0.3	refer to guideline	refer to guideline
DDT	0.009	-	0.09	-	-
Deltamethrin	0.04	-	0.4	-	-
Diazinon	0.004	-	0.04	-	-
Dicamba	0.1	-	1	refer to guideline	refer to guideline
Dichlobenil	0.01	-	0.1	refer to guideline	refer to guideline
Dichloroprop	0.1	-	1	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Dichlorvos	0.005	-	0.05	-	-
Diclofop-methyl	0.005	-	0.05	-	-
Dicofol	0.004	-	0.04	-	-
Dieldrin plus Aldrin	0.0003	-	0.003	-	-
Difenzoquat	0.1		1		
Diflubenzuron	0.07	-	0.7	-	-
Dimethoate	0.007	-	0.07	-	-
Diquat	0.007	-	0.07	-	-
Disulfoton	0.004	-	0.04	-	-
Diuron	0.02	-	0.2	refer to guideline	refer to guideline
EDB (ethylene dibromide)	0.001		0.01		
Endosulfan	0.02	-	0.2	-	-
Endothal	0.1	-	1	-	-
EPTC	0.3	-	3	-	-
Esfenvalerate	0.03	-	0.3	-	-
Ethion	0.004	-	0.04	-	-
Ethoprophos	0.001	-	0.01	-	-
Etridiazole	0.1	-	1	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Fenamiphos	0.0005	-	0.005	-	-
Fenarimol	0.04	-	0.4	-	-
Fenitrothion	0.007	-	0.07	-	-
Fenoprop	0.01	-	0.1	-	-
Fensulfothion	0.01	-	0.1	-	-
Fenthion	0.007	-	0.07	-	-
Fenvalerate	0.06	-	0.6	-	-
Fipronil	0.0007	-	0.007	-	-
Flamprop-methyl	0.004	-	0.04	-	-
Fluazifop-p-butyl[2]	-	-	0.1[2]	-	-
Flumetsulum[2]	-	-	0.035[2]	-	-
Fluometuron	0.07	-	0.7	refer to guideline	refer to guideline
Fluproponate	0.009	-	0.09	-	-
Flutriafol[3]	-	-	0.3[2]	-	-
Formothion	0.05		0.5		
Fosamine	0.03		0.3		
Glyphosate	1	-	10	-	-
Haloxyfop	0.001	-	0.01	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Heptachlor (including its epoxide)	0.0003	-	0.003	-	-
Heaflurate	0.03	-	0.3	-	-
Hexazinone	0.4	-	4	-	-
Imazapyr	9	-	90	-	-
Iprodione	0.1	-	1	-	-
Lindane (γ-HCH)	0.01	-	0.1	-	-
Malathion	0.07	-	0.7	-	-
Mancozeb (as ETU, ethylene thiourea)	0.009	-	0.09	-	-
MCPA	0.04	-	0.4	-	-
Metaldehyde	0.02	-	0.2	-	-
Metham (as methyl isothiocyanate, MITC)	0.001	-	0.01	-	-
Methidathion	0.006	-	0.06	-	-
Methiocarb	0.007	-	0.07	-	-
Methomyl	0.02	-	0.2	-	-
Methoxychlor	0.3		3		
Methyl bromide	0.001	-	0.01	-	-
Metiram (as ETU, ethylene thiourea)	0.009	-	0.09	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Metolachlor/s–Metolachlor	0.3	-	3	-	-
Metribuzin	0.07	-	0.7	-	-
Metsulfuron-methyl	0.04	-	0.4	-	-
Mevinphos	0.005	-	0.05	-	-
Molinate	0.004	-	0.04	-	-
Monocrotophos	0.002	-	0.02	-	-
Napropamide	0.4	-	4	-	-
Nicarbazin	1	-	10	-	-
Nitralin	0.5	-	5	-	-
Norflurazon	0.05	-	0.5	-	-
Omethoate	0.001	-	0.01	-	-
Oryzalin	0.4	-	4	-	-
Oxamyl	0.007	-	0.07	-	-
Paraquat	0.02	-	0.2	refer to guideline	refer to guideline
Parathion	0.02	-	0.2	-	-
Parathion methyl	0.0007	-	0.007	-	-
Pebulate	0.03	-	0.3	-	-
Pendimethalin	0.4	-	4	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Pentachlorophenol	0.01	-	0.1	-	-
Permethrin	0.2	-	2	-	-
Picloram	0.3	-	3	-	-
Piperonyl butoxide	0.6	-	6	-	-
Pirimicarb	0.007	-	0.07	-	-
Pirimiphos ethyl	0.0005	-	0.005	-	-
Pirimiphos methyl	0.09	-	0.9	-	-
Polihexanide	0.7	-	7	-	-
Profenofos	0.0003	-	0.003	-	-
Propachlor	0.07	-	0.7	-	-
Propanil	0.7	-	7	refer to guideline	refer to guideline
Propargite	0.007	-	0.07	-	-
Proparzine	0.05	-	0.5	-	-
Propiconazole	0.1	-	1	-	-
Propyzamide	0.07	-	0.7	-	-
Pyrasulfatole	0.04	-	0.4	-	-
Pyrazophos	0.02	-	0.2	-	-
Pyroxsulam	4	-	40	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Quintozene	0.03	-	0.3	-	-
Quizalofop-p-ethyl[2]	-	-	0.4[2]	-	-
Simazine	0.02	-	0.2	-	-
Spirotetramat	0.2	-	2	-	-
Sulprofos	0.01	-	0.1	-	-
2,4,5-T	0.1	-	1	refer to guideline	refer to guideline
TCA (Trichloroacetic acid)	-	-	-	refer to guideline	refer to guideline
Tebuconazole[2]	-	-	1[2]	-	-
Temephos	0.4	-	4	-	-
Terbacil	0.2	-	2	-	-
Terbufos	0.0009	-	0.009	-	-
Terbuthylazine	0.01	-	0.1	-	-
Terbutryn	0.4	-	4	-	-
Tetrachlorvinphos	0.1	-	1	-	-
Thiobencarb	0.04	-	0.4	-	-
Thiometon	0.004	-	0.04	-	-
Thiophanate	0.005		0.05		
Thiram	0.007	-	0.07	-	-

	ADWG (2011)[1]		DoH (2014)[2]	ANZECC & ARMCANZ (2000)[3]	
	Drinking water health value	Drinking water aesthetic value	Non-potable groundwater use (NPUG)	Short-term irrigation water	Long-term irrigation water[4]
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Toltrazuril	0.004	-	0.04	-	-
Triadimefon	0.09	-	0.9	-	-
Triadimenol[2]	-	-	2[2]	-	-
Trichlorfon	0.007	-	0.07	-	-
Triclopyr	0.02	-	0.2	-	-
Trifluralin	0.09	-	0.9	-	-
Vernolate	0.04	-	0.4	-	-
Other parameters					
Hardness as CaCO3	200	-	-	-	-
pH	6.5–8.5	-	-	6.0–8.5 groundwater 6.0–9.0 (surface water)	6.5–8.5

Table D1 notes:

1. NHMRC & ARMCANZ 2011, *Australian drinking water guidelines*.
2. DoH 2014, *Contaminated sites ground and surface water chemical screening guidelines*.
3. ANZECC & ARMCANZ 2000, *Australian water quality guidelines for fresh and marine water quality*.
4. Long-term irrigation values are applicable to the application of irrigation water for up to 100 years in a non-domestic setting. For shorter irrigation periods, short-term irrigation guidelines may be more appropriate, see Table 4.2.10 of ANZECC & ARMCANZ (2000).
5. H_2S measured as sulfide ion. In water, hydrogen sulfide will be in equilibrium with the sulfide and

hydrosulfide ions. The ratio will depend on pH, temperature and salinity.

6. Because it is possible that nitrate and nitrite may occur simultaneously in drinking-water, and the two have a common toxic effect, these compounds should be considered together when judging compliance with the guidelines. See NHMRC & ARMCANZ (2011) *Australian drinking water guidelines* for more information.
7. Value less than 10x health value due to health effects on livestock and domestic animals.
8. For PFAS, values equal to the drinking water guideline values are appropriate Tier 1 screening levels for non-potable uses such as watering gardens in situations where consumption of home-grown produce is a viable/plausible exposure pathway. In such cases, a Tier 2 assessment of home-grown produce is recommended, noting that direct testing of home-grown fruit and vegetables and specific consumption data, where available, is most appropriate for health risk assessment. Where block sizes or land use significantly limit the potential cultivation of home-grown produce (i.e. standard urban residential blocks or urban industrial land) 10x ADWG may apply.

Table D2: Microbiological assessment levels for water

Intended use (environmental value)	***E.coli*[1] (thermotolerant coliforms) (trigger value)**
Agriculture[2]	
Raw human food crops in direct contact with irrigation water	<10 cfu[4] / 100 ml
Raw human food crops not in direct contact with irrigation water	<1,000 cfu / 100 ml
Pasture and fodder for dairy animals (without withholding period)	<100 cfu / 100 ml
Pasture and fodder for dairy animals (with withholding period of five days)	<1,000 cfu / 100 ml
Pasture and fodder (for grazing animals excluding pigs and dairy animals)	<1,000 cfu / 100 ml
Silviculture, turf, cotton etc. (with restricted public access)	<10,000 cfu / 100 ml
Urban recreational areas, open spaces, parks and gardens[3, 5]	
Municipal use – public open spaces, sports grounds, golf courses etc. with unrestricted access and application	<1 cfu / 100 ml
Municipal use with some restricted access and application	<10 cfu / 100 ml
Municipal use with enhanced restrictions on access and application	<1,000 cfu / 100 ml
Drinking water	**Refer to ADWG**

Table D2 notes:

1 *E.coli* to be used as a faecal pathogen indicator. Where salinity exceeds one per cent (10,000 ppm) *Enterococci* should be substituted for *E.coli.*

2 ANZECC & ARMCANZ (2000)

3 EPHC (2006)

4 cfu = colony forming units

5 Adapted from Table 8 in DoH (2011)

Table D3: Ecological assessment levels for selected chemical stressors relevant to specific regions in Western Australia

South West

Values included here are screening values intended to be applied for slightly disturbed ecosystems. Values in cells shaded yellow are sourced from ANZECC and NHMRC (1992); values in cells shaded orange are based on Dove and Sammut (2000); all remaining values are sourced from ANZECC and ARMCANZ (2000) (Table 3.3.6).

	Ecosystem type				
	Rivers and streams	**Freshwater lakes and reservoirs**	**Wetlands**	**Estuaries**	**Marine** [1]
	(µg/L)	**(µg/L)**	**(µg/L)**	**(µg/L)**	**(µg/L)**
Total nitrogen	1200	350	1500	750	see note 1
NOx	150	10	100	45	see note 1
Ammonium NH_4^+	80	10	40	40	see note 1
Total phosphorus	65	10	60	30	see note 1
Filterable reactive phosphorus	40	5	30	5	see note 1
Iron	300	300	300	pH > 6: 1000 pH < 6: 300	pH > 6: 1000 pH < 6: 300
pH	6.5 - 8.0	6.5 - 8.0	7.0 - 8.5	7.5 - 8.5	8.0 - 8.4

Pilbara and Kimberley regions

Values included here are screening values intended to be applied for slightly disturbed ecosystems. Values in cells shaded yellow are sourced from ANZECC and NHMRC (1992); values in cells shaded orange are based on Dove and Sammut (2000); all remaining values are sourced from ANZECC and ARMCANZ (2000) (Table 3.3.8).

	Ecosystem type				
	Rivers and streams	Freshwater lakes and reservoirs	Wetlands	Estuaries	Marine[1]
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Total nitrogen	Lowland river: 200-300 Upland river: 150	350	350 - 1200	250	see note 1
NOx	Lowland river: 10 Upland river: 30	10	10	30	see note 1
Ammonium NH_4^+	Lowland river: 10 Upland river: 6	10	10	15	see note 1
Total phosphorus	10	10	10 - 50	20	see note 1
Filterable reactive phosphorus	Lowland river: 4 Upland river: 5	5	5 - 25	5	see note 1
Iron	300	300	300	pH > 6: 1000 pH < 6: 300	pH > 6: 1000 pH < 6: 300
pH	6.0 - 8.0	6.0 - 8.0	6.0 - 8.0	7.0 - 8.5	8.0 – 8.4

Table D3 notes:

1. For the management of marine nutrient enrichment issues, the guideline *Technical guidance protecting the quality of Western Australia's marine environment* (EPA 2016) provides further information on appropriate levels of protection applicable to marine waters in Western Australia. The department does not recommend using concentrations of nutrients in marine waters as indicators of ecosystem health, but instead that you monitor productivity indicators (e.g. chlorophyll *a*, algal biomass etc.) as environmental quality guidelines.