ENVIRONMENT PROTECTION AUTHORITY

SITE CONTAMINATION

GUIDELINES FOR THE ASSESSMENT AND REMEDIATION OF GROUNDWATER CONTAMINATION

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EPA South Australia

Site contamination: Guidelines for the assessment and remediation of groundwater contamination

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ABBREVIATIONS

ADWG	Australian Drinking Water guideline
Auditor	Site contamination auditor
BUA	Beneficial use assessment
Consultant	Site contamination consultant
CSM	Conceptual site model
CUTEP	Clean up to extent practicable
DNAPL	Dense non-aqueous phase liquid
DRA	Detailed risk assessment
DWLBC	Department of Water, Land and Biodiversity Conservation
(The) EP Act	Environment Protection Act 1993
(The) EP(SC) Regulations	Environment Protection (Site Contamination) Regulations 2008
EPA	South Australian Environment Protection Authority
K	Hydraulic conductivity
LNAPL	Light non-aqueous phase liquid
NAPL	Non-aqueous phase liquid
NEPM	National Environment Protection Measure
NHMRC	National Health Medical Research Council
PCA	Potentially contaminating activity
ROA	Risk options assessment
RTEN	Remediation to extent necessary
SCAO	Site contamination assessment order
SCAR	Site contamination audit report
SRA	Screening risk assessment
SRO	Site remediation order
TDS	Total dissolved solids
Water Quality EPP	Environment Protection (Water Quality) Policy 2003

SUMMARY

The Environment Protection Authority (EPA) has prepared this guideline to provide details about the assessment and remediation of groundwater contamination to ensure the protection of human health and/or the environment. This guideline also outlines the roles, responsibilities and obligations of site contamination consultants and site contamination auditors in relation to site contamination under the *Environment Protection Act 1993* (the EP Act) and the *Environment Protection (Site Contamination) Regulations 2008* [the EP(SC) Regulations] in South Australia. This guideline describes in detail how site contamination of groundwater that is not trivial is to be assessed and remediated.

The guideline is intended to assist site contamination auditors and site contamination consultants understand and comply with the legislative requirements of the EP Act and the EP(SC) Regulations in relation to assessment and remediation of groundwater contamination.

This guideline describes in detail the following:

- risk-based system and an overview of the assessment and remediation process (Section 2)
- process of undertaking a screening risk assessment (SRA) to determine if groundwater contamination of underground water exists at the site (Appendix 2)
- process of undertaking a detailed risk assessment (DRA) to determine the nature and extent of the groundwater contamination (Section 2)
- guidance on undertaking a beneficial use assessment to determine what beneficial use/s of groundwater to be protected at the site (Section 2)
- requirements for the development of a remediation options assessment (ROA) for sites that require remediation (Section 3)
- process for the determination of whether an remediation to extent necessary (RTEN) opinion is required (Section 3)
- mandatory requirements for auditors in providing an RTEN opinion (Section 4)
- requirements for information to be included in reports submitted to the EPA and auditors (Appendix 3).

The guideline also provides a glossary of key terms, guidance documents and a series of flow charts to clarify the assessment and remediation process of groundwater contamination.

1 INTRODUCTION

1.1 Purpose

The purpose of this guideline is to provide details on the Environment Protection Authority's (EPA) expectations for the assessment and remediation of site contamination of underground water[1] to ensure the protection of human health and the environment and to provide the mandatory process that site contamination auditors must follow in the assessment and remediation of groundwater.

This guideline describes in detail how site contamination of groundwater[2] that is not trivial as defined in Section 5B of the *Environment Protection Act 1993* (EP Act) is to be assessed and remediated.

The framework outlined in this document is to be used for the assessment of groundwater contamination and provides guidance on its implementation. The process is based on current national and international accepted approaches and is in accordance with the Objects of the EP Act[3]. The framework should ensure that all risks are clearly identified and can be appropriately assessed.

The EPA has established a risk-based system of remediation based on the protection of human health and the environment relative to the present and potential future uses of the groundwater.

Any assessment or remediation reports for groundwater contamination provided to the EPA are expected (if required by an order) to have addressed the relevant components of this guideline. While not all components of this guideline will be relevant to the assessment and remediation of all sites, the process will still be the same. The extent to which the process is followed will depend on site-specific conditions.

This guideline should assist site contamination auditors (auditors) and site contamination consultants (consultants) to develop and implement groundwater assessment and remediation strategies that are consistent with EPA requirements.

It will also be a useful tool for local councils, industry, water users and other members of the community.

1.2 Scope of the guideline

This guideline applies only to groundwater contamination; it does not apply to any other waters or soils. Guidance on remediation of soil can be found in the EPA Guideline, *Environmental management of on-site remediation (2008).*

This document is set out as follows:

Section 2 Assessing groundwater contamination—outlines the foundation for the risk-based system, ways of identifying if groundwater has been impacted by chemical substances from a potentially contaminating activity and describes how to undertake preliminary and detailed assessments.

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1 For the purposes of this guideline, underground water will be referred to as groundwater.

2 For the purpose of this guideline, site contamination of groundwater will be referred to as groundwater contamination.

3 Section 10 of the EP Act.

Section 3 Remediation of groundwater contamination—outlines the remediation hierarchy including when remediation proposals can be undertaken by consultants and when an auditor is required for a remediation to extent necessary (RTEN) process.

Section 4 Groundwater requirements for auditors—outlines the mandatory requirements for auditors on the RTEN process.

1.3 Legal framework

The principal legislation dealing with site contamination in South Australia is the EP Act. In particular the following sections of the EP Act relate to the assessment and remediation of groundwater:

- Section 5B of the EP Act

  (1) For the purpose of this Act, **site contamination** exists at a site if—Chemical substances are present on or below the surface of the site in concentrations above the background concentrations (if any); and

  (a) The chemical substances have, at least in part, come to be present there as a result of an activity at the site or elsewhere; and

  (b) The presence of the chemical substances in those concentrations has resulted in—

  (i) Actual or potential harm to the health and safety of human beings that is not trivial, taking into account current or proposed land uses; or

  (ii) Actual or potential harm to water that is not trivial; or

  (iii) Other actual or potential environmental harm that is not trivial, taking into account current or proposed land uses.

- Section 83A of the EP Act

  Notification of site contamination of underground water

  (2) A person to whom this section applies must notify the Authority in writing as soon as reasonably practicable after becoming aware of the existence of site contamination at the site or in the vicinity of the site (whether arising before or after the commencement of this section) that affects or threatens water occurring naturally under the ground or introduced to an aquifer or other area under the ground.

- Section 103H—Site contamination assessment orders

  (1) If—

  (a) The Authority is satisfied that site contamination exists at a site; or

  (b) The Authority suspects that site contamination exists at a site because a potentially contaminating activity of a kind prescribed by regulation has taken place there;

  the Authority may issue a site contamination assessment order of the site to the appropriate person.

- Section 103I—Voluntary site contamination assessment proposals

  (1) The Authority may agree not to issue a site contamination assessment order to a person in relation to a known or suspected site contamination if the person undertakes to carry out an assessment in accordance with any approved voluntary site contamination assessment proposal.

- Section 103J—Site remediation orders

  (1) If—

  (a) The Authority is satisfied that site contamination exists at a site; and

  (b) The Authority considers that the remediation of the site is required, taking into account current or proposed land uses,

  the Authority may issue a site remediation order in respect of the site to an appropriate person.

- Section 103K—Voluntary site remediation proposals

  (1) The Authority may agree not to issue a site remediation order to a person in relation to site contamination if the person undertakes to carry out remediation in accordance with the approved voluntary site remediation proposal.

  The EPA has the legislative power to prohibit or restrict the taking of water affected by site contamination under Section 103S of the EP Act:

- Section 103S – Prohibition or restriction on taking water affected by site contamination

  (1) If the Authority is satisfied that—

  (a) There is site contamination that affects or threatens water; and

  (b) Action is necessary under this section to prevent actual or potential harm to human health or safety,

  the Authority may, by notice in the Gazette, prohibit or restrict the taking of water.

1.4 Core principles

The EPA has issued this guideline to provide a best practice framework for the assessment and remediation of groundwater contamination in South Australia. **This is not a legislative guideline except where undertaken by an auditor. The EPA will take these guidelines into account when considering whether to issue site contamination assessment (SCAO) or site remediation orders[4] (SRO) relating to groundwater.**

The EPA has developed core principles and concepts to assist with the assessment and remediation process. This guideline provides the framework that enables the legislative requirements of the EP Act and the recommended process in the National Environment Protection (Assessment of site contamination) Measure or NEPM (NEPC, 1999) to be met. These principles and concepts are outlined in the following sections.

1.4.1 Site contamination

This guideline relates to the site contamination of groundwater as defined in the EP Act[5]. It does not cover the assessment and remediation of groundwater that falls outside of the definition of site contamination. The methodologies presented are primarily to deal with groundwater contamination that occurred prior to 1995. The EPA may also use this guideline to manage breaches of the *Environment Protection (Water Quality) Policy 2003* (Water Quality EPP) or licence conditions.

1.4.2 Background concentration

Site contamination does not exist at a site if the chemical substances present on or below the surface of the site are the result of the natural environment, and are not present as a result of the activity that has occurred at the site or elsewhere. It may be necessary at some sites to

[4] Section 103(H) and 103(J) of the EP Act.

[5] Section 5B of the EP Act.

determine the contribution of the chemical substances from the natural environment as well as the contribution from the site. The EPA has developed a guideline on the determination of background concentrations[6].

1.4.3 Harm to water that is not trivial

In order for site contamination to exist at a site with respect to groundwater, there must be actual or potential harm to water that is not trivial. The EPA has produced a guideline on harm to water that is not trivial[7] which provides guidance on how this is determined.

1.4.4 Notification of site contamination of underground water that affects or threatens water

Section 83A of the EP Act requires a specific person (owner, occupier, auditor and/or consultant) to notify the EPA in writing as soon as reasonably practicable after becoming aware of the existence of site contamination at the site or in the vicinity of the site that affects or threatens water occurring naturally under the ground or introduced to an aquifer or other area under the ground. There is no requirement to notify if the person has reason to believe that the EPA is aware of the existence of site contamination. Further details on what is required under the Section 83A notification process is outlined in another guideline[8].

Once the EPA has received notification of such site contamination it will then decide whether or not further action is required at the site. This decision will be risk based and may require assessment or remediation to be undertaken.

1.4.5 Beneficial use assessment

In order to determine the beneficial uses of groundwater that need to be protected at the site or in the vicinity of the site, a beneficial use assessment (BUA) should be undertaken.

The EPA expects that groundwater will be assessed on the basis of its suitability for current or realistic future beneficial use and the risk that use may pose to human health and/or the environment. The detailed risk assessment (DRA) should take into account all factors that are relevant to any realistic proposed and potential future uses of the groundwater. By adopting this approach the potential receptors determine the level of protection required and ultimately the level of remediation that will be required.

The concept of a BUA has been developed in accordance with the principles of the NEPM[9]. The BUA should assess the groundwater on the basis of its suitability for current or realistic future use and the risk that the use may pose to human health and the environment. The requirements for a BUA are contained within Section 3.4 of this document.

1.4.6 Potentially contaminating activities

The likelihood for groundwater contamination to exist is determined by the presence of a current or previous potentially contaminating activity (PCA)[10]. If a PCA has occurred on or

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6 EPA Guideline, *Site Contamination: Determination of background concentrations (2008).*

7 EPA Guideline, *Site Contamination: How to determine actual or potential harm to water resulting from site contamination (2008).*

8 EPA Guideline, *Site Contamination: Notification of site contamination that affects or threatens underground water (2008).*

9 Schedule B (6) National Environment Protection (Site Contamination) Measure—Guideline on Risk Based Assessment of Groundwater Contamination.

10 Regulation 5 and Schedule 1 of the Environment Protection (Site Contamination) Regulations 2008.

near a site and there is potential that chemical substances associated with that activity have caused actual or potential harm to water, then a risk-based assessment should be undertaken to identify whether this is the case.

1.4.7 Remediation

Remediation is defined in the EP Act[11] as having a corresponding meaning to remediate. The definition of remediate is as follows:

> Remediate a site means to treat, contain, remove or manage chemical substances on or below the surface of the site so as to—
>
> (a) eliminate or prevent actual or potential harm to the health or safety of human beings that is not trivial taking into account current or proposed land uses; and
>
> (b) eliminate or prevent as far as reasonably practicable—
>
> (i) actual or potential harm to water that is not trivial; and
>
> (ii) any other actual or potential environmental harm that is not trivial, taking into account current or proposed land uses.

Once the initial assessment and characterisation of the site is complete and it has been demonstrated that groundwater contamination exists, an assessment of the remediation options will need to be undertaken.

1.4.8 Remediation options assessment

A consultant develops and submits the remediation options assessment (ROA) to the EPA unless an auditor has been engaged to provide an RTEN opinion. This report outlines the remediation methods and strategies to be implemented at sites. See Section 3.3 for information on the requirements of an ROA. Where an RTEN opinion is required the ROA is prepared by the consultant but reviewed by an auditor and forms the basis of the RTEN opinion.

1.4.9 Remediation to extent necessary

The EPA has developed the concept of RTEN. This is a risk-based concept that requires remediation only to a point of necessity. For high-risk sites, it is the role of an auditor to ascertain that the level of remediation recommended by consultants is appropriate for the identified level of risk to human health and the environment associated with that site.

The EPA recognises that the remediation of groundwater back to the original beneficial use is not always possible. Similarly, where remediation is possible there are often many limitations (eg risk to off-site users). The RTEN approach will consider the limitations associated with the remediation of a site. Where appropriate, the RTEN will enable remediation strategies to be developed and implemented for sites where remediation of the groundwater to the proposed beneficial use is not necessary, based on the identified level of risk at the site.

The requirements for when an RTEN opinion should be undertaken are outlined in detail in Section 4.

1.4.10 Water restriction and prohibition zones

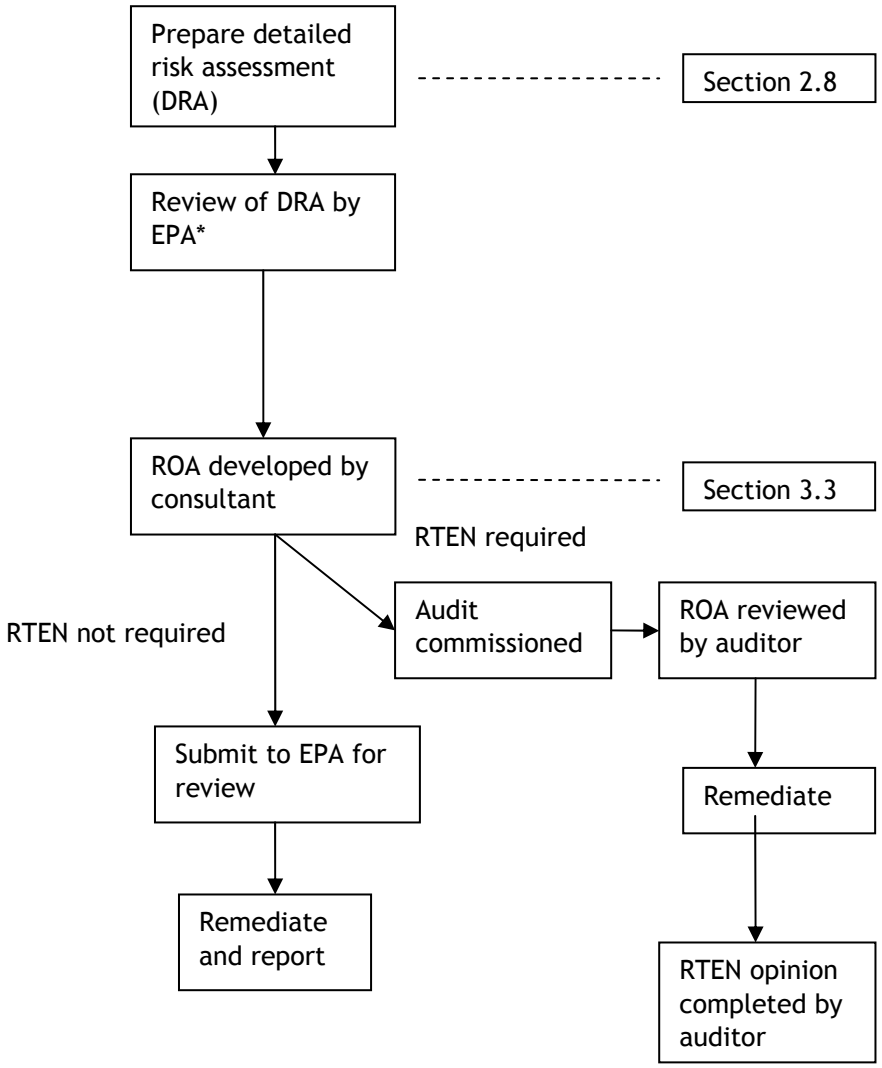
Pursuant to Section 103S of the EP Act, the EPA will be able to prohibit or restrict the use of groundwater where site contamination exists and there is a risk to human health. For more information on the establishment of water restriction and prohibition zones refer to the EPA guideline, ‘Site contamination: water restriction and prohibition zones’ (to be published).

[11] Section 3(1) of the EP Act.

As a result of the assessment and remediation process, the EPA may make a determination based on the work undertaken at a site as to whether there is a need to prohibit or restrict the use of groundwater. The prohibition or restriction on the use of groundwater is not limited to the land—the source of the contamination—but it can also cover the entire area of the plume and where necessary may include a 'buffer zone'.

1.5 Stages in the assessment and remediation process

The main stages associated with the assessment and remediation of groundwater contamination is presented in Figure 1. A detailed flow diagram outlining all the requirements of the assessment and remediation process is depicted in Appendix 1.



* If an auditor has reviewed DRA, there is no requirement for the EPA to review.

Figure 1 Stages of assessment and remediation of groundwater contamination

1.6 Regulatory involvement

All persons who undertake assessment and remediation have a responsibility under the EP Act not to cause environmental harm. If a person causes serious or material environmental harm, it is a criminal offence under the EP Act.

The EPA requires that the guidelines are used in the assessment and remediation of groundwater contamination when these are being used by auditors, or as a result of the issuing a SCAO or a SRO. If assessment and/or remediation are undertaken in a manner independent of these guidelines and the EPA considers that site contamination may still exist at the site, the EPA may issue a SCAO or a SRO to ensure that the assessment and remediation is undertaken in accordance with these guidelines.

The EPA will use these guidelines to define the requirements of a SCAO or a SRO in relation to groundwater contamination. Orders typically require a person to undertake a specified action within a certain period of time. Failure to comply with an order is an offence.

The EPA encourages consultants to use these guidelines and to communicate with the EPA throughout the assessment and remediation process. This will ensure that an appropriate standard of work is being undertaken at the site.

On the basis of the information provided, the EPA may recommend that additional assessment or remediation is undertaken. Such recommendations would be based on a risk based decision-making process.

1.7 Reporting requirements

The EPA recommends that the detailed risk assessment (DRA) and ROA reports are to be submitted to the EPA to ensure that they are consistent with this and other relevant guidelines, unless an auditor has been engaged to provide an RTEN opinion. It is a requirement that auditors provide a RTEN opinion to the EPA in the format of a site contamination audit report (SCAR). Consultants and auditors should follow reporting requirements (Appendix 3) and submit reports containing sufficient and appropriate information to allow a review by the EPA and any other stakeholders.

1.8 Application of this guideline

This guideline assumes the following:

- Actual or potential harm to water that is not trivial has been established at the site and therefore by definition site contamination exists. If it has not been determined whether there is actual or potential harm to groundwater that is not trivial, then an assessment will need to be undertaken to determine if site contamination exists. This assessment may be in the form of a screening risk assessment as outlined in Appendix 2.
- Assessment and remediation is being undertaken by the appropriate person. If the appropriate person is not responsible for off site contamination, the EPA should be contacted for guidance[12].
- If an auditor is engaged in the assessment process, there is no requirement for the EPA to review the DRA if the auditor endorses all the components of the DRA.

In accordance with the Environment Protection (Site Contamination) Regulations 2008, specifically Regulation 12(2)(c), it is a requirement of an auditor's accreditation that 'an auditor must not, when acting as an auditor, fail to comply with any guidelines issued from time to time by the Authority (insofar as they may be relevant in the circumstances of any particular case). Auditors must therefore comply with this guideline when they are undertaking an audit involving the assessment and remediation of groundwater contamination' (Guidelines for the site contamination audit system 2009).

[12] The EPA may be required to determine who is the appropriate person for the off-site assessment and remediation.

This guideline is not intended to prescribe technologies; rather it provides a framework for how the EPA expects that assessment and remediation of groundwater contamination will be undertaken.

1.9 Guidance on groundwater

There are several guidelines that relate to the protection and assessment of groundwater. The Water Quality EPP outlines obligations with respect to the discharge of pollutants into waters. This policy does not have retrospective operation and cannot be used to deal with groundwater contamination that occurred prior to 2003. It is not the intent of this guideline to provide guidance on the assessment and remediation of groundwater that can be managed under the Water Quality EPP. However the breach of the Water Quality EPP may cause site contamination and the EPA may require assessment and remediation in accordance with this guideline. It is the primary intent of the EPA to manage these sites in accordance with the EP Act, the Water Quality EPP and, if relevant, environmental authorisations.

The NEPM is a statutory instrument that reflects agreed national objectives and contains guidelines for assessing groundwater contamination.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000) identify generic water quality criteria that protect environmental values from a range of chemical substances. The document also outlines a process for undertaking assessments of water quality to determine whether the water can sustain aquatic ecosystems.

Appendix 5 provides a list of reference documents used in developing the principles in this guideline.

2 ASSESSMENT OF GROUNDWATER CONTAMINATION

A risk based assessment will need to be commissioned by the appropriate person[13] and undertaken by an appropriately qualified person to determine what level of risk these chemical substances pose to the environment and/or human health. For more information on determining who is an appropriate person refer to the EPA Information Sheet, *Site Contamination—Responsibility for Site Contamination (2009).* If an assessment determines that there is a risk to human health and/or the environment, the EPA may require remediation at the site. Information on remediation can be found in Section 4.

Sites that are identified through the risk assessment process as having a high risk to human health or the environment will be considered as a priority site and may require immediate remediation by the appropriate person.

2.1 Human health and/or environmental risk

Before remediation requirements can be determined for the site, a human health and/or environmental risk assessment must be undertaken. In the first instance the EPA may only recommend a qualitative risk assessment be undertaken to determine the potential effects of the chemical substances in the groundwater.

A qualitative risk assessment uses the 'source–pathway–receptor' model and involves the following components:

- assessing the source and properties of the chemical substance (solubility, portioning, toxicity, etc)
- identifying and confirming the beneficial uses in the vicinity of the site
- determining groundwater flow direction and the potential exposure of the receptors to the chemical substances (eg the site may be located hydraulically down-gradient of a sensitive receiver and an assessment has demonstrated that impacted groundwater will not migrate towards the receiver)
- assessing the impact on water quality in the receiving environment by comparing to water quality criteria
- evaluating the volatilisation pathways for volatile chemical substances.

The EPA will require that a quantitative risk assessment be performed in the following circumstances:

- where ecosystem protection is the principal beneficial use and harm to water that is not trivial has occurred; or
- the beneficial uses of the groundwater are for a potable water supply and harm to water that is not trivial has occurred.

These assessments are important in defining the remediation requirements including the degree and timing of the remediation. Assessors should consider appropriate remediation strategies that may be required at the site. The assessor may be able to determine relatively early in the assessment phase that an RTEN opinion will be required for the site. If this is the case, the assessor should consider involving an auditor at this stage to provide guidance on the RTEN process.

[13] Defined in Section 3(1) of the EP Act.

The risk assessment should consider both deliberate and inadvertent exposure to groundwater contamination for both on- and off-site receptors.

2.2 Notification of significant hazardous circumstances

When an assessor is undertaking investigative work on a site, the assessor is expected to notify the EPA as soon as reasonably practicable if any significant hazardous circumstances are identified. Such circumstances include:

- accumulation of or significant risk of accumulation of asphyxiating, toxic or flammable gas (eg landfill gas), in an enclosed space where there is risk of an explosion or other similar risk
- free flammable hydrocarbon products appearing at the surface or within sub-surface conduits where access to these is not adequately controlled (eg stormwater, sewer or service conduits off-site) and where the presence of these products may pose an explosion or other risk
- discharge of groundwater contamination to waters at concentrations that are likely to have impacts on aquatic life
- presence of inappropriately controlled dangerous goods on-site, whether below or above ground such that they present a significant risk to human health, environment or to structures
- off-site transport of contaminated soil or groundwater that is likely to result in harm or site contamination at another property
- inappropriate management of remediation activities that may result in significant impacts to adjacent and nearby land and the community.

Determining whether a particular situation represents a significant hazardous circumstance will require the assessor to exercise their independent professional judgment. In general, any notification of significant hazardous circumstance should occur verbally as soon as the assessor becomes aware of it. Verbal notification should be followed up in writing within 48 hours.

In addition, where the nature of the hazard warrants it (eg an immediate, uncontrolled explosion hazard), advice should also be provided to:

- police and/or fire brigade; and/or
- EPA's 24 hour/7 day Incident Line, Tel: 8204 2004 (metro) or 1800 100 833 (country).

2.3 National risk assessment framework documents

There are a number of national risk assessment documents that provide guidance for undertaking a risk-based assessment and, in particular, in relation to groundwater. This guideline has been based on the documents listed below. For clarification of the requirements for risk assessment refer to these documents.

2.3.1 NEPM

The NEPM provides a national framework for the assessment of groundwater contamination. It outlines general processes for conducting human health and environmental risk assessments.

Schedule B(6) of the NEPM provides a framework for a risk-based assessment of groundwater.

2.3.2 enHealth

The Department of Health and Ageing and the Health Council have published G*uidelines for assessing human health risks from environmental hazards (2002)* and the *Australian exposure assessment handbook (2003)*. The publications are primarily focused on human health but provide guidance for environmental health risk assessment for sites that have been impacted by contamination.

2.3.3 Australian Standards

AS/NZS 4360:2004 Risk management provide a generic guide for measuring risk but has not specifically been developed for providing guidance on the risk of contamination of groundwater. The standard provides generic guidance for establishing and implementing effective risk management processes in any organisation. It demonstrates how to establish the proper context and then how to identify, analyse, evaluate, treat, communicate and monitor risks.

HB 203:2006 Environmental risk management—Principles and process presents an integrated framework of principles, practices and criteria for implementing best practise in environmental risk management. Guidance in this standard is based on the process in AS/NZS 4360:2004.

2.4 Human health risk assessment

The framework for undertaking a quantitative health risk assessment is outlined in the NEPM and enHealth documents. This framework consists of four stages:

- issue identification
- hazard assessment
- exposure assessment
- risk characterisation.

This framework provides quantitative estimation of risk and is based on an estimated exposure to a chemical substance and the likelihood that this will give rise to an adverse effect.

The EPA expects that a quantitative health risk assessment is undertaken in accordance with the NEPM and the enHealth guidelines.

2.5 Ecological risk assessment

The framework for an ecological risk assessment is similar to the one adopted for the human health risk assessment. The framework is outlined in Schedule B(5) of the NEPM and in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).

The NEPM recommends that ecological risk assessment are undertaken as a staged approach comprising three levels of assessment. Each level has the same components with increasing degrees of complexity and data collection requirements. The level of assessment that may be required depends upon the following factors:

- nature and extent of the site contamination
- sensitivity of the receiving environment
- availability of exposure and toxicity data.

The potential for on- and off-site receptors should be considered at every site being assessed.

The components of an ecological risk assessment are the same regardless of the level of screening being undertaken. The five basic components are:

- identification of the problem
- identification of the receptor
- exposure assessment
- toxicity assessment
- risk characterisation.

Detailed information on the tiers and components of the ecological risk assessment can be found in Schedule B(5) of the NEPM and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).

2.6 Stages in the assessment process

The EPA has adopted a two-stage process for the assessment of groundwater contamination, developed in accordance with the NEPM. The first stage of the process involves an initial SRA which will determine if groundwater contamination exists at a site. The second stage of this process is a DRA which will determine the level of risk that the chemical substances present to human health and/or the environment.

2.7 Screening risk assessment

If it has not been determined that groundwater contamination exists at a site, a screening risk assessment (SRA), as outlined in Appendix 2, should be undertaken.

The SRA will determine whether or not site contamination of groundwater as defined by the EP Act exists at the site (refer to Section 1.7). **This guideline assumes that a SRA has been undertaken at the site and that site contamination of groundwater exists.** If the EPA has been notified through the Section 83A process, it is likely that a SRA has already been undertaken. However if the EPA considers that the SRA has not been undertaken to a level that addresses the risk at the site, it may require that the SRA be reassessed and resubmitted by the provisions of a SCAO.

2.8 Detailed risk assessment

The primary goal of a DRA is to obtain an accurate measure of the nature and extent of the concentration of a chemical substance(s) and the level of risk that the chemical substance(s) poses to human health and/or the environment.

The DRA will determine the degree of exposure and the urgency of any remediation, and also what the remediation targets will be.

Once the EPA has reviewed the DRA and considers that the BUA and level of risk are appropriate for the site, an assessment of the remediation options can be undertaken.

The DRA of the site is made up of the following components:

- a conceptual site model (CSM)
- a BUA to determine what beneficial use/s of groundwater need to be protected at the site
- determination of human health and/or environmental risk
- changes in site condition.

These are discussed in detail in the following sections.

2.8.1 Conceptual site model

The CSM is fundamental to site characterisation. It needs to be developed by a person with appropriate expertise in the area of hydrogeology as one of the first steps of site characterisation prior to any intrusive works being undertaken. The CSM provides a framework needed for identifying and filling data gaps and is used as a basis for developing remediation strategies at the site and needs to accurately reflect site conditions. As more detailed information becomes available and the nature of the site contamination is better understood, the CSM should be progressively revised and updated.

The CSM is a representation of the physical hydrogeological system and its hydrological behaviour. It describes the groundwater in the vicinity of the site, how the site interacts with the groundwater and potential pathways by which chemical substances may migrate.

The CSM needs to identify complete and potential pathways between the source and the receptor. Where the pathway is incomplete the exposure to the chemical substances via that pathway cannot occur. It must also consider the potential for new exposure pathways to be created (for example by a change in land use).

Particular attention in the development of the CSM should be focused on the proper location and installation of monitoring wells, and the implementation of appropriate sample collection procedures and laboratory analyses.

Remediation technologies that do not perform as expected at sites are often due to the development of an inadequate CSM, and are not a result of the remediation technology.

The CSM should include, but is not be limited to:

- review of all environmental assessment work undertaken at the site
- local and regional geology and hydrogeology, identifying all aquifers at or in the vicinity of the site and the relationship between the aquifers including:
  - representative drilling logs of the area
  - well logs including construction details
  - existing monitoring wells and records of registered wells in the vicinity of the site.

  This information is available from the Department of Water, Land and Biodiversity Conservation (DWLBC) website <https://des.pir.sa.gov.au/desHome.html>.
- a basic assessment of hydraulic conductivities and porosities
- investigation of the groundwater flow domain for aquifer of interest, including:
  - expected elevation of groundwater
  - any lateral and vertical hydraulic gradients
  - likely groundwater flow direction
  - seasonal variation in groundwater flow direction
  - sources of recharge and extraction
  - possible discharge points
  - likely impact on deeper aquifers
  - any other hydraulic barriers or boundaries
  - hydraulic interconnection between aquifers, and
  - factors relating to fate and transport.

- identification of the chemical substances including:
  - chemical compositions
  - physical characteristics—density, viscosity, mobility, volatility and solubility
  - persistence of the chemical substance
  - toxicity of the chemical to humans and/or ecology
  - physical-chemical and biochemical transformations which may occur as the chemical substances migrate and/or degrade.
- assessment of sources including:
  - identify location of all source/s and type of chemical substance/s
  - whether it is necessary to assess the on-site soil contamination as an ongoing source of groundwater contamination. This includes a determination of concentrations of chemical substances in the soil matrix and an evaluation of the potential for dissolution into aqueous phase and migration to the water table
  - the nature of the chemical substance including composition, age, and volume.
- dimensions of the groundwater plume (vertical and horizontal extent)
- stability of the groundwater plume. At a minimum the assessor should demonstrate that the plume is stable, expanding or contracting
- modes of migration of the chemical substance (eg leaching through soils)
- receptors and exposure pathways including:
  - identification of potential receptors including surface water bodies, groundwater dependent ecosystems and vapour flux receptors
  - how exposure will occur (ie the exposure pathway route)
  - a diagrammatic representation of the various exposure pathways
  - determining if exposure pathways are complete
  - future potential receptors and exposure due to land use change.

All data should be incorporated into the CSM as it becomes available. The updated CSM should then be used to identify any remaining data gaps and additional work that needs to be undertaken.

2.8.2 Beneficial use assessment

Approach

An important stage of a DRA is to undertake a BUA to determine what beneficial use/s of groundwater need to be protected at the site. The BUA is linked to the environmental values as defined in the Water Quality EPP but the determination of the beneficial use of the aquifer does not result in the environmental values for the aquifer being changed in the Water Quality EPP.

In accordance with the NEPM[14], a BUA should assess the groundwater on the basis of its suitability for current or realistic future use and the risk that the use may pose to human health and the environment. **The EPA requires the protection of existing and potential**

[14] NEPM Schedule B(6)—Guideline on Risk Based Assessment of Groundwater Contamination.

beneficial uses of groundwater. In this guideline, beneficial use refers to the existing and potential beneficial use of the groundwater.

Potential realistic beneficial uses are those uses that could be supported by the background[15] groundwater quality, and are based on the inherent ability of the aquifer to support those uses. For example a potable beneficial use is considered likely if there is potential future usage of the aquifer for that purpose without any significant pre-treatment (eg desalination).

All beneficial uses of groundwater will need to be identified. Groundwater may have a beneficial use for any of the following:

- Aquatic ecosystems: these include surface water (including marine) ecosystems and groundwater ecosystems. The BUA should consider marine ecosystems as a beneficial use where groundwater is likely to discharge to the marine environment.
- Potable use: this water is intended for human consumption (drinking and domestic use).
- Recreation and aesthetics: primary contact covers activities that involve full body contact with the water such as swimming, surfing, diving and water skiing. Aesthetic (visual) use does not involve physical contact with the water but covers the visual appearance and enjoyment of the water.
- Industrial use: this covers the incorporation of water into any industrial process, such as bottled water or beverages and includes activities such as cooling, heating, washing and evaporation.

The following scenarios are not a beneficial use of the water but need to be considered in the BUA:

- Human health in non-use scenarios: this includes exposure to volatile chemicals through vapour flux where there is no contact with the groundwater.
- Buildings and structure: this includes protection from chemical substances degrading building materials through contact (eg weakening of footings).

There may also be a need to ensure that groundwater in certain areas is free from chemical substances that may cause damage to pipes and underground services. For example hydrocarbons and solvents can degrade PVC pipes and conduits. Similarly, service trenches can act as a preferential pathway for volatiles.

Where it has been determined that there is more than one beneficial use of an aquifer, the EPA will apply the most stringent protected environmental value at the site.

A beneficial use of an aquatic ecosystem should be considered as being appropriate in the area if there are existing receptors. These receptors may be in the form of wells, springs, rivers, marine or wetlands. These receptors will be assumed to interact with groundwater unless it is demonstrated that there is no pathway between the groundwater and the receptor.

Requirements of a beneficial use assessment

The EPA recommends that a systematic approach is taken towards establishing the beneficial use of the aquifer and that the BUA is undertaken by a suitably qualified and experienced hydrogeologist. In determining the beneficial use of the aquifer, it must be demonstrated that the information used is relevant to the aquifer at the site. Lithological and stratigraphic heterogeneities and variabilities of aquifer parameters and water chemistry must be considered when establishing the beneficial use of the aquifer. The EPA will accept aquifer

[15] Refer to EPA guideline, Site contamination: Determination of background concentrations.

data from an adjacent location if it can be shown that the data is from the same hydro-stratigraphic unit as the aquifer being tested. However, site-specific information usually provides a more accurate picture.

The beneficial use of an aquifer is determined on a site-specific basis. In some cases it will be easy to determine the beneficial use. For example if drill hole records indicate that groundwater in the vicinity of the site is used for domestic purposes, then this water has a beneficial potable use, unless it can be demonstrated that the water is not used for potable purposes but has some other use. The EPA acknowledges that DWLBC do not distinguish the types of domestic use and as such the use may not necessarily be for potable purposes but for irrigation of gardens. The assessor will need to determine the type of use that is likely for that water. For example the shallow aquifer through metropolitan Adelaide would not be considered for a potable water supply. Based on the salinity of the water and the fact that a town water supply is available for potable use, the assessor would consider that the use of the water from the shallow aquifer is for irrigation for domestic purposes. However if water of the same salinity was being utilised in a regional area with no mains water supply, it may be assumed that the beneficial use of the water is for potable purposes.

Site stratigraphy

An assessment of the site stratigraphy should provide detailed information on the occurrence and flow of groundwater at the site. The amount of detail in the assessment should reflect the hydrogeological complexity of the site.

Stratigraphy must be correlated across the site between enough different locations to determine the continuity and thickness of the aquifer. At all locations, the lithological profile must be logged based on soil type, appearance and hydraulic properties.

Saturated thickness

It is important to determine the saturated thickness of the aquifer for a BUA. If the beneficial use of the aquifer is already known and the chemical substance is a light non-aqueous phase liquid (LNAPL), then there may not be a need to determine the full thickness of the aquifer.

For an unconfined aquifer, the saturated thickness is the vertical distance from the standing water level to the base of the unit. For a confined aquifer, the saturated thickness is equal to the stratigraphic thickness of the aquifer (ie the distance from the upper surface of the permeable unit to its base).

The thickness of the aquifer should be recorded on the well log along with the depth that water was intersected and a final standing water level.

Characterisation of the aquifer

The aquifer affected by groundwater contamination at the site needs to be characterised. This involves recognising any different lithologies and hydraulic properties in the aquifer over the site to:

- ensure that the lithology encountered on the site is consistent with the general geology of the area
- identify any small-scale stratigraphic variations, such as thin alternating sequences. Coarse grained sediments typically possess higher hydraulic conductivities and act as preferential pathways for chemical substances.

Determination of hydraulic interconnectivity of aquifer

In order to establish the beneficial use of the groundwater at a site it needs to be established which aquifers are/or could be affected by groundwater contamination. For example, if

groundwater contamination has been identified in a shallow aquifer, it needs to be demonstrated that the contamination does not extend to nor has the potential to affect a deeper aquifer.

Interconnection between aquifers may occur as a result of stratigraphic connections, artificial penetrations or leakage through confining layers. Where it has been determined that there is a hydraulic connection between aquifers and that the two units behave as one, the aquifers may be considered as one.

The information in Table 1 presents the type of information that can be used to allow for a determination of aquifer interconnectivity.

Table 1 Information needed to determine hydraulic interconnectivity

Type of information	Examples for use in determining hydraulic connectivity	
	Not interconnected	**Interconnected**
Stratigraphic data Thickness, continuity, hydraulic properties of confining layer	Homogenous, unfractured, continuous clay strata in confining layer >5 m in thickness	Confining unit is laterally discontinuous, fractured or composed of permeable material
Standing water level Relative hydraulic heads in separate aquifers	Significant SWL difference between wells screened above and below the confining unit	SWL are the same above and below the confining unit
Impacted groundwater Presence or absence of chemical substances in groundwater		Impacted groundwater present in all aquifers
Natural groundwater quality Contrast in groundwater quality characteristics (TDS, major ion distribution)	Separate aquifers exhibits significantly different TDS and/or major ion distribution from the impacted aquifer	
Field hydraulic conductivity test In-situ hydraulic conductivity tests undertaken on confining unit	Confining unit is laterally continuous with vertical hydraulic conductivity $\leq 10^{-9}$ m s^{-1}	Confining unit has vertical hydraulic conductivity $\geq 10^{-9}$ m s^{-1}
Aquifer pumping test Field test to evaluate effect of pumping unaffected aquifer on SWL in impacted aquifer	No measurable SWL drop observed in impacted aquifer within 24-hour period of continuous pumping from unaffected aquifer	Measurable SWL drop observed in impacted aquifer as a result of pumping unaffected aquifer

Determination of current groundwater use

The current groundwater use and the use of any hydraulically interconnected units must be determined. Locations of licensed wells and their purposes can be obtained from the Drillhole Enquiry System located on the DWLBC website <https://des.pir.sa.gov.au/desHome.html>.

The EPA recommends that the locations of all wells within an appropriate distance of the site be identified. It may be necessary in some cases to verify the location, status and the purpose

of a well to determine if the information is accurate and if it can be used in the determination of current groundwater use. For example if the database indicates that an operational domestic well is located near the site and the groundwater conditions on the site indicate that the groundwater would be unsuitable for domestic use, it may be necessary to verify the purpose of the well.

It is also important to note that if the beneficial use of the groundwater is not potable and there are registered groundwater wells for domestic usage in the vicinity of the site in the same aquifer, then the EPA will consider the aquifer suitable for potable use, unless it can be shown that the wells are not used for that purpose.

If there are wells within a 2-km radius of the site that are used for a purpose not compatible with the proposed beneficial use, but these wells are up-hydraulic gradient and it can be demonstrated that the chemical substances will not impact on the wells, the EPA will have regard to the proposed beneficial use.

Determination of realistic potential use

The EPA considers that beneficial use of groundwater is potable unless proven otherwise. To determine whether or not an aquifer has a realistic potential potable use the EPA recommends undertaking the following steps:

- check with DWLBC and SA Water to determine if the aquifer is of drinking water quality and may be utilised in the future
- identify nature/type of groundwater users in the area
- refer to Total Dissolved Solids (TDS) as an indicator parameter.

As discussed previously, the EPA considers that groundwater has a realistic potential potable use if the aquifer in its ambient state can be utilised for that purpose without significant pre-treatment. For some regional areas the aquifer may be considered as having a realistic future potable use if the only pre-treatment required would be reverse osmosis.

The EPA considers that groundwater with a TDS concentration of less than 2,000 mg/L is suitable for a potential drinking water supply and should have the same level of remediation as potable unless site-specific factors (such as low yield) would render the use unlikely. TDS is not an appropriate indicator to use for other beneficial uses.

It should always be assumed that groundwater is discharging to an identified surface water body unless it can be demonstrated that it is not. All beneficial uses of that surface water (such as recreational and potable usage) warrant consideration unless the site has been fully characterised and it has been determined that discharge to the surface water will not occur. This investigation will also need to take into consideration any potential changes in groundwater flow direction.

Determination of natural groundwater quality

In order to determine the beneficial use of the groundwater, the nature of the groundwater needs to be determined. This **does not** relate to the background concentrations of the chemical substances due to the PCA that has occurred at the site. Rather it relates to the naturally occurring chemical substances that are present in the groundwater. For example, to determine a beneficial use, the TDS of the groundwater must be known. To determine the natural groundwater quality, unless there is reliable information available, samples should be collected from one or more background wells in the affected aquifer and any interconnected aquifers. Where there is published data (eg DWLBC and EPA ambient monitoring networks) it may be appropriate to use this data at the site; however, the age and the integrity of this data need to be considered.

To determine natural groundwater quality in the affected aquifer, the EPA recommends analysing samples for TDS, metals, major ions, organics (eg nitrate) and any other chemical substances that the assessor considers could be naturally elevated in the groundwater. Collection and analysis of groundwater samples must be undertaken in accordance with the EPA Guideline, *Regulatory monitoring and testing—Groundwater sampling (2007)*.

If there are elevated concentrations of chemical substances in the groundwater as a result of natural background concentrations, this may change the beneficial use of the water. For example the groundwater may have a TDS that would make the groundwater suitable for potable use; however where the concentration of arsenic (not attributable to site contamination) is elevated above the protected environmental value the water may not be used for potable purposes without some form of pre-treatment.

To determine the appropriate beneficial use of the groundwater the following protected environmental values are to be used:

- Water Quality EPP (Schedule 1 and 2)
- Australian Drinking Water Guideline (ADWG)
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000).

By comparing the concentrations of chemical substances in the groundwater with these guidelines, it should be possible to determine a beneficial use of that water. If it is unclear as to what the beneficial use of the groundwater is, then the assessor should contact the EPA.

Determination of aquifer productivity

The ambient concentration of chemical substances in groundwater is not the only parameter that is necessary in determining the beneficial use of the aquifer. Aquifer parameters and aquifer yield determinations also need to be considered. Any aquifer yield calculation and hydraulic parameter must be determined or estimated from the affected aquifer using appropriate methods.

In identifying aquifer yield, it must be recognised that information about the aquifer on a regional scale may not be valid locally. For example, a fractured rock aquifer may have a low yield on a regional scale and would not sustain certain beneficial uses, but on a local scale the yield may be enough to sustain these uses.

There are beneficial uses that do not require significant yield but cannot be disregarded in context. These uses include wetlands, rivers or creeks that are hydraulically connected to the aquifer that is being assessed. If the ambient quality indicates that the groundwater could be used for a potable resource but the aquifer properties and the well yield indicate that the aquifer cannot sustain that use, then the EPA will consider a different beneficial use for the aquifer.

Measurement of hydraulic conductivity

Wells used for the purposes of measuring hydraulic conductivity (K) have to be properly constructed and developed so that an accurate indication of the hydraulic properties can be determined.

All design and interpretation of the methods used to determine hydraulic conductivity must be undertaken and interpreted by a suitably qualified person with an appropriate level of experience (eg a hydrogeologist).

Measurements of K have to be undertaken at a sufficient number of locations to provide a representative characterisation of the affected aquifer. When an aquifer has a K that is too low to effectively test (for example no recharge is observed during a test period of appropriate duration) then an assumption that K is less than 1×10^{-7} m/sec may be

appropriate, provided the assessor can justify that K is reflective of the aquifer and is not due to the design, construction or development of the well (eg insufficient well screen, partial penetration).

If slug tests are used to measure K, then the tests must be conducted at a minimum of three locations over the site to provide a representative measure of variability. Also a minimum of three slug tests must be undertaken at each well to evaluate the possibility that 'skin effects'[16] are dominating the results.

The representative K for an aquifer is the geometric mean of the results from each well for the aquifer. The representative K of a single well is the arithmetic mean of the results from that well. The geometric mean is defined as:

$$\mathrm{K} = \sqrt[n]{K_1 \cdot K_2 \cdot \ldots K_n}$$

Where,

K = representative hydraulic conductivity

K_1 = well hydraulic conductivity values

n = number of measurements

The general procedure for a single well test involves:

- measuring the initial standing water level
- measuring an instantaneous positive or negative change of water level, and
- measuring the recovery towards standing water level at appropriate time intervals.

Aquifer sustainability

In order for an aquifer to be representative of a beneficial use, it must be able to sustain that beneficial use. All well yield determinations are considered to be representative of a sustainable aquifer. However a short-term hydraulic test cannot always predict the consequence of long-term withdrawal from an aquifer. Alternative methods may need to be applied to demonstrate that an aquifer is not sustainable.

The assessor must ensure that the aquifer yield is representative of the aquifer and is not influenced by the design, construction or development of the well (eg insufficient well screen, partial penetration).

Ephemeral saturation (seasonal aquifers)

If it can be demonstrated that an aquifer is historically ephemeral (not saturated all the time) and does not have a hydraulic connection with other aquifers, the EPA will consider that the use of that aquifer be changed based on the premise that it does not produce a sustainable yield. However, this will need to be demonstrated to the EPA, through such methods as documented historic water levels.

Examples of ephemeral saturation include aquifers that are dry on a predictable basis. These may be due to a perched aquifer underlain by unsaturated soils during dry weather periods. However if that aquifer is able to be used for a beneficial use during the period when the aquifer is saturated then the beneficial use will be the one that it is currently being utilised for.

Aquifers of limited hydrogeological extent

[16] See glossary.

The assessor may be able to demonstrate that the aquifer is not extensive laterally and/or volumetrically and/or be hydraulically isolated from other aquifers and other sources of recharge. In such scenarios the aquifer may not sustain long-term pumping and as a result a different beneficial use may be considered. To demonstrate this, site-specific and regional investigations may need to be undertaken. It will be necessary to determine the geometry of the affected aquifer.

Karst or fractured rock aquifers

A karst aquifer is defined as an aquifer of soluble carbonate rock in which water flows through joints, fractures, faults, bedding plane and/or cavities which have been enlarged by dissolution.

A fractured rock aquifer is one that exhibits breaks, whether or not caused by displacement, resulting from mechanical failure due to stress and includes cracks, joints, faults and other mechanical discontinuities where groundwater movement is limited mainly to fractures.

In environments where the karst or fractures are the primary control on groundwater flow, and porous flow is not the dominant flow mechanism, then all aquifer parameter measurements and calculations are to be undertaken with methods that are appropriate for karst or fractured rock.

In these units, unless it can be demonstrated otherwise, the beneficial use of the aquifer will be the current or realistic future use based on TDS. If there is the potential for the presence of groundwater dependant ecosystems, these must be considered as part of the BUA.

2.8.3 Changes in site conditions

When a DRA is undertaken, the assessor has to consider all relevant information for the site. If conditions change at the site (eg change of land use) or new information becomes available, the DRA should be reviewed to determine if the changes affect the outcomes of the initial DRA. If, as part of the site investigation, previously unidentified site contamination is found, the EPA should be contacted and the DRA re-evaluated where necessary.

2.8.4 Who can undertake a detailed risk assessment

A detailed risk assessment should only be undertaken by consultants and auditors who have demonstrated experience and qualifications in undertaking such work.

2.8.5 Reporting requirements for a detailed risk assessment

Appendix 3 provides a template of the requirements recommended by the EPA for inclusion in the detailed risk assessment submitted for review.

2.8.6 Outcomes of detailed risk assessment

The EPA will review the DRA to ensure that the level of risk appropriate for the site and that the outcomes have been prepared in accordance with this guideline and any other relevant guidelines.

If as part of the DRA, an auditor has been engaged to provide a SCAR in the form of an RTEN opinion or any other audit requirement, the EPA will not review the DRA for the site. If the auditor supports the outcomes of the DRA, the EPA does not need to review the DRA.

Based upon the conclusions of the DRA, if it has been determined that there is a risk to human health and/or the environment, a ROA will need to be prepared. An ROA is not necessary if there is no risk to human health and/or the environment.

The EPA may recommend a periodic review of the DRA for sites that have demonstrated that there is no risk to human health and/or the environment to ascertain that the level or risk has not changed at these sites.

3 REMEDIATION

The ultimate goal of remediation of groundwater should be to select a socially and environmentally acceptable and cost-effective strategy that removes the threats to human health and the environment.

3.1 Overview

Once a DRA has shown that the site poses a risk to human health and/or the environment, the EPA may require remediation to be carried out.

The EPA recommended approach for the remediation of groundwater contamination involves either the development of a remediation proposal (in the form of a ROA) or an RTEN opinion. The approach selected will depend upon the level of risk identified. For example, remediation of groundwater that is likely to impact on a town water supply well, will require an RTEN opinion compared to a site that has no off-site impacts and where the plume has been demonstrated to be stable.

Figure 2 presents an overview of the remediation process.

3.2 Difference between audit and non-audit sites

The EPA does not expect assessment and remediation of groundwater contamination will differ between sites that are being audited for different reasons (eg to satisfy requirements of the *Development Act 1993* or the EP Act).

Audits may be carried out for the purpose of determining one or more matters[17], including determining the suitability of a site for its intended use. If a site is the subject of an audit for any purpose and assessment and remediation of groundwater is required, it is expected that this is undertaken in accordance with these guidelines.

If it is determined as a result of the DRA or at any earlier stage of the assessment process that an RTEN opinion is required, the appropriate person will have to commission an audit and engage an auditor.

If an RTEN opinion is required for a site that is not already subject to an audit, it will be necessary to commission an audit for this purpose.

Where a site is already subject to an audit and it is determined in accordance with this guideline that an RTEN opinion is not required, then the audit process must continue to be carried out in accordance with the relevant EPA guideline.

Where ongoing remediation is required to address groundwater contamination at a site subject to audit, the EPA expects that the auditor will include appropriate conditions in the audit report addressing what remediation is or remains necessary for the beneficial use of the water.

[17] For more information refer to the EPA guideline: *Site contamination—Guidelines for the site contamination audit system* (2009).

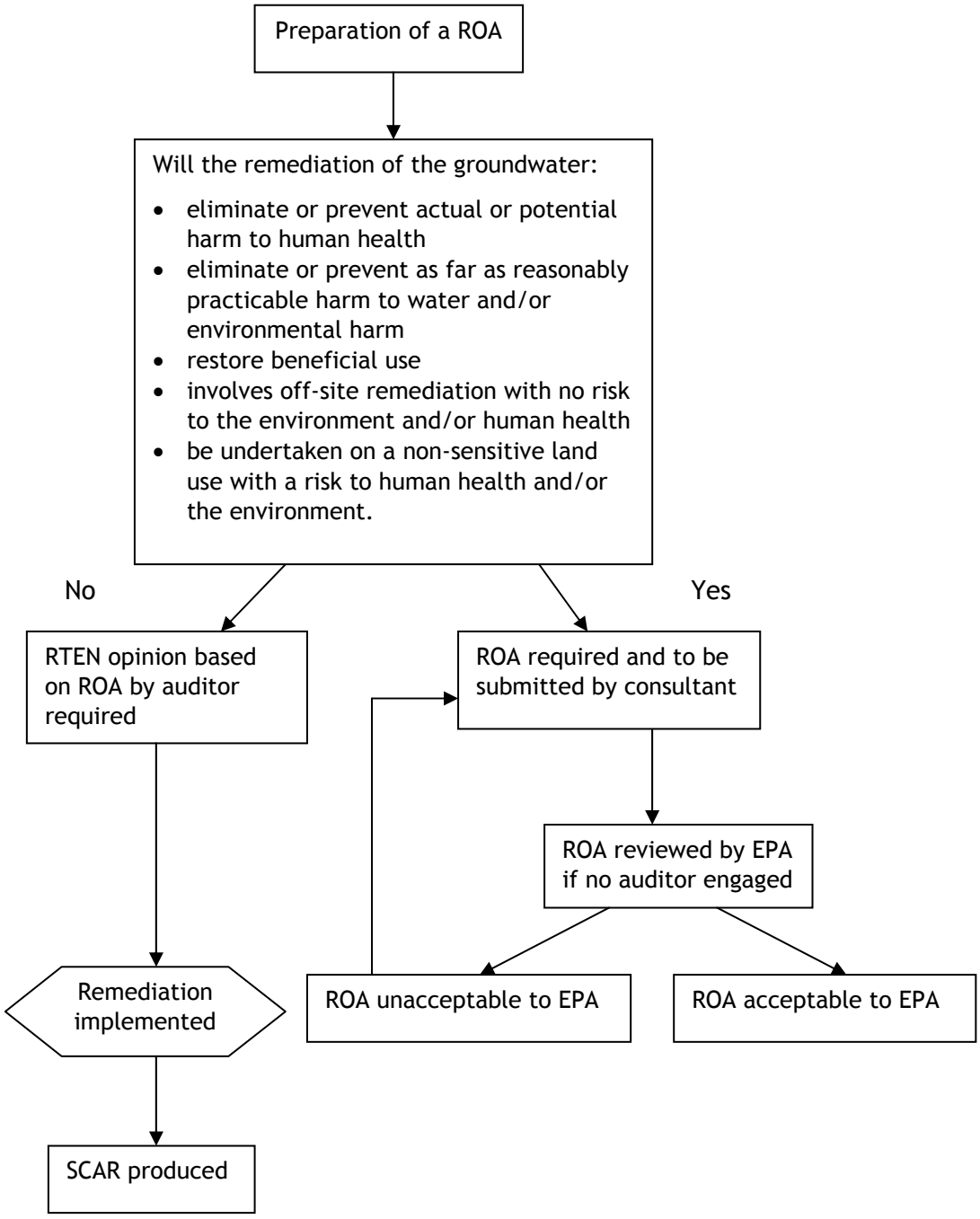


Figure 2 Overview of remediation process

The EPA expects remediation of groundwater will be prioritised in order to minimise the risk to human health and to restore potable aquifers and aquifers that are hydraulically connected to surface waters.

Components of remediation process may include but are not limited to:

- notification to stakeholders of the presence of groundwater contamination
- containment of the plume
- removal of the source
- active or passive removal of chemical substances
- interim action to mitigate an immediate human health risk

- ongoing monitoring of groundwater
- development of contingency plans
- restriction or prohibition on the taking of groundwater.

The most appropriate remediation measure at a site will depend upon the following factors:

- nature and extent of the contamination
- the risk to human health and/or the environment
- the availability of practical remediation technology
- community expectations
- the likelihood of remediation
- the ability of the remediation method to prevent further migration of the chemical substances
- the timeframe to undertake the remediation.

The EPA must consider the Objects of the EP Act which give rise to the consideration of the community's right to utilise groundwater. There may be a need to consult with the community on the proposed remediation strategy where they may be affected.

The EPA recommends that the following criteria are considered when evaluating remediation methodologies for a site:

- long-term reliability and effectiveness, along with the degree of certainty that the final remediation method will remain protective of human health and the environment, considering the risks of the site from treatment residuals and any containment systems
- the timeframe for remediation, ongoing responsibilities and access to the site
- reduction of the toxicity, mobility or mass of chemical substances through remediation and how the method addresses the principal threats posed by groundwater contamination
- the degree to which the methodology reduces the toxicity, mobility or volume of groundwater contamination
- the remediation process to be used and the amount of chemical substances that will be treated, the degree to which the methodology is irreversible and the types of treatment residuals that will be produced
- short-term effectiveness and short-term risk the remedies might pose, along with the amount of time it will take for remediation design, construction and implementation
- ease or difficulty of remediation implementation considered as appropriate; the technical feasibility of constructing, operating and monitoring the remediation
- the availability of services and materials, including capacity and location of needed treatment, storage and disposal services
- capital as well as operation and maintenance costs
- the impact on the day-to-day use of the site (eg infrastructure)
- the degree to which the remediation is acceptable to the surrounding community
- the degree to which the remediation would be acceptable to the EPA.

The EPA encourages the appropriate person to focus their evaluations on realistic remediation methods and tailor the scope and substance of the remediation assessment to reflect the complexity of the groundwater contamination and hydrogeological conditions at the site.

The EPA recommends that where there is a straightforward solution (eg standard engineering solutions which have proven effective in similar situations), it may not be necessary to evaluate more than one remediation method. However if only one method is evaluated, the EPA will take into account whether this method is appropriate at the site and may require justification of the proposed remediation method.

3.3 Remediation options assessment

Once a DRA has been provided to the EPA that demonstrates there is a risk to human health and/or the environment, a ROA of the site needs to be prepared. The ROA can be prepared by the consultant who has undertaken the DRA and should be developed in conjunction with the DRA where possible.

The ROA can be submitted by a consultant and/or auditor for sites that have minimal risk to human health and the environment. It is developed for sites that have minimal impact on human health and the environment. If any of the answers in Table 2 is **NO** then an RTEN[18] opinion will be required.

Table 2 provides a template that should be submitted in the Executive Summary of the ROA report to determine if an RTEN opinion is required.

Table 2 Triggers for an RTEN opinion

Will the remediation of the groundwater:		
• eliminate or prevent actual or potential harm to human health?	NO	YES
• eliminate or prevent as far as reasonably practicable harm to water and/or environmental harm?	NO	YES
• restore beneficial use?	NO	YES
• involve off-site remediation with no risk to human health?	NO	YES
• be undertaken on a **non-sensitive** land use with no risk to human health (ie will it be on a sensitive use)?	NO	YES

If the level of risk at a site with an ROA in operation increases over the life of the ROA then the EPA will require that an RTEN opinion be submitted. For information on when an RTEN opinion is required, refer to Section 4.5.

The ROA must be submitted to the EPA for review. If the submission does not adequately address the level of risk or the remediation strategy at the site, the EPA may require any of the following be undertaken by a SCAO or a SRO:

- the ROA be revised and resubmitted, or
- an auditor is engaged to provide an RTEN opinion.

[18] For more information on a RTEN opinion refer to Section 4.3.

The ROA should take into consideration the following:

Selection of remediation technology

The selection of the remediation methodology for a site should be based on the DRA and should take into account the objectives of the EP Act[19]. Remediation technologies should be assessed according to:

- reliability and effectiveness
- reduction of chemical substance mass, toxicity and mobility
- timeframe for implementation
- cost—financial considerations relating to the equipment, installation and ongoing operational and monitoring costs
- logistics—access to the site, availability of materials and infrastructure and the disposal of wastes
- selecting the remediation method based on the current and expected future land uses at the site
- availability of technologies
- energy use and sustainability
- emissions (noise, volatiles and odour)
- immediate risks to human health and the environment.

Some remediation methods involve the discharge of chemical substances to air, land or water. The proposed remediation methodology should ensure that there is no adverse impact on the receiving environment. Where injection of a chemical substance is a requirement of the remediation methodology, the appropriate person must demonstrate that there will be no adverse impact on the receiving environment and that all relevant legislation including the Water Quality EPP is adhered to and, if required, an exemption is obtained.

Source control

Source control is a critical part of the selection of remediation technologies at a site. Source control refers to a range of actions (eg removal, in-situ treatment and containment) designed to protect human health and the environment by eliminating or minimising migration of, or exposure to groundwater contamination.

The EPA considers that most sites will need to control or eliminate the source of the groundwater contamination to achieve site-specific remediation goals. The determination of whether or not source control is required is based on the DRA. If the appropriate person considers that source control is not required (there is no current or future risk from the source) then this will need to be reported to the EPA. The appropriate person should also consider the following factors when determining how the source will be managed:

- long-term reliability of any control measures
- short-term risks
- community acceptance.

[19] Section 10 of the EP Act.

The appropriate person may consider that containment of a source is appropriate where:

- there is no remediation technology available that can be implemented within a reasonable timeframe
- only partial removal of a non-aqueous phase liquid (NAPL) is achievable
- the CSM indicates that the environment is not suited to source removal (eg fractured rock aquifer)
- the volume of material makes the implementation of any treatment impracticable, or
- the remediation method would result in an increase in the overall risk to human health and the environment.

Non-aqueous phase liquids

If a NAPL is present in the groundwater on site, it must be removed as far as reasonably practicable unless the DRA demonstrates that the NAPL does not pose a risk to human health and/or the environment and that it will not migrate over time.

Remediation timeframes

The remediation timeframe is an estimate of when groundwater quality will achieve a required beneficial use at a certain location. The EPA considers that remediation timeframes should be reasonable, linked to specific goals and based on site conditions. Factors that should be taken into account when developing remediation timeframes include:

- potential risks from exposure to groundwater contamination
- current and reasonably expected future land and groundwater use(s)
- type, source(s), and extent of contamination
- hydrogeological characteristics
- reliability of exposure controls
- design and capabilities of remediation technologies
- availability of treatment and/or disposal options
- community preferences
- financial resources of the appropriate person.

The EPA considers that the time taken to undertake remediation must be related to the level of risk at the site. There may be a need at higher-risk sites to remediate via a method that is not the optimal method for the site but will reduce the level of risk at the site.

For data interpretation purposes, a five-year period will provide an indication of the performance of the remediation system. Trend analysis of data should consider the climatic conditions and the possibility that changes in water levels at a site may result in the rebound of chemical substances. For example, when water levels decline, the smear zone for an LNAPL may not contribute to site contamination. However when water levels rise, the smear zone will contribute to groundwater contamination.

If an intermediate remediation goal is required, the timeframe to achieve that goal should be reasonable and based on site-specific factors. At sites where it is anticipated that the timeframe for the final remediation goal will be lengthy, establishing timeframes for intermediate remediation goals can provide meaningful measures.

The EPA recognises that the uncertainty associated with the remediation may make it impossible to specify a remediation timeframe with a high level of confidence. It is not always

possible to predict the length of time before the groundwater is returned to its beneficial use due to the following complexities:

- types of chemical substances,
- hydrogeological characteristics
- interactions of chemical substances
- technology limitations.

Under such circumstances, assessors should still attempt to predict the time needed to achieve the final remediation goal.

If monitored natural attenuation (MNA)[20] or ongoing monitoring are the only requirements for the remediation at the site and it is proposed that these continue longer than the five-year period, the EPA may require ongoing reporting. For additional information on the use of MNA and ongoing monitoring requirements refer to the EPA Information Sheet, 'Site contamination: Monitored natural attenuation and management monitoring' (to be published). However if the results indicate that the risk associated with the monitoring are increasing, then an RTEN opinion may be needed at a later stage.

3.3.1 Reporting requirements for a remediation options assessment report

Appendix 3 provides a template of the requirements that the EPA recommends are included in a ROA report provided to the EPA for review.

Where the duration of the remediation exceeds three months, the EPA requires the submission of progress reports. Submission timeframes for these reports are to be determined in the remediation schedule. Information on what is to be provided in these reports is included in Appendix 3.

3.4 Remediation to extent necessary

The EPA has determined that only an auditor can provide an RTEN opinion to the EPA; however this does not preclude the consultant from developing the remediation strategy at the site in the form of a ROA and having an independent auditor provide the RTEN opinion in accordance with the proposed remediation strategy.

It is recommended that where it has been identified an RTEN opinion is required, an auditor be engaged as soon as possible to provide guidance through the process.

For additional information on the requirements on the RTEN process refer to Section 4.2.

3.4.1 Difference between remediating to extent necessary and practicable

The EPA considers that there is a difference between remediating to the extent necessary and what remediation is practicable on sites.

The Macquarie Dictionary defines practicable as 'able to put into practise or done'. The EPA considers that just because a remediation strategy can be undertaken at a site and is technically feasible because it is practicable, does not mean that, a selected form of remediation is necessary at the site to prevent or eliminate the risk to human health and the environment.

The EPA considers that RTEN means undertaking remediation on a site to a level that is necessary to protect human health and the environment. For example, the EPA may require

[20] Refer to EPA information sheet, Site contamination: Monitored natural attenuation and management monitoring' (to be published).

that free phase hydrocarbon be removed from an aquifer where the groundwater is a risk to human health but may not require the removal of the free phase hydrocarbon if the site is located in an area where it can be demonstrated there is no risk to human health and the environment.

If groundwater has been impacted in an area where it can be demonstrated that there is no risk to human health or the environment now or in the reasonably foreseeable future (eg a remote location not in the vicinity of any sensitive receiving environment), the remediation strategy for that site would be different to a site located in a residential area and impacting on human health.

RTEN is not necessarily a lower level of remediation than practicable. For example, if the groundwater contamination presents a risk to human health, the EPA may require that the level of remediation that is required is to the extent practicable for the site (eg increased monitoring) due to the level of risk at the site.

3.4.2 When an RTEN opinion is required

An RTEN opinion must be provided to the EPA by an auditor if the remediation at the site will **not** achieve the following results:

- the elimination or prevention of actual or potential harm to human health
  - if the remediation strategy proposed for the site involves short-term remediation goals that result in harm to human health remaining on site (eg there is a vapour risk from the groundwater contamination which has the potential or has already impacted on properties).
- the elimination or prevention as far as reasonably practicable of harm to water and/or environmental harm
  - if after undertaking the remediation and having done everything reasonably practicable there is still harm to water and/or environmental harm.
- the restoration of the beneficial use
  - if the remediation methodology at the site will not restore the groundwater back to the beneficial use that was determined in the BUA (this does not include MNA or ongoing monitoring). Site-specific target levels may be set for sites.
- no risk to human health where remediation involves off-site remediation
  - the EPA considers off-site remediation has the potential to impact on adjoining properties and there is less control over the land use outside of the impacted site. As such remediation methods involving off-site remediation in areas that pose a risk to human health are a higher risk than other areas.
- no risk to human health from the groundwater contamination on land being used for a sensitive use
  - if the remediation will be undertaken on land that is being used for a sensitive use (eg residential, school) and poses a risk to the human health on the site. For example if a groundwater plume extends under residences and the risk assessment has identified that there is a risk to human health.

3.5 Staged remediation approach

The EPA considers that at some sites it will be necessary to implement a staged approach to remediation. In these situations the following process should be adopted:

- short-term remediation goals: to control the risk to human health or the environment

- intermediate remediation goals: occur between short term and long term goals and allow the appropriate person to achieve remediation on complex sites
- final remediation goals: defining what is required to achieve remediation of the groundwater so that the groundwater is restored to its beneficial use within a reasonable timeframe.

The EPA recommends that a professional with suitable qualifications and experience in remediation, in conjunction with the appropriate person implement the remediation goals in terms of clearly defined site-specific remediation objectives.

3.5.1 Short-term remediation goals

The EPA's expectation of short-term remediation goals is that humans are not being exposed to unacceptable concentrations of chemical substances and that groundwater contamination is not migrating beyond its current extent.

The DRA undertaken in the assessment stage (discussed in Section 3) will have identified if there is any current human exposure to groundwater contamination and would have delineated the extent of the plume.

Risk to human health

The remediation methodology should have considered all the direct and indirect ways that humans could be exposed to groundwater contamination. This includes risk of exposure to volatile chemical substances that may migrate via groundwater or via primary/secondary contact with groundwater contamination.

Migration of groundwater contamination

The plume should have been defined using an appropriate number of groundwater monitoring wells.

The EPA does not differentiate between groundwater contamination on and off site with respect to remediation targets.

The intent of this indicator is to demonstrate that the groundwater plume is not expanding regardless of whether the groundwater contamination is on or off site. However remediation of an off-site plume will often be of a higher priority and may require an intermediate (and sometimes urgent) remediation goal. It is harder to control the exposure and pathways outside of the site boundary.

3.5.2 Intermediate remediation goals

Intermediate remediation goals are site-specific measures that demonstrate progress towards final remediation goals.

The EPA recommends the establishment of intermediate remediation goals when the appropriate person can demonstrate that the goals provide progress towards final remediation goals and focus resources, improve environmental conditions and enhance the performance of the remediation. The achievement of the intermediate remediation goals does not relieve an appropriate person from meeting any site-specific final remediation goals. Intermediate remediation goals are often appropriate for sites with complex groundwater contamination.

The EPA considers that intermediate remediation goals help to prioritise the remediation strategy of a site and allow a phased approach to the remediation on site and the refinement of subsequent work. This approach also allows the appropriate person to achieve intermediate remediation goals at high priority areas of the site and address lower priority areas at a later time.

The EPA may consider that intermediate remediation goals are not appropriate for sites where the final remediation goals can be achieved within a short timeframe (eg months to five years).

If the appropriate person is unsure about the appropriate remediation strategy at the site and to what extent the final remediation strategy may work, the assessor may implement an intermediate remediation goal to assess and trial a technology prior to a formal evaluation and selection of the final remediation method.

Some examples of intermediate remediation goals include:

- source control (eg various combinations of removal, containment and treatment)
  - Pump and treat groundwater to prevent a groundwater plume from migrating off site. The DRA has identified a source (an area of impacted soil) that is contributing to the groundwater plume. The assessor determines that remediation of the source to an appropriate level is an intermediate remediation goal; monitored natural attenuation may be able to be the remediation method for the remaining groundwater plume.
- remediating off-site plumes
  - An off-site groundwater plume with vapours—installation of vapour recovery wells under homes to minimise exposure to humans. By focusing on achieving remediation of the off-site groundwater plume as an intermediate remediation goal, the site is able to reduce the risk to humans by not relying solely on the vapour recovery system.
- prioritising work
  - A large site has several areas that need to be remediated, but has limited resources or space for the remediation. The EPA and the appropriate person work together to establish a sequence of intermediate remediation goals directed towards the final remediation goal. In establishing the work to be undertaken the EPA and the appropriate person will consider the relative risk associated with the contamination in different areas. A series of intermediate remediation goals can then be established with different timeframes for the different areas based on risk.
- trialling remediation methods
  - Groundwater contamination exists and it is proposed to remediate via a pump and treat method; however it is unclear due to the heterogeneity of the aquifer if this methodology will work. A trial is proposed to be undertaken on a portion of the plume area to determine the effectiveness of the method. An intermediate goal is made based on the methodology with a timeframe that is reasonable to determine the effectiveness of the method.

3.5.3 Final remediation goals

The EPA expects that as a final remediation goal groundwater should be returned to its maximum beneficial use wherever necessary within a timeframe that is reasonable for the proposed remediation option. However it is acknowledged that at some sites it may be impossible to restore the beneficial use of the aquifer and as such site-specific concentrations for chemical substances may be established for the site. Any establishment of site-specific target levels would need to provided in an RTEN opinion.

3.6 Institutional controls

Institutional controls are non-engineered measures such as administrative and legislative controls that minimise the potential for human exposure to plumes by limiting land and groundwater use.

The EPA expects to use institutional controls such as water restriction and prohibition zones[21] to supplement remediation methods to prevent or limit exposure to groundwater contamination. These controls are applicable during all stages of remediation. The EPA does not consider the use of water restriction and prohibition as a form of remediation; it is an institutional control that is used to minimise the risk to human health.

Where there is groundwater contamination off site and remediation will be required, the EPA may require that consultation with relevant stakeholders is undertaken (this may include the community, industry or local government) to determine the impacts on the stakeholders.

[21] For more information refer to EPA guideline 'Site Contamination—Water restriction and prohibition zones' (to be published).

4 GROUNDWATER REQUIREMENTS FOR AUDITORS

The EPA has determined that an RTEN opinion can only be provided by an auditor.

An RTEN opinion may be necessary for a site that is already subject to a site contamination audit being carried out. However it is envisaged that the majority of RTEN opinions will be for sites that are not being audited. However once the determination has been made that an RTEN opinion is required, the site will then become subject to an audit.

An audit is defined in the EP Act as:

> **Site contamination audit** means a review carried out by a person that—
>
> (a) examines assessments or remediation carried out by another person in respect of known or suspected site contamination on or below the surface of a site; and
>
> (b) is for the purpose of determining any one or more of the following matters:
>
> (i) the nature and extent of any site contamination present or remaining on or below the surface of the site;
>
> (ii) the suitability of the site for a **sensitive use** or another use or range of uses;
>
> (iii) what remediation is or remains necessary for a specified use or range of uses.

The EPA considers that an RTEN opinion falls within the definition of an audit, specifically (b)(iii). When providing an RTEN for a site not otherwise subject to an audit, an auditor must carry out the RTEN as an audit—for matters (b)(i) and (iii) above.

When providing an RTEN opinion, the auditor must comply with all relevant requirements of guidelines issued by the EPA.

In particular, an auditor must carry out an audit and prepare the subsequent audit report in accordance with the EPA guideline, Site Contamination—Guidelines for the site contamination audit system. An audit that involves the assessment and remediation of groundwater it must be done in accordance with this guideline.

The potential for groundwater at the audit site to have been contaminated by site activities must be assessed as part of an audit. In assessing whether site contamination exists, the auditor must consider that the assessments have used an appropriate methodology to determine that site contamination exists at the site with groundwater contamination.

Where chemical substances are present, and result in groundwater contamination being identified at the audit site, the auditor must consider whether:

- the audit site is the source of the contamination or whether the groundwater contamination arises from outside the audit site
- the audit site is the source of the contamination, and if there is off-site groundwater contamination the auditor must consider who is the appropriate person for the off-site groundwater contamination
- the groundwater contamination impacts or has the potential to impact on the beneficial use of the groundwater.

and then:

- what remediation is or remains necessary.

Where groundwater contamination exists, the auditor must take into account whether the DRA has identified the need for remediation and whether RTEN is required at the audit site.

The auditor must consider the potential for impact to be caused by the groundwater contamination, including offsite, taking into account the beneficial uses of the groundwater (refer to Section 3.4).

As part of the remediation strategies developed at the site the auditor should also consider who is the appropriate person for the off-site contamination. If it was not considered, and it is determined that the person who commissioned the audit is responsible for the off-site groundwater contamination the EPA may require a different remediation strategy than one that considers on-site remediation only.

4.1 Off-site groundwater contamination

Auditors must consider the potential for, or the existence of, site contamination (including chemical substances retained or contained) at the audit site that affects or threatens water outside the boundaries of the audit site. The auditor must also consider impacts to the audit site from site contamination from another site. In doing so the auditor must take into account the beneficial uses of groundwater in the area. If any off-site groundwater issue is identified the auditor must advise and consult with the EPA as soon as reasonably practicable.

Where contamination of groundwater may be remediated to the boundaries of the audit site, the auditor must consider the potential for the residual off-site groundwater contamination to migrate back onto the site being audited. In this case, the potential for resulting site contamination and/or impacts on the land use(s) must be considered.

Where residual chemical substances remain in groundwater on and/or off site but do not adversely impact on the land uses being considered at the audit site (for example, after remediation has been implemented at the audit site to the extent necessary refer to Section 4.8), the auditor is expected to clearly identify this in the audit report and where possible indicate the area likely to be impacted by the groundwater contamination. The EPA will then determine if further action may be necessary (for example the declaration of a groundwater restriction or prohibition of use zone under section 103S of the EP Act).

4.2 RTEN opinion

If an auditor is requested to provide an RTEN opinion on groundwater contamination at a site, it must be provided for in the scenarios in Section 3.4.2.

An auditor may be engaged by an appropriate person to provide a review of the ROA of the site to determine that the level of remediation proposed for the site by the consultant is appropriate to the level of risk to human health and the environment.

The auditor needs to ensure that the ROA has been undertaken in accordance with this guideline and provides sufficient level of information to enable an RTEN opinion to be made. The auditor needs to ensure the RTEN process is completed where necessary to the extent that the auditor can complete the audit report.

If the auditor is unclear as to why an RTEN opinion is being sought, clarification should be obtained from the consultant.

The auditor must ensure as part of the RTEN opinion:

- all assessment reports undertaken previously have adequately considered:
  - the nature and extent of the site contamination
  - the risk of the site contamination on human health and/or the environment.
- the adequacy of the data available to support the remedial design

- whether the remediation proposal has examined the adequacy and practicability of other remedial options and not just the preferred option
- the technical feasibility of the proposed remediation in being able to meet the objectives of the remediation proposal
- whether the likely timeframe for remediation is reasonable
- whether the monitoring requirements are adequate for the remedial design, and
- what validation requirements are in place for the remediation proposal.

4.2.1 Beneficial use assessment

If a BUA has been undertaken as part of the DRA process and the auditor supports the beneficial use, there is no requirement for the EPA to review the BUA.

4.2.2 Site specific target levels

If the ROA has site-specific target levels for the chemical substances identified at the site, the auditor must ensure that these concentrations adequately reflect the level of risk at the site.

4.3 Outcomes of an RTEN opinion

An auditor must provide an RTEN opinion as part of an audit report.

Where an auditor is of the opinion that RTEN will be achieved via the selected remediation technology the auditor must provide an opinion to the EPA outlining this in the form of a SCAR.

The EPA requires that the auditor will provide a statement based on the information reviewed at that point in time. If the level of risk changes at the site, there may be a need for the appropriate person to have the RTEN reviewed.

The auditor may include conditions in the audit report based on the RTEN opinion on matters including but not limited to the following:

- the remediation technology is installed as per the ROA requirements
- a review of the ROA be undertaken periodically to ensure that the methodology is performing as required
- a review of the monitoring results be undertaken on a regular basis to ensure that the ROA is valid for the site
- engineering or institutional controls be placed over an area of the site or in the vicinity of the site relating to the groundwater contamination to ensure that there is no risk to human health
- the EPA to be notified if the level of risk changes at the site
- controls on the use of the groundwater that does not involve the risk to human health. The auditor can recommend that restrictions be placed on environmental uses of water
- what remediation is or remains necessary for the beneficial use of the water.

An auditor cannot include a condition in an audit report that a water restriction and prohibition zone be established by the EPA. Pursuant to section 103S of the EP Act, the EPA must be satisfied that certain requirements have been met before declaring a water restriction or prohibition zone over a certain area. However the auditor can recommend as part of the audit report that the EPA consider declaring a prohibition or restriction zone. For

more information on the determination of water restriction and prohibition zones refer to the EPA Guideline, Site Contamination—Determination of water restriction and prohibition zones.

Templates for the reporting requirements of RTEN are included as Appendices 3 and 4.

5 GLOSSARY

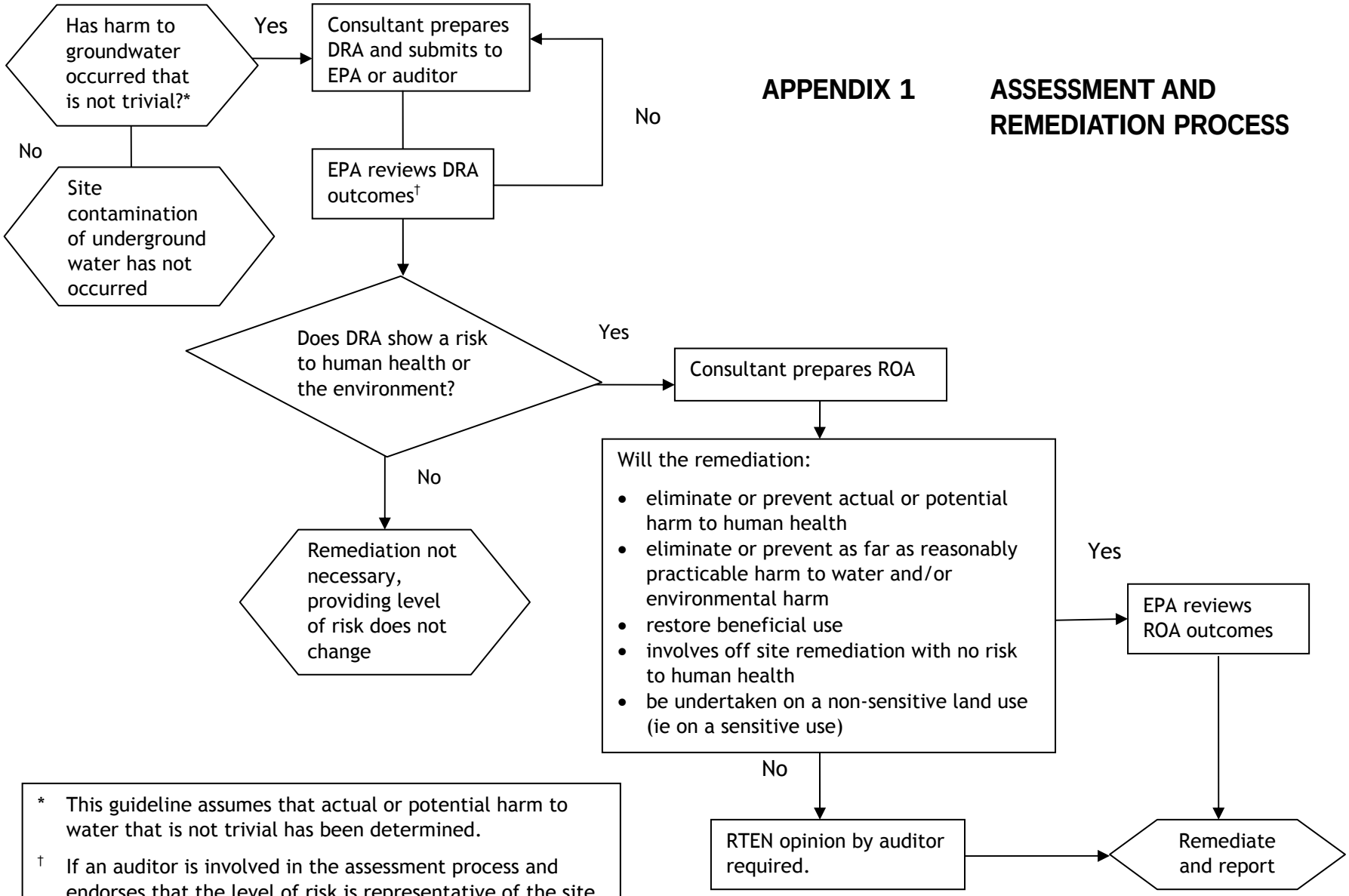
Appropriate person	In relation to the issuing of a site contamination assessment order or a site remediation order, means the person who is the appropriate person under Part 10A to be issued with the order.
Aquatic ecosystem	Any watery environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment.
Aquifer	Permeable rock or sediment in a geological formation, or group of formations, or part of a formation that can transmit water.
Assessor	Suitably qualified professionals with experience in environmental investigations and contaminated site management.
Audit	Refer to site contamination audit.
Auditor	A natural person accredited by the EPA as a site contamination auditor pursuant to the EP Act.
Audit report	A site contamination audit report as defined in section 3(1) of the EP Act.
Background concentration	In relation to chemical substances on a site or below its surface, means results from carrying out assessments of the presence of the substances in the vicinity of the site in accordance with guidelines issued by the Authority. Refer to the EPA publication, Site contamination: Determination of background concentrations (2008).
Beneficial use assessment (BUA)	Assessment undertaken by a site contamination consultant to determine the current and realistic potential use of the groundwater.
Chemical substances	Means any organic or inorganic substance, whether a solid, liquid or gas (or combination thereof), and includes waste.
Conceptual site model (CSM)	A description of the site, geology, hydrogeology, sources of contamination, receptors and exposure pathways by which the contamination may reach and impact on receptors.
Detailed risk assessment (DRA)	An investigation which confirms and delineates potential or actual site contamination through a comprehensive sampling and analysis program and risk assessment.
Exposure	Contact of a chemical, physical or biological agent with the outer boundary of an organism eg inhalation, ingestion or dermal contact.

Exposure pathway	The course a chemical or physical agent takes from a source to a receptor. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at a site or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point and an exposure route.
Groundwater	Has the same meaning as 'underground water'.
Groundwater contamination	Has the same meaning as 'site contamination of underground water'.
Groundwater restriction and prohibition zone	Means a declaration under Section 103S of the EP Act.
Harm to water that is not trivial	Refer to the EPA publication, Site contamination: How to determine actual or potential harm to water that is not trivial (2008).
Hydraulic conductivity	A coefficient of proportionality describing the rate at which water can move through a permeable medium.
Hydraulic gradient	The change in static head (of groundwater) per unit distance in a given direction.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Limit of reporting	The lowest detectable concentration of a substance that can be reliably reported, using a specific laboratory method and instrument (also Practical Quantitation Limit). The value is calculated from the instrument detection limits and with appropriate scale-up factors applied. The scale-up factors are affected by the analytical procedures and methods and the size of the sample.
Potable	Water suitable from both health and aesthetic considerations, for drinking and culinary purposes.
Protected environmental value	In relation to waters or a particular body of water, means such of the following beneficial aspects or uses of water as are designated by the Water Quality EPP: • aquatic ecosystem • recreation use and aesthetics • potable use • agricultural/aquaculture use • industrial use.
Quality assurance (QA)	The implementation of checks on the success of quality control (eg replicate samples, analysis of samples of known concentration).
Quality control (QC)	The implementation of procedures to maximise the integrity of monitoring data (eg cleaning procedures, contamination avoidance, sample preservation methods).

Receptor	An entity, such as a person or ecosystem, which may be adversely affected by exposure to a chemical substance.
Remediation options assessment (ROA)	Report submitted to the EPA or a site contamination auditor identifying the remediation methodology and strategies to be implemented at a site.
Remediation to extent necessary (RTEN) opinion	A site contamination audit report provided on what remediation is or remains necessary at a site undertaken in accordance with these guidelines.
Risk assessment	Process of estimating the potential impact of a chemical, biological or physical agent on a specified human population or ecological system under specified conditions and timeframe.
Screening risk assessment (SRA)	An investigation consisting of a desktop study, a detailed site inspection and, where appropriate, limited sampling. The scope of a SRA should be as necessary to determine whether site contamination is present or likely to be present and to ascertain whether a DRA is required.
Significant hazardous circumstances	Means a state of danger to human beings or the environment whether imminent or otherwise, resulting from the location, storage or handling f any substance having toxic, corrosive, flammable, explosive, infectious or otherwise dangerous characteristics.
Site	An area of land (whether in the same ownership or occupation).
Site contamination assessment order	A site contamination assessment order under Part 10A.
Site contamination auditor	A person accredited under Division 4 of Part 10A as a site contamination auditor.
Site contamination audit report (SCAR)	See audit report.
Site contamination consultant	A person other than a site contamination auditor who, for fee or reward, assesses the existence or nature or extent of site contamination.
Site remediation order	A site remediation order under part 10A.
Slug test	An aquifer test made either by pouring a small instantaneous charge of water into a well or by withdrawing a slug of water from a well.
Skin Effect	Result of fine cuttings or films from fluids that remain on the borehole wall from drilling.
Trivial	Refer to EPA Information Sheet, Site contamination: what is site contamination? (2009).
Volatile	Physical property of a chemical that indicates its potential to transform from an adsorbed, dissolved or liquid phase into a vapour phase under standard atmospheric conditions. Highly volatile substances have a low boiling point or subliming (high vapour) pressure.

Water	Means: • water occurring naturally above or under the ground; or • water introduced to an aquifer or other area under the ground; or • an artificially created body of water or stream that is for public use or enjoyment.
Water quality criteria	In relation to protecting a particular protected environmental value, means the maximum concentrations of chemical substances permitted by the Environment Protection (Water Quality) Environment Protection Policy 2003 to be in water, or the minimum or maximum levels for certain characteristics of water.
Well	A hole drilled into an aquifer for the purpose of monitoring or extracting water. Another common term is 'bore'

APPENDIX 1 ASSESSMENT AND REMEDIATION PROCESS



* This guideline assumes that actual or potential harm to water that is not trivial has been determined.

† If an auditor is involved in the assessment process and endorses that the level of risk is representative of the site, there is no requirement for the EPA to review the DRA.

APPENDIX 2 SCREENING RISK ASSESSMENT METHODOLOGY

Screening risk assessment

The SRA is an initial assessment to determine if site contamination of groundwater exists at a site.

Where groundwater contamination is identified or suspected (because of a PCA having occurred), a SRA should be undertaken to identify if site contamination exists. The SRA will be used to determine whether or not a detailed risk assessment needs to be undertaken. The figure below presents an overview of the SRA process.

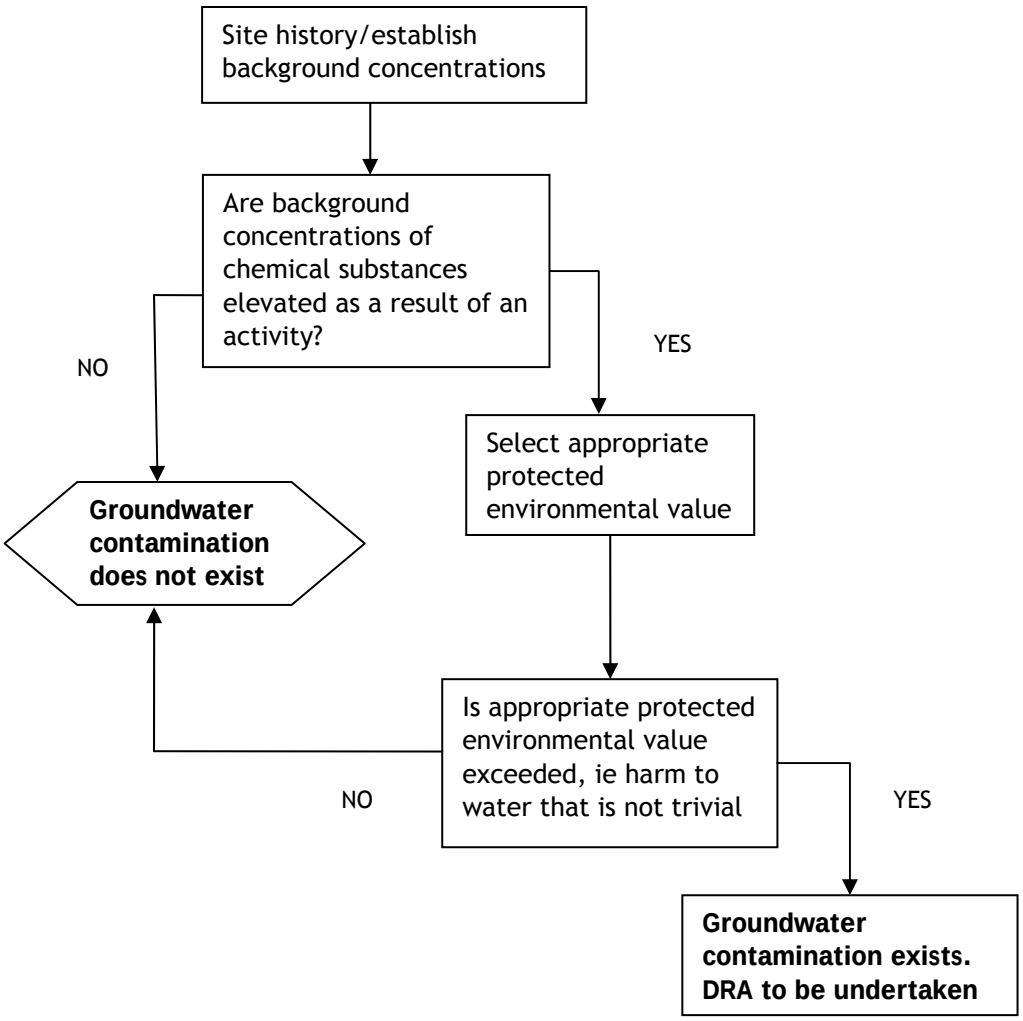


Figure 3 Screening risk assessment

The SRA is an initial evaluation of the site and is made up of the following components:

- site history
- preliminary site conceptual model—a desktop study of the site (including geological and hydrogeological features)
- determination of background concentrations (if required)

- comparing concentrations to appropriate protected environmental values
- determining if site contamination exists at a site.

The SRA should begin with investigating readily available information. If the information is not readily available then intrusive investigations may need to be undertaken to determine if groundwater contamination exists at a site.

Guidance on how to undertake assessments for site contamination can be found in Schedule B(2) of the NEPM. The EPA expects that the construction and sampling of wells is undertaken in accordance with the EPA guideline, Regulatory monitoring and testing: groundwater sampling, and Schedule B(2) of the NEPM.

Site history

The site history should contain all information which will assist the appropriate person in identifying whether or not site contamination exists at the site as well as the nature and extent of the groundwater contamination. The site history should cover but is not limited to the following[22]:

Present owners, occupiers and current users of the site

If the present owners, occupiers or users of the site are not the appropriate person for the groundwater contamination then, the appropriate person (if known) should be included in the assessment process.

Previous occupiers

These are to be listed chronologically from the first landholder to the most recent. This list is to include any unknown periods where the previous occupiers are unknown or uncertain.

Current and previous PCAs

A chronological list of activities to be compiled, including any time periods where the activity is unknown or uncertain. If possible, include site plans of the activities illustrating potential sources of site contamination.

It is anticipated that the list of activities will include the nature of the products and the waste produced on site, as well as waste disposal locations. All waste disposal locations should be identified on the site plans.

Discharges to land and water

The quantities and types of discharge should be identified; this also includes any product spills, losses or incidents.

Site plan

The following site plans are to be provided:

- a current site plan with scale bar and indicating directional north
- chemical storage and transfer areas
- waste disposal locations
- sewer and underground service locations
- general contours of the site
- drainage patterns on the site

[22] Based on Schedule B(2) of the NEPM.

- locality map
- aerial photos both current and historic of the site and adjacent land uses
- any other environmentally significant features.

Zoning

If possible include not only current zoning of the site and adjoining land but also historic zoning.

Interview information

Documentation of interviews with all interested parties should be included. Information that cannot be verified it should be treated with caution. Recollections and anecdotal evidence should be cross checked.

History of adjacent land uses

There may be site contamination at the site which is not the result of the activity that has occurred at the site but may be a result of the migration of the chemical substances in the groundwater. Past and present uses of adjacent land that may have caused the impact should be identified where possible.

Information source

All sources of information should be referenced and verified if needed by the EPA. If it was not possible to obtain any of the site history information, this should also be documented.

Preliminary conceptual site model

A desktop study of the site can be seen as a preliminary conceptual site model and involves the following:

- finding available information on local geology and hydrogeology
- identifying aquifers and water bearing layers and undertaking a literature assessment of their hydraulic properties
- investigating the regional and local (if possible) groundwater flow directions and gradients
- identifying possible recharge sources, discharge points and other hydraulic boundaries
- identifying potential receptors (current water users in the area)
- identifying natural hydrogeochemistry of the water
- obtaining information on any special management areas or water restriction and prohibition zones in the vicinity of the site.

Determination of background concentrations

For actual or potential harm to groundwater that is not trivial to exist, the concentration of chemical substances has to be in excess of background concentrations and have to be present at the site as a result of an activity. The EPA has published a guideline on determining background concentrations[23] that provides information on the definition of background concentrations.

Whilst it is not essential to determine the background concentrations of the chemical substances in the groundwater, any chemical substances (regardless of concentration) that

[23] EPA Guidelineline, Site contamination: Determination of background concentrations.

are reported to the EPA may be considered to be above the background concentration and as such may constitute site contamination unless otherwise demonstrated.

Comparing concentrations to appropriate protected environmental values

In order to establish if actual or potential harm to groundwater exists at a site it is necessary to compare the quality of the groundwater with the selected protected environmental values. More detail on the selection of appropriate protected environmental values can be found in the EPA guideline, Site Contamination: How to determine actual or potential harm to water that is not trivial resulting from site contamination.

The EPA considers that actual harm to water that is not trivial has occurred if chemical substances are in excess of background concentrations and:

- above the water quality criteria for the appropriate protected environmental value, or where there is no value
- above the laboratory limit of reporting using a laboratory method approved by the Authority[24].

If site contamination exists, a DRA needs to be undertaken to determine the remediation strategy for the site.

Potential harm to groundwater

If it has been determined there is no actual harm to groundwater and the only risk is from potential harm, then the potential harm will have to be managed so that it does not become actual harm.

Evaluation of immobile chemicals

The following guidance is provided to determine if there is potential harm from immobile chemicals in the soil to the groundwater. Some chemical substances have a relatively low transport potential due to their high soil adsorption coefficients. These chemical substances may over time become irreversibly sorbed to soil and therefore immobile under normal conditions.

A chemical substance may be considered immobile if the assessor can demonstrate the following:

- an appropriate soil model is undertaken to demonstrate the leaching potential of the chemical substances from the soil. The EPA expects this model to be run for a simulation period of 100 years. This time period has been selected because it is near the upper limit of human life expectancy and transport is not likely after this length of time as the chemical substances would be irreversibly sorbed
- leachability testing in accordance with the relevant Australian Standards indicates that the chemical substances will not leach from the soil
- the chemical substance was not discharged as part of a mixture that could affect the mobility of the chemical substance
- a co-solvent is not present that can affect the mobility of the chemical substance
- soil texture at the site is not coarser than a sandy loam
- soil pH has not been altered by the discharge of acids and bases
- the chemical substance is not present as a non-aqueous phase liquid (NAPL)

[24] For a list of methods approved by the Authority, an EPA Guideline will be published at a later date.

- there is at least 1 m between the base of the soil contamination and the highest groundwater level.

The EPA will also consider that potential harm to water does not exist in the following scenarios:

- soil removal—removal of all contaminated soil that may act as a source for site contamination of groundwater
- removal of pathways—for example placing of liners between contaminated soil to prevent leaching to groundwater or sealing of the surface to prevent recharge.

APPENDIX 3 REPORTING REQUIREMENTS

KEY ✓ Include this section ✓(R) Include readily available information
✓ (S) Summary is adequate if detailed information was included in a previously referenced report

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
Executive summary						
• Background	✓	✓	✓	✓	✓	✓
• Objectives of investigation	✓	✓	✓	✓	✓	✓
• Scope of work	✓	✓	✓	✓	✓	✓
• (Where appropriate) a summary of sampling results in a tabulated format outlining exceedences of appropriate protected environmental value	✓	✓	✓	✓	✓	✓
• (Where appropriate) the determined beneficial use of the aquifer	N/A	✓	✓	✓	✓	✓
• Level of risk to human health and/or environment	✓	✓	✓	✓	✓	✓
• Summary of conclusions and recommendations	✓	✓	✓	✓	✓	✓
• RTEN opinion and (where applicable) conditions	N/A	N/A	N/A	✓	N/A	✓
• RTEN assessment checklist	N/A	N/A	N/A	✓	✓	✓
Scope of work						
• Clear statement of the scope of work	✓	✓	✓	✓	✓	✓

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
General information						
• Brief description of previous work undertaken on the site	✓	✓	✓	✓	N/A	✓
• List of previous reports	✓	✓	✓	✓	N/A	✓
Site details						
• Name of site contamination auditor (if applicable)	N/A	N/A	N/A	✓	N/A	✓
• Term of appointment	N/A	N/A	N/A	✓	N/A	✓
• EPA reference for audit	N/A	N/A	N/A	✓	N/A	✓
• Name of person requesting work	✓	✓	✓	✓	✓	✓
• Site owner	✓	✓	✓	✓	✓	✓
• Appropriate person[25](if known)	✓	✓	✓	✓	✓	✓
Site identification						
• Site address (street number, name and suburb)	✓	✓	✓	✓	✓	✓
• Certificate of title details	✓	✓	✓	✓	✓	✓
• Lot number and Deposited plan number	✓	✓	✓	✓	✓	✓
• Locality map	✓	✓	✓	✓	✓	✓
• Current site plan	✓	✓	✓	✓	✓	✓

[25] As defined in the EP Act.

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Local government authority	✓	✓	✓	✓	✓	✓
• Current council zoning	✓	✓	✓	✓	✓	✓
Site history						
• Present owners, occupiers and users of the site	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Previous occupiers	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Historic council zoning	✓(R)	✓	✓	✓	N/A	✓
• Chronological list of PCAs and land use activities including information gaps and uncertainties	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Discharges to land and water	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Review of aerial photographs including adjacent land uses	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Site photographs (labelled and dated)	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Current site plan with scale bar and indicating directional north	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Plan of chemical storage and transfer areas (including USTs)	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Plan of waste disposal locations	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Plans of sewer and underground service locations	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Potential chemical substances associated with activities	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Potential sources of site contamination and potential off site impacts	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Documentation of interviews	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• History of adjacent land uses	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Verification of information sources	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
Site condition						
• Topographic contours of the site	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Drainage patterns on the site	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Visible evidence of contamination (discoloured soil)	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Odours	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Presence of drums, waste and fill material	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Condition of building and roads	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
• Any other environmentally significant features	✓(R)	✓(S)	✓(S)	✓(S)	✓(S)	✓(S)
Conceptual site model						
• Local geology and hydrogeology	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Identification of aquifers on and in the vicinity of the site	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Site borehole, well and test pit logs	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Location and extent of any imported fill	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Delineation of the vertical and horizontal extent of the site contamination (where not delineated, justification for the non delineation)	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Regional groundwater flow direction	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Basic assessment of hydraulic conductivity and porosities	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Identifying recharge sources, discharge points and other hydraulic boundaries	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Identifying potential receptors	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Identifying natural hydrogeochemistry of the groundwater	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Information on special management areas or water restriction and prohibition zones	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Description of construction of any groundwater wells	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Depth to groundwater	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Direction of groundwater flow	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Modes and migration of any chemical substances	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Diagrammatic representation of the site (cross section)	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Diagrammatic representation of exposure pathways	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Persistence of the chemical substances	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• (Where applicable) evaluation of immobile chemical substances	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Physical–chemical and biochemical transformations which occur as chemical substances migrate through sub-surface to groundwater to point of extraction	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Identify any changes or potential changes in site conditions (land use change)	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
Determination of background concentration						
• Background concentration of chemical substances in vicinity of site	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Method used to determine background concentration (include all information used in this determination)	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
Existence of site contamination						
• Comparison of background concentration	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Comparison of on-site concentration to the appropriate protected environmental value or laboratory limit of reporting	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Statement if site contamination of water exists at the site	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
Sampling and sampling plan methodology				Include brief summary		Include brief summary
• Sampling analysis and data quality objectives[26]	✓	✓	N/A	✓(S)	✓	✓(S)
• Justification for the selection of well locations and well density	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Justification for the sampling depth and frequency	✓(R)	✓	N/A	✓(S)	✓	✓(S)

[26] For guidance refer to NSW EPA Audit guidelines.

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Justification for the analytical methods and detection limits(where NATA[27] accreditation lab is not used and/or LOR[28] are above the protected environmental value)	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Analyte selection	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Description of sampling methods	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Decontamination procedures between wells	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Inclusion of field checklists and purge sheets (original sheets only)	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Sample handling procedure	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• COC[29] procedures identifying for each sample, the sampler, nature of the sample, collection date and time, analyses to be performed, preservation method, departure time from the site and courier	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Sample preservation methods	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Detailed description of any field screening methods	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Tabulated field parameter measurements	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Details of sampling team	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Statement of duplicate frequency	✓(R)	✓	N/A	✓(S)	✓	✓(S)

27 National Association of Testing Authority.

28 Laboratory limit of reporting.

29 Chain of custody.

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Field blank results	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Rinsate sample results	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Trip blank results	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Field instrument calibration (when used)	✓(R)	✓	N/A	✓(S)	✓	✓(S)
QA/QC data evaluation (field and laboratory)						
• Evaluation of all QA/QC information against the stated data quality objectives including completeness of data, representativeness of data	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• RPDs[30] for intra- and inter-laboratory duplicates	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Copy of signed COC forms acknowledging receipt at the laboratory	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Record of holding times and justification where exceeded	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Analytical methods used	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Laboratory accreditation for methods used	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Summary of laboratory QA/QC	✓(R)	✓	N/A	✓(S)	✓	✓(S)
• Limits of reporting for analysis undertaken	✓(R)	✓	N/A	✓(S)	✓	✓(S)

[30] Relative percent difference.

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
Results						
• Table listing all selected assessment criteria	✓(R)	✓	N/A	✓	✓	✓
• Summary of previous results if appropriate	✓(R)	✓	N/A	✓	✓	✓
• Summary of all results showing sample numbers and assessment criteria	✓(R)	✓	N/A	✓	✓	✓
• All results above assessment criteria highlighted	✓(R)	✓	N/A	✓	✓	✓
• Site plan showing sample locations	✓(R)	✓	N/A	✓	✓	✓
• Site plan showing extent of groundwater contamination exceeding selected appropriate environmental value for each analyte	✓(R)	✓	N/A	✓	✓	✓
Beneficial use assessment						
• Map of current groundwater use in within a 2-km radius of the site	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Details of all wells within a 2-km radius of the site including construction, logs, yield, use, etc	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Details of any future realistic use	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Details of any environmental beneficial uses that need to be considered	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• Details of any aquifer testing undertaken at or in the vicinity of the site (including methodology and calculations)	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)
• ambient groundwater quality results	✓(R)	✓	✓(S)	✓(S)	✓(S)	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• justification for change in beneficial use	✓(R)					
• identify beneficial use of aquifer	✓(R)					
Human health and/or ecological risk assessment						
• Details of the risk to human health and/or the environment	✓(R)	✓	✓(S)	N/A	✓(S)	✓(S)
• Methodology to determine the level of risk	✓(R)	✓	✓(S)	N/A	✓(S)	✓(S)
• All data used in establishing the level of risk	✓(R)	✓	✓(S)	N/A	✓(S)	✓(S)
Remediation assessment						
• Goal of remediation (short, medium or long term)	N/A	N/A	✓	✓(S)	✓	✓(S)
• Update results not previously reported on	N/A	N/A	✓	✓(S)	✓	✓(S)
• Discussion on what remediation is or remains necessary	N/A	N/A	✓	✓(S)	✓	✓(S)
• Technical overview of remediation methods considered	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Summary or results relating to pilot studies, treatability or bench scale studies to support remedy selection	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Rationale for selection of remediation method	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Timeframe for remediation	N/A	N/A	✓	✓(S)	✓	✓(S)
• Consent of adjoining landowners (if required)	N/A	N/A	✓	✓(S)	N/A	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Detailed information and plans on the remediation methodology, including:	N/A	N/A	✓	✓(S)	N/A	✓(S)
– description of the chemical content of the fluids and substances to be discharged or placed onto or into the ground to implement remediation	N/A	N/A	✓	✓(S)	N/A	✓(S)
– process diagram for the remediation method	N/A	N/A	✓	✓(S)	N/A	✓(S)
– if degradation is the dominant process, details are to be provided on the breakdown products	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Description of the method for each area of concern	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Contingency plan if the remediation method is not operating as expected	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Identification of all areas where remediation will be undertaken on a scaled map specifying:	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Location of any treatment units	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Volume of media to be remediated in each area	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Location and depth of chemical substances to be remediated	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Sample locations for post remediation samples	N/A	N/A	✓	✓(S)	✓	✓(S)
• Description of soil, dust, noise and odour control and monitoring during the remediation (if required)	N/A	N/A	✓	✓(S)	✓	✓(S)
• Details of ongoing monitoring for the length of the activity	N/A	N/A	✓	✓(S)	✓	✓(S)
• Sampling and analytical methods for monitoring samples	N/A	N/A	✓	✓(S)	✓	✓(S)
• Resource requirements	N/A	N/A	✓	✓(S)	✓	✓(S)

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Impacts on the receiving environment	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Discharges, byproducts and co-products generated via the remediation process and the description of any controls to address impacts from these products	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Demonstrated performance range of the technology	N/A	N/A	✓	✓(S)	N/A	✓(S)
• Site restoration plans following completion (if known)	N/A	N/A	✓	✓(S)	✓	✓(S)
• Hours of operation	N/A	N/A	✓	✓(S)	✓	✓(S)
• Names and phone numbers of appropriate personnel to contact during the remediation process	N/A	N/A	✓	✓(S)	✓	✓(S)
• Staged progress reporting	N/A	N/A	✓	✓(S)	✓	✓(S)
• Occupational health and safety plan	N/A	N/A	✓	✓(S)	✓	✓(S)
Remediation schedule						
• Timeframes for implementation of remediation	N/A	N/A	✓	✓(S)	✓	✓(S)
• Period of reporting	N/A	N/A	✓	✓(S)	✓	✓(S)
Remediation progress reports						
• Works to be scheduled and completed in the reported period	N/A	N/A	N/A	N/A	✓	N/A
• Works actually initiated and completed in the reporting period	N/A	N/A	N/A	N/A	✓	N/A
• Works not initiated or completed and reasons for not complying with the remediation schedule	N/A	N/A	N/A	N/A	✓	N/A
• Discussion of any problems or delays in	N/A	N/A	N/A	N/A	✓	N/A

implementation, including proposals for correction						
Report section and information to be included	**Screening risk assessment**	**Detailed risk assessment**	**Remediation options assessment**	**Remediation to extent necessary opinion**	**Remediation progress report**	**Audit report**
• Modifications from original ROA	N/A	N/A	N/A	N/A	✓	N/A
• Groundwater flow maps	N/A	N/A	N/A	N/A	✓	N/A
• Trends of concentrations of chemical substances at or in the vicinity of the site	N/A	N/A	N/A	N/A	✓	N/A
• (Where applicable) a summary of the volume of groundwater treated at the site since the last reporting period	N/A	N/A	N/A	N/A	✓	N/A
• Summary table of all the monitoring results for the reporting period	N/A	N/A	N/A	N/A	✓	N/A
• Any incidents that have occurred	N/A	N/A	N/A	N/A	✓	N/A
• Any additional supporting documentation (eg photographs, laboratory results)	N/A	N/A	N/A	N/A	✓	N/A
• Revised remediation schedule taking into account any changes	N/A	N/A	N/A	N/A	✓	N/A
• Details on the progress against the ROA						
RTEN OPINION						
• List of reports reviewed	N/A	N/A	N/A	✓	N/A	✓
• Summary of remedial works undertaken	N/A	N/A	N/A	✓	N/A	✓
• Risks to future occupiers	N/A	N/A	N/A	✓	N/A	✓
• Recommendations on the installation of the remediation technology	N/A	N/A	N/A	✓	N/A	✓

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
• Recommendations for ongoing review of the remediation system and monitoring results	N/A	N/A	N/A	✓	N/A	✓
• Recommendations regarding the establishment of prohibition or restriction zone (if appropriate)	N/A	N/A	N/A	✓	N/A	✓
• Consideration of responsibility of the appropriate person (ie onsite only)	N/A	N/A	N/A	✓	N/A	✓
• Any other recommendations that the auditor considers necessary for RTEN to be achieved	N/A	N/A	N/A	✓	N/A	✓
• Recommendations on controls on the beneficial use (eg environmental use)	N/A	N/A	N/A	✓	N/A	✓
• Opinion that the RTEN process will achieve the proposed outcomes in the proposed timeframe	N/A	N/A	N/A	✓	N/A	✓
Conclusions and recommendations						
• Brief summary of all findings	✓	✓	✓	✓	✓	✓
• Assumptions used in reaching the conclusions	✓	✓	✓	✓	✓	✓
• Extent of uncertainties in the results	✓	✓	✓	✓	✓	✓
• Where remedial action has been undertaken, a list summarising the activities	✓	✓	✓	✓	✓	✓
• A statement detailing the limitations of the investigations	✓	✓	✓	✓	✓	✓
• Recommendations for further work, if appropriate	✓	✓	✓	✓	✓	✓

Report section and information to be included	Screening risk assessment	Detailed risk assessment	Remediation options assessment	Remediation to extent necessary opinion	Remediation progress report	Audit report
Electronic and hard copy reporting						
• Signed hard copy of report	✓	✓	✓	✓	✓	✓
• Appendices may be provided in electronic format only	✓	✓	✓	✓	✓	✓
• Searchable Adobe PDF file of report (must be an accurate copy of the original)	✓	✓	✓	✓	✓	✓
• Electronic files must not be locked with any form of password	✓	✓	✓	✓	✓	✓
• Related documents may be included as an electronic appendix	✓	✓	✓	✓	✓	✓
• Analytical data to provided in an Excel spreadsheet (chemistry and location details of wells)	✓	✓	✓	✓	✓	✓

APPENDIX 4 RTEN TEMPLATES

RTEN Summary Table

Site details	Description
Name of auditor	
Date and period of appointment	
Name of person requesting RTEN opinion	
Site owner	
Appropriate person/s	As defined in the EP Act
Reason for RTEN opinion	State which reason from Section 4.7 of this guideline
Site address	
Current certificate of titles	
Zoning	As per local government

RTEN Assessment checklist

Area of site	
Past use of site	Brief site history of the site
Surrounding land uses	Adjacent land uses
Current use of site	
Proposed future use of site	If applicable, if same as current use state as current
Geology	Brief description of local geology
Groundwater beneficial use	As determined by beneficial use proposal
Groundwater depth	As measured by field investigations
Groundwater flow direction	As determined from field investigations
Nearest receptor	Describe receptor and distance from the site
Remediation option table	For information on remediation options table refer to summary options table on the next page
Vapour risk	Refer to section in report that is relevant

Residual mass estimates	Refer to section in report that is relevant (if applicable)
Groundwater monitoring plan	Refer to section in report that is relevant
Well search	Reference section in report and DWLBC results
Groundwater use restrictions	Refer to section in report that is relevant
Water quality summary table	Refer to relevant section and tables
Plume and/or soil chemical substance maps	Refer to figures in report

Auditors Opinion

Remediation summary options

Method	Description	Technical considerations	Logistical considerations	Financial considerations	Ongoing management
Type of method assessed, eg source removal	Brief description of method, eg remove contaminated soil and pump and groundwater	Include the ability to remove the chemical substance within a reasonable timeframe	Considerations include site access, availability of materials and infrastructure	Include cost of remediation, including equipment, installation and ongoing monitoring and maintenance	Include type of management, eg groundwater monitoring plan, exclusion zone

APPENDIX 5 GUIDANCE DOCUMENTS

Agriculture and Resource Management Council of Australia and New Zealand 1995, *Guidelines for groundwater protection in Australia,* ARMCANZ, Canberra, viewed 21 January 2009, <www.mincos.gov.au/__data/assets/pdf_file/0010/316099/guidelines-for-groundwater-protection.pdf>

American Society for Testing and Materials 2003, *Guide for developing conceptual site models for contaminated sites*, ASTM E1689-95e1.

American Society for Testing and Materials 2004, *Standard guide for risk based corrective action,* ASTM E2081-00.

Australian and New Zealand Environment and Conservation Council 2000, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* ANZECC & ARMCANZ, Canberra.

Bureau of Environmental Remediation/Remedial Section 2004, *Considerations for groundwater use and applying RSK standards to contaminated groundwater*, viewed 21 January 2009, <www.kdheks.gov/ber/policies/BER_RS_045.pdf>.

Department of Environment 2003, *Assessment Levels for Soil, Sediment and Water*, November 2003, Contaminated Sites Management Series, DOE, Perth, viewed 21 January 2009, <http://portal.environment.wa.gov.au/portal/page?_pageid=193,186707&_dad=portal&_schema=PORTAL>.

Department of Environmental Protection 2001, *Development of Sampling and Analysis Programs*, DEP, Perth, viewed 21 January 2009, <http://portal.environment.wa.gov.au/portal/page?_pageid=193,186707&_dad=portal&_schema=PORTAL>.

——2001, *Reporting of site assessments*, DEP, Perth, viewed 21 January 2009, <http://portal.environment.wa.gov.au/portal/page?_pageid=193,186707&_dad=portal&_schema=PORTAL>.

——2004, U*se of monitored natural attenuation for groundwater remediation,* DEP, Perth, viewed 21 January 2009, <http://portal.environment.wa.gov.au/portal/page?_pageid=193,186707&_dad=portal&_schema=PORTAL>.

——2006, *The use of risk assessment in contaminated site assessment*, DEP, Perth, viewed 21 January 2009, <http://portal.environment.wa.gov.au/portal/page?_pageid=193,186707&_dad=portal&_schema=PORTAL>.

Department of Environment and Climate Change 1997, *Contaminated Land Management Act 1997,* DECC, Sydney, viewed 21 January 2009, <www.environment.nsw.gov.au/legislation/legislation.htm>.

——2006, *Consideration of environmental values of water when issuing prevention notices,* DECC, Sydney, viewed 21 January 2009, <www.environment.nsw.gov.au/water/envwater.htm>.

——2007, *Guidelines for the Assessment and Management of Groundwater Contamination*, DECC, Sydney, viewed 21 January 2009, <www.environment.nsw.gov.au/resources/clm/groundwaterguidelines07144.pdf>.

Department of Health and Ageing & EnHealth 2002, *Environmental health risk assessment: Guidelines for assessing human health risks from environmental hazards*, Commonwealth of Australia, viewed 21 January 2009, <enhealth.nphp.gov.au/council/pubs/pdf/envhazards.pdf>.

Environment ACT 2000, *Contaminated sites environment protection policy,* viewed 21 January 2009, Environment ACT, Canberra, viewed 21 January 2009, **<**www.tams.act.gov.au/__data/assets/pdf_file/0009/48807/contaminatedsitesepp.pdf**>.**

EPA Region 1 New England 1996, *Groundwater use and value determination guidance. A resource based approach to decision making,* EPA, New England, viewed 21 January 2009, <www.epa.gov/region1/brownfields/guidance/gwater.pdf>.

EPA Victoria 2002, *Prevention and management of contamination of land in Victoria, state environment protection policy,* EPA Vic, Melbourne, viewed 21 January 2009, <http://epanote2.epa.vic.gov.au/EPA%5Cpublications.nsf/PubDocsLU/854?OpenDocument>.

——2002, *The clean up and management of polluted groundwater,* Information Bulletin 840, EPA Vic, Melbourne.

——2006, *Hydrogeological assessment (groundwater quality) guidelines,* Publication 668, EPA Vic, Melbourne.

Fetter CW 1998, *Contaminant hydrogeology*, Prentice Hall Inc, Englewood Cliffs, NJ, USA

——2000, *Applied hydrogeology*, Prentice Hall Inc, Englewood Cliffs, NJ, USA

Freeze RA & Cherry JF 1979, *Groundwater*, Prentice Hall Inc, Englewood Cliffs, NJ, USA

McCauley C and Bokermann C 2007, *CUTEP and GQRUZ—regulatory tools for managing groundwater quality in Victoria, Australia,* GQ07: Securing groundwater quality in urban and industrial environments.

Ministry for the Environment 1999, *Guidelines for assessing and managing petroleum hydrocarbon contaminated sites in New Zealand,* MFE, Wellington, viewed 21 January 2009, <www.mfe.govt.nz/publications/hazardous/oil-guide-jun99/>.

National Environment Protection Council 1999, *National environment protection (assessment of site contamination) measure 1999*, NEPC, Adelaide, viewed 21 January 2009, <www.ephc.gov.au/taxonomy/term/44>.

New Jersey Department of Environment Protection 2008, *Technical requirements for site remediation*, NJAC 7:26E, Trenton, viewed 21 January 2009, <www.state.nj.us/dep/srp/regs/techrule/>.

——2008, *Chapter 7.9c Ground water quality standards,* NJAC, Trenton, viewed 21 January 2009, <www.state.nj.us/dep/srp/regs/gwqs/gwqsfaq.pdf>.

——2008, *Guidance for the evaluation of immobile chemicals for the impact to the ground water pathway,* NJAC, Trenton, viewed 21 January 2009, <www.nj.gov/dep/srp/guidance/rs/immobile_chemicals.pdf>.

South Australian Environment Protection Authority 2003, *Environment Protection (Water Quality) Policy 2003 and Explanatory Report,* SA EPA, Adelaide, viewed 21 January 2009, <www.epa.sa.gov.au>.

Schedule B (6) National Environment Protection (Site Contamination) Measure: Guideline on Risk Based Assessment of Groundwater Contamination.

Standards Australia 2004, *Risk management,* AS/NZS 4360:2004.

State of Connecticut Department of Environment Protection 2006, *Guidance for groundwater monitoring for demonstrating compliance with the Connecticut remediation standards regulations,* CDEP, Hartford, 21 January 2009, <www.ct.gov/dep/lib/dep/site_clean_up/guidance/gwm_guidance_for_demonstrating_compliance_with_ct_rsr.pdf>.

Texas Commission on Environmental Quality 2001, *Application of remedy standards A and B RG-366/TRRP-28,* TCEQ, Austin, 21 January 2009, <www.tceq.state.tx.us/remediation/remguidance.html>.

——2003, *Groundwater classification,* TCEQ regulatory guidance RG-366/TRRP-8, TCEQ, Austin, 21 January 2009, <http://www.tceq.state.tx.us/files/rg-366_trrp_08.pdf_4232466.pdf>.

UKTAG 2005, *Outline of groundwater classification for the purposes of the water framework directive,* UKTAG, 21 January 2009, <www.wfduk.org/stakeholder_reviews/stakeholder_review_1->.

United States Environment Protection Agency 2002, *Handbook on groundwater protection and clean up policies for RCRA corrective action*, EPA/530/R-01/015, US EPA.

——2004, *Handbook of Groundwater Protection and Cleanup Policies for RCRA Corrective Action,* US EPA, 21 January 2009, <www.epa.gov/epawaste/hazard/correctiveaction/index.htm>.

——2004, *Ground water, use, value and vulnerability as factors in setting clean up goals,* US EPA, 21 January 2009, <gwtf.clu-in.org/docs/options/gw_use_paper.pdf>

Virginia Department of Environmental Quality 2002, *Guidance for addressing contaminated groundwater at voluntary remediation program sites,* Guidance memo No. 03–2002 (9 VAC 20-160), DEQ, Richmond, viewed 21 January 2009, <www.deq.state.va.us/export/sites/default/vrp/pdf/vrpgg.pdf>.

Washington State Legislature, *Selection of cleanup actions*, WAC 173-340-360, 21 January 2009, <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-360>.

——, *Overview of cleanup standards*, WAC 173-340-700, 21 January 2009, <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-700>.

——, *Overview of cleanup standards*, WAC 173-340-720, 21 January 2009, <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720>.