



Explanatory note

The following guideline provides general guidance in relation to investigation levels for soil, soil vapour and groundwater in the assessment of site contamination.

This Schedule forms part of the National Environment Protection (Assessment of Site Contamination) Measure 1999 and should be read in conjunction with that document, which includes a policy framework and assessment of site contamination flowchart.

The original Schedule B6 to the National Environment Protection (Assessment of Site Contamination) Measure 1999 has been repealed and replaced by this document.

The National Environment Protection Council (NEPC) acknowledges the contribution of the Western Australian Department of Environment and Conservation and the New South Wales Environment Protection Authority to the development of this Schedule.

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1 Introduction

1.1 Background

This Schedule provides a framework for the risk-based assessment of groundwater that has been affected, or may have been affected, by site contamination. The general process outlined for the assessment of contaminated groundwater is compatible with the policy framework (outlined in the Measure) and the site assessment process shown in Schedule A. The aim of this process is to minimise the risk of adverse human health and environmental impacts arising from contaminated groundwater and to ensure that the quality of groundwater is appropriate for its environmental values.

The framework is applicable to the assessment of groundwater quality arising from point-source contamination (for example, leaks from fuel storage depots, sheep and cattle dips). This Schedule is not intended to address all aspects of the management of groundwater quality, or to replace the regulatory requirements of individual jurisdictions for the assessment and management of groundwater contamination. Nor is it generally applicable to other broadscale groundwater issues associated with agriculture, catchment management or salinity. These resource management issues are administered by jurisdictions through various regulatory processes.

This framework is intended to be used in conjunction with Schedule B2, which includes guidance on related matters such as groundwater monitoring, the characterisation of groundwater contamination and the application of contaminant fate and transport modelling.

Detailed groundwater investigations should only be undertaken by appropriately qualified and experienced groundwater professionals. Their advice should be sought early in the assessment process to avoid remobilisation of assessment personnel and associated additional costs.

1.2 Relationship with other national guidelines

The framework recognises nationally developed approaches, policies and water quality criteria developed to protect groundwater, surface water and sources of public drinking water supply. This includes guidelines developed under the National Water Quality Management Strategy to protect marine and freshwater quality (ANZECC & ARMCANZ 2000) and for managing risks in recreational waters (NHMRC 2008) and, in addition, the Australian Drinking Water Guidelines (NHMRC & NRMMC 2011).

The framework for risk-based assessment of groundwater applies these national guidelines to the specific issue of assessing the quality of groundwater impacted by site contamination.

1.3 Definition of contaminated groundwater

In the context of a contaminated site assessment, groundwater is considered to be contaminated when its quality is such that it is not suitable for the current or realistic future use or presents the likelihood of causing an unacceptable environmental or human health impact in the discharge environment. This differs from the National Water Quality Management Strategy definition in the *Guidelines for groundwater protection in Australia* (ARMCANZ & ANZECC 1995). The latter considers groundwater to be contaminated whenever there is a change in water quality that produces a noticeable or detectable change in its characteristics. Therefore, if a change in groundwater quality is detected or is reasonably suspected, relevant jurisdictional policies should also be taken into account regarding groundwater protection.

2 Site assessment process and terminology

2.1 Site assessment process

The site assessment process is shown in Schedule A. Once the need for an assessment is triggered, a preliminary site investigation (PSI) should be conducted using the guidance outlined in Schedule B2. The scope of the PSI should be sufficient to identify the potential contaminants of concern and the environmental media that are potentially affected by these contaminants.

A detailed site investigation (DSI) is required when the results of the PSI indicate that contamination is present or is likely to be present and there is insufficient information to delineate the extent of contamination and to enable site management strategies to be devised. Monitoring of groundwater conditions is an important part of the site assessment process to determine seasonal, and where appropriate, longer-term trends. The detailed investigation stage should identify the nature of the contamination and delineate its lateral and vertical extent to a sufficient degree that an appropriate level of risk assessment may be undertaken and, if necessary, to provide the basis for the development of an appropriate remediation or management strategy.

This more detailed investigation should result in an estimation of the current and projected contaminant concentrations in the receiving environment at the points of existing and realistic future use. Contaminant fate and transport modelling may be required to estimate the contaminant concentrations at these points. The investigation process should consider:

- all potential exposure pathways
- the properties of the contaminants such as persistence and bioavailability
- the likely temporal variability in contaminant concentrations
- the physicochemical and biochemical transformations that occur between the contamination source and the point of current or future realistic use.

Further guidance on related matters such as groundwater monitoring, the characterisation of groundwater contamination and the application of contaminant fate and transport modelling can be found in Schedule B2.

2.2 Groundwater investigation levels

Groundwater investigation levels (GILs) are defined as ‘the concentration of a contaminant in groundwater above which further investigation (point of extraction) or a response (point of use) is required’. Selected GILs are tabulated in Table 1C of Schedule B1 and are sourced from the:

- Australian water quality guidelines for fresh and marine water (AWQG) (ANZECC & ARMCANZ 2000)
- Australian drinking water guidelines (ADWG) (NHMRC & NRMCC 2011)
- Guidelines for managing risk in recreational water (GMRRW) (NHMRC 2008).

The GILs are designed to avoid unacceptable impact to exposed populations or ecosystems under a range of circumstances. For example, the GILs for protection of freshwater and marine water ecosystems were derived using a statistical distribution method and were calculated at four different protection levels, where the data permitted, and are applied according to the ecosystem condition. The aquatic ecosystem protection GILs presented in Table 1C of Schedule B1 are applicable to ‘slightly – moderately disturbed’ ecosystems. The AWQG should be consulted for additional values for protection of disturbed ecosystems and pristine ecosystems.

For guidance on the selection of relevant GILs—see Section 3.

Levels marginally in excess of the GILs do not imply unacceptability or that a significant human health or ecosystem impact is likely to be present. Subject to an appropriate investigation and assessment process, a decision not to take further action or to take further action may be justifiable based on the findings.

GILs are not intended to be clean-up levels. The decision on whether clean-up is required (and to what extent), should be based on site-specific assessment. Risk assessment is one aspect of making the decision; however, other considerations such as practicality, timescale, effectiveness, community acceptance, cost and durability are also important.

The referenced source documents should be consulted for information on how to develop site-specific criteria where generic guidelines are not available or applicable.

2.3 Conceptual site model

In order to commence an effective risk-based assessment of a site, a preliminary understanding of the potential site issues is necessary. The understanding of the site is referred to as a conceptual site model (CSM) and describes the source(s) of contamination, the pathway(s) by which contaminants may migrate through the various environmental media, and the populations (human and/or ecological) that may be exposed. For further information on the issues to be considered in the development of a CSM, refer to Schedules B2 (Sections 4 and 8) and B4.

2.4 The tiered approach

The risk assessment process for contaminated sites is usually undertaken in stages or ‘tiers’ involving progressively more detailed levels of data collection and analysis. In this guidance, the tiers are referred to as Tier 1, Tier 2 and Tier 3. The approach provides for assessment at a level of complexity that is appropriate for the problem under consideration. As the amount of data and assessment detail increases, and the CSM is refined and data gaps are filled, the level of uncertainty decreases. In turn, the level of uncertainty in the risk assessment process is reduced.

2.5 The basis for groundwater risk assessment

Groundwater should be assessed on the basis of its environmental values and the risk that the current (or realistic future) use may pose to human health and/or the environment. With regard to realistic future uses, consideration should be given to the quality and yield of the aquifer, the likely demand for water resources in the vicinity of the site, and technological practicalities.

The assessment process for groundwater contamination differs from that for land contamination in that there is greater emphasis on suitability for current and realistic future uses, compared with the emphasis on current and intended uses with soil assessment. The focus on the protection of environmental values and realistic future uses (based on the inherent capacity of the aquifer to support those uses) is derived from the following considerations:

- groundwater contamination may be persistent and difficult to contain or to remediate within a short timeframe
- some groundwater contamination may persist beyond current planning horizons, affecting future uses that today are not considered likely
- the stress on Australia’s water resources is expected to increase, highlighting the importance of protecting groundwater resources for the future.

With soil assessment, land use and the level of contact between the most sensitive human or ecological receptor and the contaminated soil primarily determine the level of protection required. In the case of groundwater, consideration may include a combination of several different exposure scenarios and multiple potential receptors, for example, groundwater may be used for irrigation purposes, pass

beneath a freshwater lake and then go on to discharge into the marine environment. Potential receptors will differ in each scenario and acceptable contaminant levels may well be different for each receptor. An assessment of groundwater contamination should consider the sensitivity of receptors in each exposure scenario.

3 Framework for applying water quality guidelines in the risk-based assessment of contaminated groundwater

3.1 Introduction

This section provides a framework for the use of the following guidelines in the risk-based assessment of contaminated groundwater:

- *Australian water quality guidelines for fresh and marine water (AWQG)* (ANZECC & ARMCANZ 2000)
- *Australian drinking water guidelines (ADWG)* (NHMRC & NRMMC 2011)
- *Guidelines for managing risk in recreational water (GMRRW)* (NHMRC 2008).

These guidelines present criteria for potential contaminants of concern. These criteria are adopted as GILs in this NEPM and form the basis for the assessment of contaminated groundwater and associated risks. The GILs are trigger levels which, if exceeded, have the potential to cause a problem and so trigger further investigation or management action.

The criteria defined within the ADWG apply at the point of use, for example, at the tap, and are applicable to any water, including bore water, where that water is intended for potable use. In this Schedule, the ADWG criteria are used as investigation levels for comparison with groundwater quality monitoring data (Tier 1 and 2) and, for example, the results of contaminant fate and transport modelling (Tier 3). A management response should be considered if the ADWG are (or are likely to be) exceeded at the point of use.

The assessment framework is based on identifying the receptors (human and/or ecological) for groundwater that is contaminated and determining the level of protection required by referring to the appropriate set of guidelines within the AWQG, the ADWG and the GMRRW.

Schedule B1 of this NEPM introduces Health Screening Levels (HSLs) for groundwater, for protection of human health from petroleum hydrocarbon vapours. Schedule B1 and references therein should be consulted for details of the application of the groundwater HSLs.

3.2 Groundwater environmental values

Environmental values are values or uses of the environment that are conducive to public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharge and deposits. The AWQG, ADWG and GMRRW set out criteria for water quality relating to a number of environmental values:

- ecosystem protection
- aquaculture and human consumers of food
- agricultural water (irrigation and stock water)
- recreation and aesthetics
- drinking water
- industrial water.

For each environmental value, a set of guideline criteria is presented for potential contaminants of concern.

Ecosystem protection, in this context, refers to aquatic ecosystems which depend at least in part on groundwater to maintain ecosystem health (groundwater-dependent ecosystems). Depending on the site setting, this may include surface water bodies such as wetlands, streams and rivers reliant on groundwater base flow, some estuarine and near-shore marine systems, as well as aquifer and cave

ecosystems. Consideration of the water body/groundwater characteristics will determine whether the freshwater or marine water GILs are the most appropriate to apply.

Table 1. Summary of relevant guidelines to protect environmental values of groundwater.

Environmental value	Relevant guideline
Ecosystems	AWQG (fresh and marine ecosystem guidelines)
Drinking water	ADWG
Recreational use*	GMRRW
Industrial use <ul style="list-style-type: none"> • Agricultural use (irrigation and stock watering) • Aquaculture 	<ul style="list-style-type: none"> • AWQG (irrigation and stock watering guidelines) • AWQG (aquaculture)

* The recreational and aesthetics sections of the AWQG have been superseded by the GMRRW (NHMRC 2008).

3.3 Background groundwater quality

The application of the policy framework includes consideration of background groundwater quality. Background groundwater quality is considered to be the sum of both ambient and natural sources in the local area of a site. Very few organic chemicals would be expected to have elevated natural background levels in groundwater. However, in the case of metals, metalloids and some inorganic substances, background concentrations may be elevated due to both natural and ambient background contributions.

The assessment of background water quality should be undertaken at an area(s) that is not affected by the activities that have contributed to the contamination present at the site. For example, it may be appropriate to collect samples unaffected by the contamination upgradient of the impacted area; otherwise a suitable area in the vicinity of the site, which is unlikely to have been impacted by the potential contaminants of concern, should be selected. Further information may be found in SA EPA (2008).

In addition to the potential contaminants of concern identified in the conceptual site model, it is recommended that the sampling and analysis plan should include the analysis of major ions to assist with differentiation between contaminated and non-contaminated groundwater.

Sufficient sampling in terms of both areal and temporal considerations should be undertaken to establish the natural variation in groundwater quality due to seasonal effects. Where sufficient concentration data is available for statistical analysis, the 80th percentile of the background concentration data may be used for comparison with the site data (ANZECC & ARMCANZ 2000).

3.4 Fundamentals of the tiered approach

3.4.1 Tier 1

A Tier 1 assessment is the first stage of assessment and provides an initial screening of the site data. This includes:

- reviewing site contamination history, identifying all past and present contaminating activities and associated potential contamination
- reviewing available information about local and regional geology and hydrogeology
- identifying aquifers and confining layers, groundwater flow domain, potential receptors

- identifying natural geochemistry of the groundwater system
- sampling of site groundwater monitoring wells and identifying seasonal trends in groundwater quality
- comparing site data with relevant GILs.

The purpose of Tier 1 assessment is to determine whether further assessment is required. It includes a comparison of monitoring data from the site with relevant GILs (such as those listed in Table 1C Groundwater Investigation Levels in Schedule B1). The relevant GILs should be selected on the basis of the environmental values identified in the conceptual site model.

Exceedence of Tier 1 criteria is generally used to determine whether there is a need to collect more data and/or progress to a Tier 2 assessment. An assessment of the significance of exceedences may be necessary where they are marginal or present over a limited area. Under some circumstances further assessment of contaminants exceeding Tier 1 criteria may not be conducted (e.g. where the extent of the exceedence and cost of remediation is small and further assessment is not cost-effective). Where further assessment of contaminants exceeding Tier 1 criteria is not proposed, a clear and transparent explanation should be provided.

This means that a groundwater sample from a monitoring well with contaminant levels above the GILs will trigger further investigation rather than initiate remedial action. However, site-specific consideration should be given to water quality impacts that cause variations from ambient water quality even when GILs are not exceeded. This is because individual jurisdictions may operate protective strategies for groundwater that require action at levels below the GILs or whenever levels of contaminants above ambient background are detected. Such issues are the responsibility of jurisdictions.

3.4.2 Tier 2

A Tier 2 assessment is typically required when one or more contaminants are present at the site at levels that exceed Tier 1 guidance criteria, or if there are no appropriate Tier 1 criteria, or if there are unresolved and significant uncertainties identified in the Tier 1 assessment.

Tier 2 assessment includes consideration of the site-specific conditions and the modification of Tier 1 generic GILs according to the site conditions, including actual exposure. For example, the toxicity of some metals (Cd, Cr III, Cu, Pb, Ni and Zn) to freshwater biota is known to reduce with increasing water hardness (ANZECC & ARMCANZ 2000). The AWQG are conservatively presented on the basis of low hardness (30 mg/L CaCO₃) and the relevant GILs may be modified for increased levels of hardness according to the algorithm presented in ANZECC & ARMCANZ 2000.

Exceedence of Tier 2 criteria may result in a need for a Tier 3 assessment. As with Tier 1 exceedences, an assessment of the significance of exceedences may be necessary where they are marginal or present over a limited area. If Tier 2 criteria are exceeded, but further assessment (or action) is not proposed, the information and logic used to inform the decision should be documented clearly and transparently.

If no modification of the Tier 1 criteria is applicable, then the risk assessor may decide to proceed directly to Tier 3.

3.4.3 Tier 3

A Tier 3 assessment may be required where exceedence of Tier 2 site-specific target levels is judged to represent a potentially unacceptable risk to human health and/or the environment. The Tier 3 assessment typically focuses on the risk-driving contaminants in more detail and generally requires additional site investigation to reduce critical uncertainties in the risk assessment.

Tier 3 risk assessments compare groundwater contaminant concentrations at the point of exposure (point of use) with existing generic GILs or can incorporate additional information such as ecosystem/environmental variability and exposure to derive modified, site-specific response levels.

The relevant jurisdictional policy should be consulted when modifying GILs at the point of use. For example, when determining criteria for groundwater discharging to a surface water body, these should be determined on a site-specific basis, as some jurisdictions allow for a mixing zone or water treatment, whereas others apply the GILs at the point of discharge without mixing in order to protect benthic organisms.

Further information is available in Schedule B2 and ANZECC & ARMCANZ (2000).

Example Tier 3 activities include:

- contaminant fate and transport modelling to predict groundwater quality at existing (and realistic future) receptors using a range of aquifer conditions to assess the significance of the site contamination at the point of exposure/use – refer Schedule B2
- consideration of metal speciation (speciation modelling or chemical measurement) – refer AWQG
- biological effects testing (for example direct toxicity testing) – refer AWQG.

3.5 Risk management

At the point of use or exposure, GILs may be considered as response levels: the response may include further investigation or management as appropriate.

Contaminant levels marginally in excess of the GILs do not imply unacceptability or that a significant human health or ecosystem risk is likely to be present. The decision on whether clean-up is required (and, if so, to what extent) should be based on site-specific assessment. Risk assessment is one aspect of making the decision though other considerations such as practicality, timescale, effectiveness, cost, durability, relevant regulatory policy, and community acceptance are also important.

A management plan for unacceptable levels of contamination may include one or more of the following:

- work plan
- determination of site-specific clean-up criteria
- development of site management options
- determination of clean-up methods
- implementation plan of remedial actions
- water treatment at the point of use
- restriction on the use of the aquifer
- provision of alternative water supply
- future monitoring and information provisions.

These management issues are beyond the scope of the NEPM and are matters administered by jurisdictions.

4 Bibliography

ANZECC & ARMCANZ 2000, National water quality management strategy. Australian and New Zealand guidelines for fresh and marine water quality, Australian and New Zealand Conservation Council and Agriculture, & Resource Management Council of Australia and New Zealand.

ARMCANZ & ANZECC 1995, National water quality management strategy. Guidelines for groundwater protection in Australia, Agriculture and Resource Management Council of Australia and New Zealand & Australian and New Zealand Environment and Conservation Council, Australia.

NHMRC 2008, National water quality management strategy. Guidelines for managing risk in recreational water, National Health and Medical Research Council, Australia.

NHMRC & NRMCC 2011, National water quality management strategy. Australian drinking water guidelines, National Health and Medical Research Council and National Resource Management Ministerial Council, Australia.

SA EPA 2008, Site contamination - Determination of background concentrations, South Australia Environmental Protection Authority, Adelaide, Australia.

5 Glossary

Ambient background means the condition of groundwater representative of the area surrounding the site not attributable to an identifiable point source(s). The impacts of widespread diffuse sources of groundwater contamination are included within 'ambient background'.

Aquifer is a rock or sediment in a geological formation, group of formations or part of a formation which is capable of being permeated permanently or intermittently and can thereby transmit water.

Background groundwater quality means the condition of groundwater in the vicinity of a site which is the sum of the ambient and natural background.

Bioavailability is a general term meaning the amount of a contaminant that is absorbed into the body following dermal contact, ingestion or inhalation.

Contaminated groundwater means groundwater that has contamination at such a level that the condition of groundwater is such that it is not suitable for the current or realistic future use or presents the likelihood of causing an unacceptable environmental or human health impact in the discharge environment.

Contamination means the condition of land or water where any chemical substance or waste has been added as a direct or indirect result of human activity at above background level and represents, or potentially represents, an adverse health or environmental impact.

Discharge area means an area in which there are upward components of hydraulic head in the aquifer. Groundwater flowing toward the land surface in a discharge area may escape as a spring, leading to a discharge, seep or base flow, or by evaporation and transpiration.

Environmental value is a value or use of the environment which is conducive to public benefit, welfare, safety or health and which requires protection from the effects of pollution, waste discharge and deposits.

Groundwater-dependent ecosystem means an ecosystem that is wholly or partially dependent on groundwater for ecosystem health. For groundwater risk assessment this may include surface water bodies such as wetlands and rivers with groundwater base flow, some estuarine and near-shore marine systems, as well as aquifer and cave ecosystems.

Groundwater investigation level (GIL) is the concentration of a groundwater parameter at which further investigation (point of extraction) or a response (point of use) is required. Includes Australian water quality guidelines/drinking water guidelines/guidelines for managing risk in recreational water criteria and site-specific derived criteria.

Groundwater means all waters occurring below the land surface.

Natural background means the condition of groundwater derived/originating from natural processes in the environment as close as possible to natural conditions, exclusive

of specific anthropogenic activities or sources.

Point source means a source of contamination which comes from a contaminating activity at a particular site.

Receptor is the entity (organism, population, community, or set of ecological processes) that may be adversely affected by contact with, or exposure to, a contaminant of concern.

Response level means the concentration of a contaminant at a specific site, based on a site assessment, for which some form of response is required to provide an adequate margin of safety to protect public health and/or the environment.

Risk assessment is a process intended to calculate or estimate the risk to a given target organism, system, or sub-population, including the identification of attendant uncertainties, following exposure to a particular contaminant, taking into account the inherent characteristics of the agent of concern as well as the characteristics of the specific target system.

Risk is the probability of an adverse effect in an organism, system or sub-population caused under specific circumstances by exposure to a contaminant.

Risk management is a decision-making process involving consideration of political, social, economic, and technical factors with relevant risk assessment information relating to a hazard to determine an appropriate course of action.

Tier 1 assessment is a risk-based analysis comparing site data with generic published screening criteria (Tier 1 criteria) for various environmental values.

Tier 2 assessment is a site-specific assessment in which risks to potentially exposed populations are assessed using site-specific data on pathways, and the characteristics of the exposed populations. In Tier 2, site data is compared with generic criteria modified for site-specific conditions.

Tier 3 assessment is a further step from a Tier 2 evaluation and examines the specific risk-driving factors in more detail. This often involves additional data collection and may incorporate more sophisticated modelling techniques. In Tier 3, site data is compared with site-specific target levels.

Well is a hole drilled into an aquifer for the purpose of monitoring or extracting groundwater. This generic term includes bores, water wells and tubewells.

6 Shortened forms

ADWG	Australian Drinking Water Guidelines
ANZECC	Australian and New Zealand Environment and Conservation Council
AWQG	Australian Water Quality Guidelines
CSM	conceptual site model
DSI	detailed site investigation
HIL	health investigation level
HSL	health screening level
GIL	groundwater investigation level
GMRRW	Guidelines for managing risk in recreational waters
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NRMMC	National Resource Management Ministerial Council
PSI	preliminary site investigation