Department of
Environment and Conservation

Contaminated Sites Management Series

THE USE OF RISK ASSESSMENT IN CONTAMINATED SITE ASSESSMENT AND MANAGEMENT

Guidance on the Overall Approach

November 2006

PREFACE

The Department of Environment and Conservation (DEC) has prepared this guideline to provide consultants, local government authorities, industry and other interested parties with a reference document which outlines the purpose and requirements for conducting site-specific health and ecological risk assessments for contaminated sites in Western Australia.

ACKNOWLEDGMENTS

DEC acknowledges GHD Pty Ltd and the Department of Health (DoH) for their assistance with preparing the guideline.

LIMITATIONS

The guideline only applies to people investigating or managing contaminated sites. The contents provide guidance only and are not intended to provide a methodology for the assessment of sites. Competent people should be engaged to provide specific advice in relation to the assessment of contaminated sites.

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

DISCLAIMER

The information provided in this document is made available in good faith and is believed accurate at the time of publication (or at the time of release on the internet). However, the document is intended to be a guide only and should not be seen as a substitute for obtaining appropriate advice or making prudent inquiries. The information is provided solely on the basis that readers will be responsible for making their own assessment of the matters discussed and that they should verify all relevant representations, statements and information. Changes in legislation, or other circumstances, after the document has been published may impact on the accuracy of any information or advice contained in the document and readers should not rely on the accuracy of information presented in this document.

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CONTAMINATED SITES MANAGEMENT SERIES

The guideline forms part of a management series developed by DEC's Land and Water Quality Branch to help in the assessment and management of contaminated sites in Western Australia (WA). The management series guidelines encourage consistent and accurate reporting by informing consultants, industry and landowners of the information required by DEC to enable appropriate management of contaminated land and groundwater in WA.

The Contaminated Site Management Series comprises the following guidelines:

- Assessment Levels for Soil, Sediment and Water
- Bioremediation of Hydrocarbon Contaminated Soils in Western Australia
- Certificate of Contamination Audit Scheme
- Community Consultation
- Contaminated Sites and the Landuse Planning Process
- Contaminated Sites Auditors Guidelines for Accreditation, Conduct and Reporting
- Development of Sampling and Analysis Programs
- Disclosure Statements
- Potentially Contaminating Activities, Industries, and Land Uses
- Reporting of Known or Suspected Contaminated Sites
- Reporting on Site Assessments
- Site Classification Scheme
- The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach; and
- Use of Monitored Natural Attenuation for Groundwater Remediation

Copies of these guidelines are available from DEC's library located at The Atrium, 168 St Georges Terrace, Perth, WA 6000 or from DEC's website at www.dec.wa.gov.au/contaminatedsites.

STAGED APPROACH TO SITE INVESTIGATIONS

DEC has developed the Contaminated Sites Management Series of guidelines to encourage a consistent approach to contaminated site assessment and management. A **staged approach to site investigation** is a primary objective of the series in order that appropriate resources are allocated to the project.

The purpose of the following flowchart is to highlight to the reader the appropriate reference guideline(s) during each stage of site investigation.

Stages of Site Investigation	Contaminated Sites Management Series guidelines
Stage 1 **Preliminary Site Investigation** **(PSI)**	Potentially Contaminating Activities, Industries and Landuses Reporting of Known or Suspected Contaminated Sites Community Consultation The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach Reporting on Site Assessments
Development of a HSEP and SAP*	
Stage 2 **Detailed Site Investigation** **(DSI)**	Community Consultation Assessment Levels for Soil, Sediment and Water Reporting on Site Assessments The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach
Development of a HSEP and SAP*	
Stage 3 **Site Management Plan (SMP)**	Community Consultation Reporting on Site Assessments The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach Use of Monitored Natural Attenuation for Groundwater Remediation Bioremediation of Hydrocarbon Contaminated Soils in Western Australia
Development of a HSEP and SAP*	
Stage 4 **Remediation, Validation and Ongoing Management**	Community Consultation Assessment Levels for Soil, Sediment and Water Reporting on Site Assessments Use of Monitored Natural Attenuation for Groundwater Remediation The Use of Risk Assessment in Contaminated Site Assessment and Management: Guidance on the Overall Approach

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

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1. Introduction

1.1 Purpose of the guideline

The purpose of the guideline is to outline the approach adopted by DEC in relation to risk assessment for the investigation and management of contaminated site issues. It is anticipated that the guideline will be used by environmental consultants, proponents and the general community to gain an understanding of how risk associated with contaminated sites should be addressed for the purposes of the *Contaminated Sites Act 2003*.

More detailed technical information on carrying out risk assessments is included in various guidelines referred to in this document and the forthcoming companion guideline in the Contaminated Sites Management Series: *The Use of Risk Assessment in Contaminated Site Assessment – Technical Guidance*.

A risk assessment of contaminated land should be carried out by suitably qualified and experienced professionals.

In the guideline, it is assumed that the subject site is suspected of posing a risk to human health or the environment and that the site has already been, or is about to be, reported to DEC in accordance with the *Contaminated Sites Act 2003*. Reference should be made to the Contaminated Sites Management Series guideline, *Reporting of Known or Suspected Contaminated Sites* (DEC, July 2006) for information to consider when determining whether a site should be reported to DEC under the provisions of the *Contaminated Sites Act 2003*.

1.2 The *Contaminated Sites Act 2003* and risk

The *Contaminated Sites Act 2003* defines "contaminated" as "*having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value*". Therefore, for a site to be considered "contaminated" there needs to be a risk (i.e. a source, pathway and receptor) that has either materialised, or has the potential to materialise.

DEC's objective is for contaminated sites to be managed according to the magnitude of the risk or potential risk that the site presents to human health, the environment and/or any environmental value. This process allows people responsible for remediation to prioritise actions at a suspected or known contaminated site in order to eliminate or mitigate the risks posed by the site within an appropriate timeframe.

Sites identified as posing a current risk to human health, the environment or environmental values, should be considered high priority and may require immediate implementation of interim management measures.

Where a site is found to be contaminated, DEC requires the derivation of site-specific response/clean-up levels in accordance with the National Environment Protection Measure (NEPM) and the enHealth Guidelines for ecological and/or health risk assessment, based on sound and accurate field and analytical results.

It may be necessary to conduct more than one phase of risk assessment during the assessment and remediation process. For example, one risk assessment may be necessary to evaluate the potential risk posed by a site under the current land use, while a further risk assessment may be required to validate a site after remediation has been completed to ensure that the remediation objectives have been achieved.

1.3 National risk assessment framework documents

There are a number of national guidance documents for conducting human health and environmental risk assessment in Australia. Risk assessments should comply with the methods outlined in the following documents:

1.3.1 NEPM

The *National Environment Protection (Assessment of Site Contamination) Measure* (NEPC, 1999) (referred to here as the NEPM) produced by the Federal National Environmental Protection Council provides a national framework for conducting human health and ecological risk assessments in Australia.

"Risk" is defined in this document as "*the probability in a certain timeframe that an adverse outcome will occur in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular dose or concentration of a hazardous agent, i.e. it depends on both the level of toxicity of the hazardous agent and the level of exposure*". The NEPM addresses assessment of contamination, but does not consider remediation or management of risk and risk-based assessment of groundwater.

1.3.2 enHealth

The Department of Health and Ageing and enHealth Council have published *Guidelines for Assessing Human Health Risks From Environmental Hazards* (enHealth, 2002) and the *Australian Exposure Assessment Handbook* (enHeath, 2003) (referred to here as the enHealth guidelines). These documents contain the same definition of "risk" as presented in the NEPM, and present a similar framework for carrying out risk assessments. While the guidance is focused on human health, it provides guidance for environmental health risk assessment for contaminated sites, as well as air pollutants, food and water. The enHealth guidelines consider both the assessment and management of risk.

1.3.3 ANZECC (2000)

ANZECC and ARMCANZ published the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* in 2000. Guideline trigger values are presented for a range of chemicals and water quality indicators for both fresh and marine waters. Assessment guidelines are provided for varying levels of species protection. The document also provides a framework for conducting an assessment of risk to aquatic species on a site-specific basis. In addition, guideline levels have been presented for a number of water uses including irrigation and stock watering.

1.3.4 ADWG (2004)

The 2004 *Australian Drinking Water Guidelines* (ADWG) were developed by the National Health and Medical Research Council (NHMRC) in collaboration with the Natural Resource Management Ministerial Council (NRMMC). The ADWG incorporates the *Framework for*

the Management of Drinking Water Quality and provides the Australian community and the water supply industry with guidance on what constitutes good quality drinking water.

1.4 Objectives of risk assessment

Risk assessment involves assessing the potential for exposure to contamination and the severity of the effect of such exposure. It is a tool that is intended to provide the information necessary to make informed decisions regarding the requirements for management of the contamination.

The main objectives for carrying out a contaminated site risk assessment are to ensure that human health and the environment are protected, and that the necessary resources are allocated in a prioritised and defensible manner to ensure that unacceptable identified risks are reduced to tolerable (acceptable) levels.

Where risk assessment identifies the potential for unacceptable risks to be present (i.e. exposure is likely to exceed the determined maximum allowable dose or allowable exposure), then risk management is necessary to mitigate the unacceptable risks.

Risk assessment formalises the process of identification of the key issues associated with contamination, including the nature of the contamination, the potential hazards present, the significance of data gaps, and the level of uncertainty present. The assessment takes into account factors relevant to the site such as the proposed land use and the depth and distribution of the contamination.

Risk assessment requires a high degree of objectivity and scientific skill and should be carried out by appropriately experienced professionals.

1.5 Objectives of risk management

Risk management involves evaluating alternative actions for the management of unacceptable risks identified by a risk assessment of a contaminated site. An appropriate management strategy is selected and implemented based on evaluation of the alternatives.

The main objective for risk management is to ensure that risks associated with a contaminated site are proportionately and appropriately managed.

The selection of the preferred risk management strategy is based on scientific, social and economic information. The consideration of risk management options necessarily involves value judgements that take into account the information from the health and/or ecological risk assessment, together with an assessment of the relative costs, regulatory policy positions and community acceptance of the risks. The risk management process also includes undertaking any necessary monitoring and evaluation of the results and actions taken, and communication of results to stakeholders and the general public.

Australian Standard AS/NZ 4360 presents a framework for carrying out risk management and general guidance which can be applied to decision making for contaminated sites.

The principles and process of environmental risk management are explained, and guidance provided on implementation, in the Standards Australia handbook HB203:2006 *Environmental Risk Management – Principles and Process*. It is based on the generic risk management process developed in AS/NZS 4360 and offers a clear, consistent model and an integrated framework for environmental risk management.

1.6 Community consultation

Community consultation is an ongoing process that should occur throughout the assessment and management processes. Early community consultation is most likely to result in building community credibility of the organisations involved and result in an outcome which receives broad community acceptance.

The process of identifying potential stakeholders and inviting them to participate in the community consultation process should be as inclusive as possible. DEC requires proponents to take reasonable measures to invite potentially interested parties to participate in the process, and the process undertaken should offer reasonable opportunities for community involvement. It is important to maintain open communication at all times, and ensure that the community is able to access appropriate information throughout the assessment process.

More information can be found in the Contaminated Sites Management Series guideline, *Community Consultation* (DEC, 2006) available from the DEC website www.dec.wa.gov.au/contaminatedsites, which may be helpful in developing a community consultation strategy.

The following documents may also be helpful:

- Citizens and Civics Unit (2004), *Consulting Citizens – Engaging with Aboriginal Western Australians.* CCU publications are available from <http://www.ccu.dpc.wa.gov.au>;
- Citizens and Civics Unit (2003), *Consulting Citizens – Planning For Success*;
- Citizens and Civics Unit (2002), *Consulting Citizens – A Resource Guide;*
- enHealth Council *et al* (2002), *Environmental Health Risk Assessment* – Section 2.2 Community Consultation and Involvement;
- DoE* (2003), *Interim Industry Guide to Community Involvement*;
- DoE* (2003), *Community Involvement Framework*;
- *National Environment Protection (Assessment of Site Contamination) Measure (1999) – Schedule B(8) Guideline on Community Consultation and Risk Communication*; and
- International Association for Public Participation (IAP2, 2000), *Public Participation Toolbox.*

* Now the Department of Environment and Conservation

2. Application of risk assessment to contaminated sites

2.1 Staged approach

In accordance with the provisions of the *Contaminated Sites Act 2003*, some level of risk assessment will be required for all suspected and known contaminated sites reported to DEC.

A staged approach to site contamination is presented in Schedule B(4) (figure 4 II) and B(5) (figure 4 I) of the NEPM Guidance document and forms the basis for risk assessment of contaminated sites in Australia. The goal of the staged approach is to use simple conservative assumptions in preliminary assessments to identify which issues are likely to present the greatest risk, allowing more detailed (site-specific) risk assessment to focus on these issues. This approach allows resources to be focused on the more critical issues associated with a site in a prioritised and defensible manner to ensure that any unacceptable risks will be reduced to an acceptable level.

DEC recommends adopting a staged approach for risk assessment, involving:

- Tier 1: screening risk assessment
- Tier 2: intermediate risk assessment
- Tier 3: detailed (site-specific) risk assessment.

DEC recommends adopting a staged approach, which includes risk assessment, for site investigations. This approach is outlined in the Contaminated Sites Management Series documents *Assessment Levels for Soil, Sediment and Water (DoE, 2003) and Development of Sampling and Analysis Programs (DEP*, 2001).* These documents should be consulted when carrying out a screening or more detailed risk assessment.

2.2 Conceptual site model

A critical element at each level of risk assessment is the development, or further development, of a conceptual site model (CSM) that describes the possible pathways by which exposure to potential contamination at the site may occur. The initial CSM is then revised as more detailed information on the site becomes available and the nature of the contamination and the issues arising are better understood.

For exposure to occur, a complete pathway must exist between the source of contamination and the "receptor" (i.e. the person or ecosystem components potentially affected by the contamination). Where the exposure pathway is incomplete, exposure cannot occur, leaving no risk present via that pathway. However, the potential for new exposure pathways to be created, for example by a proposed change of land use, should be considered in the CSM.

An exposure pathway will typically consist of the following elements:

- a source of contamination (e.g. a spill)
- a release mechanism (e.g. migration in soil, leaching to water, emission to air)
- retention in the transport medium (e.g. soil, groundwater, surface water, air)

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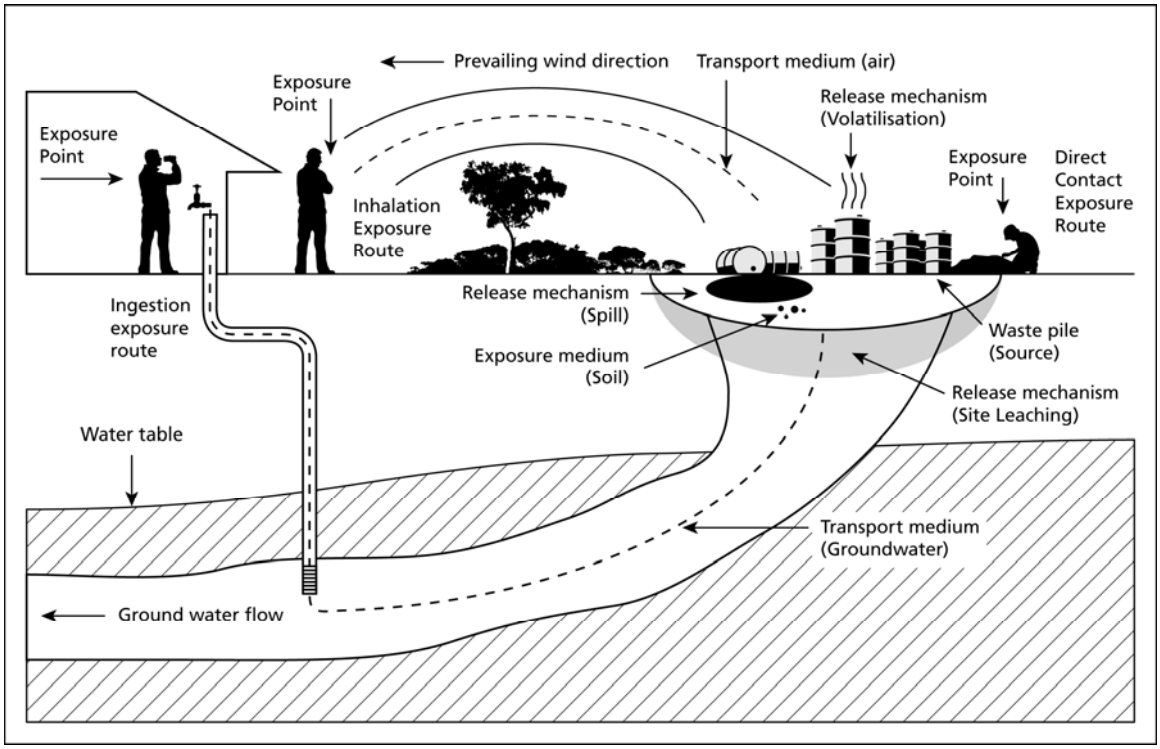
- an exposure point (e.g. where a person comes into contact with contaminated dust or soil or contaminated groundwater from a well, or in a building overlying volatile contamination)
- an exposure route (e.g. inhalation, ingestion, absorption through the skin).

Examples of exposure pathways are illustrated in Figure 1.

Figure 1: A graphical representation of a conceptual site model



The development of the CSM should include the identification of all contaminant sources, modes of migration, potential receptors of concern, and how exposure may occur (i.e. the exposure pathway route). The CSM documentation will usually include a diagrammatic representation such as Figure 1 or other means of describing the various exposure pathways and their relevance to the site.

Consideration must be given to all aspects of contamination exposure. Often the presence of contamination will give rise to a number of issues that require consideration. For example, soil contamination may pose a risk to human health through direct ingestion of soil particles or, if volatile, through volatilisation and entry into buildings or, if leachable, through migration via groundwater and exposure where the groundwater is used or supports a groundwater dependent ecosystem. All of these issues should be identified in the initial CSM and considered in the development of the site investigation program.

2.3 Tier 1 - screening risk assessment

The first stage of risk assessment comprises a Tier 1 s*creening risk assessment*. The objective of a screening assessment is to identify the relevant contamination issues, i.e. the contaminants, exposure pathways and receptors present and to screen out those contaminant-exposure pathway-receptor links which do not pose an unacceptable risk.

The assessment includes the development of a CSM, and comparing site data with generic assessment levels, such as those for soil, sediments, surface water and groundwater presented in the DoE document, *Assessment Levels for Soil, Sediment and Water* (2003).

Consideration needs to be given to the appropriateness of the assessment levels to the site, including the site setting and the exposure assumptions. The site assessment levels have been developed assuming certain exposures will occur and if the site circumstances are such that standard exposure assumptions are not likely to apply, then some adjustment may be warranted (refer to section 2.4 *Tier 2 intermediate risk assessment*). For example, if contamination is to be effectively contained under building structures (such as a multi-storey building), then it may be reasonable to assume that residents in the building will not ingest soil as has been assumed in the development of the soil assessment levels.

After a Tier 1 screening risk assessment has been completed there are a number of possible options:

- If the Tier 1 screening risk assessment is considered to adequately characterise the risks associated with the contamination, then the assessor may use the findings to determine the requirements for management of the unacceptable risks identified.
- If the Tier 1 screening risk assessment does not adequately characterise the risks associated with the contamination (e.g. the assumptions underlying the site assessment levels are not appropriate for the site), then the assessor may elect to proceed with a Tier 2 (simple) risk assessment.
- If it is known that a Tier 2 intermediate risk assessment will not adequately characterise the risks at the site (e.g. assessment levels have not been published for the contaminant or exposure scenario) then the assessor may proceed with a Tier 3 (detailed) risk assessment.

A cost-benefit analysis may help in deciding which step to take. For example, carrying out a more detailed investigation and assessment may result in lower costs for remediation, offsetting the increased investigation and assessment costs and reducing overall costs. However, this is not always the case. A more detailed investigation and assessment may show that the generic assumptions do not adequately consider the relevant exposure situation and may result in more stringent requirements for remediation.

Example of a Tier 1 screening risk assessment:

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

In order to determine if the contamination of the soil might adversely affect the use of the site for residential purposes, a screening assessment is carried out comparing the measured concentrations of the metals in the soil with generic soil assessment levels. If the concentrations are below the human health and ecological investigation or assessment levels then this suggests that no further action is required with respect to the soil to protect human health and on-site plant growth in gardens.

However, before the assessment is finalised it is important to ensure that the contamination, if

left in place, would not give rise to other undesirable effects, which include:

- Leaching of contaminants giving rise to groundwater contamination (unlikely if the concentrations are restricted to the surface soil and are less than the Ecological Investigation Levels).
- Odour (unlikely in the case of metals; direct field observations would confirm this).
- Emission of volatiles that could enter through the floor of buildings and accumulate, adversely affecting the health of residents or occupants (not applicable for metals).
- Erosion of contaminated soil following rain, leading to contamination of adjacent properties or waterways.

2.4 Tier 2 - intermediate risk assessment

If the site setting and exposure scenario significantly differ from the assumptions that underlie the site assessment levels, it may be necessary to adjust the soil or water assessment levels and develop modified generic assessment levels which more closely reflect the exposure scenario. Caution is required when carrying out this process, because some of the assumptions that underlie the soil and water assessment levels reflect policy positions which should not be changed (for example consumption of two litres of water per day in the development of the *Australian Drinking Water Guidelines*). Further information is provided in the NEPM Schedule B (4) Sections 6.10 and 6.11. It may still be appropriate to use the unmodified generic criteria for the assessment of contaminant concentrations at off-site locations (e.g. contaminant concentrations in groundwater at a sensitive receptor).

It is essential that the basis for any change to the generic assumptions is fully justified and clearly documented. There must be an expectation that the assumed exposure scenario will adequately represent the site land use and potential offsite impacts with a reasonable degree of conservativeness. For example, if it is assumed that soil will be contained under a building and exposure via ingestion will not occur, then consideration should be given to whether future maintenance could involve exposure to the contamination.

Modified generic investigation levels/site response levels and the information upon which they are based must be reviewed by DEC, Department of Health (DoH) and/or an accredited contaminated site auditor to ensure that they are acceptable before use.

After a Tier 2 intermediate risk assessment has been completed there are a number of possible options:

- If the Tier 2 intermediate risk assessment is considered to adequately characterise the risks associated with the contamination, then the assessor may use the findings to determine the requirements to manage the unacceptable risks identified.
- If the Tier 2 intermediate risk assessment does not adequately characterise the risks associated with the contamination then the assessor may proceed to a Tier 3 detailed (site-specific) risk assessment.

A cost-benefit analysis may assist in deciding whether to proceed beyond a Tier 2 intermediate risk assessment to a Tier 3 detailed (site-specific) risk assessment.

Example of Tier 2 simple risk assessment:

A site proposed for high-density residential development is found to have heavy metals (e.g. lead and copper) in the soil at concentrations that exceed DEC - adopted health assessment levels for soil for high density residential development (HIL D). In this case the screening

assessment would highlight that the assessment levels are exceeded, suggesting that further investigation and possibly clean up is required.

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

In this specific exposure scenario, it may be considered acceptable to permit soils with contaminant concentrations in excess of the generic assessment levels (HIL D) to remain on site. However, before this proposal could be accepted, there are a number of factors to be considered:

- The works associated with the building's construction should not result in the redistribution of contaminated soil elsewhere on the site where subsequent exposure could occur. It is possible that the development and implementation of a suitable site management plan could address this issue.
- The building works should be carried out so as not to pose an unacceptable level of risk to the occupational health of workers (consider application of relevant WorkSafe standards).
- The requirement for an appropriate site management plan for future works or maintenance that would involve excavation and exposure of soil under the building, which may occur if new utilities or services were to be provided, or existing services required maintenance. If such works are anticipated, then it may be possible to develop a suitable site management plan. If all building works were subject to control through a management body, such as a Body Corporate, then it may be reasonable to assume that the site management plan would be implemented.
- The contamination is not volatile such that volatile contaminants could migrate through the sub-base or building floor or along service conduits or trenches (unlikely if the contamination only involves metals).
- The contamination is above the seasonal high water table (if the contamination was below the water table it could give rise to groundwater contamination) and is not leachable and will not leach into groundwater.
- The presence of contamination is indicated by a memorial on the relevant Certificates of Title so that contamination is reconsidered when the site is redeveloped.

2.5 Tier 3 - detailed (site-specific) risk assessment

A Tier 3 detailed risk assessment is carried out when a Tier 1 screening risk assessment and/or a Tier 2 intermediate risk assessment (which are based on generic assessment levels) does not, or cannot, adequately assess the level of risks present at the site. It involves developing site-specific investigation or response levels for contaminants where generic assessment levels are not available or are not appropriate for the site. It may involve, for example, specialised contaminant fate and transport modelling and/or a toxicity assessment of particular contaminants.

In a detailed risk assessment the use of site-specific information may result in less conservative exposure assumptions being adopted, reflecting the better understanding of the site and consequent reduced levels of uncertainty. These more realistic assumptions may result in site response levels (acceptance criteria) that correspond to higher concentrations of

contaminants than the generic assessment levels used for screening purposes, but which are nevertheless protective of human health, the environment and environmental values.

A cost-benefit analysis may assist in deciding whether to proceed beyond a Tier 1 screening risk assessment or a Tier 2 intermediate risk assessment to a Tier 3 detailed (site-specific) risk assessment. Note that a more detailed assessment (generally requiring more detailed investigation data) may result in lower costs for remediation; however, this is not always the case.

Site-specific response levels and the site information upon which they are based must be reviewed by an accredited contaminated sites auditor and/or DEC and DoH to ensure they are acceptable before use.

If it is clear that a Tier 3 detailed (site-specific) risk assessment is required, a Tier 1 screening risk assessment can be used to identify those issues and contaminants which are of major concern, allowing the Tier 3 detailed (site-specific) risk assessment to focus on the critical elements.

For example, if soil contamination was identified in the Tier 1 screening risk assessment to be acceptable with regard to human health and ecological risk, but issues with respect to contaminants in groundwater migrating to a nearby water body were identified as a potential problem, then the Tier 3 detailed (site-specific) risk assessment should concentrate on evaluating the risks associated with groundwater contamination and the requirements for management of these risks.

Examples where detailed risk assessment may or may not be required:

- If it is clear that a serious problem exists and immediate action is required, the available resources should initially be directed to manage the risks. Such management may include the implementation of immediate mitigation measures followed by an assessment of the residual risks. If it is clear from the subsequent assessment that the contamination no longer poses an unacceptable risk, no further action would be required.
- If it is clear that the assumptions in a Tier 1 screening risk assessment are not relevant to the site and a modification of the assessment criteria is not possible to appropriately characterise the conditions that apply at the site, it may be appropriate to proceed directly to a Tier 3 detailed (site-specific) risk assessment. Examples of this are where there are no soil assessment levels for the contaminants of concern, or the proposed use of the site does not match any of the land use scenarios for which soil assessment levels have been defined (e.g. agricultural land).

At all stages of the site assessment process, options exist to carry out more detailed investigation and assessment, or to proceed directly to risk management. Figure 2 outlines the recommended staged approach and a suggested decision making process for undertaking risk assessment and determining whether remediation is required.

It is likely that a Tier 3 detailed (site-specific) risk assessment will not be necessary in many instances as the issues will be self-evident and the Tier 1 screening risk assessment or Tier 2 intermediate risk assessment process will provide sufficient information to determine a suitable risk management strategy.

Example of a Tier 3 detailed (site-specific) risk assessment:

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

However, this might not be the case if the contamination was found to be located throughout the soil profile (e.g. the contamination was to be associated with deep fill) and found to extend beneath the water table at the site, so that contamination may leach into the groundwater. For example, consider the case where the groundwater is of potable quality, an extraction well exists on the neighbouring property, and analysis of a groundwater sample from an on-site well in the vicinity of the contamination indicates that the assessment levels applicable to the use of the groundwater are exceeded.

This scenario indicates a potential risk to the neighbour by the contamination leaching from the soil and migrating via the groundwater to the neighbour's well.

In this situation a Tier 3 detailed (site-specific) risk assessment would be necessary to better understand the risk to the neighbour and, the need for and urgency of remediation. This may involve further investigation such as sampling of the neighbour's well, the installation and sampling of additional groundwater wells, establishing actual groundwater use, leaching tests of the soil, and contaminant fate and transport modelling to evaluate the potential migration of the contamination in the groundwater. Intervention, such as the provision of an alternative potable water supply or treatment of the well water may be appropriate, depending on the likely level of impact.

2.6 Changes in site condition

When a risk assessment is carried out, the assessment should consider all the pertinent information. Should conditions materially change at the site (e.g. change of land use) or new information becomes available, the proponent should review the risk assessment to determine the impact of the changes on the outcomes of the risk assessment and the recommended risk management strategy. It is the proponent's responsibility to notify DEC (or the contaminated sites auditor where the site assessment and management plan is yet to be endorsed by the auditor) when there is a material change.

Where previously unidentified contamination (in non-trivial quantities) is found during remediation or site redevelopment works, the proponent should notify the contaminated sites auditor and/or DEC immediately and the risk assessment and management strategy re-evaluated as appropriate.

Examples where DEC/contaminated sites auditor should be notified of a change in condition of a site:

Example 1

A risk assessment has been carried out for a site based on a proposed development comprising commercial land use. After completion and approval of the assessment, it is decided to turn part of the land into public open space (which is a more sensitive land use than commercial). DEC and/or the contaminated sites auditor should be notified of the change of proposed land use and the risk assessment should be reviewed and re-submitted with respect to the new proposed land use scenario.

Example 2

A groundwater plume has been fully delineated (both horizontally and vertically), and a Tier 3 detailed (site-specific) risk assessment, involving contaminant fate and transport modelling, has been conducted which suggests that monitored natural attenuation (MNA) is a suitable means of remediation for the site. An extensive groundwater monitoring program is in place to assess the progress of natural attenuation in reducing groundwater contamination. However, after two years of monitoring it is evident that the levels of contamination are not decreasing as predicted, and trigger levels have been, or are likely to be, exceeded. In these circumstances it is not appropriate to wait until trigger levels have been exceeded before contingency measures are implemented.

A critical review of the monitoring results and a comparison with the Tier 3 detailed (site-specific) risk assessment predictions should be included in each monitoring report. The assumptions made in the Tier 3 detailed (site-specific) risk assessment should be reviewed on an annual basis in the context of the new information and the risk assessment revised if appropriate. The adequacy of contingency measures and the trigger levels which trigger their implementation should also be reviewed in the monitoring report.

2.7 Risk management

The framework for carrying out risk management outlined by enHealth is consistent with that outlined in Australian Standard AS/NZ 4360. The standard provides a framework for risk management. In AS/NZ 4360 risks are defined as "event driven" and risks are ranked in terms of probability of occurrence or frequency (i.e. likelihood) and severity (i.e. consequence). In AS/NZ 4360 the likelihood and consequence is ranked on a simple 1 – 5 basis, and the estimate of risk is qualitative or semi-quantitative.

The approach outlined in AS/NZ 4360 can be useful when considering the likelihood that a situation or consequence will arise, the severity of that situation or consequence, and prioritising action(s) that should be undertaken.

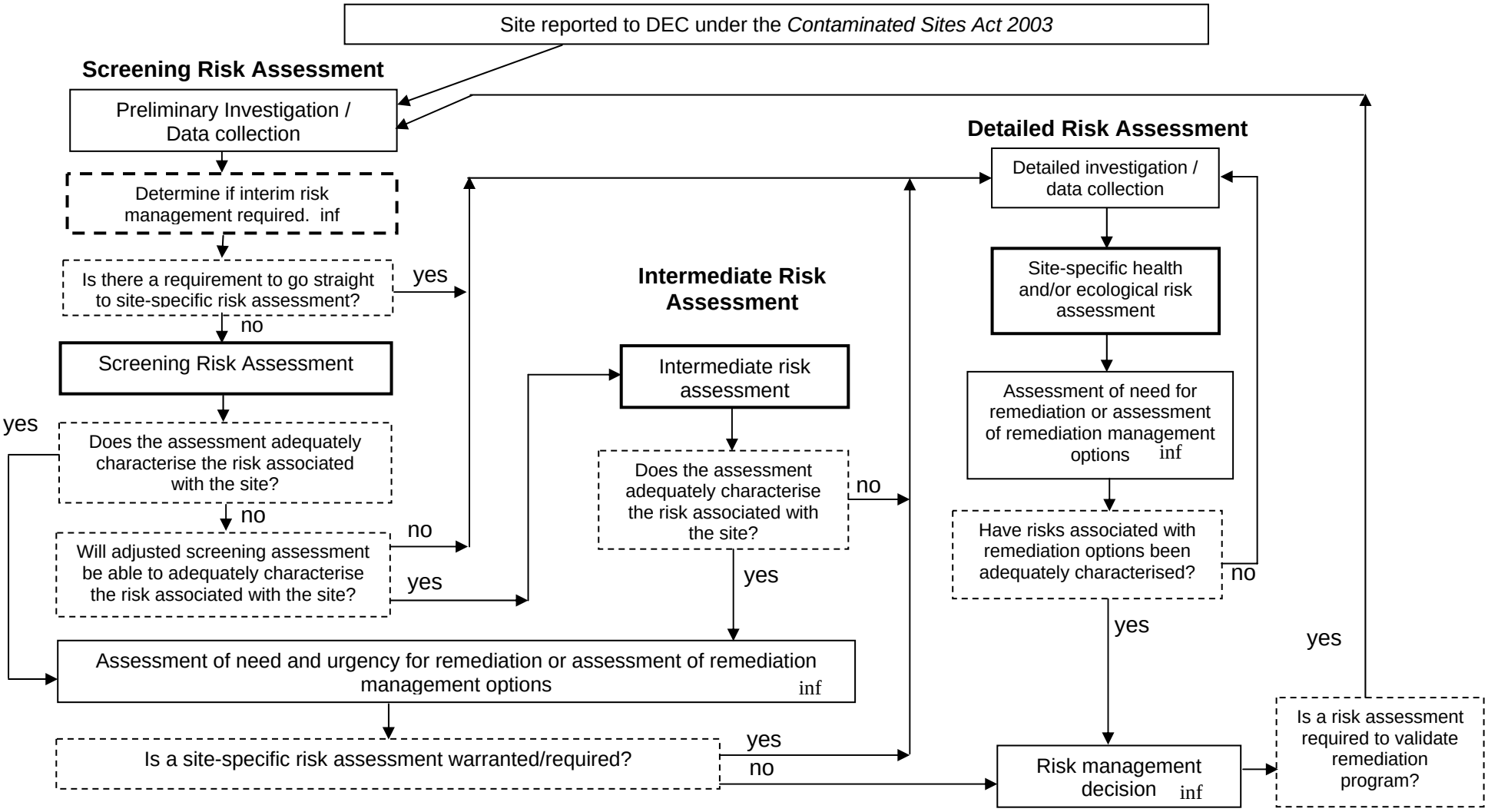
The principles and process of environmental risk management are explained and guidance on implementation provided in the companion Standards Australia document HB203:2006 *Environmental Risk Management – Principles and Process*. The document is based on the generic risk management process developed in AS/NZS 4360 and offers a clear, consistent model and an integrated framework for environmental risk management.

The implementation of AS/NZ 4360 can be considered as an extension of the conceptual site model. The analysis should consider the potential exposure scenarios ("event") and the likelihood, and severity of exposure ("risk"). The analysis should be used to assist in making management decisions for mitigating risk, giving priority to the highest risk issues. This process may also be used for assessing adequacy of remediation plans and proposed developments, to ensure that the final outcome is protective of human health, the environment and relevant environmental values.

While risk assessment forms an integral part of the decision-making process, there are other factors which need to be considered in the overall management of the site. These issues may include social and economic factors relevant to the site.

More information on risk management is included in Section 5 of this document.

Figure 2: Risk assessment decision-making process



inf: DEC should be informed of potential hazard if identified

Examples of situations where the approach outlined in AS/NZ 4360 may be useful:

Example 1 A decision needs to be made if contamination present at depth poses such a high risk that it requires remediation. It may be that the contamination is at such a depth (for example more than 5m below surface) that it is very unlikely that it would be encountered or exposed in the course of the normal activities that would take place on the site. If the contamination were minor and exposure to the contamination unlikely to give rise to serious health effects or affect groundwater, then it may be concluded from an assessment of likelihood and consequence that the overall risk is low and it might be acceptable to leave the contamination in place.

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

Example 2 A site contains a localised volume of groundwater contamination where contaminant levels exceed the drinking water and irrigation water criteria. The area is served by scheme water and it is very unlikely that the groundwater would be used in practice for a sensitive use that potentially could give rise to a serious problem (e.g. potable uses). An assessment of the likelihood and consequence in this situation might conclude that the risk is low and that remediation is not required. However, a memorial should be lodged on the Certificate of Title to alert any new owners to the potential problem.

3. Detailed risk assessment framework – human health

3.1 Introduction

The framework for carrying out a detailed health risk assessment is outlined in the NEPM and enHealth (2002). The framework involves four stages:

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

This framework has been adopted widely across Australia. It provides for a quantitative estimation of risk, based on an estimated exposure to a contaminant (or dose), and the likelihood that this will give rise to an adverse affect (dose response).

Risk management is an extension of the risk assessment process by way of implementation of actions to mitigate unacceptable risks. Risk assessment and risk management form an integrated process as shown in Figure 3.

The stages of the framework for risk assessment outlined in this section are explicitly defined for conducting a Tier 3 detailed (site-specific) risk assessment. However, it should be noted that the process outlined here is the same framework that is used to derive the generic assessment levels for soil that are used in the Tier 1 screening risk assessment. Hence, this risk assessment framework is inherent in all three levels of risk assessment.

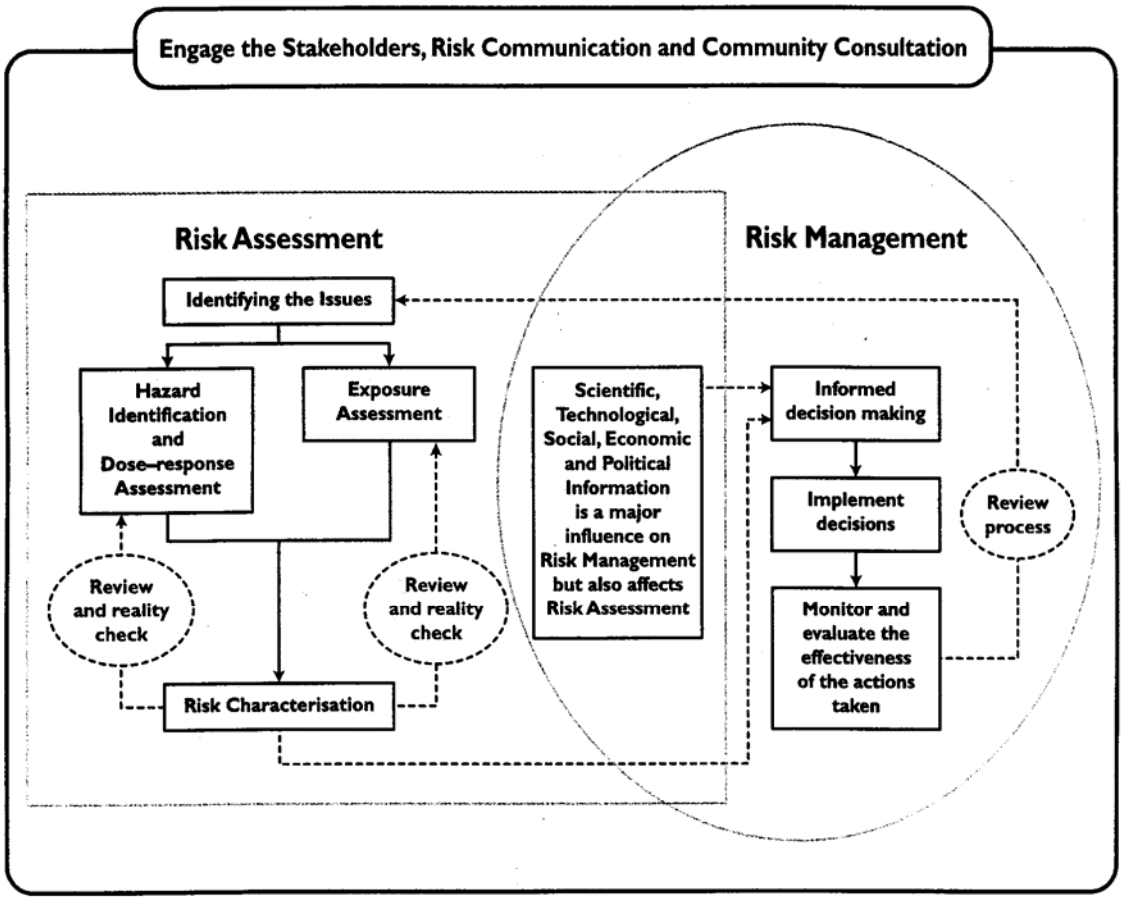
3.2 Issue identification

Issue identification is the process of identifying the concerns that the risk assessment needs to address and establishes the context for the risk assessment. Issue identification comprises several phases, including:

- identification of environmental health issues and determining whether there are hazards amenable to risk assessment
- putting the hazards into their environmental health context (classification and prioritising of problems and hazards)
- identification of potential interactions between agents
- defining the scope and objectives of the risk assessment.

A conceptual site model (as discussed in Section 2.1) should be developed or revised during this stage to help identify the potential issues and hazards at the site.

Figure 3: Relationship of risk assessment and risk management in the Australian framework for human health risk assessment



(Figure 2, enHealth (2002))

3.2.1 Quality of input data

Data collection is a significant component of issue identification. The quality of a risk assessment depends on the quality of input data on which the risk assessment is based. The goal of data collection is to adequately characterise the nature and extent of contamination issues arising from a site.

Most data collection will occur as part of the preliminary and detailed site investigations. Consideration should be given to the history of the site, the nature of the contamination, the geological and hydrogeological setting, and any sensitive land uses and use of groundwater in the vicinity of the site. Site investigations must adequately characterise potential contamination issues at a site, and must include adequate quality assurance and quality control measures. The sampling requirements may need to be formulated to provide information on specific issues that need to be addressed as part of a detailed risk assessment (e.g. groundwater fate and transport modelling). More information can be found in the publication, *Development of Sampling and Analysis Programs,* (DEP, 2001).

The quality and quantity of data obtained during a site investigation must be adequate and appropriate for the level of detail required to conduct the risk assessment. All data used in the assessment, including field and laboratory data, must be validated. The presence of data gaps should be considered and assessed for their significance and potential impact on the results to identify critical issues which may require further investigation.

More information on sampling plans and QA/QC requirements can be found in *Development of Sampling and Analysis Programs* (DoE, 2001) and Schedule B(2) of the NEPM.

3.3 Hazard assessment

Hazard assessment, also known as toxicity assessment, refers to the nature of the contamination and the potential risk that may occur from exposure to such contamination. There are two elements to the toxicological assessment: hazard identification and dose-response assessment.

3.3.1 Hazard identification

Hazard identification examines the capacity of an agent to cause adverse health effects. It is a qualitative description based on the type and quality of the data, complementary information (e.g. genetic toxicity), and the weight of evidence from these various sources. Key issues include:

- nature, reliability and consistency of human and animal studies;
- the availability of information about the mechanistic basis for activity; and
- the relevance of the animal studies to humans.

3.3.2 Dose-response assessment

The dose-response assessment examines the quantitative relationships between exposure and the effects of concern. The determination of whether there is a hazard is often dependent on whether a dose-response relationship is present. Key issues include:

- the relationship between the extrapolation models selected and available information on biological mechanisms
- how appropriate data sets were selected from those that show the range of possible potencies both in laboratory animals and humans
- the basis for selecting interspecies scaling factors to account for scaling doses from experimental animals to humans
- relevance of the exposure route used in the studies to a particular assessment and the interrelationships of potential effects from different exposure routes
- environmental conditions (e.g. pH, organic matter, clay content, temperature)
- the relevance to the assessment of the expected duration of exposure and the exposure durations in the studies forming the basis of the dose-response assessment
- the potential for differing susceptibilities in population subgroups.

The recommended approach that should be taken with regard to toxicity assessment is outlined in the enHealth guidelines (enHealth, 2002).

3.4 Exposure assessment

Exposure assessment involves the determination of the magnitude, frequency, extent, character and duration of exposures in the past, present and the future.

An initial requirement for exposure assessment is an understanding of the presence of an agent and its concentrations and distributions, identification of exposed populations and potential exposure pathways. This initial requirement makes up the basis of the conceptual site model (Section 2.1).

An understanding of fate and transport models for the agent is also important. Transport and fate will be affected by environmental media, geographical scale, pollutant source characteristics and nature of the risk agent, the receptor population, exposure routes, environmental conditions and the timeframe for exposure.

The recommended approach that should be taken with regard to exposure assessment is outlined in the enHealth guidelines (enHealth, 2002). Guidance specific to contaminated land is also presented in Schedule B(4) & B(5) of the NEPM.

3.5 Risk characterisation

Risk characterisation is the final step in the risk assessment process that:

- integrates the information from hazard assessment and exposure assessment
- provides an evaluation of the overall quality of the assessment and the degree of confidence the authors have in the estimates of risk and conclusions drawn
- documents the uncertainties present and the nature of the assumptions made within the assessment
- describes the risks to individuals and populations in terms of nature, extent and severity of potential adverse health effects
- communicates results of the risk assessment to the risk manager
- provides key information for risk communication.

Risk characterisation may involve comparing environmental data, exposure data, intakes and biological monitoring results with established criteria. The level of risk can be described either qualitatively (high, medium or low risk) as in AS/NZ 4360 (refer to Section 2.6) or quantitatively (with a numerical estimate).

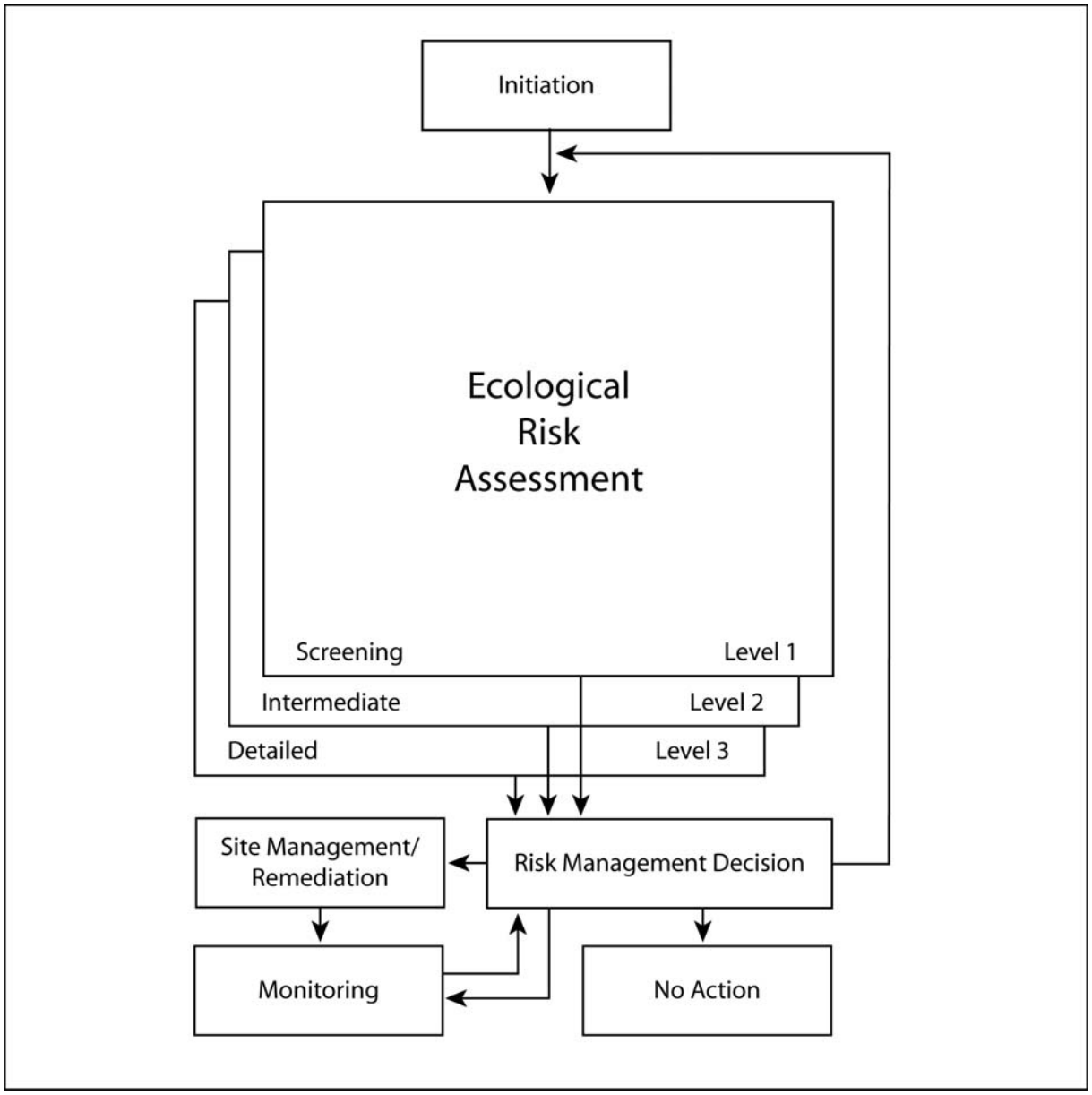
The recommended approach that should be taken with regard to risk characterisation is outlined in the enHealth guidelines (enHealth, 2002) and in Schedule B(4) of the NEPM.

4. Risk assessment framework – ecological

4.1 Framework

The framework for ecological risk assessment (ERA) is comparable to that for human health risk assessment. It is outlined in Schedule B (5) of the NEPM for soil, and in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) for groundwater and surface water. The NEPM proposes a staged approach to ecological risk assessment as for human health. The framework is illustrated in Figure 4 below.

Figure 4: Australian Framework for Ecological Risk Assessment



(from NEPM Schedule B(5))

The ERA framework is an iterative process that comprises three levels of assessment. Each level consists of the same basic components but incorporates an increasing degree of complexity and data collection requirements as assessment proceeds from Tier 1 through to Tier 3. The level of assessment required depends upon many factors including the nature and

extent of the contamination, the sensitivity of ecological receptors and the availability of relevant exposure and toxicity data.

In many instances, the on-site ecological value may be very low (e.g. highly modified industrial sites) and the need for remediation will be driven by the protection of human health, groundwater resources and any off-site environmental receptors. The potential presence of both on-site and off-site ecological receptors should be considered in every site investigation and risk assessment.

4.2 Levels of ecological risk assessment

The recommended staged approach offers a degree of flexibility which allows the framework to be applied to sites of highly varied complexity.

The levels of assessment may be summarised as follows:

4.2.1 Tier 1 screening risk assessment

The first stage of a risk assessment comprises a Tier 1 screening risk assessment. The objective of a screening risk assessment is to identify the relevant contamination issues, i.e. the contaminants, exposure pathways and receptors present and to screen out those contaminant-exposure pathways-receptor linkages which do not pose an unacceptable risk. The Tier 1 screening risk assessment:

- is also known as a Level 1 ecological risk assessment;
- is a simple screening method to suit generic situations and protect all biota (terrestrial and aquatic) likely to inhabit a state, region or land use; and
- involves comparing soil and groundwater contaminant concentrations for identified contaminants of concern at the site with existing generic ecological investigation levels for soil (EIL_{soil}) or guideline trigger values for aquatic ecosystems (ANZECC & ARMCANZ, (2000)).

Examples of where a Tier 1 screening risk assessment may be appropriate:

- Public open space parkland contains elevated concentrations of heavy metals in surface soil and generic EIL_{soil} for the heavy metals are available.
- Elevated concentrations of ammonium, phenol and naphthalene are present in groundwater. The contamination is migrating towards a river located 300m downgradient of the site. In a Tier 1 screening risk assessment, measured groundwater concentrations on-site would be compared with the relevant trigger levels for freshwater ecosystems presented in ANZECC (2000).

The DEC guideline *Assessment Levels for Soil, Sediment and Water* (DoE, 2003), and the documents referenced therein, is recommended as the initial reference document for generic soil and water criteria.

4.2.2 Tier 2 intermediate risk assessment

If the site setting and exposure scenario significantly differ from the assumptions that underlie the site assessment levels, it may be necessary to adjust the soil or water assessment levels and develop modified generic assessment levels which more closely reflect the exposure scenario. Caution is required when carrying this process out, because some of the assumptions

that underlie the soil and water assessment levels reflect policy positions which should not be changed. It may still be appropriate to use the unmodified generic criteria for the assessment of contaminant concentrations at off-site locations (e.g. contaminant concentrations in groundwater at a sensitive receptor).

A Tier 2 intermediate risk assessment:

- is also known as a level 2 ecological risk assessment
- is largely a desktop assessment with some field studies (i.e. site-specific data) which provides an increased level of detail to components of the ERA process
- derives modified (site-specific) EIL_{soil} or aquatic trigger levels for contaminants of concern at the point of exposure
- compares on-site soil concentrations of contaminants of concern with the modified EIL_{soil} to characterise risk
- may use groundwater fate and transport modelling to estimate off-site concentrations of contaminants in groundwater to compare to generic assessment levels at the point of exposure (or modified generic assessment levels) to characterise the risk.

Examples of where a Tier 2 intermediate risk assessment may be appropriate:

- Where the contaminant of concern may be present in one or more chemical species or forms which have different properties (e.g. bioavailability, toxicity). For example, arsenic occurs either as the trivalent form; As(III) or pentavalent form; As(V) in soil and groundwater. A modified generic assessment level for soil could be derived from speciation of the arsenic form present at the site and consideration of the susceptibility of the receptors at risk.
- Where consideration is given to the levels of contaminants which are protective of the flora and fauna actually present at the site and its vicinity, rather than the protection of all possible species.
- Where consideration is given to the specific exposure scenarios of the receptors. Elevated concentrations of ammonium, phenol and naphthalene are present in groundwater. The contamination is migrating towards a river located 300m downgradient of the site. In a Tier 2 intermediate risk assessment, a simple groundwater model could be used to assess potential natural attenuation and estimate the groundwater concentration at the point of discharge.

4.2.3 Tier 3 detailed (site-specific) risk assessment

A Tier 3 detailed risk assessment is carried out when a Tier 1 screening risk assessment and/or a Tier 2 intermediate risk assessment (which are based on generic assessment levels) does not, or can not, adequately assess the level of risks present at the site. It involves developing site-specific investigation or response levels for contaminants where generic assessment levels are not available or are not appropriate for the site. It may involve, for example, specialised contaminant fate and transport modelling and/or a toxicity assessment of particular contaminants.

A Tier 3 detailed (site-specific) risk assessment:

- is also known as a level 3 ecological risk assessment
- uses field studies and computer models to quantify exposure levels
- gathers detailed site-specific information gathered as part of receptor identification, exposure assessment and toxicity assessment
- derives site-specific EIL_{soil} or water trigger levels for contaminants of concern that take into account ecological values on- and off-site
- may use detailed groundwater fate and transport modelling to estimate offsite concentrations of contaminants of concern to be compared with site-specific assessment levels (or modified generic assessment levels at the point of exposure) to characterise the risk.

Examples of where a Tier 3 detailed (site-specific) risk assessment may be required:

- A national park, which is known to contain native species, is impacted by contamination. Assessment may require a detailed biological survey of the site and surrounding area and toxicity assessment.
- Groundwater contamination is present hydraulically upgradient of a protected wetland. Detailed hydrogeological investigations, modelling and ground truthing may be required to determine the level of contamination at the site which presents a unacceptable risk to the wetland ecosystem.
- A complicated groundwater system with tidal influences is discharging into a bay containing a seagrass meadow ecosystem. A biological survey will be required to identify the sensitive species at risk. An extensive groundwater monitoring program will be necessary to provide the data required to construct a suitable three-dimensional fate and transport model which simulates the potential variations in groundwater discharge and dispersion and hence levels of contamination in sediment and water to which organisms may be exposed.

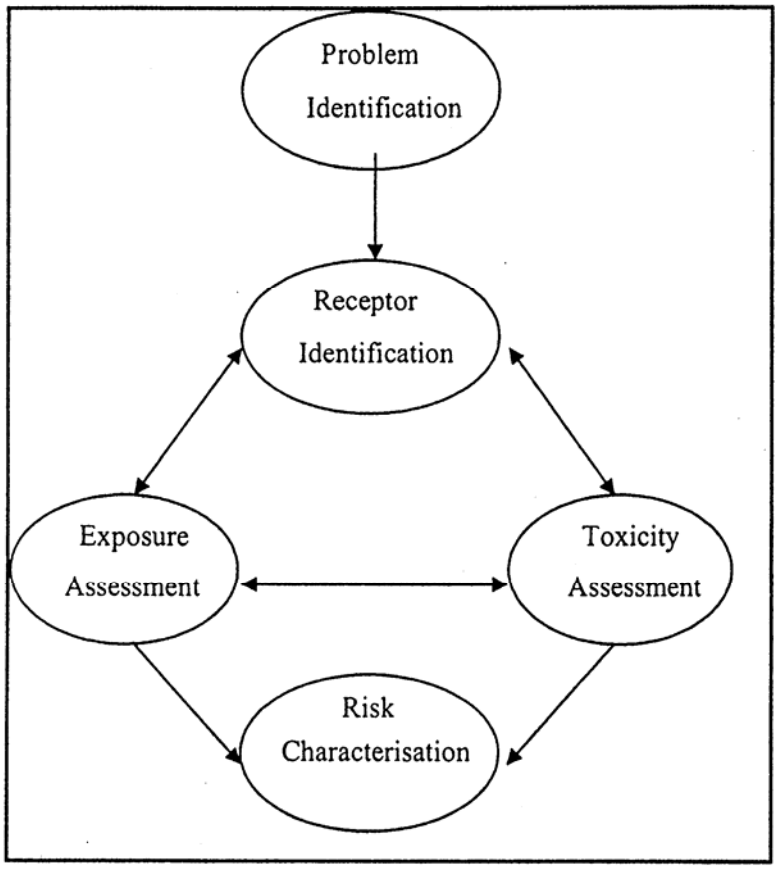
4.3 Components of an ecological risk assessment

Regardless of the level of assessment, the assessment consists of five basic components:

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

These components and the iterative relationships between them are shown in Figure 5.

Figure 5: Components of an Ecological Risk Assessment



(Extract from NEPM Schedule B(5))

The components are analogous to those in human health risk assessment and are often carried out in conjunction with those for a human health risk assessment. For example, problem identification for both human and ecological receptors would be carried out as part of the development of the conceptual site model (CSM) as described in Section 2.2.

For specific details on conducting environmental risk assessments refer to NEPM Schedule B(5) for soil, and the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000) for groundwater and surface water risk assessments.

Before commencing a Tier 3 detailed (site-specific) risk assessment, the scope of the assessment should be discussed with the appointed accredited contaminated sites auditor or DEC.

5. Risk management

5.1 Overview

Risk management is the process of evaluating alternative actions and selecting options in response to a potential environmental hazard to mitigate the potential risks. The decision making process should incorporate an assessment of relevant technical, social and economic factors.

A framework for the integration of risk assessment and risk management is illustrated in Figure 3 (enHealth (2000)). The framework includes making decisions, taking actions, monitoring and subsequent review, as well as the interaction between risk assessment and risk management.

Where levels of contamination on-site have been determined to be unacceptable, EPA Guidance Statement No 17, *Guidance Statement for Remediation Hierarchy for Contaminated Land* (EPA, July 2000) should be taken into account when assessing remediation methods or options for the remediation of the contaminated land. The guidance document contains the following two principles which should be considered and addressed:

Principle 1

Preferably, contaminated material shall be either treated on-site and the contaminants reduced to acceptable levels or, be treated off-site and returned for re-use after the contaminants have been reduced to acceptable levels.

Principle 2

Disposal of contaminated material to an approved waste disposal facility or landfill or 'cap and contain' management options will only be considered if:

- treatment of the contaminated material is shown or demonstrated not to be practicable;
- the options to dispose to landfill or 'cap and contain' are undertaken in an environmentally acceptable manner; and
- the risk of disturbance of the contaminant exceeds the risk of leaving it undisturbed and contained on site.

5.2 Setting environmental health criteria and remediation goals

enHealth provides a framework in Section 11 of its 2002 guidance document on setting generic and site-specific criteria that are protective of human health and those aspects of the environment that can improve human health. These criteria are termed "environmental health criteria". The methodology is effectively the reverse of a human health risk assessment, whereby a tolerable daily intake is determined and, from that, soil and groundwater criteria protective of human health are derived. Figure 9 in the enHealth document presents a flow chart for this methodology.

In addition, when setting environmental health criteria, consideration should be given to a number of related issues including the potential for multiple chemical exposures, the presence of acute risks; background contaminant levels and the predicted severity of health effects (refer to Section 11.1 of the 2002 enHealth guideline).

As previously stated, the process of deriving environmental health criteria is the reverse of assessing risks. The process starts with the target acceptable risk, the maximum allowable

dose is then estimated that would give rise to this level of risk and, from this, the source concentration is then estimated that would result in this level of exposure. This process should not be used as justification for causing or allowing contamination to reach a level equivalent to the environmental health criteria (or equivalent ecological health criteria).

It must be stressed that environmental health criteria have the objective of indicating concentrations of contaminants that must not be exceeded if human health is to be protected. As such, the environmental health criteria do not constitute remediation targets.

In general, remediation goals should be formulated after consideration of all the relevant factors, including the requirements for minimising risk where there is significant uncertainty, protecting current and future groundwater use, the health of ecological systems, and relevant environmental values.

The setting of remediation goals will also need to consider the distribution of the contamination (i.e. whether it is uniform or occurs in localised areas), the future use of the site, the capabilities of the available remediation technologies and legal and social considerations (including community consultation).

As such, the remediation goals should be more stringent than the environmental health criteria. If it is not feasible to reduce contamination levels to below the environmental health criteria, then an alternative strategy must be found, or in the case of a feasibility assessment for a proposed development, the project may have to be reconsidered or abandoned.

The objective of the risk management process is to obtain an outcome that is suitable for the actual or intended use of the land (including groundwater) and which is protective of human health, the environment and environmental values.

5.3 Risk communication

As part of the evaluation of remediation options, the risk management process should incorporate appropriate risk communication with stakeholders. The perception of risk by the public can be a significant factor when considering the feasibility of remedial options and therefore it is important for the appropriate stakeholders to be informed and consulted on the potential risks associated with the site contamination and the pros and cons of each remediation option being considered.

The extent of community consultation required will vary according to site-specific conditions including the nature and extent of contamination, whether site assessment and/or remediation is likely to affect the amenity of the local area by giving rise to nuisance conditions (such as noise, odour or dust) and whether the site, or contaminant has a history of sensitivity for the community. The community consultation process should include those stakeholders in the vicinity of the site who may be physically affected by the site investigation and/or remediation (e.g. through risks to health or the environment, the presence of contaminated groundwater plumes, loss of amenity, nuisance conditions) or non-physically (e.g. through concerns about possible effects of contamination on their health).

In general, it is important to provide a realistic assessment of the potential for impact, and to avoid an overly optimistic assessment of the situation. If, for example, it is likely that some odours may occur during a remediation program (even if control measures will be put in place

and implemented to minimise odours), then this should be communicated to potentially affected parties.

An appropriate level of community consultation is required when investigating, remediating and managing contaminated sites in WA. Factors to be considered when determining the appropriate level of community consultation to be carried out by site owners/proponents are discussed in the Contaminated Sites Management Series guideline *Community Consultation* (DEC, 2006).

Where issues are deemed to be sensitive in nature (for example recognised health impact on existing residents), the emotive response that some contaminants (e.g. dioxins) invoke potential amenity impact (e.g. nuisance odours), then more extensive community consultation should be conducted to consider remedial options and the establishment of remediation targets.

Community consultation should be an ongoing process that occurs throughout the assessment and management process. It is important to maintain open lines of communication to provide the community with an opportunity to access relevant information during the investigation and remediation process.

6. Glossary

Agent	Any chemical, physical or biological substance being assessed, unless otherwise noted.
Analyte	The physical or chemical element or compound, or other parameter to be determined.
ANZECC	Australian and New Zealand Environment and Conservation Council.
Aquifer	A geological unit (i.e. rock or unconsolidated materials) that can store and transmit water in reasonable amounts to a water well.
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
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand.
Assessment levels	Guideline concentrations of analytes adopted by DEC to indicate the potential presence of contamination and to trigger requirement for further investigation and assessment of risk at a site.
Auditor	An accredited contaminated sites auditor under the *Contaminated Sites Act 2003*.
Background concentration	Naturally occurring, ambient concentrations of substances in the local area of a site. The soil and water quality in the immediate area of a site may be affected by man-made factors, in which case, the background soil and/or water quality should be determined from a comparable geological/hydrogeological setting, which is minimally affected by anthropogenic activities.
Beneficial use	The use of the environment, or of any portion thereof, which is: conducive to public benefit, public amenity, public safety, public health or aesthetic enjoyment and which requires protection from the effects of emissions or of activities referred to in paragraph (a) or (b) of the definition of "environmental harm" in Section3A(2) of the *Environmental Protection Act 1986*; or identified and declared under Section 35(2) of the *Environmental Protection Act* 1986 to be a beneficial use to be protected under an approved policy.
Bioavailable	The fraction of the total of a chemical which can be taken up and assimilated by organisms or biota.
Bore/borehole	A hole drilled into an aquifer for the purpose of sampling, monitoring or extracting groundwater. Another commonly used term is 'well'.
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes. Includes o-, m- and p-xylene isomers
Carcinogen	Chemical, biological or physical cancer-causing agent.
Competent person or professional	A person possessing the skills, knowledge, experience, and judgement to perform the assigned tasks or activities satisfactorily.
Composite sample	The bulking and thorough mixing of equal quantities (sub-

	samples) of soil samples collected from more than one sample location to form a single soil sample for chemical analysis.
Contaminant	A substance which presents or has the potential to present a risk of harm to human health, the environment or any environmental value.
Contaminated	In relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value.
CS Act	*Contaminated Sites Act 2003*
CSM, Conceptual Site Model	A description of the site, geology, hydrogeology, sources of contamination, receptors and exposure pathways by which the contamination may reach and impact on receptors.
DEC (also DoE and DEP)	Department of Environment and Conservation, previously Department of Environment (DoE) and before that Department of Environmental Protection (DEP).
DoH	Department of Health.
Detailed site investigation (DSI)	An investigation which confirms and delineates potential or actual contamination through a comprehensive sampling and analysis program and risk assessment.
Diffuse source	Geographically widespread area of contamination, such as agricultural areas or large industrial complexes, which contains numerous point sources.
Dose	A stated quantity or concentration of a substance to which an organism is exposed over a continuous or intermittent duration of exposure. It is most commonly expressed as the amount of test substance per unit weight of test organism/animal. (e.g. mg/kg/body weight).
Dose-response assessment	Determination of the relationship between the magnitude of the dose or level of exposure to a chemical and the incidence or severity of the associated adverse effect.
Ecosystem	Unit including a community of organisms, the physical and chemical environment of that community, and all the interactions between those organisms and between the organisms and their environment.
Ecosystem health condition	A condition of the ecosystem which is Relevant to the maintenance of ecological structure, ecological function or ecological process and which requires protection from the effects of emissions or activities (as referred to in (a) and (b) of the definition of environmental harm); or Identified and declared under Section 35(2) of the *EP Act* to be an ecosystem health condition to be protected under an approved policy.
EIL **Ecological investigation level**	The concentration of a substance above which further appropriate investigation and evaluation will be required.
Endpoint	(a) An observable or measurable biological event used as an indicator of the effect of a chemical and the incidence or

	severity of the associated adverse effect; or (b) Measured attainment response as applied to management goals
Environment	Living things and their physical, biological and social surroundings and interactions of all these things.
Environmental harm	Direct or indirect – (a) harm to the environment involving removal or destruction of, or damage to – native vegetation; or the habitat of native vegetation or indigenous aquatic or terrestrial animals; (b) alteration of the environment to its detriment or degradation or potential detriment or degradation; alteration of the environment to the detriment or potential detriment of an environmental value; or alteration of the environment of a prescribed kind as specified in the *EP Act*.
Environmental health	Those aspects of human health determined by physical, biological and social factors in the environment.
Environmental value	Means - (a) beneficial use; or (b) an ecosystem health condition.
EP ACT	*Environmental Protection Act 1986*
Exposure	Contact of a chemical, physical or biological agent with the outer boundary of an organism e.g. inhalation, ingestion or dermal contact.
Exposure assessment	The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent (e.g. air concentration) of exposure to one or more contaminated media for the general population, for different subgroups of the population or for individuals.
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.
Exposure route	The way a chemical enters an organism after contact e.g. by inhalation or dermal absorption.
Fate	Disposition of a substance in various environmental media (e.g. soil, sediment, water and air) as a result of transport, transformation and degradation.
Groundwater **(also underground water)**	All waters occurring below the land surface. Also reffered to as "underground water".
Hazard	The capacity of an agent to produce a particular type of adverse health or environmental effect, e.g. one hazard associated with

	benzene is that it can cause leukaemia.
Health investigation level **HIL**	The concentration of a substance above which further appropriate investigation and risk assessment will be required.
Hydraulic gradient	The change in the static head (of groundwater) per unit distance in a given direction.
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Interim Sediment Quality Guidelines-High (ISQG-High)	Probable-effects concentrations below which biological effects could possibly occur. Concentrations at or above the ISQG-High represent a probable-effects range within which effects would be expected to occur more frequently.
Interim Sediment Quality Guidelines-Low (ISQG-Low)	A threshold concentration, below which the frequency of adverse effects is expected to be very low.
Investigation levels	The concentration of a contaminant above which further investigation and risk assessment and possibly remediation will be required.
Landfill	A site used for disposal of solid material by burial in the ground that is licensed as a landfill under the *Environmental Protection Act 1986.*
Lifetime	Covering the average lifespan of an organism (i.e. taken as 70 years for humans).
Limit/level of detection	The minimum concentration or mass of analyte that can be detected at a known confidence level.
Limit/level 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.
Local background	Concentrations of substances in the local area of a site which includes any diffuse contamination from anthropogenic activities.
Media	Environmental media include air, water, soil and sediment.
Model	A mathematical representation of a biological, physical or chemical system intended to mimic the behaviour of the real system, allowing description about empirical data and prediction about untested states of the system.
NATA	National Association of Testing Authorities.
NEPC	National Environment Protection Council.
NEPM	National Environment Protection Measure. In this document, means the National Environment Protection (Assessment of Site Contamination) Measure 1999.
NHMRC	National Health and Medical Research Council.
Pharmacokinetics	The study of the action of drugs in the body and includes the method and rate of excretion and duration of effects.

Point source	Localised source of contamination such as leaking storage tanks and drums.
Potable water	Water suitable from both health and aesthetic considerations, for drinking and culinary purposes.
Practicable	Means having regard to, amongst other things, local conditions and circumstances (including costs) and to the current state of technical knowledge.
Practical quantitation limit (PQL)	The lowest concentration of a substance that can be reliably reported, using a specific laboratory method and instrument (also known as Limit of Reporting)
Practitioners	Suitably qualified professionals with experience in environmental investigations and contaminated site management.
Preliminary site investigation (PSI)	An investigation consisting of a desktop study, a detailed site inspection and, where appropriate, limited sampling. The scope of a preliminary site investigation should be as necessary to determine whether contamination is present or likely to be present and to determine whether a detailed site investigation is required.
PDWSA **Public drinking water source Area**	An area allocated for the collection/abstraction of water for public drinking water supply.
Quality assurance (QA)	The implementation of checks on the success of quality control (e.g. replicate samples, analysis of samples of known concentration).
Quality control (QC)	The implementation of procedures to maximize the integrity of monitoring data (e.g. 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 contaminant.
Remediation	In general, means action taken to eliminate, limit, correct, counteract, mitigate or remove any contaminant or the negative effects of the contaminant on the environment or human health. With respect to the CS Act and a site that is contaminated remediation includes: the attempted restoration of the site to the state it was in before the contamination occurred; the restriction, or prohibition, of access to, or use of, the site; the removal, destruction, reduction, containment or dispersal of the substance causing the contamination, or the reduction or mitigation of the effect of the substance; the protection of human health, the environmental or any environmental value from the contamination.
Response level	Concentration of a contaminant at a specific site based on a site assessment for which some form of response is required, to provide an adequate margin of safety to protect public health and/or the environment.
Risk	Means the probability in a certain timeframe that an adverse outcome will occur in a population and/or ecosystem of a specified area that is exposed to a particular dose or concentration of a

	hazardous agent, i.e. it depends on both the level of toxicity of the hazardous agent and the level of exposure.
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.
Risk communication	An interactive process involving the exchange among individuals, groups and institutions of information and expert opinion about the nature, severity and acceptability of risks and the decisions taken to combat them.
Risk management	The process of evaluating alternative actions, selecting options and implementing them in response to risk assessments. The decision making will incorporate scientific, technological, social, economic and political information. The process requires value judgments, e.g. on the tolerability and reasonableness of costs.
Sediment	Unconsolidated particles of sand, clay, silt and other substances that settle at the bottom of a body of water.
Site	An area of land including underground water under that land and surface water on that land.
Stressor	A physical, chemical or biological entity that can induce an adverse response in a receptor. It includes any release of chemicals, other human actions and natural catastrophes.
Stygofauna	Subterranean aquatic fauna.
Threshold concentration	The lowest concentration above which some effect (or response) will be produced and below which it will not.
TDI, tolerable daily intake	An estimate of the intake of a substance which can occur over a lifetime without appreciable health risk.
Toxicity	The quality or degree of being poisonous or harmful to plant, animal or human life.
Uncertainty	The lack of knowledge about the correct value e.g. a specific exposure measure or estimate.
Validation	The process of demonstrating that a site has been remediated successfully. Involves the collection and analysis of samples to demonstrate that contaminant concentrations are below acceptable limits and do not pose a risk to human health, the environment or environmental values.
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.
Watertable	The surface of an unconfined aquifer or confining bed at which the pore water pressure is equal to atmospheric pressure. It can be measured by installing piezometers or groundwater bores into the zone of saturation and measuring the water level in those bores.
Well	A hole drilled into an aquifer for the purpose of sampling, monitoring or extracting groundwater.
Wetland	An area of seasonally, intermittently or permanently waterlogged or inundated land whether natural or otherwise; and includes lakes,

	swamps, marshes, springs, damplands, tidal flats and estuaries.

Adapted from enHealth (2002); NEPM, (1999); *Environmental Protection Act 1986* and *Contaminated Sites Act 2003*

7. REFERENCES

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

Citizens and Civics Unit (2002) - *Consulting Citizens: A Resource Guide.* Department of the Premier & Cabinet, Western Australia (http://www.ccu.dpc.wa.gov.au)

Citizens and Civics Unit (2003) - *Consulting Citizens: Planning For Success.* Department of the Premier & Cabinet, Western Australia (http://www.ccu.dpc.wa.gov.au)

Citizens and Civics Unit (2004) - *Consulting Citizens: Engaging with Aboriginal Western Australians.*

Department of the Premier & Cabinet, Western Australia and ATSIC, Aboriginal & Torres Strait Islander Services, Department of Indigenous Affairs Western Australia, (http://www.ccu.dpc.wa.gov.au)

Department of Environment and Conservation (2006), *Community Consultation*. Contaminated Sites Management Series.

Department of Environment and Conservation (2006), *Contaminated Sites Auditors: Guidelines for Accreditation, Conduct and Reporting*. Contaminated Sites Management Series.

Department of Environment* (2003), *Assessment Levels for Soil, Sediment and Water*, November 2003. Contaminated Sites Management Series.

Department of Environmental Protection* (2000), *Certificate of Contamination Audit Scheme*, Draft, July 2000. Contaminated Sites Management Series.

enHealth (2002), *Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards*. Department of Health and Ageing and enHealth Council.

Contaminated Sites Act 2003, State Law Publisher, Western Australia

National Environment Protection Council (NEPC) (1999) *National Environment Protection (Assessment of Site Contamination) Measure.*

National Health and Medical Research Council (NHMRC) and Natural Resource Management Ministerial Council (NRMMC) *Australian Drinking Water Guidelines 2004*

Standards Australia (1999), AS/NZS 4360:1999, *Risk Management*.

* Now the Department of Environment and Conservation