Contaminated Sites Management Series

The Use of Risk Assessment in Contaminated Site Assessment

Guidance on the overall approach

Draft for public comment

January 2005

Department of Environment
Government of Western Australia

PREFACE

This draft version of *The Use of Risk Assessment in Contaminated Site Assessment – Guidance on the overall approach* has been prepared by the Department of Environment (DoE) to provide consultants, local government authorities, industry and other interested parties with a document which outlines the purpose and requirements for conducting site specific health and ecological risk assessments for contaminated sites in Western Australia.

The draft version has been released for public comment. Any comments on this draft should be forwarded to the Land and Water Quality Branch of the DoE by ***13 May 2005***. All comments will be reviewed and considered, and where appropriate, incorporated into the final version.

Written comments on this draft guideline should be forwarded to:

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ACKNOWLEDGMENTS

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LIMITATIONS

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

This guideline should be used in conjunction with the texts referenced, 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.

Information presented in this document does not constitute, and is not intended to be used as legal advice nor used as an interpretive instrument. In the event of any inconsistency between this document and relevant legislation, provisions of the relevant legislation will prevail.

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CONTAMINATED SITES MANAGEMENT SERIES

This guideline forms part of a management series being developed by the Land and Water Quality Branch of the DoE 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 the DoE 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 Site Auditor Accreditation Scheme
- 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
- Use of Monitored Natural Attenuation for Groundwater Remediation

Reference and compliance with these guidelines should ensure that the general requirements of the DoE are satisfied.

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

TABLE OF CONTENTS

Figure Index

GLOSSARY

Agent	Any chemical, physical, biological substance or social factor being assessed, unless otherwise noted.
Background concentration	Ambient concentrations in the local area of a site (not associated with site contamination).
Background local	Background conditions that consider broad scale anthropogenic conditions.
Beneficial use(s)	The environmental or any element or segment of the environment that is conducive to public benefit, welfare, safety, health or aesthetic enjoyment and which requires protection from the effects of waste discharges, emissions or deposits.
Bioavailability	Availability of contaminants in a form in which organisms or biota can assimilate contaminants e.g. contaminants in a dissolved state or capable of being solubilized once ingested are generally highly bioavailable. EnHealth (2002) definition: The ratio of the systemic dose to the applied dose (ie the dose taken in by the body system eg entering bloodstream, divided by the dose entering the body eg amount ingested).
Conceptual Site Model (CSM)	A description of the site, geology and hydrogeology, sources of contamination, receptors, and pathways by which the contamination may reach and impact on receptors.
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 animal (eg 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.
Ecological risk assessment	The process of estimating the potential of a chemical,

	biological, physical or social agent on a specified ecological system under a specific set of conditions and for a certain timeframe.
Environmental health	Those aspects of human health determined by physical, biological and social factors in the environment. Environmental health practice covers the assessment, correction, control and prevention of environmental factors that can adversely affect health, as well as the enhancement of those aspects of the environment that can improve human health.
Exposure	Contact of a chemical, physical or biological agent with an organism, eg inhalation, ingestion or dermal contact.
Exposure assessment	The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent (eg 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 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 eg by inhalation, or dermal absorption.
Hazard	The capacity of an agent to produce a particular type of adverse health or environmental effect, eg one hazard associated with benzene is that it can cause leukaemia.
Health risk assessment	The process of estimating the potential of a chemical, biological, physical or social agent on a specified human population system under a specific set of conditions and for a certain timeframe.
Lifetime	Covering the average life span of an organism (eg 70 years for humans)
Model	A mathematical representation of a biological system intended to mimic the behaviour of the real system, allowing description about empirical data and prediction about untested states of the system.

Pharmacokinetics	The study of the action of drugs in the body: method and rate of excretion; duration of effect; etc.
Receptor	An entity (such as a person), animal or ecosystem that could be harmed by exposure to the contaminant
Risk	The probability that, in a certain timeframe, an adverse outcome will occur in a person, 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, ie it depends on both the level of toxicity of the agent and the level of exposure.
Risk assessment	The process of estimating the potential impact of a chemical, physical, microbiological or psychosocial hazard on a specified human population or ecological system under a specific set of conditions and for a certain 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 judgements, eg on the tolerability and reasonableness of costs.
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, eg a specific exposure measure or estimate.
Volatile	Physical property of a chemical that indicates its potential to transform from an adsorbed dissolved or liquid phase into a vapour phase (ie air) under standard atmospheric conditions.

(Extracted from enHealth, 2002)

1. INTRODUCTION

1.1 PURPOSE OF THIS DOCUMENT

The purpose of this document is to outline the approach adopted by the Department of Environment (DoE) for using risk assessment to assess and manage contaminated site issues. It is anticipated that this document will be used by environmental consultants, proponents and the general community to gain an understanding of how the risk associated with contaminated sites should be assessed for the purposes of implementation of the *Contaminated Sites Act 2003*.

Detailed technical information on carrying out risk assessments is included in the various guidelines referred to in this document. Risk assessment of contaminated land can be technically complex and should only be carried out by suitably qualified and experienced individuals or teams.

This guideline document assumes that the subject site is suspected of posing a risk to human health or the environment and that the site has already been reported to the DoE in accordance with the *Contaminated Sites Act 2003*. Reference should be made to the DoE guidance document on *Reporting of Known or Suspected Contaminated Sites* (revised version, February 2005) for information to consider when assessing whether a site should be reported to DoE.

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 an actual risk that has either materialised, or has the potential to materialise.

The DoE's goal for contaminated site assessment and management is for sites to be managed according to the magnitude of the risk or potential risk that the site presents to human health, the environment or any environmental value. This allows for the prioritisation of action at a site to eliminate or mitigate the risks posed by the site within an appropriate timeframe.

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

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

There may also be requirements for conducting more than one risk assessment for an individual site throughout the assessment and remediation process. For example, one risk assessment may be necessary for evaluating the potential risk of a site. Another risk assessment may be required to validate a site after remediation to ensure that the remediation goals were achieved. This may be particularly important for groundwater if conditions at the site change as a result of remediation and development activities.

1.3 NATIONAL RISK ASSESSMENT 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, ie it depends on both the level of toxicity of the hazardous agent and the level of exposure*". The NEPM addresses assessment of contamination, and does not consider remediation or management of risk.

1.3.2 EnHealth

The Department of Health and Ageing and enHealth Council has published "Guidelines for assessing human health risks from environmental hazards" (enHealth, 2002) (referred to here as the enHealth guidelines). This document contains the same definition of "risk" as presented in the NEPM, and presents a similar framework for carrying out risk assessments. While the guidance is focused on human health, it extends guidance not only for contaminated land, but also to other media such as air, water and food. The enHealth guidelines consider both assessment and management of risk.

1.3.3 ANZECC (2000)

ANZECC/ARMCANZ have published the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). Trigger values are presented within this document for a range of chemicals and water quality indicators in both fresh and marine waters. Assessment guidelines are provided for varying levels of species protection. The document also provides a framework for conducting assessment of risk to aquatic species for more detailed assessments. In addition, trigger levels have been presented for a number of water uses including irrigation use and stock watering.

1.4 OBJECTIVES OF RISK ASSESSMENT

Risk assessment involves the assessment of 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 that is necessary to make decisions regarding the requirements for management of the contamination.

The main objectives for carrying out a risk assessment for a contaminated site 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 any unacceptable risks will be reduced to an acceptable level.

Where risk assessment identifies the potential for exposure to exceed the determined maximum allowable dose or allowable exposure, then *risk management* is necessary to reduce the potential health or environmental risk.

Risk assessment formalises the process of identification of the key issues associated with contamination, including the nature of the contamination, the potential hazards present, data gaps, and the level of uncertainty. The assessment also takes into account factors relevant to a site such as the proposed land use, physico-chemical and bioavailability characteristics of the particular contaminants, and the depth and distribution of the contamination. Risk assessment requires a high degree of objectivity and scientific skill.

1.5 OBJECTIVES OF RISK MANAGEMENT

Risk management involves evaluating alternative actions for the management of the risks that have been identified in a risk assessment of a contaminated site, and selecting and implementing an appropriate management strategy for the site.

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

The selection of the preferred risk management strategy is based on scientific, social and economic information. Risk management options are selected based on value judgements that take into account the information from the health and/or ecological risk assessment together with an assessment of the societal tolerability of the risks, reasonableness of costs, and regulatory policy positions. Risk management includes any necessary monitoring and evaluation of the actions taken, and communication of results to stakeholders and the general public.

A framework for carrying out risk management is outlined in Australian Standard AS4360. The standard is intended to provide guidance on risk management for industrial and occupational hazard applications, and can be applied in making risk management decisions for contaminated sites.

1.6 COMMUNITY CONSULTATION

Community consultation is an ongoing process that should occur throughout the assessment and management processes. 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.

Further information can be found in the Contaminated Sites Management Series guideline *Community Consultation* (2002) and on the DoE website <www.environment.wa.gov.au> which may be helpful in developing a community consultation strategy. The following documents may also be helpful:

- Citizens & Civics Unit (2004), *Consulting Citizens – Engaging with Aboriginal Western Australians.* CCU publications are available from <http://www.ccu.dpc.wa.gov.au>;
- Citizens & Civics Unit (2003), *Consulting Citizens – Planning For Success*;
- Citizens & Civics Unit (2002), *Consulting Citizens – A Resource Guide;*
- EnHealth Council et al (2002), *Environmental Health Risk Assessment* – Section 2.2 Community Consultation and Involvement, and
- NEPC (1999) *NEPM – Schedule B(8) Guideline on Community Consultation and Risk Communication.*

2. APPLICATION OF RISK ASSESSMENT FOR CONTAMINATED SITES

2.1 STAGED APPROACH

With the enactment of the *Contaminated Sites Act 2003,* a risk assessment will be required for all sites reported to the Department of Environment. Depending on the site circumstances and the stage of the investigation a risk assessment may involve a simple desktop study, or may involve a process of complex contaminant fate and transport modelling.

A staged approach to site contamination is presented in Schedule B(4) and B(5) of the NEPM Guidance document (refer to Figure 4-II of the 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 be the greatest with respect to 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.

DoE recommends a staged approach be adopted for risk assessment, involving:

- Screening risk assessment,
- Simple risk assessment, and
- Detailed risk assessment.

DoE recommends that a staged approach, which includes risk assessment, should be adopted for site investigations. This approach is outlined in the DoE document *Assessment Levels for Soil, Sediment and Water*. This document should be the primary reference for carrying out a preliminary or screening risk assessment.

2.2 CONCEPTUAL SITE MODEL

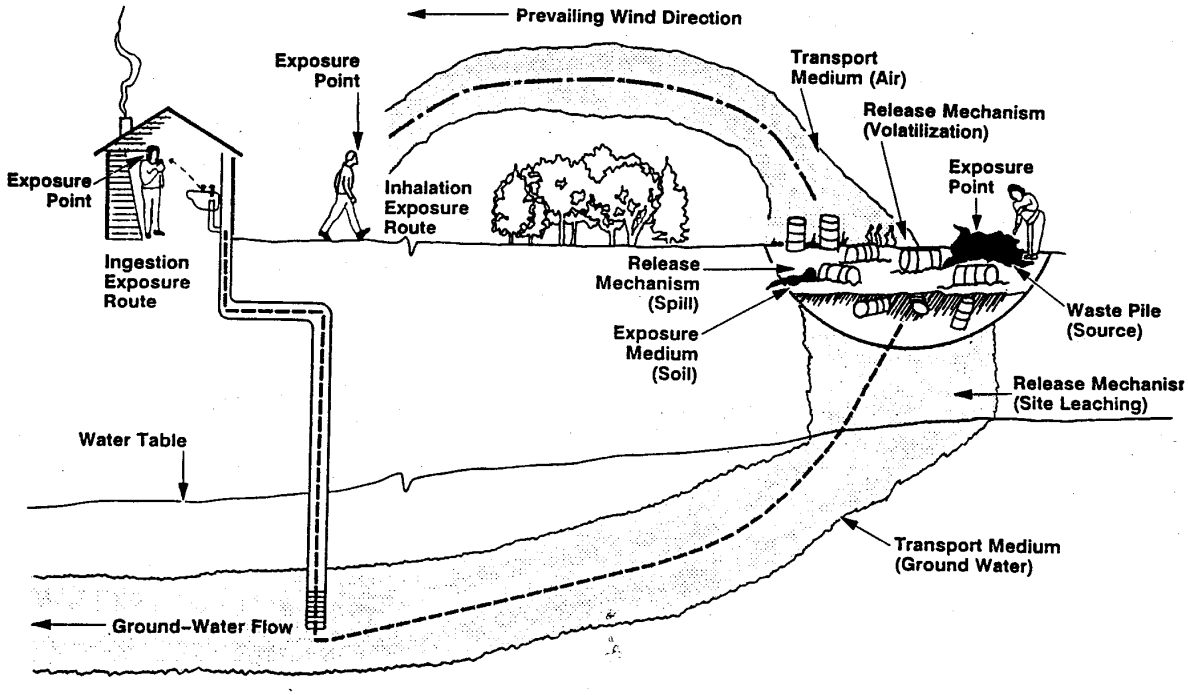
A critical element to each level of risk assessment is the development of a Conceptual Site Model that describes the pathways by which exposure to any contamination at the site may occur. A Conceptual Site Model should be first developed as part of the screening risk assessment, and then revised and improved as more detailed information on the contamination becomes available and the issues and nature of the site are better understood.

For exposure to occur, a complete pathway must exist between the source of contamination and the "receptor" (ie, the person or ecosystem components potentially affected). Where the exposure pathway is incomplete, there is no exposure and hence no risk via that pathway. An exposure pathway will typically consist of the following elements:

- Source of contamination (eg a spill)
- Release mechanism (eg migration in soil, leaching to water, emission to air)
- Retention in the transport medium (eg soil, groundwater, surface water, air)
- Exposure point (eg where a person comes in contact with contaminated dust or soil or contaminated groundwater from a well, or in a building overlying volatile contamination)
- Exposure route (eg inhalation, ingestion, absorption through the skin).

Examples of exposure pathways are illustrated in Figure 1.

Figure 1: An example illustration of some exposure pathways



The Conceptual Site Model should include all of the exposure pathways, and may include a diagram such as Figure 1 or other means of describing the various exposure pathways and their relevance. The development of the model will include the identification of all sources, modes of migration, all potential receptors of concern, and how exposure may occur (ie. exposure route).

It is essential that consideration 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 in groundwater and exposure where the groundwater is used. All of these issues should be identified in the Conceptual Site Model.

Examples of where a contaminated site may pose a risk to human health, the environment or any environmental value. (For a more complete discussion, refer to the DoE guidance document *Reporting of Known or Suspected Contaminated Sites, 2004*.)

- Contaminants present in surface soil significantly affect the growth of plants, or affect the health of persons via direct skin contact, or ingestion or inhalation of particulates.
- Contaminants present in soil or groundwater volatilise and migrate through the overlying soil into the air or into buildings built over the contamination, affecting the health of persons via inhalation.
- Contaminated groundwater migrates and discharges to a surface water body, eg creek, river, or lake.
- Contaminated groundwater migrates to a groundwater well that is being used for domestic or commercial use.

2.3 TIER 1 - SCREENING RISK ASSESSMENT

The first stage of risk assessment is called a *Screening Risk Assessment* and can also be referred to as a *Preliminary Risk Assessment* or a *Tier 1 Assessment*. The goal of this assessment is to identify the important contamination issues, ie the major contaminants, receptors and exposure pathways. This assessment includes the development of a Conceptual Site Model, and assessment of soil, sediments, surface water and groundwater as presented in the DoE document *Assessment Levels for Soil, Sediment and Water* (Nov 2003).

Consideration needs to be given to the appropriateness of the site assessment levels, including the site setting and the exposure assumptions. The site assessment levels have been developed assuming certain exposures will occur. If the site situation is such that exposure will not occur, then some adjustment may be warranted. For example, if contamination is 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 assessment has been completed there are a number of possible options.

- If the Tier 1 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 or remediation of the contamination.
- If the Tier 1 assessment does not adequately characterise the risks associated with the contamination (eg the assumptions underlying the site assessment levels are not appropriate for the site), then the assessor may proceed with a Tier 2 (simple) risk assessment.
- If it is known that a Tier 2 (simple) assessment will not adequately characterise the risks at the site (eg, site assessment levels have not been published for the contaminant or exposure situation) then the assessor may proceed with a Tier 3 (detailed) risk assessment.

A cost-benefit analysis may assist in deciding which step to take. For example, carrying out a more detailed investigation and assessment may result in lower cost 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 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 metals (eg, lead and copper) in the 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 can be carried out that comprises comparing the measured concentrations of the metals in the soil with the DoE 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 or plant growth (eg, for gardens).

However, before this matter is finalised, it would be important to ensure that the contamination would not give rise to other effects, such as:

- Leaching and giving rise to groundwater contamination (unlikely if the concentrations are restricted to the surface soil and are less than the Ecological Assessment Levels);
- Odour (unlikely in the case of metals; direct field observations would confirm this);
- Volatiles that could enter through the floor of buildings, and adversely affect the health of residents living in the building (not expected to be a problem for metals); or
- Erosion of contaminated soil following rain, leading to contamination of adjacent properties or waterways (unlikely if the Ecological Assessment Levels are complied with).

2.4 TIER 2 - SIMPLE RISK ASSESSMENT

If the site setting and exposure scenario differs from the assumptions that underlie the Site Assessment Levels, it may be necessary to adjust the soil or water assessment levels to develop site-specific response levels to reflect the site situation. Caution is required when carrying this out, because some of the assumptions that underlie the soil and water assessment levels reflect policy positions and should not be changed. Further information on this is provided in the NEPM health guidance Schedule B(4) Sections 6.10 and 6.11.

It is essential that the basis for any change from the generic assumptions be clearly documented and justified. Any change proposed must be justifiable and there must be a reasonable expectation that the situation assumed will reflect what will apply in the future. For example, if it is assumed that soil will be contained under a building and ingestion will not occur, then consideration should be given to whether the building will be redeveloped in the future, or maintenance may be needed, which would expose the contamination.

Site-specific response levels and the site contamination and risk assessment information upon which they are based will be reviewed by the DoE, DoH or an accredited contaminated site auditor to ensure that they are acceptable.

After a Tier 2 assessment has been completed there are a number of possible options.

- If the Tier 2 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 or remediation of the contamination.

- If the Tier 2 assessment does not adequately characterise the risks associated with the contamination then the assessor may proceed with a Tier 3 (detailed) risk assessment.

A cost-benefit analysis may assist in deciding whether to proceed beyond a Tier 1 assessment to a more detailed assessment.

Example of Tier 2 or Simple Risk Assessment

A site proposed for high-density residential development is found to have heavy metals (eg, lead and copper) in the soil at concentrations that exceed the DoE assessment levels for soil for high density residential development. In this case the screening assessment would show that the DoE assessment levels are exceeded, suggesting that clean up is required.

However, if the soil contamination is located where the building is proposed to be, then it might be that the contamination would be effectively contained under the floor slab of the building and persons would then not come into contact with the contamination. This 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 situation it may be appropriate to accept concentrations of contamination higher than the DoE assessment levels. However, before these were to be accepted, there are a number of conditions that would need to be satisfied:

- The works associated with construction of the building will not result in distribution of contaminated soil elsewhere on the site where exposure could occur. It is possible that the development and application of a site management plan for the building works could address this issue.
- The contamination levels do not pose a risk to the health of workers involved in the building works. Because soil assessment levels are not available for this situation, it may be necessary to carry out a Tier 3 (detailed) risk assessment to assess this situation, or alternatively the construction works may be carried out with an appropriate level of personnel protection.
- There will not be the requirement in the future for works that would involve excavation and exposure of soil under the building, such as may occur if new utilities or services were to be provided, or existing services required maintenance. If there were to be the potential for such works, then it may be possible to develop and apply a site management plan. If building works were subject to control through a commercial entity such as a Body Corporate, then it may be reasonable to assume that such a plan would be complied with.
- The contamination is not volatile such that volatile contaminants could migrate through the floor or along service conduits or trenches (unlikely if the contamination only involves metals).
- The contamination is not below the water table (if the contamination was below the water table it could give rise to groundwater contamination).
- The contamination will not be forgotten and pose a risk at the end of the life of the development (ie when the site is re-developed).

2.5 TIER 3 - DETAILED RISK ASSESSMENT

A *Detailed Risk Assessment*, also referred to as a *Site-Specific Risk Assessment*, may be carried out if required. This level of risk assessment may involve specialised contaminant fate and transport modelling as well as a toxicity assessment of particular contaminants.

In a detailed risk assessment the use of site-specific information may allow less conservative assumptions to be adopted, reflecting a reduced level of uncertainty and a better understanding of the site. This may result in site response levels (acceptance criteria) that correspond to higher concentrations of contaminants than the Site Assessment Levels used for screening purposes, but which are nevertheless still protective of human health, the environment and environmental values.

A cost-benefit analysis may assist in deciding whether to proceed beyond a Tier 1 or a Tier 2 assessment to more detailed assessments. Note that a more detailed assessment may result in lower cost for remediation; however, this is not always the case.

Site-specific response levels and the site contamination and risk assessment information upon which they are based will be reviewed by the DoE, DoH or an accredited contaminated site auditor to ensure that they are acceptable.

If it is clear that a detailed assessment is required, then a screening assessment should be carried out first to identify those issues and contaminants which are of major concern, allowing the detailed assessment to focus on the critical elements.

For example, if soil contamination was identified in the screening 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 detailed 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 there is a serious problem and immediate action is required, a detailed assessment may not be necessary and the available resources should be directed to management of the risks. Such management may include the need for immediate interim measures should the potential risk be high and there is a need for urgent action.
- If it is clear from the preliminary assessment that the contamination does not pose a concern, no further action would be required.
- If it is clear that the assumptions in the preliminary assessment are not relevant and a simple adjustment is not possible to properly characterise the conditions that apply at a site, it may be more appropriate to proceed directly with a detailed 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 (eg, agricultural land).

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

DoE expects that:

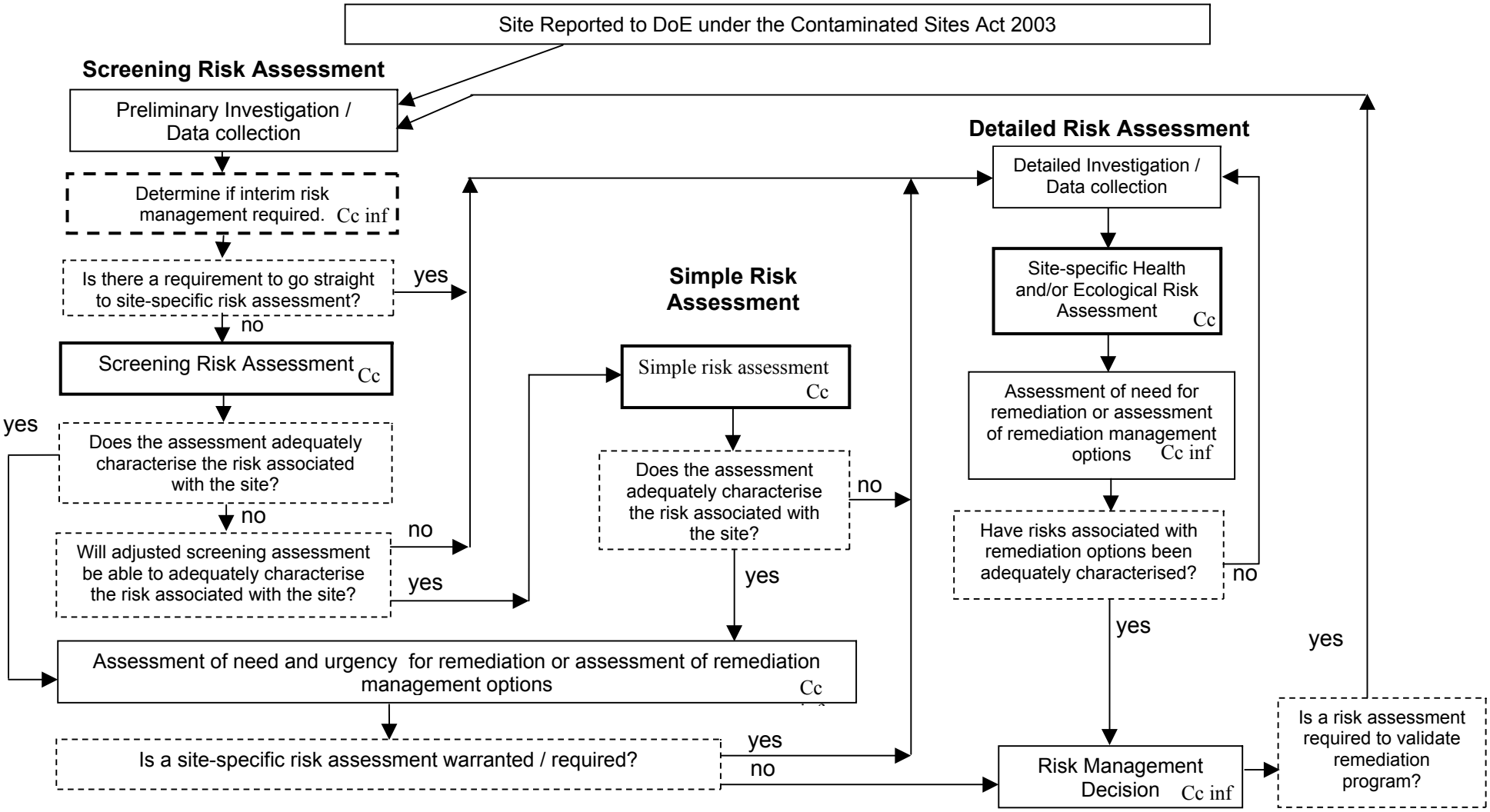
- A detailed risk assessment will not be necessary in many instances as problems will be "obvious" and the risk screening phase will provide sufficient information and assessment to reach a conclusion on a risk management strategy.
- When a risk assessment is carried out, the assessment should consider all the pertinent information. Should conditions change at the site (eg, change of land use) or new information becomes available, the proponent should review the risk assessment to determine the impact on the conclusions and recommendations of the risk assessment and risk management strategy, and should notify DoE where there is a material change.

In the case where previously unidentified contamination is found and it is considered that this could significantly affect the conclusions of a risk assessment and risk management strategy, the DoE should be notified immediately and the risk assessment and management strategy re-evaluated.

Examples where DoE should be notified of a change in condition of a site

- A risk assessment has been carried out for a site based on the proposed development of commercial land use. After completion of the assessment, it is decided to turn part of the land into public open space. DoE should be notified of the change of the proposed land use and the risk assessment should be reviewed with respect to the new proposed land use scenario.
- A groundwater monitoring program is in place to assess the performance of natural attenuation of a contamination plume, and the results of the monitoring show that the levels of contamination are not decreasing as expected and trigger levels have been, or are likely to be, exceeded. Where a clear trend is present, the assessor should not wait until trigger levels have been exceeded before considering implementing contingency measures.

Figure 2: Risk assessment decision making process



Cc: Community consultation should be included in discussions
inf: DoE should be informed of potential hazard if identified

Example of detailed risk assessment

In the previous example the scenario suggested that high levels of metals might be considered acceptable if contained under a building slab.

However, this might not be the case if the contamination were to be located throughout the soil profile (eg the contamination were to be associated with deep fill) and were to extend beneath the water table at the site. For example, consider the case where the groundwater is of potable quality, an extraction well exists on the neighbouring property, and measurement of a sample of groundwater from a 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 moving from the soil into the groundwater.

In this situation a detailed 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 the installation of additional groundwater wells), leaching tests on the soil, and contaminant fate and transport modelling to evaluate the future migration of the contamination in the groundwater.

2.6 RISK MANAGEMENT

The framework for carrying out risk management outlined by enHealth is consistent with that outlined in Australian Standard AS4360. The standard is intended to provide guidance on risk management for industrial and occupational hazard applications, and can be helpful in making risk management decisions for contaminated sites. In AS4360 risks are defined as "event driven" and therefore risks are ranked in terms of probability of occurrence or frequency (ie likelihood) and severity (ie consequences). In AS4360 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 AS4360 can be useful when considering the likelihood that a situation or consequence will arise, the severity of that situation or consequence, and therefore the action that should be taken.

The implementation of AS4360 should be considered as an extension of the Conceptual Site Model. The analysis should consider the potential exposure scenarios ("event"), the likelihood, and the 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 should 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 any environmental values.

While risk assessment may form an integral part of the decision-making process, other issues also need to be considered that may be just as important, if not more so in the overall management of the site. These issues can include, for example, considerations of the social, economic and political factors that are relevant to the site.

Further discussion on Risk Management is presented in Section 5.

Examples of situations where the approach outlined in AS4360 may be useful

An example is a site where it needs to be determined whether contamination remaining at depth poses such a high risk that it requires remediation. It may be that the contamination is at such a depth that it will be very unlikely that it would ever 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 would be unlikely to give rise to serious health effects, then it may be concluded from an assessment of likelihood and consequence that the risk is low and it might be acceptable to leave the contamination in place.

However, if the depth of contamination is relatively shallow and it is quite possible that works might be carried out in the future that would result in contaminated soil becoming accessible to persons at the site, and the contamination is serious and could adversely affect human health if it were to be exposed, it may be concluded from the assessment of the likelihood and consequence that the risk is high and it would not be acceptable to leave the contamination in place.

Another example is the situation where groundwater contamination exceeds the drinking water and irrigation water assessment levels, the affected area is very localised, and it is very unlikely that the groundwater would actually be used for a use that would give rise to a serious problem (eg for drinking purposes). An assessment of the likelihood and consequence in this situation may conclude that the risk is low and that the contamination may remain in place without remediation. However, a memorial should be lodged on the title of the land to alert any new owners to the potential problem.

3. DETAILED RISK ASSESSMENT FRAMEWORK – HUMAN HEALTH

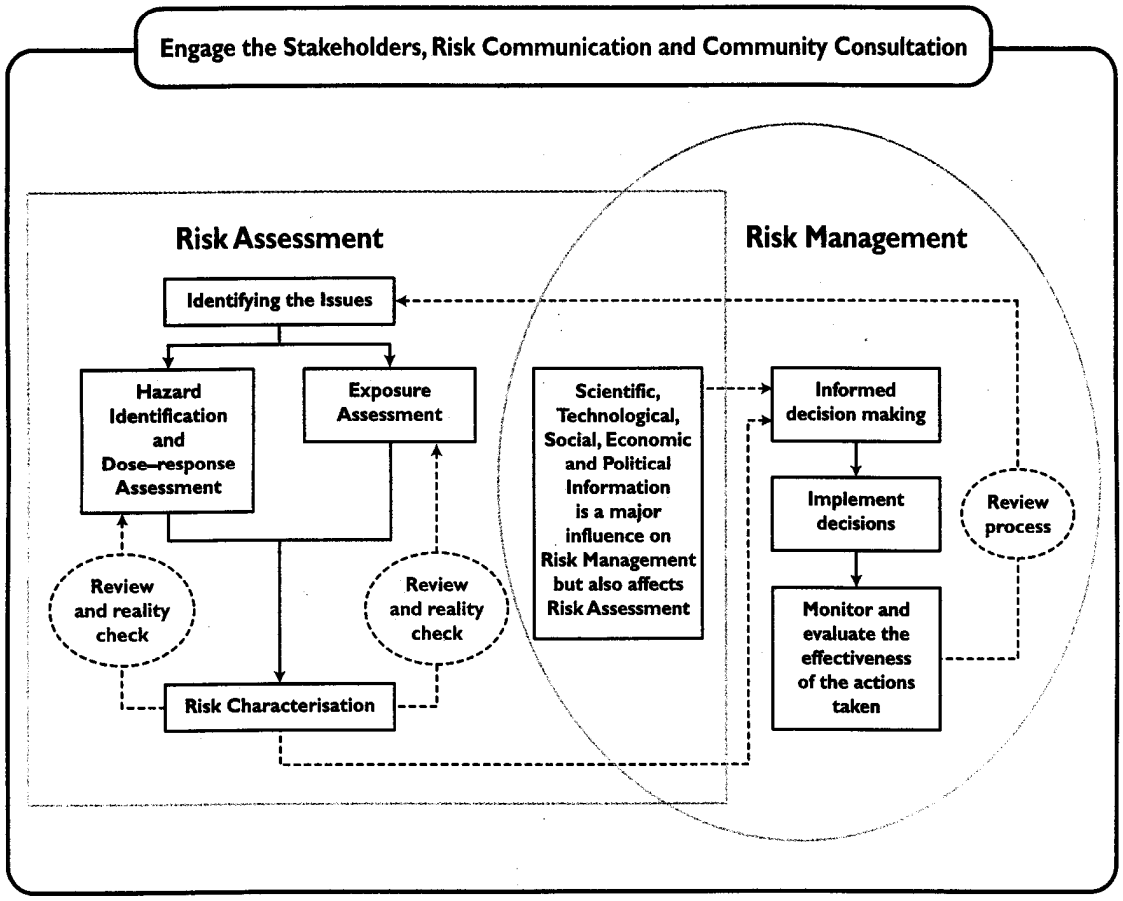
3.1 INTRODUCTION

The framework for carrying out a detailed health risk assessment has been outlined by 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 (ie, the "dose response").

Figure 3: Australian framework for human health risk assessment



(Extract from enHealth, 2002)

Risk management is an extension of the risk assessment process by way of implementation of actions to mitigate risk. 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 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 risk assessment. Hence, this risk assessment framework is inherent in all tiered levels of risk assessment.

The stages of the framework for carrying out a detailed human health risk assessment are discussed in the following sections.

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:

- 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; and
- 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.

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 from which the assessment is based. The goal of data collection is to adequately characterise the nature and extent of contamination issues arising from a site.

Most of the data collection will occur as part of the preliminary and detailed site investigations. Consideration should be given to the history of the site, nature of contamination, nature of geology and hydrogeology, and neighbouring sensitive land uses and use of groundwater. Soil and groundwater investigation plans 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 the detailed risk assessment (eg, groundwater fate and transport modelling). Further information on this can be found in the DoE's *Development of Sampling and Analysis Programs, 2001.*

The quality of data that is used in risk assessments must be adequate and appropriate for the level of detail required for conducting the risk assessment. All data must be checked for accuracy, including QA/QC of laboratory sampling results. Data gaps must be assessed to evaluate potential issues that may not have been identified. Sampling plans must be appropriate for the requirements of the risk assessment, for example, a detailed groundwater fate and transport model will require a suitable number of monitoring wells placed at appropriate locations. The NEPM Schedule B(2) outlines the requirements for data collection in detail.

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 in humans and other animals. It is a qualitative description based on the type and quality of the data, complementary information (eg structure-activity analysis, genetic toxicity, pharmacokinetic), 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 animal 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 (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; and
- the potential for differing susceptibilities in population subgroups.

The 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 medium, geographical scale, pollutant source characteristics and nature of the risk agent, the receptor population, exposure routes, environmental conditions and the timeframe.

The 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.

Part 2, Division 1 of the *Contaminated Sites Act 2003* outlines the process for reporting known, or suspected contaminated sites in Western Australia. For further information consult the DoE guideline *Reporting of Known or Suspected Contaminated Sites (* 2005).

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;
- 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; and
- 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 (ie by putting risks into categories such as ‘high’, ‘medium’ or ‘low’) such as that described in AS4360 (refer to Section 2.6) or quantitatively (with a numerical estimate).

The 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.

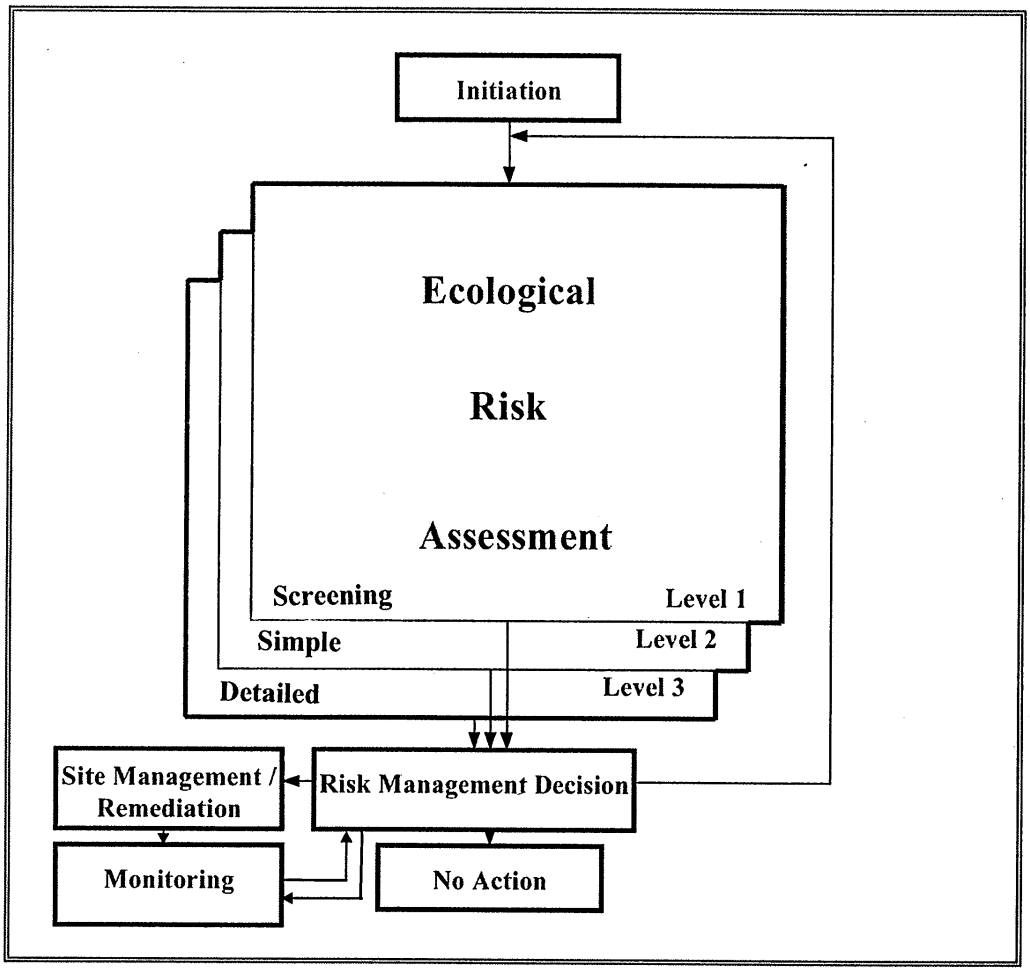
4. RISK ASSESSMENT FRAMEWORK – ECOLOGICAL

4.1 FRAMEWORK

The framework for Ecological Risk Assessment (ERA) is similar to that of the framework for human health risk assessment, and is outlined in the NEPM Schedule B(5) 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 that is similar to that for human health risk assessment. The framework is presented in Figure 4.

Figure 4: Australian Framework for Ecological Risk Assessment



(Extract from NEPM Schedule B(5))

The framework is an iterative process that has three levels of ERA. Each level consists of the same basic components but incorporates an increasing degree of data collection and complexity and decreasing uncertainty as an assessment proceeds from Level 1 to 3. The level of assessment required depends upon many factors including statuary requirements, the type of contaminant, the degree of contamination, the availability of appropriate receptors, exposure and toxicity data and the sensitivity of ecological values.

Not all site contamination assessments will require the formal assessment of ecological risk. In many instances, eg some highly modified sites, the ecological values to be protected may

be very low and the risk assessment will be driven by other factors such as the protection of human health.

4.2 LEVELS OF ECOLOGICAL RISK ASSESSMENT

Assessment at a higher level is built upon information and knowledge gained from the previous level. This staged approach offers a great degree of flexibility that allows the framework to be applied to sites of highly varied complexity.

The levels of assessment may be summarised as follows:

4.2.1 Level 1 ERA

- Also known as Screening Ecological Risk Assessment.
- Simple screening method to suit generic situations and protect all biota (land and aquatic) likely to inhabit a state, region or land use;.
- Involves comparison of soil and groundwater contaminant concentrations at the site with existing generic EIL_{soil} (ecological investigation level for soil) or toxic trigger levels for water (presented in ANZECC 2000 Guidelines).

Examples of Level 1 ERA

- Public open space parkland contains elevated concentrations of metals in surface soil. Concentrations are compared with EIL_{soil} presented in NEPM.
- Elevated concentrations of hydrocarbons in groundwater. Groundwater migrating towards river located 300m downgradient of the site. Measured groundwater concentrations on site compared with trigger levels for pristine waters presented in ANZECC 2000.

The document *Assessment Levels for Soil, Sediment and Water* (DoE 2003) and the documents referenced therein should be used as the initial reference for soil and water criteria for Level 1 ERAs.

4.2.2 Level 2 ERA

- Also known as Simple Ecological Risk Assessment.
- Level 2 ERA is largely a desktop study with some field studies (ie some site specific data) that provide an increased level of detail to components of the ERA process.
- Derives modified (site-specific) EIL_{soil} or water trigger levels for contaminants of concern at point of exposure.
- On site soil concentrations of contaminants of concern are compared with the modified EIL_{soil} to characterise the risk.
- Simple groundwater fate and transport modelling may be used to estimate offsite concentrations of contaminants of concern to be compared with the modified water trigger levels to characterise the risk.

Examples of Level 2 ERA

- Consideration given to specific chemical form present in soil and groundwater, and differences in chemical behaviour and/or toxicity to receptors.
- Consideration given to species known to inhabit or visit a site rather than protect all possible species.
- Highest level of protection may only be required for protected locations or pristine water resources. a lower level of protection may be appropriate to highly modified land and water or groundwater.
- Consideration given to specific exposure scenarios of the receptors. For example, if a creek is 300m away 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 Level 3 ERA

- Also known as Detailed Ecological Risk Assessment.
- Field studies and sophisticated computer models are used to quantify exposure levels.
- Detailed site-specific information gathered as part of receptor identification, exposure assessment and toxicity assessment.
- Level 3 ERZ derives modified (site-specific) EIL_{soil} or water trigger levels for contaminants of concern that take into account ecological values at the site.
- Complex groundwater fate and transport modelling may be used to estimate offsite concentrations of contaminants of concern to be compared with the modified water trigger levels to characterise the risk.

Examples of Level 3 ERA

- A national park, which is known to contain native species, is impacted by contamination. Assessment may require a biological survey of the site and surrounding area.
- A complicated groundwater system with tidal influences is discharging into a bay containing a coral system. A biological survey may be required. In addition a complex three-dimensional fate and transport model may be required to simulate groundwater discharge and dispersion.

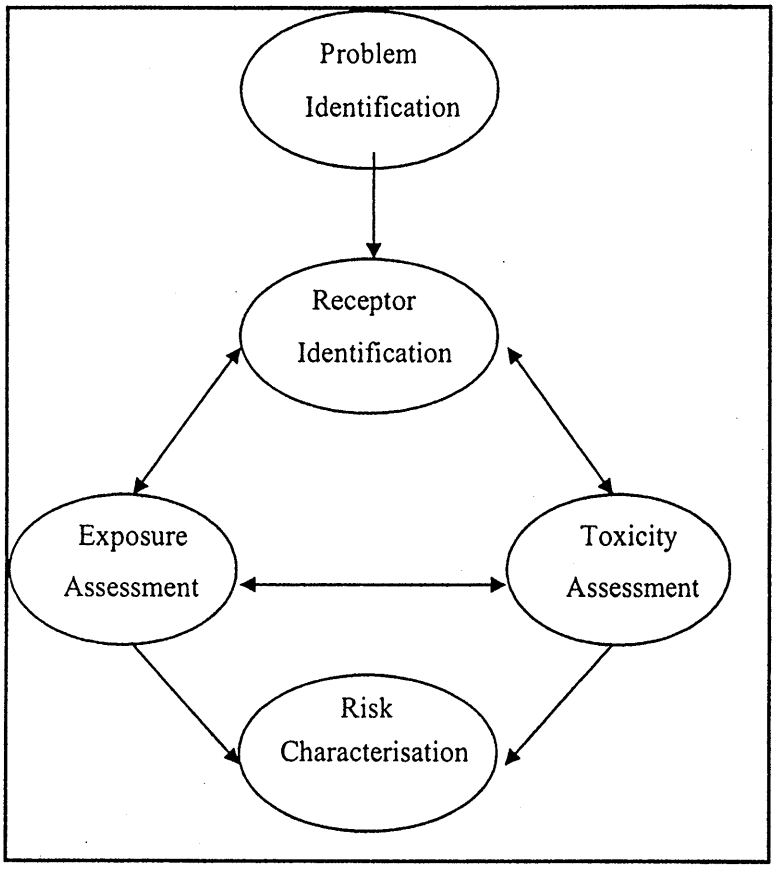
4.3 COMPONENTS OF AN ECOLOGICAL RISK ASSESSMENT

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

- Problem Identification
- Receptor Identification
- Exposure Assessment
- Toxicity Assessment
- Risk Characterisation

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

Figure 5: Components of an Ecological Risk Assessment



(Extract from NEPM Schedule B(5))

The components listed above are analogous to human health risk assessment and are often carried out in conjunction with human health risk assessment. For example, Problem Identification would incorporate an extension of the Conceptual Site Model (CSM) as described in Section 2.2.

For specific details on conducting environmental risk assessments refer to the 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.

Prior to commencing a Level 3 Ecological Risk Assessment, the scope of the assessment should be discussed with DoE or the appointed accredited contaminated site auditor.

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 will incorporate an assessment of relevant technical, social and economic factors.

The enHealth guidance presents a framework for risk management. This includes making decisions, taking actions, monitoring and subsequent review. These elements, as well as the interaction between risk assessment and risk management, are illustrated in Figure 3.

5.2 SETTING ENVIRONMENTAL HEALTH CRITERIA AND REMEDIATION GOALS

EnHealth provides a framework in Section 11 of their 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 human health risk assessment, whereby a tolerable daily intake is derived and, from that, soil and groundwater criteria that are protective of human health are derived. Figure 9 in the enHealth document presents a flow chart for this methodology. In addition consideration needs to be given to a number of issues presented in Section 11.1 of the enHealth guidelines, including multiple chemical exposure, acute risks, background levels and severity of health effects.

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 on the basis of many other considerations, including the requirements for minimising risk where there is uncertainty, and protecting groundwater use, ecological systems, and environmental values. The setting of remediation goals will also need to consider the distribution of the contamination (ie whether it is uniform or occurs in localised areas), the future use of the site, the available remediation technology and economic feasibility, and legal and social considerations (including community consultation).

DoE expects that the management of contaminated sites should be directed to obtain an outcome that is suitable for the actual or intended use of the land including groundwater. Human health should be protected in all circumstances. For sensitive land uses (eg low density residential) amenity issues should be addressed (ie no offensive odours or visual nuisances). Where plant growth is an integral part of the land use (eg parkland, low density residential) then avoiding phytotoxicity should be an objective for land management. Protection of ecosystems from contaminated groundwater should consider the nature of the habitats present (and species present) and the background level of impact on the ecosystem.

As such, the remediation goals should be more stringent than the environmental health criteria, and often will result in clean-up targets much lower than the environmental health criteria. If a management option cannot reduce residual contamination below the environmental health criteria, then an alternative strategy must be found, or in the case of feasibility assessment for a development, the project may have to be abandoned.

Examples of environmental values to be protected

- The health of persons who live or work at the site. The Soil Assessment Levels may be appropriate for this, or a more detailed risk assessment may be carried out to define these goals with more certainty.
- The aesthetic quality of the site (i.e. visual and odour), when the land is to be used for a sensitive use such as residential.
- The growth of plants, where this is a relevant requirement at the site.
- The use of groundwater. This may involve estimating soil targets that will protect the groundwater, or may involve direct measurement of the groundwater quality and the effect of existing contamination to determine appropriate targets.
- The use of land or surface water off-site, such as where contamination may migrate from the site in rainfall run off.

5.3 RISK COMMUNICATION

As well as the evaluation of remediation options, risk management processes incorporate communication processes. Often risk perception can be a driver for remediation and so it is important for the appropriate stakeholders to be informed of the potential risks associated with site contamination and the pros and cons of each remediation option being considered. Public perception and community consultation can become a significant factor in the decision-making process.

An appropriate level of community consultation is required when investigating, remediating and managing all contaminated sites in WA. The DoE guideline document *Community Consultation* should be referred to when determining the appropriate level of community consultation required.

The extent of community consultation required will vary according to site-specific conditions including the nature and degree of contamination, whether site assessment and/or remediation is likely to affect the amenity of the locality or give rise to nuisance conditions (such as noise, odour etc.) and whether the site, locality or contaminant has a history of controversy. For all contaminated site investigations and management, the community consultation process should at least include those stakeholders in the vicinity who may be physically affected by the site investigation and/or remediation (eg, 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 contamination).

In general, it is important to provide a realistic assessment of the potential for impact, and to not provide an overly optimistic assessment of the situation. If, for example, it is likely that some odours will occur during a remediation program even though control measures will be formulated and carefully applied to avoid odours, then this should be indicated.

Where risk issues are deemed to be sensitive in nature, (for example health impact on existing residents, the nature of the contamination, amenity impact (either visual or odorous), impact on protected wetlands), then higher levels of community consultation will be required to assist in the establishment of environmental protection targets.

Community consultation is an ongoing process that occurs at all stages of the assessment and management process. It is important to maintain open communication at all times, and to ensure that the community is able to access appropriate information throughout the process.

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