


Schedule B1



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

This Schedule forms part of the National Environment Protection (Assessment of Site Contamination) Measure as varied 2011 and should be read in conjunction with that document, which includes a policy framework and assessment of site contamination flowchart.

This guideline replaces Schedule B1 to the National Environment Protection (Assessment of Site Contamination) Measure 1999.

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Investigation levels for soil and groundwater

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1 Introduction

The purpose of site assessment is to determine the human health and ecological risks associated with existing site contamination and to inform any remediation or management plan to make the site fit for the proposed land use. The appropriate use of investigation levels is an integral component of the assessment process.

All site assessment will require the consideration of human health and ecological risks and risks to groundwater resources. In addition, assessment of sites with petroleum hydrocarbon contamination will need to consider the presence or potential formation of phase separated hydrocarbons and the risks that may arise from fire or explosion, and risks to buried infrastructure including infiltration of services and aesthetics.

The selection of the most appropriate investigation levels for use in a range of environmental settings and land-use scenarios should consider factors including the protection of health, ecology, groundwater and aesthetics. A balance between the use of soil and groundwater criteria and site-specific considerations is essential practice in site assessment.

This Schedule details a framework for the use of investigation levels. The framework is based on a matrix of human health, and ecological soil and groundwater investigation levels and guidance for specific contaminants. The derivation of health-based investigation levels is outlined in Schedule B7, and the risk assessment methodologies are detailed in Schedule B4. Schedule B5a outlines a risk-based framework for site-specific ecological risk assessment. The derivation of ecological investigation levels is outlined in Schedule B5c and the methodology is detailed in Schedule B5b. Reference is also made to the derivation and use of health and ecological screening levels in site assessment.

The National Environment Protection (Assessment of Site Contamination) Measure as varied 2011 (Measure) does not provide guidance on prevention of site contamination. Owners and occupiers of sites on which potentially contaminating activities are occurring are subject to the environmental protection legislation applying in each jurisdiction. This includes licensing of industrial activities which either prohibits the discharge of wastes onto land or applies relevant controls. Regulations apply appropriate controls to contaminant sources to minimise any ongoing contamination of sites and their application is the principal strategy for prevention of soil and groundwater contamination.

2 Derivation of investigation levels

2.1 Introduction

The purpose of this section is to describe soil and groundwater criteria that can be used to appraise the potential risks to human health and ecosystems from site contamination. Levels of various commonly encountered soil and groundwater contaminants are provided which account for risks associated with a range of land uses from contamination in soil, soil gas and groundwater and consider, where possible, the soil type and the depth of contamination.

In this Schedule, the principal terms used are investigation levels and screening levels. Further explanations (and qualifications to their use) are provided in other Schedules to this Measure. Investigation levels and screening levels are applicable to the first stage of site assessment.

2.1.1 Definitions

In this Schedule, the principal terms used are investigation levels and screening levels. Further explanations (and qualifications to their use) are provided in other Schedules to this Measure. Investigation levels and screening levels are applicable to the first stage of site assessment.

Ecological investigation levels (EILs) depend on specific soil physicochemical properties and land use scenarios and generally apply to the top 2m of soil.

Ecological screening levels (ESLs) for petroleum hydrocarbon materials broadly apply to coarse and fine grained soils and various land uses. They are applicable to the top 3m of soil.

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

Health investigation levels (HILs) are generic and apply across Australia to all soil types generally to a depth of 3 m below surface.

Health screening levels (HSLs) for petroleum hydrocarbons depend on physicochemical properties of soil as it affects hydrocarbon vapour movement in soil and the characteristics of building structures. They apply to different soil types, land uses and depths below surface to >4 m and have a range of limitations.

Investigation and screening levels provide the basis of Tier 1 risk assessment. A **Tier 1 assessment** is a risk-based analysis comparing site data with investigation and screening levels for various land uses to determine the need for further assessment or development of an appropriate management strategy. Further details on the tiered risk assessment process are described in other Schedules to this Measure.

Investigation levels and screening levels are the concentrations of a contaminant above which further appropriate investigation and evaluation will be required. Ecological investigation levels (EILs) may also be referred to as soil quality guidelines in relevant references (see Schedules B5b and B5c).

Petroleum hydrocarbon '**management limits**' are limited to petroleum hydrocarbon compounds. They are maximum values that should remain in a site following evaluation of human health and ecological risks and risks to groundwater resources and apply to all soil depths based on site-specific considerations. These limits are to consider the formation of phase separated hydrocarbons, fire and explosion risks, damage to buried infrastructure and aesthetics.

2.2 Human health-based soil and groundwater criteria

2.2.1 Health investigation levels

The health risk assessment methodology that forms the basis for calculation of HILs is provided in Schedule B4. The derivation of HILs is presented in Schedule B7 and utilises the enHealth *Australian exposure factor guidance* (in press). Table 1A(1), found at the end of this Schedule, provides a summary list of HILs.

HILs are scientifically based, generic assessment criteria designed to be used in the first stage (Tier 1 or 'screening') of an assessment of potential risks to human health from chronic exposure to contaminants. They are intentionally conservative and are based on a reasonable worst-case scenario for specific land-use settings. The HILs are referred to by regulators, auditors and consultants in the process of assessing site soil contamination. For the purposes of site assessment, HILs apply generally to the top 3 m of soil for low-density residential use. Site-specific conditions should determine the depth to which HILs apply for other land uses.

HILs are not intended to be clean-up levels. The decision on whether clean-up is required, and to what extent, should be based on site-specific assessment triggered by an exceedance of the HIL. Health risk assessment is the primary essential aspect of making site decisions. However, other considerations such as practicality, timescale, effectiveness, cost, sustainability and associated ecological risk assessment are also relevant.

HILs establish the concentration of a contaminant above which further appropriate health investigation and evaluation will be required. Levels slightly in excess of the HILs do not imply unacceptability or that a significant health risk is likely to be present. Exceeding a HIL means 'further investigation needed', not 'risk is present, clean-up required'. HILs are designed to be used as an indicator for a more detailed (Tier 2) risk assessment.

The HILs are conservatively derived and are designed to be protective of human health under the majority of circumstances of contaminants, soil types and human susceptibilities. They are derived for four generic land-use categories as follows:

- **HIL A** Standard residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake,(no poultry), includes children's day care centres, preschools and primary schools.
- **HIL B** Residential with minimal opportunities for soil access, includes dwellings with fully and permanently paved yard space such as high-rise buildings and flats.
- **HIL C** Includes developed open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths. Does not include undeveloped public open space which should be subject to a site-specific assessment where appropriate.
- **HIL D** Commercial/industrial includes premises such as shops, offices, factories and industrial sites.

The land-use scenarios are described in detail in other Schedules. To make generic estimates of potential human exposure to soil contaminants, scientifically based assumptions are made about the environment, human behaviour, the physicochemical characteristics of contaminants, and the fate and transport of contaminants in soil within each of these land-use categories.

The HILs are derived by integrating these exposure estimates with toxicity reference values, that is, tolerable daily intakes (TDI), acceptable daily intakes (ADI), and reference doses (RfD), to estimate the soil concentration of a substance that will prevent exceedance of the toxicity reference value under the defined scenario. The toxicity reference values are generally based on the known most sensitive significant toxicological effects. Where toxicity reference values come from multiple sources, their underlying assumptions, defaults and science policy should be compatible and generally similar.

2.2.2 Interim HILs for volatile organic chlorinated compounds

Interim HIL soil gas levels for selected volatile organic chlorinated compounds (VOCCs) have been developed (see Table 1A(2) at the end of this Schedule). These HILs provide Tier 1 guidance for health risks from soil contamination sources and groundwater plumes associated with this group of compounds. The values may be applied for general site assessment and sub-slab environments for evaluation of potential health risks for the 0-1 m sub-slab profile. It should be noted that the derived values are necessarily conservative.

They have interim status pending further scientific work on volatile gas modelling from the sub surface to building interiors for chlorinated compounds including consideration of different soil types and land uses.

2.2.3 Health screening levels (HSLs) for petroleum compounds

Site contamination by petroleum hydrocarbon compounds is frequently encountered. The complex mixtures of aliphatic and aromatic compounds that comprise TPH products (total petroleum hydrocarbon) present human health concerns predominantly through exposure to vapours from contaminant sources and by direct contact with affected soils and groundwater. At the time of this Measure, there is no validated vapour intrusion model specifically developed for Australian conditions. Predictive modelling of sub-surface vapour movement in soil and penetration of building structures is a field of intensive data collection and research. For the purpose of this Measure, the use of the most recent research, modelling and derivation approaches adopted in developed international jurisdictions has been considered and adapted as far as practicable for Australian conditions, to derive soil criteria for petroleum hydrocarbons.

HSLs for TPH compounds, based on the TRH analytical method (total recoverable hydrocarbon) comprising BTEX and specified carbon chain fractions have been developed by the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) under its risk characterisation and communication program. The development process to produce best practice guidance was overviewed by a policy advisory group with health, environmental, assessment and remediation, petroleum industry and regulatory expertise. A specialised technical working group provided on going technical support and review during all stages of development work. The project was subject to international peer review in the latter stages of development.

The HSLs have been developed to be protective of human health by determining the reasonable maximum exposure from site sources for a range of situations commonly encountered on contaminated sites and for proposed land uses. They apply to the same land-use settings as HILs and include the additional dimensions of groundwater, soil gas, soil type and depth to identify the relevant site criteria. HSLs for soil, groundwater and soil gas are developed for various soil types and depths below surface and apply to exposure to petroleum hydrocarbons through the predominant vapour exposure pathway.

There are many site-specific, soil-specific and building-specific variables that affect the level of the HSL and these factors must be considered in risk assessment. It is incumbent on contaminated-land professionals to become familiar with the limitations and sensitivities associated with HSLs and their application through the published CRC CARE references prior to their use in site assessment.

2.2.3.1 HSL methodology

The principal references for the methodology and the application and sensitivity of derived HSLs are Friebe and Naderbaum (2010a, 2010b, 2010c).

Vapour migration through a range of soil types and intrusion into building spaces is a specialist area. Predictive modelling of vapour intrusion is dependent on the properties of the specific chemical and a range of soil physicochemical variables.

Soil and groundwater HSLs are based on three-phase equilibrium theory and the soil vapour is limited by the maximum solubility limit of the chemical in the soil pore water phase or the groundwater. The soil saturation concentration of a particular contaminant is the condition where pore water is at its solubility limit and soil vapour is at the maximum. When a calculated HSL in soil or groundwater exceeds this limit, the vapour in the soil or above groundwater cannot result in an unacceptable vapour risk and is denoted as NL (not limiting) in summary HSL tables. Soil vapour HSLs are based on the vapour pressures of individual chemicals. Calculated soil vapour HSLs that exceed the possible maximums are similarly denoted as NL.

The Johnson and Ettinger model (US EPA 2004) has been widely used and studied and is adopted as the primary method to determine vapour exposure. The model has been used assuming a finite source and without biodegradation. The adaption of the model to Australian conditions has considered a range of soil and building variables including soil moisture, soil organic carbon content, building ceiling height, areal ratio of cracks in concrete slabs, air exchange rate and concrete slab thickness.

There are inherent limitations in deriving soil and groundwater criteria from this approach. Documented assumptions are supported by references related to sensitivity and applications (Friebe and Naderbaum 2010a, 2010b) and the assessment approach has been widened to include assessment of soil gas concentrations. Exposure parameters of the individual carcinogenic and non-carcinogenic compounds of concern have been adopted from enHealth's *Australian Exposure Factor Guidance 2010*.

The HSLs have been derived using accepted approaches to assessment for non threshold cancer risk and threshold non cancer risk.

The four carbon chain fractions shown for site assessment using TRH analysis have been utilised in the development of HSLs based on the fractions adopted in the *Canada-wide standard for petroleum hydrocarbons (PHC) in soil* (CCME 2008). In addition, HSLs have been developed for benzene, toluene, ethyl benzene, xylenes (BTEX) and naphthalene. The values for BTEX must be subtracted from the TRH analytical result to obtain the F1 value.

F1 $C_6 - C_{10}$

F2 $>C_{10} - C_{16}$

F3 $>C_{16} - C_{34}$

F4 $>C_{34}$

Detailed information on the model inputs and assumptions (for example, soil properties, sub-slab attenuation, organic carbon content, chemical properties, building modelling parameters) and overall limitations are provided in Friebe and Nadebaum (2010a).

2.2.3.2 HSLs and multiple-lines-of-evidence approach

To provide a balanced assessment of the health risk from TPH contamination, criteria have been developed to cover a range of site-specific conditions including land use, soil type and depth. This enables a multiple-lines-of-evidence approach (also see Schedule B2) to assessment of petroleum impacted sites involving consideration of contamination in soil, groundwater and soil gas.

Soils are classified as sand, silt and clay using the US soil texture classification (Friebe & Nadebaum 2010a) as follows.

SAND : sand, sandy clay loam, sandy clay, sandy loam, loamy sand, loam

SILT: silt loam, clay loam, clay

CLAY; silty clay, silty clay loam, silt

HSLs are provided in a series of Tables for the F1-F4 TPH fractions, BTEX and naphthalene. It is essential that BTEX and naphthalene results are subtracted from TRH values as the latter includes these in the laboratory reported value.

HSLs for soil in Table 1A(3) and groundwater in Table 1A(4) have been developed for sand, silt and clay soils for the critical vapour intrusion pathway. (Both tables can be found at the end of this Schedule). Descriptions of the broad soil types are provided in Friebe and Nadebaum (2010a). The HSLs are derived for various soil depths and for low and high density residential use, recreational parkland and open space, and industrial and commercial uses equivalent to the HIL land-use categories discussed in other Schedules to this Measure. It should be noted that land-use category B, high-density residential, applies to a particular situation for the scenario where there are residents on a ground floor in a multi-storey building in which the slab on ground is in direct contact with the soil. The presence of basement or ground level car parking for high-density residential would require the application of the land-use category D, commercial/industrial. The HSL values are not relevant to floors above ground level.

HSLs for soil and groundwater are complemented by soil gas HSLs in Table 1A(5) for equivalent land uses and various soil depths. Additional values for direct soil contact in Table 1A(6) are provided. (Both tables can be found at the end of this Schedule).

2.2.3.3 Biodegradation

The modelling approach in HSL derivation did not include biodegradation. Under the CRC CARE program, research was reported by CSIRO (Davis, et al. 2009A, 2009B) on underslab biodegradation of petroleum hydrocarbon contamination. This research identified the site conditions that are conducive to biodegradation of petroleum hydrocarbon compounds in the underslab sub-surface.

The presence of oxygen at >5% in soil at a depth 1 m below the surface immediately adjacent to the concrete slab will enable the application of biodegradation multiplication factors of 10 and 100 to HSL values >2-<4 m and >4 m depth, respectively. This biodegradation factor is limited to a maximum slab width of 15 m with oxygen access on both sides of the slab for Tier 1 screening purposes. A distance of 7-8 m from the exposed soil at the slab boundary is considered the maximum lateral underslab penetration of oxygen. The biodegradation factors do not apply to VOCCs. For the purpose of this Measure, assessment for biodegradation is considered a Tier 1 activity.

Application of the biodegradation factor may result in levels of TPH, BTEX and naphthalene that are acceptable for human health risk assessment for the specific land use but may not be acceptable for protection of the environment. However, site results should be considered with reference to relevant ecological and 'management levels' which may become the predominant consideration. Management levels should be applied after human health, ecological risks and risks to groundwater resources have been assessed.

2.2.3.4 Use and limitations of HSLs

Soil and groundwater HSLs provide the principal assessment criteria for open excavations (such as tank removal operations) while greater emphasis is placed on soil gas in assessing potential health risks from hydrocarbon sources and groundwater plumes under buildings. In other situations, evaluating all contaminant phases will provide the most accurate site assessment. Soil gas measurements may provide a more accurate representation of vapour risks depending on site-specific conditions.

In the following site circumstances, HSLs for assessing petroleum hydrocarbon contamination from fuel storage or other sources will have limited application, depending on site conditions. In these cases a site-specific approach will need to be developed which is likely to involve direct intervention:

- groundwater contaminated with petroleum hydrocarbons is present at less than 2 m below the ground or basement surface or contaminated groundwater is entering a basement
- a measurable separated layer of free phase petroleum hydrocarbon in any borehole or monitoring well is present
- hydrocarbon odour from site contamination is present in buildings or utilities which indicates a preferential migration pathway and an immediate human health risk.

The conditions will require more detailed site specific assessment including consideration of the ecological screening levels (ESLs) and the 'management limits' described in this Schedule, and identification of an appropriate management response.

Jurisdictions may adopt policies for local conditions to manage widely varying soil, site or building conditions (for example, large seasonal moisture variations and differing air exchange rates in tropical areas). The application and sensitivity documents (Friebel & Nadebaum 2010b, 2010c) provide details. Direct contact HSLs relate to dermal exposure only and have limited application in site assessment; for example, they may be applicable for surface contamination such as fresh surface spills where some direct and temporary contact is possible. Any exposure to a contaminated surface (other than of short, temporary duration) at the levels of the direct contact HSLs would cause a vapour exposure risk. It is inappropriate to use direct contact HSLs as the only site assessment criteria to determine acceptable land uses. Site assessment must include all relevant human exposure pathways and assessment of ecological risks. The application of relevant ecological and 'management' criteria for petroleum compounds is provided in this Schedule. Assessment of petroleum impacts must also evaluate risks to groundwater and involve appropriate consideration of aesthetics. There are limitations in the application of the HSLs, and reference to relevant HSL table footnotes and the published references are essential for appropriate interpretation.

2.3 Asbestos materials in soil

This guidance applies to asbestos materials in soil and does not address asbestos issues related to occupational health and safety, waste management or mining sites which are covered by specific regulations in each jurisdiction. Site assessors should be aware of the relevant Occupational Health & Safety legislation relating to asbestos and its disposal when operating on sites. Similarly, this guidance does not apply to asbestos materials as wastes such as demolition materials stacked on the surface of land or asbestos materials in buildings.

The Measure contains guidance for site contamination for asbestos in soil in this Schedule and in Schedule B2 that deals primarily with assessment but is inextricably linked to the following issues:

- whether appropriate assessment has been undertaken to implement a suitable management or remediation strategy
- ensuring adequate protection of human health and the environment for the reasonable current and long-term use of a site
- health management measures necessary during the conduct of site investigations and any remediation activities.

In Australia, asbestos has been used as a reinforcing agent in cement sheeting for walls and roofs; in cement building products, such as vinyl tiles, pipes, gutters and flooring; and in insulating board, lagging and sprays. The manufacture of asbestos cement sheeting and high-pressure piping ceased in the 1980s and houses built in Australia since then are unlikely to contain asbestos. Many older homes in all Australian communities still contain asbestos cement products, especially sheet material used in eaves or for cladding of external walls and roofs. If asbestos materials can be maintained in good condition, it is recommended that they be left alone and periodically checked to monitor their condition (enHealth 2005).

The guidance in this Schedule and in Schedule B2 emphasises that the assessment and management of asbestos contamination should take into account the very low human health risk posed by most occurrences of soil contamination by bonded asbestos. It is only airborne fibres which present a hazard and if the asbestos is bound in a matrix like cement, it is not readily released to the air except through substantial physical damage.

In contrast, soil contamination by asbestos material that is crumbling, readily broken or consists of a fibrous material or residue is much less common but also more hazardous and requires careful management to minimise the generation of airborne fibres.

Schedule B2 presents more detailed information on the assessment of asbestos contamination, but an overview is presented here.

ACM is commonly encountered in redevelopment sites where former buildings included common asbestos building materials (see enHealth, 2005, Chapter 3). ACM in Australia typically contains 10–15 per cent asbestos by weight, bound in a cement matrix. ACM in sound condition, even if broken or fragmented, represents a low human health risk.

If site history or site inspection indicates the possibility or occurrence respectively of asbestos contamination, an assessment should be undertaken. This should take the form of a preliminary site assessment followed by, only if necessary, a detailed site assessment (see Schedule B2 and WA 2009 guidelines). The results of any assessment should inform an appropriate response or management strategy. For example, if a preliminary site assessment clearly indicates the extent of contamination to consist only of scattered ACM fragments on the surface, then remediation is relatively simple. After remediation, the exposed surface of the site under assessment should be free of visible ACM fragments and all ACM should be removed from the top 10 cm of soil as far as practicable. Alternatively, a 30 cm layer of topsoil can be layered over the site.

It is an inappropriate response to declare a site a human health risk on the basis of the presence of ACM alone. However, where the asbestos is not firmly bound in a matrix it may represent a significant human health risk and is defined in two categories.

- Unbonded asbestos or fibrous asbestos (FA) includes loose fibrous material such as insulation products and low density board (up to 70% asbestos in calcium silicate). For the purposes of site assessment, FA includes any material that is easily powdered or made pasty with clear separation of asbestos fibres by moderate hand pressure.
- Asbestos fines (AF) includes free fibres of asbestos, small fibre bundles and fragments of ACM that pass a 7 mm x 7 mm sieve.

Both fibrous asbestos and asbestos fines materials have the potential to generate free asbestos fibres which can pose a considerable inhalation risk if made airborne.

Assessment criteria

For ACM in sound condition, the use of a basic criterion of 0.01% w/w asbestos in soil is adopted for Australian sites as a conservative approach.

The Netherlands' (Swartjes & Tromp 2008) applies a criterion of 0.1% w/w asbestos for ACM in sound condition. The Netherlands' level is based on an extensive database of field and simulation trials using both friable and bonded ACM which have confirmed that this soil criterion will ensure that asbestos air levels remain below current levels of detection and equate with a negligible risk to the public. The WA Department of Health has produced *Guidelines for the assessment, remediation and management of asbestos-contaminated sites in Western Australia* (2009) which were designed specifically to improve the characterisation of asbestos soil contamination and use a basic criterion of 0.01% w/w asbestos in soil for (ACM) in sound condition. These guidelines are more conservative than the Netherlands' criterion to account for local (dry) conditions and the precautionary Australian practice of treating all forms of asbestos as equivalent.

The following levels for various land uses adopted from the WA guidance are appropriate screening criteria for assessment of asbestos contamination by appropriate sampling and quantification as % w/w by gravimetric methods.

0.01 % w/w asbestos in ACM – standard residential use

0.04 % w/w asbestos in ACM - residential, minimal soil access

0.02 % w/w asbestos in ACM – parks etc.

0.05 % w/w asbestos in ACM - commercial/industrial

More conservative criteria equivalent to a nominal 0.001% w/w asbestos are applicable for FA and AF assessment. A systematic visual assessment (see WA 2009 guidelines) by a qualified and experienced assessor (refer Schedule B9) is required to determine if FA or AF are present.

If FA is not detected by systematic visual inspection, then quantification is not required as it can be assumed that the soil level of FA is <0.001%w/w. If FA is detected, there is no practical sampling and laboratory method to quantify dispersed FA at this level and the focus should be to ensure that asbestos is appropriately remediated or managed.

If easily visible AF or small fibre bundles are detected, then it may be possible to undertake semi-quantitative estimates of the % w/w AF by conventional gravimetric methods. These small fragments may need to be considered as FA if an evaluation of their structural integrity reveals a capacity to generate free fibre. More detailed investigation and appropriate management action may be required if the w/w AF exceeds the 0.001% w/w criterion across a significant area of the site.

Characterising asbestos contamination

Asbestos Cement Material

As outlined in the enHealth guidance, *Management of asbestos in the non-occupational environment* (2005), the quantity of asbestos in soil may be estimated as follows:

$\% \text{soil asbestos} = \% \text{asbestos content} \times \text{ACM (kg)} / \text{soil volume (L)} \times \text{soil density (kg/L)}.$

The assessment and sampling methods to determine the soil % w/w asbestos from asbestos cement material (ACM) are based on the WA guidance (WA 2009) and are designed specifically to improve the characterisation of asbestos soil contamination. The screening method relies on the systematic collection of samples of known weight and the separation of ACM by sieving for separate weighing. WA guidance also allows separation of ACM by spreading as well as sieving in appropriate circumstances to minimise fibre release. ACM measurements are recommended for total asbestos contamination where FA and AF are not likely to be significant.

Fibrous asbestos and asbestos fines

The %w/w asbestos in soil estimates of FA and AF provide an acceptable screening approach only for those sites which contain small ACM fragments and/or visible fibre bundles. In addition, the assessment of any asbestos contamination should account for the usual non-homogenous distribution of the contaminant and the likely variation in 'hot spot' size.

Judgemental sampling is preferred as it may provide a qualitative assessment of the extent of the contamination and inform the management or remediation strategy. Test pits and trenches may be more reliable methods to determine the presence or extent of any asbestos contamination in cases of uncontrolled fill or when there is little available site history. Grid-based sampling using boreholes may not be reliable due to the small surface area exposed and limited capacity to determine the extent of contamination and 'hot spots' or remediation required.

2.4 Ecologically based soil criteria

Although the primary concern in most site assessments is protection of human health, the assessment should also include consideration of ecological risks and protection of groundwater resources that may result from site contamination. This section provides details on the development of site-specific ecological soil criteria for common metals and limited organic compounds including common petroleum hydrocarbons. The resulting investigation and screening levels provide the basis for Tier 1 site assessment of ecological risk.

Ecological investigation levels (EILs) have been derived for common metal contaminants in soil, arsenic, naphthalene and DDT based on a species sensitivity distribution model derived for Australian conditions (Schedule B5b). Ecological screening levels (ESLs) apply to the petroleum hydrocarbons fractions F1-F4, BTEX and benzo(a)pyrene based on a review of Canadian guidance for petroleum hydrocarbons in soil (CCME 2008) and its application to Australian conditions (Warne 2010a, 2010b). The criteria relate to various land uses and soil types for protection of soil processes, plant species and organisms that inhabit or contact soil. The criteria relate to various land uses and soil types for protection of soil processes, plant species and organisms that inhabit or contact soil.

Schedule B5a provides detailed guidance on ecological risk assessment. Appendix B of Schedule B5b provides guidance for deriving EILs which are protective of aquatic ecosystems.

2.4.1 Ecological investigation levels

2.4.1.1 EIL derivation

Derivation considers the physicochemical properties of soil and contaminants and the capacity of the soil to accommodate increases in contaminant levels above natural background while maintaining ecosystem protection for identified land uses. Depending on the availability of ecotoxicity data, the process of ecological EIL derivation is either soil specific for some common contaminants or a single value for others that apply to all soil types.

This Measure has adopted the lowest observed effect concentration (LOEC) or effective concentration 30% (EC30) data to derive EILs for various land-use scenarios. The EILs are derived for specified levels of % species protection, dependent on land uses, and is consistent with international practice in ecosystem protection.

EILs apply principally to contaminants in the top 2 m of soil at the finished surface/ground level which corresponds to the root zone and habitation of many species.

2.4.1.2 Methodology

The detailed methodology incorporated in Schedule B5b, was developed by CSIRO using data from various Australasian databases and the Australian National Biosolids Research Program, supplemented by data from the United States Environmental Protection Agency ecotoxicology database where necessary.

The methodology enables derivation of soil criteria that identify levels of contamination for various land uses and provides protection for a specified percentage of species. The approach accommodates various ecological settings, soil types and a diverse range of soil physiochemical properties and environmental fates.

Depending on the availability of appropriate data, derived EILs can account for the ageing of contaminants and the effect of certain soil physicochemical properties on toxicity and biological availability.

2.4.1.3 Added contaminant limits

Added contaminant limits (ACLs) used for EIL determination have been derived using a CSIRO-developed methodology that applies a species sensitivity distribution (SSD) risk-based approach using ecotoxicity data from a range of species. The approach is analogous to the methodology used for derivation of the Australian water quality guidelines (ANZECC & ARMCANZ 2000; NHMRC). An ACL is the added concentration of a contaminant above which further appropriate investigation and evaluation of the impact on ecological values will be required. Where insufficient data are available for the SSD method to be used, an assessment factor approach is adopted.

ACLs apply to zinc (Zn), copper (Cu), chromium III (CrIII) and nickel (Ni) for site-specific EIL determination. The EILs for arsenic (As), DDT and naphthalene are generic to all soils as a total soil contaminant concentration.

2.4.1.4 Ambient background concentration

The methodology assumes that the ecosystem is adapted to the ambient background concentration (ABC) for the locality and that it is only adding contaminants over and above this background concentration which has an adverse effect on the environment. The ABC of a contaminant is the soil concentration in a specified locality that is the sum of the naturally occurring background and the contaminant levels that have been introduced from diffuse or non-point sources by general anthropogenic activity not attributed to industrial, commercial, or agricultural activities, for example, motor vehicle emissions.

The EIL is derived by summing the ACL and the ABC.

2.4.1.5 Land-use settings and species protection

EILs have been adopted for three land-use settings:

- national parks and areas of ecological significance
- urban residential areas and public open space
- commercial and industrial land uses.

The EILs are derived on the basis of protecting 99%, 80% and 60% of species respectively in the adopted land settings using LOEC or EC30 data. These protection levels are increased by 5% where biomagnification may occur (refer Schedule B5b). LOEC is the lowest concentration used in a toxicity test that causes a toxic effect that is significantly different to the control.

EC30 data are the concentrations of contaminants that cause an effect on 30% of the test group of an organism after a specified exposure time. The data are applied across a range of species to derive individual EILs. EILs are not applicable to agricultural soils which need evaluation in relation to crop toxicity, plant contaminant uptake and detailed consideration of soil type.

An area of ecological significance is one where the planning provisions or land-use designation is for the primary intention of conserving and protecting the natural environment. This would include national parks, state parks, wilderness areas and designated conservation areas.

2.4.1.6 Ageing of contamination and the physiochemical properties of soil

In general the toxicity of soil contaminants, (both organic and inorganic), will reduce or age over time to a lower and more stable level by binding to various soil components and decreasing their biological availability. Hence, toxicity can be affected by the physicochemical or chemical properties of the soil including clay content, cation exchange capacity (CEC) measured in cmol_c/kg , pH, iron and organic carbon content.

In some cases insufficient data for a specific contaminant on aged contamination was available and, where possible, ageing factors based on relevant studies have been applied to determine a soil value for aged contamination.

A contaminant incorporated in soil for at least two years is considered to be aged for the purpose of EIL derivation. The majority of contaminated sites are affected by aged contamination. Fresh contamination is usually associated with current industrial activity and chemical spills.

ACLs are based on the soil characteristics of pH, CEC and clay content. Site assessment for Zn, Ni, and Cu will require determination of CEC of each relevant soil type on the site. Measurement of pH is also required for Zn and Cu. CrIII assessment will require determination of clay content. Empirical relationships that can model the effect of these soil properties on toxicity are used to develop soil-specific values. These soil-specific values take into account the biological availability of the element in various soils. In this approach different soils will have different contaminant EILs rather than a single generic EIL for each contaminant.

2.4.1.7 Determining site EILs

Detailed guidance on derived EILs is provided in Schedule B5c. The following information describes the steps that are taken to derive site-specific EILs.

A. EILs for Ni, CrIII, Cu, Zn and Pb aged contamination (>2 years)

Steps 1–4 describe the process for deriving site-specific EILs for the above elements using Tables 1B(1)–1B(4) which can be found at the end of this Schedule.

1. Obtain the soil CEC (cmol_c/kg) and pH when analysing for Zn Cu and CEC only for Ni and the clay content for CrIII. Sufficient samples need to be taken for these determinations for each soil type in which the contaminant occurs.

2. Establish the sample ACL for the appropriate land use and with consideration of the soil-specific pH, clay content or CEC. The ACL for Cu may be determined by pH or CEC and the lower of the determined values should be selected for EIL calculation. Note that the ACL for Pb is taken directly from Table 1(B)4.
3. Calculate the contaminant ABC in soil for the particular contaminant and location from a suitable reference site measurement or other appropriate method.
4. Calculate the EIL by summing the ACL and ABC:

$$\text{EIL} = \text{ABC} + \text{ACL}$$

B. EILs for As, DDT and naphthalene

EILs for aged contamination for DDT and naphthalene are not available and the adopted EIL is based on fresh contamination taken directly from Table 1B(4). The EILs for As, DDT and naphthalene are not dependent on soil type and are taken directly from Table 1B(4).

Note: EIL determination for fresh contamination (that is, <2 years) for the relevant contaminants should be site-specifically determined by reference to relevant tables in Schedule B5c.

2.4.1.8 Determining the ambient background concentration

Three methods for determining the ABC are recommended in the methodology for deriving EILs. The preferred method is to measure the ABC at an appropriate reference site. This approach is essential in areas where there is a high naturally occurring background.

In other situations where an appropriate reference site cannot be determined, the method based on urban metal level studies by Olszowy et al. (1995) or the method by Hamon et al. (2004) may be used.

The method of Hamon et al. (2004) may also be useful to estimate the ABC. In this method the ABC varies (depending on the element) with the soil iron and/or manganese concentration; for example, the ABC for zinc varies from 3–62 mg/kg in soils with soil iron concentrations between 0.1% and 20%. Alternatively, ABCs for old and new suburbs and high and low traffic areas for NSW, Queensland, SA and Victoria for Zn, Cu, Ni, Pb, and CrIII are available from Warne et al. (see Schedule B5b), based on Olszowy et al. (1995).

In some situations the ABC may be comparatively low and have a minor effect on the magnitude of the site EIL.

2.4.2 Ecological screening levels for petroleum hydrocarbon compounds

The Canadian Council of the Ministers of the Environment (CCME) have adopted risk-based TPH standards for human health and ecological aspects for various land uses in the *Canada-wide standard for petroleum hydrocarbons (PHC) in soil* (CCME 2008) (CWS PHC). The standards established soil values including ecologically based criteria for sites affected by TPH contamination for coarse and fine grained soil types and apply from surface to 3m depth. The TPH fractions are the four fractions (F1–F4) adopted for HSLs. The standards include other TPH compounds such as MAHs (monocyclic aromatic hydrocarbons) and specific PAHs (polycyclic aromatic hydrocarbons).

In many cases, sites assessed for TPH contamination are driven initially by human health concerns with the more volatile components (F1 and F2) in the 0–4m below-ground-level setting where the longer chain fractions may be not limiting for human health. In circumstances where human health risks are addressed through use of HSLs, ecological impacts particularly from contaminant levels assessed using biodegradation factors or those associated with the longer chain fractions (F3–F4) may become the predominant concern.

The CWS PHC approach utilises an SSD method and, when there are insufficient data for the SSD method, applies a weight of evidence approach to derive ecologically based 'Tier 1 eco soil contact' values for TPH fractions and specific compounds. The overall approach has similarities to the Australian EIL methodology by developing protective criteria based on EC25 toxicity (cf. Australia EC/LC30 and LOEC data) for residential land use and EC50 for commercial/industrial land.

ESLs for eco soil contact have been adapted from the CCME approach as detailed below. ESLs should be applied from surface to 3 m depth below ground level due to the mobility and volatility of petroleum hydrocarbon contamination in the sub surface. Consideration should be given to the realistic risk of material being re-excavated and causing an exposure risk.

2.4.2.1 *ESLs for F1–F4*

The ecotoxicity data used for the Canadian F1 and F2 (eco soil contact) values were applied to the Australian EIL methodology (Warne 2010a) to produce comparable Tier 1 values for these fractions. Based on the data quality and applicability to the Australian environment, the derived values for these fractions using the Australian methodology are adopted as moderate reliability ESLs (see Table 1B(5) at the end of this Schedule) and apply generically to both fine and coarse grained surface soils. It is recognised that consideration of F1 and F2 soil contamination will generally be driven by the relevant HSLs in site assessment, particularly when a biodegradation factor is not applied.

Due to the limited ecotoxicity data for F3 and F4, use of the Australian methodology was not applied. The data limitations were recognised in the Canadian guidance where a weight of evidence approach was used to develop values for these fractions. Adopted values for F3 and F4 (see Table 1B(5) at the end of this Schedule) are low reliability ESLs for fine and coarse grained soils and apply from the surface to 3 m below ground level (Warne 2010a, 2010b).

2.4.2.2 *BTEX and benzo(a)pyrene*

A further review of Canadian soil quality guidelines was undertaken for BTEX and benzo(a)pyrene (Warne 2010b). Values were derived using the Canadian data reduction methods, the Australian SSD method and employing the Australian levels of protection for various land uses. Data limitations have not enabled the full use of the EIL derivation methodology and the resulting values are adopted as low reliability ESLs in Table 1B(5) at the end of this Schedule.

2.5 **Physical and aesthetic 'management limits' for petroleum hydrocarbon compounds**

The CWS PHC has identified circumstances where human health and ecological concerns are addressed but other adverse effects of TPH contamination may be a consideration.

The effects include free phase formation, fire and explosive hazards, effects on buried infrastructure and aesthetic considerations leading to 'management limits' for these conditions. These values have been adopted and are included in Table 1B(6) at the end of this Schedule. These values provide interim screening levels as Tier 1 guidance for residual petroleum hydrocarbon contamination.

Application of the management limits will require consideration of site specific factors such as the depth of building basements and services or for residual contamination to be re-excavated in the use of the land in order to determine the maximum depth of application.

2.6 Groundwater investigation levels

HSLs for groundwater address the risks to human health from the vapour exposure pathway for various land uses, soil types and depths below surface. However, contaminated groundwater may pose a risk to receptors at the point of extraction or as a result of discharge into receiving environments. Contaminated groundwater may also affect groundwater resources. Site assessment should consider the risks of contaminated groundwater to all potential receptors on and off the site of origin and include the protection of groundwater resources.

Schedule B6 provides a framework for the assessment of groundwater contamination based on the National Water Quality Management Strategy *Australian and New Zealand guidelines for fresh and marine water quality* (AWQG) (ANZECC & ARMCANZ 2000), the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMCC 2004) and the *Guidelines for managing risk in recreational water* (GMRRW) (NHMRC 2008).

The guideline values provided in Table 1C at the end of this Schedule are sourced from these documents and define acceptable water quality for various contaminants at the point of use and apply to the following settings identified in the framework for groundwater assessment: aquatic ecosystems (fresh and marine), groundwater-dependent ecosystems, drinking water, recreational waters, and agricultural use (stock watering and irrigation).

When assessing groundwater contamination, the AWQG, ADWG and GMRRW are applied as investigation levels at the point of extraction and as response levels at the point of use, or where there is the likelihood of an adverse environmental effect at the point of discharge. The guideline documents should be consulted for informed interpretation and application of site-determined values.

It should be noted that some jurisdictions may have groundwater protection policies that require action even where levels do not exceed the AWQG values at the point of use.

3 Application of investigation and screening levels

3.1 General

The primary purpose of site assessment is to identify site-specific human health and ecological risks and to inform the process that will enable the land to be made 'fit for use'. Professional assessors need to be competent in the determination and application of the relevant investigation levels, screening levels and management limits for petroleum hydrocarbon compounds that are relevant to assess the risks on specific sites.

Many contaminated sites present with multiple soil and groundwater contaminants of widely varying human and ecological toxicity affected by site characteristics such as soil type and depth below surface. The particular investigation and screening levels that apply to a particular site and proposed land use need to be determined on a site-specific basis. Consequently, professional judgement should always be exercised.

A Tier 1 site assessment includes consideration of investigation levels and screening levels for human health and ecosystem protection, and any guidance on limitations for their use to address site-specific risk issues. Most site assessments will require consideration of a combination of HILs and EILs and HSLs, ESLs and management limits when petroleum hydrocarbon contamination is present.

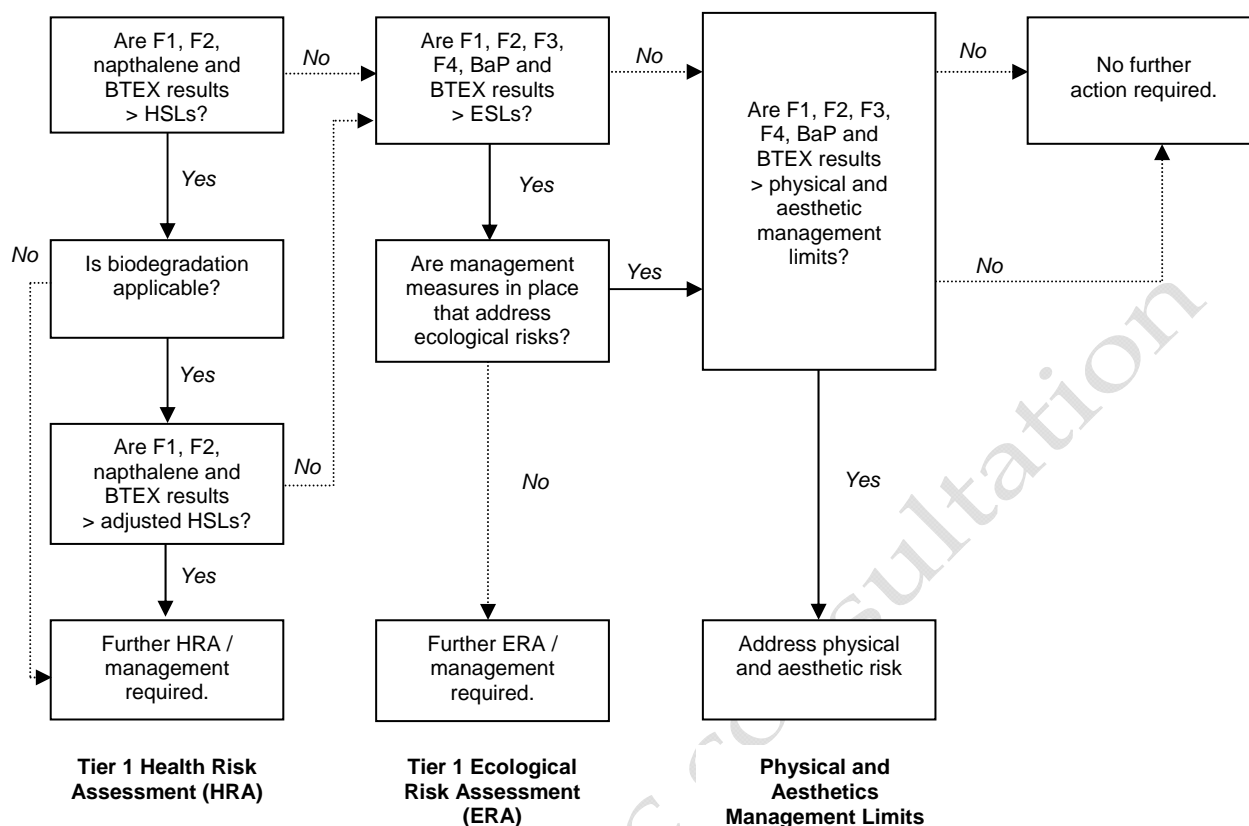
As an example, when land is being assessed for its suitability for residential uses with minimal opportunities for soil access (for example, high-density residential apartments) and where most of the site has no major sensitive ecological values to be protected, HIL B would be applied. EILs for commercial and industrial uses would be considered for areas with minimal soil access (for example, under pavement and low accessibility landscaped areas) with potential for relaxation of EIL values at depths greater than 2 m when no receptors have been identified. Relevant guidance would be applied for aesthetic considerations and specific substances (for example, ACM, radioactive substances). Groundwater investigation levels (GILs) are applicable to assessment of the risk of groundwater impacts to receptors on and off site, including groundwater resources.

If the site had previous industrial uses with contamination by petroleum hydrocarbons, HSLs may be relevant for the vapour exposure pathway from soil and groundwater contamination and include the assessment of soil gas. Careful consideration should be made of the width of the ground floor slab which has direct soil contact and soil oxygen levels to assess hydrocarbon vapour biodegradation potential. Similarly, ESLs may be relevant particularly for TRH fractions F3 and F4. Management limits should be considered to ensure gross contamination and any potential fire or explosive risks are appropriately addressed.

It may be necessary to apply HIL C and EILs for urban residential and public open space to common garden areas and accessible gardens which includes lawn areas and playgrounds. Any ground floor yard or accessible garden area allocated to an individual apartment should be assessed using HIL A criteria.

The flowchart in Figure 1 provides a general overview of the application of HSLs and ESLs for petroleum hydrocarbons including linkage to 'management limits' for TPH contamination. ESLs typically should be applied to 3 m below the surface to maintain an adequate level of ecosystem protection.

Figure 1. Flowchart – Application of HSLs and ESLs - Tier 1 human health and ecological risk and consideration of management limits



1. In all cases, when TPH values are denoted as NL, consideration must be given to ecological assessment and relevant ecological criteria
2. Physical and aesthetic 'management limits' consider the potential effects of: free phase formation; fire and explosive hazards; effects on buried infrastructure including infiltration of services; and aesthetic considerations. Management limits are considered to apply at all soil depths based on site-specific considerations. Jurisdictional policies will apply to the presence of phase separated hydrocarbons.
3. Before completing the assessment the risk to groundwater resources should be evaluated.

3.2 Soil assessment

3.2.1 General

In all cases, site assessment should be directed to development of a conceptual site model and appropriate application of data quality objectives.

Neither investigation or screening levels are clean-up or response levels nor are they desirable soil quality criteria. Their use in regulating contaminant sources and wastes for soil application is inappropriate. They should only be used for assessing existing contamination and to trigger an appropriate site-specific risk assessment or appropriate risk management options when they are exceeded.

Inappropriate use of investigation and screening levels as default remediation criteria may result in unnecessary remediation adding to development costs, causing unnecessary disturbance to the site and local environment, and potential waste of valuable landfill space. Similarly, investigation and screening levels should not be interpreted as condoning contamination to these levels. Land is usually remediated to an extent which optimises current and future land use.

Site-specific health and ecological risk assessment or development of appropriate management options should be conducted where exceedance of investigation and screening levels indicates there is the likelihood of adverse effects on human health or ecological values for that site. Before comparing measured concentrations with relevant investigation and screening levels, there should be sufficient and appropriate characterisation of the site to ensure that the comparison is meaningful and appropriate.

3.2.2 Human health soil assessment considerations

The Schedules to this Measure provide guidance about the types of exceedance of a HIL that trigger a detailed site-specific risk assessment or risk management response. A site-specific health risk assessment, when undertaken, should be conducted according to the framework on health risk assessment in Schedule B4. HILs are generic and apply to all affected sites across Australia.

HILs must only be used where there has been adequate characterisation of a site (that is, sufficient and appropriate sampling). The arithmetic mean must be compared to the values given in Table 1A(1). The relevance of localised elevated values must be considered and should not be obscured by consideration only of the arithmetic mean of the results. The results must also meet the following criteria:

- the standard deviation of the results must be less than 50% of the values given in Table 1A(1)
- no single value exceeds 250% of the relevant value given in Table 1A(1).

Assessing the impact of petroleum hydrocarbons requires site-specific consideration of the limitations that apply to HSLs. While the assumptions to derive the HSLs apply to soil and building conditions typically found in urban situations, there are factors that can affect the selected screening value. For example, air exchange rates have been set at 0.6 building volumes/hr which may be markedly different in tropical and cold climates. Similarly, soil moisture has a significant effect on penetration of volatiles into buildings.

The HSL derivation has also assumed a slab on ground construction and specific slab fracture area for transmission of volatiles and attenuation rates for underslab soil gas and building interior volatile air concentrations. The state of the slab may require consideration if it has deteriorated. Elevated buildings on concrete supports or timber poles with no direct floor contact with the soil and clear underfloor ventilation are at lower risk of penetration of volatiles and the risk decreases with the elevation of the floor above ground.

The TRH analysis does not discriminate between petroleum hydrocarbons and hydrocarbons of plant and animal origin such as organic acids, sterols and n-alkanes of plant waxes. The test extraction process may also include other industrial organic chemicals. In many soils with obvious petroleum hydrocarbon contamination, this may not be an issue of concern with knowledge of the site history and soil type. In this situation TRH is adopted as the basic screening test for petroleum hydrocarbon contamination.

However, in some cases the soil organic matter may be unusually high, for example from heavy applications of mulch, manure, compost or other natural organic material or other synthetic organic compounds that are extracted in the analytical process. This will result in false positives in the TRH test if the result is interpreted as being of petroleum hydrocarbon origin. It is recommended that, where possible, the same soil from the site that has not been affected by petroleum hydrocarbons should be analysed for reference.

Where there is any doubt the sample should be subjected to a silica gel clean-up and analysed. If interference is still a concern, the sample should be tested by gas chromatography and a mass spectrometer (GC-MS) to more accurately identify hydrocarbons of petroleum origin. In these unusual cases, an analyst report should be obtained with an interpretation of the chromatogram and the extent of petroleum hydrocarbon contamination.

3.3 Case study 1: Use of petroleum hydrocarbon screening levels. Former small-scale regional fuel depot site planned for low-density residential use

After cessation of the fuel depot use the site was filled with clean clay/soil fill to 2 m depth and used for motor vehicle and agricultural equipment storage. The following summary assessment data have been determined for the site. For the purposes of illustration, the summary data are assumed to be sufficient to describe the condition of the site and it is assumed that the maximum slab width for the proposed residential dwellings is 15 m.

Summary of Site contamination

- The geometric mean (GM) 0–2 m below surface in the clean fill layer of the identified contaminants of concern was less than investigation and screening levels
- Silt soil type
- The GM for TPH and BTEX for 2–4 m tabulated (all results less than x2 the relevant investigation and screening levels; hotspots, if present, would need to be considered separately). No soil contamination of concern was found below 4 m.
- Poor quality groundwater was found at 6 m in three wells MW1, MW2, MW3 (saline, TDS >5000mg/L, low yield <2L/sec)
- Soil gas oxygen content 9% at 1 m depth

Step 1: Document results and select soil and groundwater HSLs

Soil values mg/kg, refer Table 1A(3) for soil HSLs

| TRH | F1 | F2 | F3 | F4 | B | T | E | X |
|------|-----|-----|------|-----|-----|----|----|----|
| GM | 130 | 160 | 1100 | 260 | 1.5 | 80 | 70 | 60 |
| HSLs | 120 | NL | NL | NL | 1 | NL | NL | NL |

Note: NL indicates vapour risk not possible due to soil saturation concentration C_{sat} (see Footnote 10, Table 1A(3)).

Groundwater values mg/L, refer Table 1A(4) for groundwater HSLs

| TRH | F1 | F2 | F3 | F4 | B | T | E | X |
|------|-----|------|------|------|------|------|------|----|
| MW1 | 1.3 | 0.9 | <LOR | <LOR | 7 | 16 | 12 | 35 |
| MW2 | 0.5 | <LOR | <LOR | <LOR | <LOR | <LOR | <LOR | 4 |
| MW3 | 2.7 | 1.1 | <LOR | <LOR | 8 | 17 | 23 | 42 |
| HSLs | 6.8 | NL | NL | NL | 5.3 | NL | NL | NL |

Note: LOR is the limit of reporting. . NL indicates vapour risk not possible due to soil saturation concentration C_{sat} (see Footnote 10, Table 1A(3)).

Step 2: Tier 1 risk assessment

Questions

1. Are values greater than HSLs? **YES**, elevated F1 and benzene in soil and elevated benzene in groundwater).

| Sample | F1 | F2 | F3 | F4 | B | T | E | X |
|--------|----|----|----|----|---|---|---|---|
| GM | Y | N | N | N | Y | N | N | N |
| MW1 | N | N | N | N | Y | N | N | N |
| MW3 | N | N | N | N | Y | N | N | N |

Note: Y indicates HSL exceeded, NL indicates vapour risk not possible due to soil saturation concentration C_{sat} (see Footnote 10, Table 1A(3)).

2. Is biodegradation applicable? **YES**, Adjust soil HSL values x10 and groundwater HSL x100 (see Notes Table 1A(4)).

Adjusted HSL values

| TRH | F1 | F2 | F3 | F4 | B | T | E | X |
|-------------------------|------|----|----|----|----|----|----|----|
| Soil | 1200 | NL | - | - | 10 | - | - | - |
| Groundwater MW1, MW3 | NL | NL | - | - | NL | NL | NL | NL |

Note: Soil oxygen determinations allow a biodegradation factor of 10 for soil from 2 m -<4 m. Similarly, a biodegradation factor of 100 applies to groundwater sources >4 m and takes contaminant concentrations above the NL threshold value. NL indicates vapour risk not possible due to soil saturation concentration C_{sat} (see Footnote 10, Table 1A(3)).

3. Are values greater than adjusted HSLs? **NO**, no further health risk assessment is required.
4. Are values greater than direct contact HSLs (refer Table 1A(6))? **NO**, therefore not relevant.
5. Are ecological considerations relevant? **YES**. Compare results to ESLs.

Soil values mg/kg, refer Table 1B(5) for ESLs

| TRH | F1 | F2 | F3 | F4 | B | T | E | X |
|------|-----|-----|------|------|-----|-----|-----|----|
| GM | 130 | 160 | 1100 | 260 | 1.5 | 80 | 70 | 60 |
| ESLs | 180 | 120 | 1300 | 5600 | 65 | 105 | 125 | 45 |

6. Are any values greater than ESLs? YES, F2 and xylenes exceed ESLs (all other values are below the relevant ESL)

| Sample | F1 | F2 | F3 | F4 | B | T | E | X |
|--------|----|----|----|----|---|---|---|---|
| GM | N | Y | N | N | N | N | N | Y |

Note: Y indicates ESL exceeded, N indicates ESL not exceeded

| | |
|----------------|--|
| Outcome | Results of Tier 1 assessment show no exceedances of the adjusted or direct contact HSLs and exceedances of the ESLs for F2 and xylenes which will inform further assessment or management actions. |
|----------------|--|

Evaluation and conclusion

The site contamination does not warrant any further action from a human health perspective for the specific land use. The F2 and xylenes values only are moderately in excess of the respective ESL. The residual petroleum hydrocarbon contamination is restricted and could be considered a marginal issue for the intended land use. The assessor should give further consideration to the raw data on depth of contamination, the areal of ESL exceedances, any other relevant site-specific conditions with respect to 'management limits' including aesthetics, before deciding if further site assessment is warranted.

A significant aspect of the site is the level of groundwater contamination. The groundwater is not a risk for the proposed land use. However, it is unacceptable for human consumption and should be restricted for use by site occupants. Human use is unrealistic given the poor groundwater quality and yield. It may cause other adverse effects on potential ecosystem receptors. Further consideration should be given to groundwater contamination regarding any potential receptors and any realistic future use potential. State and local groundwater protection policies would take effect in applying controls over the presence, extraction and use of impacted groundwater.

3.4 Case study 2: Use of soil gas HILs and HSLs

A drum reconditioning works is located beside a four-storey office building in an industrial estate. A drum pre-clean area attached to the works has leaked chemical wastes to the subsurface. Limited soil and groundwater sampling, constrained by existing structures and land uses, have detected TCE, PCE and derivatives, BTEX and TPH in soil and groundwater bores. Initial results suggest a potential human health risk to ground floor occupants of the office block. Sub-slab soil gas samples were taken in the office block at 0-1 m depth and four locations to further assess the human health risk.

Step 1: Compare results to interim HILs and HSLs

Soil gas values mg/m³, refer Tables 1A(2) for interim VOCC HILs and 1A(5) for soil gas HSLs

| Sample | TCE | PCE | Vinyl chloride | B | T | E | X | C ₆ -C ₁₀ |
|--------------------|-----|-----|----------------|-----|------|------|-----|---------------------------------|
| SG1 | 22 | 110 | 6 | 7 | 25 | 44 | 60 | 120 |
| SG2 | 30 | 130 | 17 | 9 | 60 | 52 | 40 | 200 |
| SG3 | 7 | 75 | 1.5 | 4 | 8 | 18 | 20 | 80 |
| SG4 | 4 | 30 | 1.3 | 3 | 10 | 21 | 25 | 70 |
| Interim HIL or HSL | 15 | 70 | 2 | 3.7 | 4800 | 1300 | 840 | 680 |

Step 2: Tier 1 Health risk assessment (limited)

Questions

- Are results greater than HSLs ? **YES**, benzene exceeds the HSL in three locations.
- Are results greater than interim HILs? **YES**, TCE, PCE and vinyl chloride exceed interim HILs for VOCCs in three of the sampling locations.

| Sample | TCE | PCE | Vinyl chloride | B | T | E | X | C ₆ -C ₁₀ |
|--------|-----|-----|----------------|---|---|---|---|---------------------------------|
| SG1 | Y | Y | Y | Y | N | N | N | N |
| SG2 | Y | Y | Y | Y | N | N | N | N |
| SG3 | N | Y | N | Y | N | N | N | N |
| SG4 | N | N | N | N | N | N | N | N |

Note: Y indicates interim HIL or HSL exceeded, N indicates interim HIL or HSL not exceeded

| | |
|----------------|--|
| Outcome | Results of Tier 1 assessment show exceedances of the HSL for benzene and interim VOCC HILs for TCE, PCE and vinyl chloride and will inform further assessment or management actions. |
|----------------|--|

Evaluation and conclusion

The results indicate a human health risk from TCE, PCE and derivatives to ground floor occupants of the office building. The results indicate that appropriate responses to protect human health, further management/assessment such as indoor air sampling to determine actual exposure and detailed health risk assessment and mitigation measures are required. This assessment is limited to health risk considerations from VOCC exposure and does not consider any ecological risks related to soil and groundwater contamination, for example, infiltration into sewer or stormwater drainage systems or discharge into a sensitive receptor.

3.4.1 Ecological assessment

EILs and ESLs provide screening criteria to assess the effect of contaminants on a soil ecosystem. They afford the specified level of species protection within the SSD framework for organisms that frequent or inhabit soil and protect essential soil processes.

Schedule A provides an overview of the site assessment process and the application of investigation and screening levels for site-specific Tier 1 human health and ecological risk assessment. While human health will drive the first stages of assessment, ecological assessment will need consideration for all sites. Human health concerns may be addressed by the HSLs for petroleum hydrocarbons. However, there are many HSLs that are denoted as NL (refer footnotes to HSL Tables) and high levels of petroleum hydrocarbons, including free phase, may be present at the site. Similarly, many HILs for individual elements or compounds are elevated above the EILs.

In these circumstances, ecosystem risks may become the driver for site assessment. In other sites impacted by petroleum hydrocarbons, human health and ecological risks and protection of groundwater resources may be addressed and 'management limits' applied to ensure that phase separated hydrocarbon and associated risks are appropriately considered.

3.4.1.1 Other considerations in assessing ecological risks

In assessing the overall risk to the ecosystem from soil contamination the following site-specific aspects should be considered with relevant ecological soil criteria and management limits:

- the location of the site in relation to any sensitive receptors, e.g. watercourses, estuaries, groundwater resources, sensitive ecological areas
- the existing or proposed land use
- the presentation of any contaminants including areal extent, depth below finished ground level, the presence of barriers or containment that prevents or minimises the migration of contamination
- the in-situ leaching characteristics of contaminants of concern and the potential for leachate to adversely affect any accessible sensitive receptor
- the potential for any soil contaminant to be transported from the site at levels of concern by erosive forces.

Site considerations in addition to the land-use categories will determine if any additional assessment is required to address identified risks. For example, soil contaminants may cause adverse ecological effects when the contaminant is in a highly leachable form or is incorporated in exposed readily erodible soil. In this situation the contaminant may be at risk of being transported off site by water and wind action.

Similarly a site with lead (Pb) and zinc (Zn) and TPH contamination may be within EILs and ESLs for a specific land use but adjoin an area of high ecological value, such as a sensitive and protected wetland. Consideration should be given to the potential for these contaminants to migrate into the area where a 99% species protection limit applies. In other cases sites may have aged metals and metalloid contaminants with stable, cohesive soils and low in-situ leachability and pose a low risk to the ecosystem.

EILs apply principally to contaminants in the top 2 m of soil at the finished surface/ground level which corresponds to the root zone and habitation of many species. ESLs apply to the top 3m of soil due to the volatility and mobility of the contaminant type.

Management limits apply to TPH contamination to address the issues of free phase formation, fire and explosive risks and related matters elsewhere in this Schedule. In applying EILs and ESLs in commercial and high-density residential settings, greater emphasis is placed on soil levels in open landscaped areas or surface exposed areas compared to areas permanently under buildings and large concrete hardstands.

On a site-specific basis, gradation of EILs to higher values may be permitted at depths greater than 2 m provided there is sufficient assessment of risk from issues such as actual land use, proposed development basement levels, leachate characteristics, potential impacts on ground and surface water quality, the risk of vertical migration and the potential for future re-excavation and surface exposure of deeper contamination.

The relevance and scope of ecological assessment should be considered early in the development of a site conceptual model. In some cases all of the site soils will be removed during site works or relocated for the formation of new land forms. Sites may be backfilled with clean soil/fill and the fate of any excavated contaminated soil should be considered in the process.

Soil may be safe from a human health perspective but inherently have poor structure and drainage, low organic content, minimal topsoil depth and a limited ability to support plant growth and soil micro-organisms. A pragmatic approach should be taken in these situations in applying EILs to existing residential and urban development sites and residential areas where there are often practical considerations that enable soil properties to be improved by addition of ameliorants with a persistent modifying effect or by the common practice of backfilling or top dressing with clean soil.

3.5 Case study 3: Use of HILs and EILs

The site was a former electroplating works and is proposed for residential townhouse development. Prior to industrial use, the whole site was filled 0–1 m with imported clay/soil fill of uniform characteristics. The site was assessed by a detailed sampling program based on a well documented site history and no contamination of concern was found below 2 m. CrVI was not identified and no other contaminants of concern were detected.

For the purposes of illustration, the generalised geometric mean (GM) data shown are assumed to be sufficient to describe the condition of the site. All relevant contaminants of concern were identified and the original surface stratum has uniform characteristics across the site. The upper range of individual site values did not exceed twice the GM. Hot spots, if present, would need to be considered separately.

Document soil results

Site results (mg/kg)

| Depth (m) | Cu | Zn | Ni | CrIII |
|-----------|-----|-----|-----|-------|
| 0-1 | 540 | 890 | 660 | 1100 |
| 1-2 | 170 | 470 | 380 | 400 |

Phase 1: Tier 1 health risk assessment

Compare results to HILs, refer Table 1A(1) for HILs

| | Cu | Zn | Ni | CrIII |
|-------------|------|------|-----|-------|
| HIL (mg/kg) | 7000 | 8000 | 400 | NR |
| 0-1 | N | N | Y | NR |
| 1-2 | N | N | N | NR |

Note: NR= not relevant due to the low human toxicity of CrIII, Y indicates HIL exceeded, N indicates HIL not exceeded

Questions

- Are results greater than HILs? YES, elevated Ni - further health risk assessment required.

Phase 2: Calculate the site EILs

Calculate site EILs, refer Tables 1B(1), 1B(2) and 1B(3)

| | |
|---------------|--|
| Step 1 | <ul style="list-style-type: none"> Measure cation exchange capacity (CEC) + pH values from selected samples with analysis for Cu, Zn. Measure CEC for sample contaminated with Ni Measure clay content for selected samples for CrIII analysis |
|---------------|--|

Results

| Contaminant | Depth (m) | CEC (cmol/kg) | pH (pH units) | Clay Content (%) |
|-------------|--------------|------------------|------------------|---------------------|
| Cu, Zn, Ni | 0-1 | 9 | 6.0 | - |
| | 1-2 | 17 | 6.5 | - |
| CrIII | 0-1 | - | | 10 |
| | 1-2 | - | | 12 |

- Step 2**
- Determine the added contaminant limits (ACLs) using site CEC, pH and clay content data.

To determine site ACLs, refer Table 1B(1) for Zn, Table 1B(2) for Cu and Table 1B(3) for CrIII and Ni. Establish the site ACL for the appropriate land use and with consideration of the soil-specific pH, clay content or CEC as required. Select the nearest ACL value in the CEC table. The ACL for Cu may be determined by pH or CEC and the lower of the determined values should be selected for EIL calculation.

| Site ACLs (mg/kg) | Depth (m) | Cu | Zn | Ni | CrIII |
|----------------------|-----------|-----|-----|----|-------|
| | 0-1m | 200 | 400 | 50 | 400 |
| | 1-2m | 200 | 590 | 85 | 400 |

- Step 3**
- Measure or calculate the ABC.
 - 0-1 m clay/ soil fill, sample from filled area at rear of property known to be unaffected by subsequent industrial activity.
 - 1-2 m, sample of uncontaminated strata from adjacent site.

| ABC (mg/kg) | Depth (m) | Cu | Zn | Ni | CrIII |
|-------------|-----------|-----|----|-----|-------|
| | 0-1 | 4 | 65 | 2 | 7 |
| | 1-2 | 1.5 | 8 | 0.5 | 10 |

- Step 4.1**
- Calculate the site EILs: $EIL = (ABC + ACL)$ and rounded¹

¹ The following rounding rules have been applied to the EILs

| | | |
|-----|--------------|-------------------------|
| Nos | < 1 | to nearest 0.1 |
| | 1 < 10 | to nearest whole number |
| | 10 - < 100 | to nearest 5 |
| | 100 - < 1000 | to nearest 10 |
| | ≥ 1000 | to nearest 100 |

| Site EILs (mg/kg) | Depth (m) | Cu | Zn | Ni | CrIII |
|----------------------|-----------|-----|-----|----|-------|
| | 0-1 | 205 | 465 | 50 | 410 |
| | 1-2 | 200 | 610 | 85 | 410 |

Phase 2 Tier 1 ecological risk assessment

Site metal levels

| Depth (m) | Cu | Zn | Ni | CrIII |
|-----------|-----|-----|-----|-------|
| 0-1 | 540 | 890 | 660 | 1100 |
| 1-2 | 170 | 470 | 380 | 400 |

Questions

Are results greater than EILs ? **YES** , Cu, Zn, Ni and CrIII exceed EILs - further ERA or management required.

| Depth (m) | Cu | Zn | Ni | CrIII |
|-----------|----|----|----|-------|
| 0-1 | Y | Y | Y | Y |
| 1-2 | N | N | Y | N |

Note: Y indicates site EIL exceeded, N indicates EIL not exceeded.

| | |
|----------------|---|
| Outcome | Results of Tier 1 assessment show exceedances of the HIL for Ni and EILs for Cu, Zn, Ni and CrIII and will inform further assessment or management actions. |
|----------------|---|

3.5.1 Minor exceedance of investigation levels

In cases of minor exceedance of investigation or screening levels, a qualitative risk assessment may be sufficient. Case study 1 provides an example of a minor exceedance where qualitative assessment of the extent and depth of contamination for the proposed land use may be considered. A qualitative or quantitative risk assessment may lead to no further action being required or the development of site-specific response levels generated by risk assessment and agreed to in consultation between the professionals assessing the site, auditors, third party reviewers and/or the regulatory authorities.

In addition, appropriate investigation, screening and/or response levels need to be developed when:

- investigation or screening values are not available for contaminants of concern and/or data are not available to enable the derivation of guideline values
- site conditions, receptors and/or exposure pathways differ significantly from those assumed in the derivations of investigation or screening levels.

Where soil concentrations exceed the site-specific response levels, responses may range from informing landowners and users about the nature of contamination and applying appropriate site management plans, to large-scale remediation. The nature of the response must be determined on a site-specific basis.

3.6 Groundwater assessment

The Schedules to this Measure provide detailed information on the specialised requirements for groundwater data collection, quality assurance and quality control. Schedule B6 provides a framework for the risk-based assessment of groundwater that may have been affected by site contamination. The framework recognises existing, nationally developed approaches, policies and water quality criteria to protect groundwater under the national water quality management strategy and guidelines for managing risk in recreational water (NHMRC 2008) and applies them to the specific issue of assessing the quality of groundwater impacted by site contamination.

GILs are based on the AWQG, ADWG and GMRRW for various water uses and environments. GILs are not response levels or desirable groundwater criteria and are to be applied in the risk assessment framework.

The AWQG provide tabulated values based on % species protection for various aquatic environments and water uses. The appropriate settings for current and potential uses of groundwater need to be identified for the aquifer undergoing assessment. The guideline documents should be consulted for appropriate interpretation of guideline values, in consultation with relevant regulatory authorities.

These settings for use are:

- raw drinking water source (where ADWG apply)
- agricultural use – stock watering
- agricultural use – irrigation
- protection of aquatic ecosystems – freshwater
- protection of aquatic ecosystems – marine
- recreational use (where GMRRW apply).

Table 1C (at the end of this Schedule) provides for reference the GILs for drinking water, fresh and marine waters for human and aquatic receptors. The recreational and aesthetics sections of the AWQG have been superseded by the GMRRW. The GMRRW apply a factor of 10-fold to the ADWG for the purposes of recreational water quality. GILs for other receptors should be obtained directly from the 'primary industries' section of the AWQG.

When groundwater from a monitoring well contains levels of contaminants above the appropriate investigation levels, then further investigation should be carried out to determine sources of contamination and to determine the lateral and vertical extent of contaminated groundwater. Modelling, or measurements at point of use, may be needed to predict impact on receptors. If this indicates that the investigation levels are exceeded at the point of use, or in the discharge environment of the groundwater, then an appropriate response is required.

Groundwater protection may be a particular concern where associated with sandy soils containing naturally low levels of trace elements. In most situations, soil contaminants at levels below appropriate EILs or HILs do not pose a threat to local groundwater sources. However, possible impacts on groundwater should always be considered particularly for sites impacted by the volatile components of petroleum hydrocarbons and halogenated solvents. In some cases the soil may not reveal contaminants of concern while groundwater is affected.

The potential for groundwater contamination (with appropriate consideration of ambient groundwater quality) should be considered and caution exercised in the application of soil investigation levels. The form of the contaminant and its mobility should be defined in these investigations and risk-based processes.

3.7 Aesthetic considerations

Aesthetic issues generally relate to the presence of low-concern or non-hazardous inert foreign material in soil or fill resulting from human activity.

Sites that have been adequately assessed from a human health and environmental perspective may still contain such foreign material. Various refuse may be identified in bore or test pit logs as fragments of concrete, metal, bricks, pottery, glass, minor amounts of ACM, bitumen, ash, green waste, rubber, plastics and a wide variety of other waste materials.

These materials commonly occur in former industrial and filled sites. Similarly, construction and demolition waste materials, some of which are inert and non-hazardous are widely distributed in urban areas.

Other sites may have some soil discolouration from relatively inert chemical waste (for example, ferric metals) or residual odour (for example, natural sulphur odour).

There are no specific numeric aesthetic guidelines but site assessment requires balanced consideration of the quantity, type and distribution of foreign material and any realistic concerns relating to land use. Aesthetics are partly considered in the numeric 'management limits' as discussed in this Schedule.

Care must be taken to ensure adequate site characterisation, particularly when there is diverse foreign material and associated fill and an appreciable risk from site history (or lack thereof) of the presence of hazardous contaminants. For example, some ash fill may contain PAHs and metals, while other ash deposits have no contaminants of concern.

More detailed characterisation of foreign material may be sufficient to address concerns relating to potential land-use restrictions. However, it may not be economical to adequately characterise sites with uncontrolled filling of various wastes and they may present an unacceptable risk for more sensitive land uses.

General assessment considerations include:

- the risk for a person to be injured by metal, glass or other sharp objects
- that chemically discoloured soils or large quantities of various types of inert refuse, particularly if unsightly, may cause ongoing concerns to site users
- the depth of any residue in relation to the final surface of the site
- the need for and practicality of any long-term management of foreign material.

The following characteristics or presentations are examples of where site assessment may not have detected contamination above investigation or screening levels but would require further assessment:

- highly malodorous soils or extracted groundwater (e.g. hydrogen sulphide which may present a serious health risk, organosulfur compounds, strong residual petroleum odours)
- discoloured chemical deposits or staining with chemical waste other than of a minor nature

- large monolithic deposits of otherwise low-risk material, e.g. gypsum as powder or plasterboard, cement kiln dust
- presence of putrescible refuse including material that may generate hazardous levels of methane such as a deep-fill profile of green waste or large quantities of timber waste
- soils containing residue from animal burial (e.g. former abattoir sites)

In arriving at a balanced assessment, the presence of small quantities of non-hazardous inert material and low odour residue (for example, petroleum hydrocarbon odours) that will decrease over time should not be a cause of concern or limit the use of a site in most circumstances. Similarly, sites with large quantities of well-covered known inert materials that present no hazard such as brick fragments and cement wastes (for example, broken cement blocks) are usually of low concern for more sensitive uses.

Geotechnical issues related to the presence of fill should be treated separately to assessment of site contamination.

4 Additional considerations in the use of investigation and screening levels

4.1 Background variation

In natural soils there are wide ranges of concentrations for certain elements, such as chromium, manganese, nickel and vanadium. These concentrations depend on the origins of the soil. The EILs may be exceeded in certain regions and it would be more appropriate to apply regional background levels for comparison in assessment of site contamination. If such data are not already available, samples from adjacent property (not suspected of being contaminated by the activity which led to the site investigation being instigated) should be analysed to establish regional background levels.

The ABC includes the natural background and is accommodated in the current EIL methodology. The preferred method is by sampling an appropriate reference point which is not affected by the contamination that is subject of the site assessment.

Further site- and contaminant-specific assessment is required for contaminants for which EILs have not been developed.

4.2 Mineralised areas

High levels of metals, metalloids and asbestos can be associated with ore bodies. Soils in mining areas may contain elevated levels of these materials due to natural mineralisation. Some urban areas may be affected by asbestos and various elements including lead, copper, zinc and cadmium (to a lesser extent) and arsenic from the ore bodies, as well as activities associated with mining, smelting and metallurgical industries.

These environments may require specific prevention measures and community awareness programs when human settlement has occurred to enable appropriate precautions to be taken (for example, preventing the use of potentially contaminated soil or fill from a mining site for growing vegetables in the home garden, constructing driveways or filling private land and publicly accessible areas). Public information about preventing exposure to mineralised or contaminated soil is an essential component of public health programs to minimise community exposure to these contaminants.

Depending on the nature of the contaminants associated with the mining activity, contaminated soil may be one of a number of exposure pathways. Local health issues may be more effectively targeted by monitoring key community health parameters such as blood lead or by environmental monitoring of ambient air quality and dust.

4.3 Specialised assessments

Specialised forms of assessment are required for sites affected by the following contaminants:

- radioactive substances
- unexploded ordnance
- pathogenic materials and waste
- explosive gas mixtures.

In situations where these materials occur on a site under assessment, guidance should be sought from the relevant jurisdictional environmental or health authority for assessment requirements. While the general principles of site assessment are applicable to these contamination types, compliance with specialised safety protocols and assessment guidance is essential to ensure protection of human health and the environment.

4.4 Sediments

Interim sediment quality guidelines (ISQG) have been developed in the AWQG for a number of common metal, metalloid and organo-metallic contaminants and organics, principally PAHs and organo-chlorine pesticides (OCPs). The ISQG have limitations relating to the availability of appropriate ecotoxicology data and the small number of species on which they are based. Investigation and screening levels for soils should not be applied directly to the assessment of contamination of sediments. Sediment assessment is a process separate from soil assessment.

Reference to these guidelines balanced by consideration of their limitations may have application in the site-specific assessment of ecological risk for soil contaminants for sites that may impact aquatic receptors.

Table 1A(1) Health investigation levels for soil contaminants

| Chemical | Health-based investigation levels (mg/kg) | | | |
|--|---|---------------|-----------------------------|--------------------------|
| | Residential A | Residential B | Recreational ¹ C | Commercial/ industrial D |
| Metals and Inorganics | | | | |
| arsenic ² | 100 | 500 | 300 | 3000 |
| beryllium | 70 | 100 | 100 | 500 |
| boron | 5000 | 40000 | 20000 | 300000 |
| Cadmium | 20 | 140 | 100 | 800 |
| chromium (VI) | 100 | 500 | 240 | 3000 |
| Cobalt | 100 | 600 | 300 | 4000 |
| Copper | 7000 | 30000 | 20000 | 250000 |
| lead ³ | 300 | 1200 | 600 | 1500 |
| manganese | 3000 | 8000 | 9000 | 40000 |
| methyl mercury ⁴ | 7 | 30 | 10 | 200 |
| mercury (inorganic) | 200 | 600 | 400 | 4000 |
| Nickel | 400 | 900 | 800 | 4000 |
| Selenium | 200 | 1500 | 700 | 10000 |
| Zinc | 8000 | 60000 | 30000 | 400000 |
| cyanide (free) | 250 | 400 | 350 | 2000 |
| Polycyclic Aromatic Hydrocarbons (PAHs) | | | | |
| benzo(a)pyreneTEQ | 3 | 4 | 4 | 40 |
| PAHs | 300 | 400 | 400 | 4000 |
| Phenols | | | | |
| Phenol | 3000 | 50000 | 45000 | 250000 |
| pentachlorophenol | 100 | 150 | 140 | 700 |
| Cresols | 400 | 5500 | 4700 | 27000 |
| Organochlorine Pesticides | | | | |
| DDT+DDE+DDD | 260 | 700 | 400 | 4000 |
| aldrin and dieldrin | 7 | 10 | 9 | 50 |
| chlordane | 50 | 100 | 80 | 560 |
| endosulfan | 300 | 460 | 400 | 2000 |
| Endrin | 10 | 20 | 20 | 100 |
| heptachlor | 7 | 10 | 9 | 50 |
| HCB | 10 | 20 | 15 | 85 |
| methoxychlor | 400 | 550 | 500 | 2700 |
| Mirex | 10 | 20 | 20 | 100 |
| toxaphene | 20 | 35 | 30 | 170 |
| Phenoxyacetic Acid Herbicides | | | | |
| 2,4,5-T | 700 | 1000 | 900 | 5000 |
| 2,4-D | 1000 | 2000 | 1400 | 9500 |
| MCPA | 700 | 1000 | 900 | 5000 |
| MCPB | 700 | 1000 | 900 | 5000 |
| mecoprop | 700 | 1000 | 900 | 5000 |
| Picloram | 5000 | 8000 | 6500 | 37000 |
| Other Pesticides | | | | |
| Atrazine | 360 | 550 | 500 | 3000 |
| chlorpyrifos | 170 | 400 | 300 | 2000 |
| Bifenthrin | 600 | 900 | 750 | 4000 |
| Other Organics | | | | |
| PCBs | 1 | 2 | 2 | 8 |
| PBDE Flame Retardants (Br1-Br9) | 1 | 2 | 2 | 10 |

Notes:

- (1) HIL A Standard residential with garden/accessible soil (home grown produce <10% fruit and vegetable intake,(no poultry), includes children's day care centres, preschools and primary schools.
HIL B Residential with minimal opportunities for soil access; includes dwellings with fully and permanently paved yard space such as high-rise buildings and flats.
HIL C Includes developed open space such as parks, playgrounds, playing fields (e.g. ovals), secondary schools and footpaths. This does not include undeveloped public open space which should be subject to a site-specific assessment, where appropriate.
HIL D Commercial/industrial includes premises such as shops, offices, factories and industrial sites.
- (2) HIL for arsenic assumes 70% oral bioavailability. Site-specific bioavailability may be important and should be considered where appropriate

- (3) HIL for lead based on blood lead models (IEUBK for HILs A, B and C and adult lead model for HIL D where 50% oral bioavailability has been considered. Site-specific bioavailability may be important and should be considered where appropriate.
- (4) Assessment of methyl mercury should only occur where there is evidence of its potential source. It may be associated with inorganic mercury and anaerobic microorganism activity in aquatic environments. In addition the reliability and quality of sampling/analysis should be considered.
- (5) HIL for B(a)P TEQ is based on the 8 carcinogenic PAHs and TEFs (potency relative to B(a)P) adopted by CCME 2008 (refer ScB7). The B(a)P TEQ is calculated by multiplying the concentration of each carcinogenic PAH in the sample by its B(a)P TEF, given below, and summing these products.
- Benzo(a)anthracene = 0.1
 Benzo(a)pyrene = 1
 Benzo(b+j)fluoranthene = 0.1
 Benzo(k)fluoranthene = 0.1
 Benzo(g,h,i)perylene = 0.01
 Chrysene = 0.01
 Dibenz(a,h)anthracene = 1
 Indeno(1,2,3-c,d)pyrene = 0.1
- Where the B(a)P occurs in bitumen fragments it is relatively immobile and does not represent a significant health risk.
- (6) HIL for total PAH is based on the sum of the 16 PAHs most commonly reported for contaminated sites (WHO 1998). The application of the total PAH HIL must consider the presence of carcinogenic PAHs and naphthalene (the most volatile PAH). Carcinogenic PAHs reported in the total PAHs must meet the B(a)P TEQ HIL. Naphthalene reported in the total PAHs must be addressed on the basis of the relevant HSL.

Table 1A(2) Interim health investigation levels for volatile organic chlorinated compounds

| | Residential A | Residential B | Recreational C | Commercial/Industrial D |
|------------------------|---|---|---|---|
| Chemical | Interim soil gas HIL ** (mg/m ³) | Interim soil gas HIL ** (mg/m ³) | Interim soil gas HIL ** (mg/m ³) | Interim soil gas HIL ** (mg/m ³) |
| TCE | 2 | 2 | - | 15 |
| 1,1,1-TCA | 260 | 260 | - | 1800 |
| PCE | 10 | 10 | - | 70 |
| cis-1,2-dichloroethene | 2 | 2 | - | 10 |
| vinyl chloride | 0.3 | 0.3 | - | 2 |

Note:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

** Interim soil gas HILs are conservative soil gas concentrations that can be adopted for the purpose of screening sites where further investigation is required on a site-specific basis. They are based on the potential for vapour intrusion indoors using a conservative indoor air to soil gas attenuation factor of 0.01.

Table 1A(3) HSLs soil (mg/kg)

| CHEMICAL (6) | HSL-A (low density residential) | | | | HSL-B (high density residential) (5) | | | | Saturation conc. (Csat) (4) |
|--|---------------------------------|-----------|-----------|---------|--------------------------------------|-----------|-----------|---------|--------------------------------|
| | 0m to <1m | 1m to <2m | 2m to <4m | 4m+ | 0m to <1m | 1m to <2m | 2m to <4m | 4m+ | |
| <i>Sand (sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | | | |
| Toluene | 190 | 260 | 370 | NL | 160 | 220 | 310 | 540 | 560 |
| Ethylbenzene | NL | NL | NL | NL | 55 | NL | NL | NL | 64 |
| Xylenes | 45 | 70 | 110 | 200 | 40 | 60 | 95 | 170 | 300 |
| Naphthalene | 3 | NL | NL | NL | 3 | 9 | NL | NL | 9 |
| Benzene | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 360 |
| C6-C10 | 50 (7) | 85 (7) | 130 (7) | 230 (7) | 45 (7) | 70 (7) | 110 (7) | 200 (7) | 950 |
| >C10-C16 | 130 | 280 | 520 | NL | 110 | 240 | 440 | NL | 560 |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | | | |
| Toluene | 460 | NL | NL | NL | 390 | NL | NL | NL | 640 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | NL | NL | 69 |
| Xylenes | 110 | 250 | NL | NL | 95 | 210 | NL | NL | 330 |
| Naphthalene | 5 | NL | NL | NL | 4 | NL | NL | NL | 10 |
| Benzene | 0.7 | 0.9 | 1 | 2 | 0.6 | 0.7 | 1 | 2 | 440 |
| C6-C10 | 50 | 75 | 120 | 220 | 40 | 65 | 100 | 190 | 910 |
| >C10-C16 | 270 | NL | NL | NL | 230 | NL | NL | NL | 570 |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | | | |
| Toluene | 560 | NL | NL | NL | 480 | NL | NL | NL | 630 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | NL | NL | 68 |
| Xylenes | 130 | NL | NL | NL | 110 | 310 | NL | NL | 330 |
| Naphthalene | 6 | NL | NL | NL | 5 | NL | NL | NL | 10 |
| Benzene | 0.8 | 1 | 2 | 3 | 0.7 | 1 | 2 | 3 | 430 |
| C6-C10 | 60 | 100 | 180 | 340 | 50 | 90 | 150 | 290 | 850 |
| >C10-C16 | 330 | NL | NL | NL | 280 | NL | NL | NL | 560 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur, a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur.

Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 or to CRC CARE Technical Report no. 12 (Davis et al. 2009) for further information.

- (1) The key limitations in the development and application of HSLs are presented in Friebe and Nadebaum (2010d) and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebe and Nadebaum (2010a, 2010b).
- (3) Soil HSLs for vapour inhalation incorporate an adjustment factor of 10 to the vapour phase partitioning to reflect the differences observed between theoretical estimates of soil vapour partitioning and field measurements. Refer to Section 7.5 of CRC CARE Technical Report no. 10: Part 1 (Friebe and Nadebaum 2010a) for further information.
- (4) The soil saturation concentration (Csat) is the bulk soil concentration at which the porewater phase cannot dissolve any more of an individual chemical. As a consequence, the soil vapour which is in equilibrium with the porewater will be at its maximum. If the derived soil HSL exceeds Csat this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible for a petroleum mixture. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (5) Land use setting for vapour intrusion into high density residential buildings is based on occupation of ground floor. If residents occupy ground floor apartments, HSL B should be used. If ground floor consists of commercial properties or if building contains basement car park, commercial use (HSL D) should be applied instead.
- (6) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.
- (7) The HSLs for C6-C10 in sandy soil are based on a source that depletes in less than seven years, and therefore may be considered to be sub-chronic exposure. The >C8-C10 aliphatic toxicity has been adjusted to represent sub-chronic exposure, resulting in higher HSLs than if based on chronic toxicity. For further information refer to Section 8.2 and Appendix J in Friebe and Nadebaum (2010a).

Table 1A(3) HSLs soil (continued)

| Chemical ⁽⁵⁾ | HSL C (recreational) | | | | HSL D (commercial / industrial) | | | | Saturati on conc. |
|--|----------------------|--------------|--------------|-----|---------------------------------|--------------------|--------------------|-------------------|-----------------------|
| | 0m to <1m | 1m to <2m | 2m to <4m | 4m+ | 0m to <1m | 1m to <2m | 2m to <4m | 4m+ | (Csat) ⁽⁴⁾ |
| <i>Sand (sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | NL | NL | 560. |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | NL | NL | 64 |
| Xylenes | NL | NL | NL | NL | 230. | NL | NL | NL | 300 |
| Naphthalene | NL | NL | NL | NL | NL | NL | NL | NL | 9 |
| Benzene | NL | NL | NL | NL | 3 | 3 | 3 | 3. | 360 |
| C6-C10 | NL | NL | NL | NL | 260 ⁽⁶⁾ | 370 ⁽⁶⁾ | 630 ⁽⁶⁾ | NL ⁽⁶⁾ | 950 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | NL | NL | 560 |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | NL | NL | 640 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | NL | NL | 69 |
| Xylenes | NL | NL | NL | NL | NL | NL | NL | NL | 330 |
| Naphthalene | NL | NL | NL | NL | NL | NL | NL | NL | 10 |
| Benzene | NL | NL | NL | NL | 4 | 4 | 6 | 10 | 440 |
| C6-C10 | NL | NL | NL | NL | 250 | 360 | 590 | NL | 910 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | NL | NL | 570 |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | NL | NL | 630 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | NL | NL | 68 |
| Xylenes | NL | NL | NL | NL | NL | NL | NL | NL | 330 |
| Naphthalene | NL | NL | NL | NL | NL | NL | NL | NL | 10 |
| Benzene | NL | NL | NL | NL | 4 | 6 | 9 | 20 | 430 |
| C6-C10 | NL | NL | NL | NL | 310 | 480 | NL | NL | 850 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | NL | NL | 560 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m, as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur. Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum 2010a), or to CRC CARE Technical Report no. 12 (Davis et al. 2009b) for further information.

- (1) The key limitations in the development and application of HSLs are presented in Friebel and Nadebaum (2010d) and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebel and Nadebaum (2010a, 2010b).
- (3) Soil HSLs for vapour inhalation incorporate an adjustment factor of 10 to the vapour phase partitioning to reflect the differences observed between theoretical estimates of soil vapour partitioning and field measurements. Refer to Section 7.5 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum 2010a) for further information.
- (4) The soil saturation concentration (Csat) is the bulk soil concentration at which the porewater phase cannot dissolve any more of an individual chemical, and as a consequence the soil vapour which is in equilibrium with the porewater will be at its maximum. If the derived soil HSL exceeds Csat, this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible for a petroleum mixture. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (5) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.
- (6) The HSLs for C6-C10 in sandy soil are based on a source that depletes in less than seven years, and therefore may be considered to be sub-chronic exposure. The >C8-C10 aliphatic toxicity has been adjusted to represent sub-chronic exposure, resulting in higher HSLs than if based on chronic toxicity. For further information refer to Section 8.2 and Appendix J in Friebel and Nadebaum (2010a).

Table 1A(4) HSLs groundwater (mg/L)

| Chemical ⁽⁵⁾ | HSL A (low density residential) | | | HSL B (high density residential) ⁽⁴⁾ | | | Solubility |
|--|---------------------------------|-----------|-----|---|-----------|-----|----------------------|
| | 2 to <4m | 4m to <8m | 8m+ | 2 to <4m | 4m to <8m | 8m+ | limit ⁽³⁾ |
| <i>Sand (sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | 0.9 | 1 | 1 | 0.8 | 0.8 | 0.9 | 59 |
| C6-C10 | 1 | 1 | 1 | 1 | 1 | 1 | 9.0 |
| >C10-C16 | 1 | 1 | 1 | 1 | 1 | 1 | 3.0 |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | 5 | 6 | 6 | 5 | 5 | 5 | 59 |
| C6-C10 | 7 | 7 | 7 | 6 | 6 | 6 | 9.0 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | 3.0 |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | 5 | 6 | 6 | 5 | 5 | 5 | 59 |
| C6-C10 | NL | NL | NL | NL | NL | NL | 9.0 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | 3.0 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m, as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur.

Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum 2010a) or to CRC CARE Technical Report no. 12 (Davis et al. 2009) for further information.

- (1) The key limitations in the development and application of HSLs are presented in Friebel and Nadebaum 2010d and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebel and Nadebaum (2010a, 2010b).
- (3) The solubility limit is the groundwater concentration at which the water cannot dissolve any more of an individual chemical based on a petroleum mixture and, as a consequence, the soil vapour which is in equilibrium with the groundwater will be at its maximum. If the derived groundwater HSL exceeds the solubility limit, this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible for a petroleum mixture. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (4) Land-use setting for vapour intrusion into high density residential building is based on occupation of the ground floor. If residents occupy ground floor apartments, HSL B should be used. If ground floor consists of commercial properties or if building contains basement car park, commercial use (HSL D) should be applied instead.
- (5) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.

Table 1A(4) HSLs groundwater (continued)

| Chemical ⁽⁴⁾ | HSL C (recreational) | | | HSL D (commercial/ industrial) | | | Solubility |
|---|----------------------|-----------|-----|--------------------------------|-----------|-----|----------------------|
| | 2 to <4m | 4m to <8m | 8m+ | 2 to <4m | 4m to <8m | 8m+ | limit ⁽³⁾ |
| <i>SAand (sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | NL | NL | NL | 5 | 5 | 5 | 59 |
| C6-C10 | NL | NL | NL | 6 | 6 | 7 | 9.0 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | 3.0 |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | NL | NL | NL | 30 | 30 | 30 | 59 |
| C6-C10 | NL | NL | NL | NL | NL | NL | 9.0 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | 3.0 |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | NL | 61 |
| Ethylbenzene | NL | NL | NL | NL | NL | NL | 3.9 |
| Xylenes | NL | NL | NL | NL | NL | NL | 21 |
| Naphthalene | NL | NL | NL | NL | NL | NL | 0.17 |
| Benzene | NL | NL | NL | 30 | 30 | 35 | 59 |
| C6-C10 | NL | NL | NL | NL | NL | NL | 9.0 |
| >C10-C16 | NL | NL | NL | NL | NL | NL | 3.0 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m, as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur.

Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum 2010a), or to CRC CARE Technical Report no. 12 (Davis et al. 2009) for further information.

- (1) The key limitations in the development and application of HSLs are presented in Friebel and Nadebaum 2010d and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebel and Nadebaum (2010a, 2010b).
- (3) The solubility limit is the groundwater concentration at which the water cannot dissolve any more of an individual chemical based on a petroleum mixture and, as a consequence, the soil vapour which is in equilibrium with the groundwater will be at its maximum. If the derived groundwater HSL exceeds the solubility limit, this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible for a petroleum mixture. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (4) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.

Table 1A(5) HSLs soil gas (mg/m³)

| Chemical ⁽⁶⁾ | HSL A (low density residential) | | | | | HSL B (high density residential) ⁽⁴⁾ | | | | |
|---|---------------------------------|-----------|-----------|-----------|---------|---|-----------|-----------|-----------|---------|
| | 0 to <1m | 1m to <2m | 2m to <4m | 4m to <8m | 8m+ | 0 to <1m | 1m to <2m | 2m to <4m | 4m to <8m | 8m+ |
| <i>Sand(sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | | | | |
| Toluene | 1,500 | 4,400 | 8,600 | 17,000 | 34,000 | 1,300 | 3,800 | 7,300 | 15,000 | 29,000 |
| Ethylbenzene | 390 | 1,300 | 2,500 | 5,100 | 10,000 | 330 | 1,100 | 2,200 | 4,300 | 8,700 |
| Xylenes | 260 | 880 | 1,800 | 3,600 | 7,200 | 220 | 750 | 1,500 | 3,000 | 6,100 |
| Naphthalene | 0.9 | 4 | 7 | 15 | 30 | 0.8 | 3 | 6 | 10 | 25 |
| Benzene | 1 | 3 | 7 | 15 | 25 | 1 | 3 | 6 | 10 | 20 |
| C6-C10 | 210 | 750 | 1,500 | 3,100 | 6,300 | 180 | 640 | 1,300 | 2,600 | 5,300 |
| >C10-C16 | 160 | 650 | 1,400 | 2,800 | NL | 130 | 560 | 1,200 | 2,400 | 4,800 |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | | | | |
| Toluene | 1,700 | 17,000 | 38,000 | 81,000 | 170,000 | 1,400 | 14,000 | 32,000 | 69,000 | 140,000 |
| Ethylbenzene | 450 | 4,900 | 11,000 | 24,000 | 51,000 | 380 | 4,200 | 9,700 | 21,000 | 43,000 |
| Xylenes | 300 | 3,500 | 8,000 | 17,000 | 35,000 | 260 | 2,900 | 6,800 | 15,000 | 30,000 |
| Naphthalene | 1 | 15 | 30 | 70 | 140 | 0.90 | 10 | 25 | 60 | 120 |
| Benzene | 1 | 15 | 30 | 65 | 130 | 1 | 10 | 25 | 55 | 110 |
| C6-C10 | 240 | 3,000 | 7,000 | 15,000 | 31,000 | 210 | 2,600 | 6,000 | 13,000 | 26,000 |
| >C10-C16 | 190 | 2,700 | NL | NL | NL | 160 | 2,300 | 5,400 | NL | NL |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | | | | |
| Toluene | 1,800 | 27,000 | 63,000 | 130,000 | 280,000 | 1,600 | 23,000 | 53,000 | 110,000 | NL |
| Ethylbenzene | 490 | 8,000 | 19,000 | 41,000 | NL | 420 | 6,800 | 16,000 | 35,000 | NL |
| Xylenes | 330 | 5,600 | 13,000 | 29,000 | NL | 280 | 4,800 | 11,000 | 24,000 | 50,000 |
| Naphthalene | 1 | 20 | 50 | 110 | 230 | 1 | 20 | 45 | 95 | 200 |
| Benzene | 1 | 20 | 50 | 100 | 210 | 1 | 15 | 40 | 90 | 180 |
| C6-C10 | 270 | 4,900 | 12,000 | 25,000 | 52,000 | 230 | 4,200 | 9,900 | 21,000 | 44,000 |
| >C10-C16 | 210 | 4,400 | NL | NL | NL | 180 | 3,800 | NL | NL | NL |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur, a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m, as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur. Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum (2010a), or to CRC CARE Technical Report no. 12 (Davis et al. 2009) for further information.

NL - denotes no level presented as HSL exceeds concentration of pure gas.

- (1) The key limitations in the development and application of HSLs are presented in Friebel and Nadebaum 2010d and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebel and Nadebaum (2010a, 2010b)
- (3) Soil vapour HSLs should be compared to measurements of vapour sources and soil vapour above sources, and hence measurements should be taken as laterally close as possible to the soil or groundwater source. Soil vapour measurements require consideration of where the sample is taken, the current state of the site and the future state of the site. Shallow soil-gas measurements in open space areas (less than 1 m) may be subject to the influence of their surroundings such as weather conditions and moisture.
- (4) Land-use setting for vapour intrusion into high density residential building is based on occupation of the ground floor. If residents occupy ground floor apartments, HSL B should be used. If ground floor consists of commercial properties or if building contains basement car park, commercial use (HSL D) should be applied instead.
- (5) Maximum possible soil vapour concentrations have been calculated based on vapour pressures of pure chemicals. Where soil vapour HSLs exceed these values, this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (6) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.

Table 1A(5) HSLs soil gas (continued)

| Chemical ⁽⁵⁾ | HSL C (recreational) | | | | | HSL D (commercial / industrial) | | | | |
|--|----------------------|-----------|-----------|-----------|---------|---------------------------------|-----------|-----------|-----------|---------|
| | 0 to <1m | 1m to <2m | 2m to <4m | 4m to <8m | 8m+ | 0 to <1m | 1m to <2m | 2m to <4m | 4m to <8m | 8m+ |
| <i>Sand (sand, sandy clay, sandy clay loam, sandy loam, loamy sand, loam, sandy silt and silty sand)</i> | | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | 4,800 | 16,000 | 39,000 | 84,000 | NL |
| Ethylbenzene | NL | NL | NL | NL | NL | 1,300 | 4,600 | 11,000 | 25,000 | 53,000 |
| Xylenes | NL | NL | NL | NL | NL | 840 | 3,200 | 8,000 | 18,000 | 37,000 |
| Naphthalene | 410 | NL | NL | NL | NL | 3 | 15 | 35 | 75 | 150 |
| Benzene | 360 | 2,400 | 4,700 | 9,500 | 19,000 | 4 | 10 | 30 | 65 | 130 |
| C6-C10 | 86,000 | NL | NL | NL | NL | 680 | 2,800 | 7,000 | 15,000 | 32,000 |
| >C10-C16 | NL | NL | NL | NL | NL | 500 | 2,400 | NL | NL | NL |
| <i>Silt (silt, silty clay and silty clay loam)</i> | | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | 5,700 | 63,000 | NL | NL | NL |
| Ethylbenzene | NL | NL | NL | NL | NL | 1,500 | 19,000 | 54,000 | NL | NL |
| Xylenes | NL | NL | NL | NL | NL | 1,000 | 13,000 | 38,000 | NL | NL |
| Naphthalene | NL | NL | NL | NL | NL | 4 | 50 | 150 | 350 | 750 |
| Benzene | 1,800 | 12,000 | 24,000 | 48,000 | 97,000 | 4 | 50 | 140 | 320 | 670 |
| C6-C10 | NL | NL | NL | NL | NL | 850 | 11,000 | 33,000 | 77,000 | 160,000 |
| >C10-C16 | NL | NL | NL | NL | NL | 670 | NL | NL | NL | 0 |
| <i>Clay (clay, clay loam and silt loam)</i> | | | | | | | | | | |
| Toluene | NL | NL | NL | NL | NL | 6,500 | 100,000 | NL | NL | NL |
| Ethylbenzene | NL | NL | NL | NL | NL | 1,800 | 31,000 | NL | NL | NL |
| Xylenes | NL | NL | NL | NL | NL | 1,200 | 21,000 | NL | NL | NL |
| Naphthalene | NL | NL | NL | NL | NL | 4 | 85 | 240 | 560 | 1,200 |
| Benzene | 3,000 | 20,000 | 40,000 | 81,000 | 160,000 | 5 | 80 | 230 | 530 | 1,100 |
| C6-C10 | NL | NL | NL | NL | NL | 1,000 | 19,000 | 55,000 | 130,000 | 270,000 |
| >C10-C16 | NL | NL | NL | NL | NL | 800 | NL | NL | NL | 0 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

The figures in the above table may be multiplied by a factor of 10 to account for biodegradation of vapour sources from 2 m to <4 m or by a factor of 100 for 4 m and deeper. For vapour degradation to occur, a number of conditions apply, such as the maximum length of the shorter side of concrete slab and surrounding pavement cannot exceed 15 m, as this would prevent oxygen penetrating to the centre of the slab. Consideration should be given to measurement of oxygen in the subsurface to determine the potential for biodegradation to occur. Refer to Section 7.4 of CRC CARE Technical Report no. 10: Part 1 (Friebel & Nadebaum (2010a), or to CRC CARE Technical Report no. 12 (Davis et al. 2009) for further information.

NL - denotes no level presented as HSL exceeds concentration of pure gas

- (1) The key limitations in the development and application of HSLs are presented in Friebel and Nadebaum 2010d and should be referred to.
- (2) Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebel and Nadebaum (2010a, 2010b).
- (3) Soil vapour HSLs should be compared to measurements of vapour sources and soil vapour above sources, and hence measurements should be taken as laterally close as possible to the soil or groundwater source. Soil vapour measurements require consideration of where the sample is taken, the current state of the site and the future state of the site. Shallow soil-gas measurements in open space areas (less than 1 m) may be subject to the influence of their surroundings such as weather conditions and moisture.
- (4) Maximum possible soil vapour concentrations have been calculated based on vapour pressures of pure chemicals. Where soil vapour HSLs exceed these values, this indicates that to reach the maximum allowed breathable air concentrations, a soil-vapour source concentration would be required that is greater than that possible. For these scenarios no HSL is presented for these chemicals. These are denoted as 'NL'.
- (5) TPH >C16 have physical properties which make these TPH fractions non-volatile, and therefore these TPH fractions are not of concern for vapour intrusion.

Table 1A(6) HSLs direct soil contact (mg/kg)

| Chemical | HSL A (low density residential) | HSL B (high density residential) | HSL C (recreational) | HSL D (commercial/ industrial) |
|--------------|---------------------------------------|--|-------------------------|--------------------------------------|
| Toluene | 14,000 | 21,000 | 18,000 | 99,000. |
| Ethylbenzene | 4,500 | 5,900 | 5,300 | 27,000 |
| Xylenes | 12,000 | 17,000 | 15,000 | 81,000 |
| Naphthalene | 1,400 | 2,200 | 1,900 | 11,000 |
| Benzene | 100 | 140 | 120 | 430 |
| C6-C10 | 4,400 | 5,600 | 5,100 | 26,000 |
| >C10-C16 | 3,300 | 4,200 | 3,800 | 20,000 |
| >C16-C34 | 4,500 | 5,800 | 5,300 | 27,000 |
| >C34-C40 | 6,300 | 8,100 | 7,400 | 38,000 |

Notes:

Land use settings are equivalent to those described in Table 1A(1) Footnote 1.

(1) The key limitations in the development and application of HSLs are presented in Friebe and Nadebaum 2010d and should be referred to.

Detailed assumptions used in the derivation of the HSLs and information on the application of the HSLs are presented in Friebe and Nadebaum (2010a, 2010b).

Table 1B(1) ACL for aged Zn

Soil-specific added contaminant limits for aged (present in soil for at least two years) zinc in soils with pH ranging from 4.0 to 7.5 and cation exchange capacity (CEC) values ranging from 5 to 60 cmolc/kg for various land uses.

| Zn Added contaminant limits (ACL, mg added contaminant/kg) | | | | | | |
|---|--|-----|------|------|------|------|
| National park/areas with high ecological value land use | | | | | | |
| <i>pH^a</i> | <i>CEC^b (cmol_c/kg)</i> | | | | | |
| | 5 | 10 | 20 | 30 | 40 | 60 |
| 4.0 | 15 | 20 | 20 | 20 | 20 | 20 |
| 4.5 | 20 | 25 | 25 | 25 | 25 | 25 |
| 5.0 | 30 | 40 | 40 | 40 | 40 | 40 |
| 5.5 | 40 | 60 | 60 | 60 | 60 | 60 |
| 6.0 | 50 | 90 | 90 | 90 | 90 | 90 |
| 6.5 | 50 | 90 | 130 | 130 | 130 | 130 |
| 7.0 | 50 | 90 | 150 | 190 | 190 | 190 |
| 7.5 | 50 | 90 | 150 | 210 | 260 | 280 |
| Urban residential/public open space land use | | | | | | |
| <i>pH^a</i> | <i>CEC^b (cmol_c/kg)</i> | | | | | |
| | 5 | 10 | 20 | 30 | 40 | 60 |
| 4.0 | 70 | 85 | 85 | 85 | 85 | 85 |
| 4.5 | 100 | 120 | 120 | 120 | 120 | 120 |
| 5.0 | 130 | 180 | 180 | 180 | 180 | 180 |
| 5.5 | 180 | 270 | 270 | 270 | 270 | 270 |
| 6.0 | 230 | 400 | 400 | 400 | 400 | 400 |
| 6.5 | 230 | 400 | 590 | 590 | 590 | 590 |
| 7.0 | 230 | 400 | 700 | 880 | 880 | 880 |
| 7.5 | 230 | 400 | 700 | 960 | 1200 | 1300 |
| Commercial/industrial land use | | | | | | |
| <i>pH^a</i> | <i>CEC^b (cmol_c/kg)</i> | | | | | |
| | 5 | 10 | 20 | 30 | 40 | 60 |
| 4.0 | 110 | 130 | 130 | 130 | 130 | 130 |
| 4.5 | 150 | 190 | 190 | 190 | 190 | 190 |
| 5.0 | 210 | 290 | 290 | 290 | 290 | 290 |
| 5.5 | 280 | 420 | 420 | 420 | 420 | 420 |
| 6.0 | 360 | 620 | 620 | 620 | 620 | 632 |
| 6.5 | 360 | 620 | 920 | 920 | 920 | 920 |
| 7.0 | 360 | 620 | 1100 | 1400 | 1400 | 1400 |
| 7.5 | 360 | 620 | 1100 | 1500 | 1900 | 2000 |

a = pH was measured using the CaCl₂ method (Rayment and Higginson 1992).

b = CEC was measured using the silver thiourea method (Chhabra et al. 1972).

Table 1B(2) ACL for aged Cu

Soil-specific added contaminant limits for aged (present in soil for at least two years) copper contamination in soils with a pH ranging from 4.5 to 8 and cation exchange capacity (CEC) ranging from 5 to 60 cmol_c/kg for various land uses. The lowest of the CEC- or the pH-based ACLs for a particular land use that apply to a soil is the ACL to be used.

| Cu Added contaminant limits (ACL, mg added contaminant/kg) | | | | | |
|--|-----|-----|-----|-----|------|
| National park/areas with high ecological value land use | | | | | |
| CEC (cmol _c /kg) ^a based | | | | | |
| 5 | 10 | 20 | 30 | 40 | 60 |
| 30 | 65 | 70 | 70 | 75 | 80 |
| pH ^b based | | | | | |
| 4.5 | 5.5 | 6 | 6.5 | 7.5 | 8.0 |
| 20 | 45 | 65 | 90 | 190 | 270 |
| Urban residential/public open space land use | | | | | |
| CEC (cmol _c /kg) ^a based | | | | | |
| 5 | 10 | 20 | 30 | 40 | 60 |
| 95 | 190 | 210 | 220 | 220 | 230 |
| pH ^b based | | | | | |
| 4.5 | 5.5 | 6 | 6.5 | 7.5 | 8.0 |
| 60 | 130 | 190 | 280 | 560 | 800 |
| Commercial/industrial land use | | | | | |
| CEC (cmol _c /kg) ^a based | | | | | |
| 5 | 10 | 20 | 30 | 40 | 60 |
| 140 | 280 | 310 | 320 | 330 | 340 |
| pH ^b based | | | | | |
| 4.5 | 5.5 | 6 | 6.5 | 7.5 | 8.0 |
| 85 | 190 | 280 | 400 | 830 | 1200 |

a = CEC was measured using the silver thiourea method (Chhabra et al. 1972).

b = pH was measured using the CaCl₂ method (Rayment & Higginson 1992).

Table 1B(3) ACL for aged CrIII and Ni Generic added contaminant limits for aged (present in soil for at least two years) trivalent chromium and nickel in Australian soils (irrespective of the soil physicochemical properties) with various land uses.

| Contaminant | Clay content (% clay) | Added contaminant limits (mg added contaminant/kg) for various land uses | | |
|--------------|---|--|---|---------------------------|
| | | National park and areas with high ecological value | Urban residential and public open space | Commercial and industrial |
| Chromium III | 1 | 60 | 190 | 310 |
| | 2.5 | 80 | 250 | 420 |
| | 5 | 100 | 320 | 530 |
| | ≥10 | 130 | 400 | 660 |
| Nickel | CEC ^a (cmol _c /kg) | National park and areas with high ecological value | Urban residential and public open space | Commercial and industrial |
| | 5 | 5 | 30 | 55 |
| | 10 | 30 | 170 | 290 |
| | 20 | 45 | 270 | 460 |
| | 30 | 60 | 350 | 600 |
| | 40 | 70 | 420 | 730 |
| | 60 | 95 | 560 | 960 |

a = CEC measurements made using the silver thiourea method (Chhabra et al. 1975).

Table 1B(4) ACL generic Pb; generic EILs As, DDT, naphthalene

Generic added contaminant limits for lead and generic ecological investigation levels for aged (present in soil for at least two years) arsenic, DDT, lead and naphthalene in Australian soils (irrespective of their physicochemical properties) with various land uses.

| Contaminant | National park and areas with high ecological value | Urban residential and public open space | Commercial and industrial |
|--|--|---|---------------------------|
| | | | |
| Added contaminant limits (mg added contaminant/kg) | | | |
| Lead | 470 | 1100 | 1800 |
| Ecological investigation levels (mg total contaminant/kg) | | | |
| Arsenic | 40 | 100 | 170 |
| DDT¹ | 3 | 180 | 640 |
| Naphthalene¹ | 10 | 170 | 370 |

¹ = these were derived for fresh contamination but as there are no EILs for aged contamination the values for fresh contamination must be used.

Table 1B(5) ESLs for TPH fractions F1 - F4, BTEX and benzo(a)pyrene

| Chemical | Soil type | ESLs (mg/kg dry soil) low reliability for various land uses | | |
|---|-----------|---|---|---------------------------|
| | | National parks and areas with high ecological value | Urban residential and public open space | Commercial and industrial |
| F1 C ₆ -C ₁₀ ¹ | Generic | 125 | 180 | 215 |
| F2 >C ₁₀ -C ₁₆ ¹ | | 25 | 120 | 170 |
| F3 >C ₁₆ -C ₃₄ | Coarse | - | 300 | 1700 |
| | Fine | - | 1300 | 2500 |
| F4 >C ₃₄ | Coarse | - | 2800 | 3300 |
| | Fine | - | 5600 | 6600 |
| Benzene | Coarse | 10 | 50 | 75 |
| | Fine | 10 | 65 | 95 |
| Toluene | Coarse | 10 | 85 | 135 |
| | Fine | 65 | 105 | 135 |
| Ethylbenzene | Coarse | 1.5 | 70 | 165 |
| | Fine | 40 | 125 | 185 |
| Xylenes | Coarse | 10 | 105 | 180 |
| | Fine | 1.6 | 45 | 95 |
| Benzo(a)pyrene | Coarse | 0.7 | 0.7 | 0.7 |
| | Fine | 1.4 | 1.4 | 1.4 |

1 Moderate reliability ESLs.

Table 1 B(6) Management Limits for TPH fractions F1-F4

| TPH fraction | Soil type | Management Limits ¹ (mg/kg dry soil) | |
|--------------------------------------|-----------|---|---------------------------|
| | | Residential, parkland and public open space | Commercial and industrial |
| F1 C ₆ -C ₁₀ | Coarse | 700 | 700 |
| | Fine | 800 | 800 |
| F2 >C ₁₀ -C ₁₆ | Coarse | 1000 | 1000 |
| | Fine | 1000 | 1000 |
| F3 >C ₁₆ -C ₃₄ | Coarse | 2500 | 3500 |
| | Fine | 3500 | 5000 |
| F4 >C ₃₄ | Coarse | 10000 | 10000 |
| | Fine | 10000 | 10000 |

¹ Management limits are applied after consideration of relevant ESLs and HSLs .

Table 1C Groundwater Investigation levels (GILs)

| | Substance | Investigation level for drinking water ¹ (µg/L) | Investigation level for fresh water ² (µg/L) | Investigation level for marine water ² (µg/L) |
|------------------------------|--------------------------|--|---|--|
| Metals and metalloids | | | | |
| | Aluminium pH >6.5 | | 55 | ID |
| | Antimony | 3 | ID | ID |
| | Arsenic (total) | 7 | | |
| | Arsenic (As III) | | 24 | ID |
| | Arsenic (As V) | | 13 | ID |
| | Barium | 700 | | |
| | Boron | 4000 | 370 | ID |
| | Cadmium | 2 | 0.2 | 5.5 |
| | Chromium (as Cr III) | | ID | 27.4 |
| | Chromium (as Cr(VI)) | 50 | 1 | 4.4 |
| | Cobalt | | ID | 1 |
| | Copper | 2000 | 1.4 | 1.3 |
| | Lead | 10 | 3.4 | 4.4 |
| | Manganese | 500 | 1900 | ID |
| | Mercury (total) | 1 | | |
| | Mercury (inorganic) | | 0.6 | 0.4 |
| | Molybdenum | 50 | ID | ID |
| | Nickel | 20 | 11 | 70 |
| | Selenium | 10 | 11 | ID |
| | Silver | 100 | 0.05 | 1.4 |
| | Tributyltin (as µg/L Sn) | | ID | 0.006 |
| | Uranium | 20 | ID | ID |
| | Vanadium | | ID | 100 |
| | Zinc | | 8 | 15 |

| Non-metallic inorganics | | | | |
|----------------------------------|--------------------------------------|--------|------|------|
| | Ammonia | | 900 | 910 |
| | Bromate | 20 | | |
| | Chlorine | 5000 | 3 | ID |
| | Chlorine dioxide | 1000 | | |
| | Chlorite | 300 | | |
| | Cyanogen chloride (as cyanide) | 80 | 7 | 4 |
| | Fluoride | 1500 | | |
| | Hydrogen sulfide | | 1 | ID |
| | Iodide | 100 | | |
| | Nitrate (as nitrate) | 50000 | 700 | ID |
| | Nitrite (as nitrite) | 3000 | | |
| | Sulfate | 500000 | | |
| Organic alcohols | | | | |
| | Ethanol | | 1400 | ID |
| Chlorinated alkanes | | | | |
| | Carbon tetrachloride | 3 | ID | ID |
| Chloromethanes | Dichloromethane (methylene chloride) | 4 | ID | ID |
| Chloroethanes | 1,2-dichloroethane | 3 | ID | ID |
| | 1,1,2-trichloroethane | | 6500 | 1900 |
| | Hexachloroethane | | 360 | ID |
| Chlorinated alkenes | | | | |
| | 1,1-dichloroethene | 30 | | |
| | 1,2-dichloroethene | 60 | | |
| | Tetrachloroethene | 50 | | |
| Anilines | | | | |
| | Aniline | | 250 | ID |
| | 2,4-dichloroaniline | | 7 | ID |
| | 3,4-dichloroaniline | | 3 | 150 |
| Aromatic hydrocarbons | | | | |
| | Benzene | 1 | 950 | 700 |
| | Chlorobenzene | 300 | | |
| | Ethylbenzene | 300 | ID | ID |
| | o-xylene | | 350 | ID |
| | p-xylene | | 200 | ID |
| | Toluene | 800 | ID | ID |
| | Trichlorobenzenes (total) | 30 | | |
| | Total Xylenes | 600 | | |
| Polycyclic aromatic hydrocarbons | Benzo(a)pyrene | 0.01 | ID | ID |
| | Naphthalene | | 16 | 70 |
| Nitrobenzenes | Nitrobenzene | | 550 | ID |
| Nitrotoluenes | 2,4-dinitrotoluene | | 65 | ID |
| | 2,4,6-trinitrotoluene | | 140 | ID |

| | | | | |
|--|---|------|------|-----|
| Chlorobenzenes and chloronaphthalenes | 1,2-dichlorobenzene | 1500 | 160 | ID |
| | 1,3-dichlorobenzene | | 260 | ID |
| | 1,4-dichlorobenzene | 40 | 60 | ID |
| | 1,2,3-trichlorobenzene | | 10 | ID |
| | 1,2,4-trichlorobenzene | | 170 | 80 |
| Polychlorinated biphenyls (PCBs) and dioxins | Aroclor 1242 | | 0.6 | ID |
| | Aroclor 1254 | | 0.03 | ID |
| Phenols and Xylenols | | | | |
| | Phenol | | 320 | 400 |
| | 2-chlorophenol | 300 | 490 | ID |
| | 4-chlorophenol | | 220 | ID |
| | 2,4-dichlorophenol | 200 | 160 | ID |
| | 2,4,6-trichlorophenol | 20 | 20 | ID |
| | 2,3,4,6- tetrachlorophenol | | 20 | ID |
| | Pentachlorophenol | 10 | 10 | 22 |
| Nitrophenols | 2,4-dinitrophenol | | 45 | ID |
| Organic sulfur compounds | | | | |
| Phthalates | Dimethylphthalate | | 3700 | ID |
| | Diethylphthalate | | 1000 | ID |
| | Dibutylphthalate | | 26 | ID |
| Miscellaneous chemicals | | | | |
| | Acrylamide | 0.2 | | |
| | Poly(acrylonitrile-co-butadiene-co-styrene) | | 530 | 250 |
| | Chloroacetic acid | 150 | | |
| | Di(2-ethylhexyl) phthalate | 10 | | |
| | Dichloroacetic acid | 100 | | |
| | Epichlorohydrin | 0.5 | | |
| | Ethylenediamine tetraacetic acid (EDTA) | 250 | | |
| | Formaldehyde | 500 | | |
| | Hexachlorobutadiene | 0.7 | ID | ID |
| | Monochloramine | 3000 | | |
| | Nitritotriacetic acid | 200 | | |
| | Styrene | 30 | | |
| | tributyltin oxide | 1 | | |
| | Trichloroacetaldehyde (chloral hydrate) | 20 | | |
| | trichloroacetic acid | 100 | | |
| | Trihalomethanes (THMs) (Total) | 250 | | |
| | Vinyl chloride | 0.3 | | |

| | | | | |
|-------------------|-----------------|------|-------|-------|
| Pesticides | Acephate | 10 | | |
| | Aldicarb | 1 | | |
| | Aldrin | 0.3 | ID | ID |
| | Ametryn | 50 | | |
| | Amitrole | 10 | ID | ID |
| | Asulam | 50 | | |
| | Atrazine | 40 | 13 | ID |
| | Azinphos-methyl | 3 | 0.02 | ID |
| | Benomyl | 100 | | |
| | Bentazone | 30 | | |
| | Bioresmethrin | 100 | | |
| | Bromacil | 300 | ID | ID |
| | Bromophos-ethyl | 10 | | |
| | Bromoxynil | 30 | | |
| | Carbaryl | 30 | | |
| | Carbendazim | 100 | | |
| | Carbofuran | 10 | 1.2 | ID |
| | Carbophenothion | 0.5 | | |
| | Carboxin | 300 | | |
| | Chlordane | 1 | 0.08 | ID |
| | Chlorfenvinphos | 5 | | |
| | Chlorothalonil | 30 | | |
| | Chloroxuron | 10 | | |
| | Chlorpyrifos | 10 | 0.01 | 0.009 |
| | Chlorsulfuron | 100 | | |
| | Clopyralid | 1000 | | |
| | 2,4-D | 30 | 280 | ID |
| | DDT | 20 | 0.01 | ID |
| | Diazinon | 3 | 0.01 | ID |
| | Dicamba | 100 | | |
| | Dichlobenil | 10 | | |
| | Dichlorvos | 1 | | |
| | Diclofop-methyl | 5 | | |
| | Dicofol | 3 | ID | ID |
| | Dieldrin | 0.3 | ID | ID |
| | Difenzoquat | 100 | | |
| | Dimethoate | 50 | 0.15 | ID |
| | Diphenamid | 300 | | |
| | Diquat | 5 | 1.4 | ID |
| | Disulfoton | 3 | | |
| | Diuron | 30 | ID | ID |
| | DPA (2,2-DPA) | 500 | | |
| | EDB | 1 | | |
| | Endosulfan | 30 | 0.2 | 0.1 |
| | Endothal | 100 | | |
| | Endrin | | 0.02 | 0.008 |
| | EPTC | 30 | | |
| | Esfenvalerate | | 0.001 | ID |

| | | | | |
|--|--------------------|------|--------|----|
| | Ethion | 3 | | |
| | Ethoprophos | 1 | | |
| | Etridiazole | 100 | | |
| | Fenamiphos | 0.3 | | |
| | Fenarimol | 30 | | |
| | Fenchlorphos | 30 | | |
| | Fenitrothion | 10 | 0.2 | ID |
| | Fenoprop | 10 | | |
| | Fensulfothion | 10 | | |
| | Fenvalerate | 50 | | |
| | Flamprop-methyl | 3 | | |
| | Fluometuron | 50 | | |
| | Formothion | 50 | | |
| | Fosamine | 30 | | |
| | Glyphosate | 1000 | 1200 | ID |
| | Heptachlor | 0.3 | 0.09 | ID |
| | Hexaflurate | 30 | | |
| | Hexazinone | 300 | ID | ID |
| | Lindane | 20 | 0.2 | ID |
| | Malathion | | 0.05 | ID |
| | Maldison | 50 | | |
| | Methidathion | 30 | | |
| | Methiocarb | 5 | | |
| | Methomyl | 30 | 3.5 | ID |
| | Methoxychlor | 300 | ID | ID |
| | Metolachlor | 300 | ID | ID |
| | Metribuzin | 50 | | |
| | Metsulfuron | | ID | ID |
| | Metsulfuron-methyl | 30 | | |
| | Mevinphos | 5 | | |
| | Molinate | 5 | 3.4 | ID |
| | Monocrotophos | 1 | | |
| | Napropamide | 1000 | | |
| | Nitralin | 500 | | |
| | Norflurazon | 50 | | |
| | Oryzalin | 300 | | |
| | Oxamyl | 100 | | |
| | Paraquat | 30 | ID | ID |
| | Parathion | 10 | 0.0004 | ID |
| | Parathion methyl | 100 | | |
| | Pebulate | 30 | | |
| | Pendimethalin | 300 | | |
| | Permethrin | 100 | | |
| | Picloram | 300 | | |
| | Piperonyl butoxide | 100 | | |
| | Pirimicarb | 5 | | |
| | Pirimiphos-ethyl | 0.5 | | |
| | Pirimiphos-methyl | 50 | | |
| | Profenofos | 0.3 | ID | ID |

| | | | | |
|--------------------|--------------------------------------|-----|-----|-------|
| | Promecarb | 30 | | |
| | Propachlor | 50 | | |
| | Propanil | 500 | | |
| | Propargite | 50 | | |
| | Propazine | 50 | | |
| | Propiconazole | 100 | | |
| | Propyzamide | 300 | | |
| | Pyrazophos | 30 | | |
| | Quintozene | 30 | | |
| | Silvex (see Fenoprop) | | | |
| | Simazine | 20 | 3.2 | ID |
| | Sulprofos | 10 | | |
| | 2,4,5-T | 100 | 36 | ID |
| | Tebuthiuron | | 2.2 | ID |
| | Temephos | 300 | ID | 0.005 |
| | Terbacil | 30 | | |
| | Terbufos | 0.5 | | |
| | Terbutryn | 300 | | |
| | Tetrachlorvinphos | 100 | | |
| | Thiobencarb | 30 | 2.8 | ID |
| | Thiometon | 3 | | |
| | Thiophanate | 5 | | |
| | Thiram | 3 | 0.2 | ID |
| | Toxaphene | | 0.2 | ID |
| | Triadimefon | 2 | | |
| | Trichlorfon | 5 | | |
| | Triclopyr | 10 | | |
| | Trifluralin | 50 | 4.4 | ID |
| | Vernolate | 30 | | |
| Surfactants | Alcohol ethoxylated sulfate (AES) | | 650 | ID |
| | Alcohol ethoxylated surfactants (AE) | | 140 | ID |
| | Linear alkylbenzene sulfonates (LAS) | | 280 | ID |

- (1) Investigation levels are taken from the health values of the Australian drinking water guidelines (NHMRC & NRMMC 2004).
- (2) Investigation levels are taken from the 95% species protection values of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ 2000).
- ID insufficient data to derive an investigation level.

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6 Shortened forms

| | |
|---------------|---|
| ABC | ambient background concentration |
| ACL | added contaminant limits |
| ADWG | Australian drinking water guidelines |
| AF | asbestos fines |
| AWQG | Australian and NZ guidelines for fresh and marine water quality |
| CCME | Canadian Council of the Ministers of the Environment |
| CEC | cation exchange capacity |
| EC30 | effective concentration 30% |
| EIL | ecological investigation level |
| FA | fibrous asbestos |
| GIL | groundwater investigation level |
| GMRRW | Guidelines for managing risk in recreational water |
| HIL | health investigation level |
| HSL | health screening levels |
| LOEC | lowest observed effect concentration |
| SSD | species sensitivity distribution |
| TPH | total petroleum hydrocarbon |
| TRH | total recoverable hydrocarbon |
| US EPA | United States Environmental Protection Agency |
| VOCC | volatile organic chlorinated compound |

7 Glossary

Ecological investigation levels (EILs) depend on specific soil physicochemical properties and land use scenarios and generally apply to the top 2m of soil.

Ecological screening levels (ESLs) for petroleum hydrocarbon materials broadly apply to coarse and fine grained soils and various land uses. They are applicable to the top 3m of soil.

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

Health investigation levels (HILs) are generic and apply across Australia to all soil types generally to a depth of 3 m below surface.

Health screening levels (HSLs) for petroleum hydrocarbons depend on physicochemical properties of soil as it affects hydrocarbon vapour movement in soil and the characteristics of building structures. They apply to different soil types, land uses and depths below surface to >4 m and have a range of limitations.

Investigation and screening levels provide the basis of Tier 1 risk assessment. A **Tier 1 assessment** is a risk-based analysis comparing site data with investigation and screening levels for various land uses to determine the need for further assessment or development of an appropriate management strategy. Further details on the tiered risk assessment process are described in other Schedules to this Measure.

Investigation levels and **screening levels** are the concentrations of a contaminant above which further appropriate investigation and evaluation will be required. Ecological investigation levels (EILs) may also be referred to as soil quality guidelines in relevant references (see Schedules B5b and B5c).

Petroleum hydrocarbon '**management limits**' are limited to petroleum hydrocarbon compounds. They are maximum values that should remain in a site following evaluation of human health and ecological risks and risks to groundwater resources and apply to all soil depths based on site-specific considerations. These limits are to consider the formation of phase separated hydrocarbons, fire and explosion risks, damage to buried infrastructure and aesthetics.