environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

Framework for the Management of Contaminated Land

March 2010

WSP Environment & Energy
www.wspenvironmental.co.za

WSP

Contents Page

LIST OF TABLES

LIST OF FIGURES

1 Glossary

Acceptable risk	A risk that is so small and consequences so slight, or associated benefits (perceived or real) so great, that society is willing to take or be subjected to that risk.
Activity patterns	Time-use studies explore how children and adults spend their time, and the types, duration and location of activities, including eating, sleeping, working, and playing. Such activities that occur regularly according to discrete boundaries, such as land use, can be grouped together to form a pattern of behaviour that can be used to predict likely exposure.
Air dispersion factor	Describes the dispersion of fugitive dusts emitted from soils and is defined as the inverse of the ratio of geometric mean air concentration to the emission/flux at the centre of the source.
Aquifer	Groundwater-bearing formations sufficiently permeable to transmit and yield water in usable quantities. As guidance in assessing the sensitivity of groundwater resources to contamination the following general definitions should be applied. A **non-aquifer** is defined as: ■ Having insignificant yield of good quality water or ■ Moderate yield of poor quality water or ■ An aquifer which will never be utilised for water supply or which will not contaminate other aquifers **Poor aquifers** are defined by yield: ■ Low yield: 1 litres/second ■ Moderate yield: 1-5 litres/second
Asbestos	The asbestiform varieties of mineral silicates belonging to the serpentine and amphibole groups of rock-forming minerals, including actinolite, amosite (brown asbestos), anthophyllite, crocidolite (blue asbestos), chrysotile (white), tremolite, or any mixture of these.
Asbestos-Containing Material (ACM)	Products or materials that contain asbestos in an inert bound matrix such as cement or resin. Here taken to be sound material, even as fragments and not fitting through a 7 x 7 mm sieve.
Asbestos Fines (AF)	Includes asbestos-free fibres, small fibre bundles and also ACM fragments that pass through a 7 x 7 mm sieve.
Attenuation factor	Ratio of chemical concentration between two media, assuming that the concentration decreases from the source media to the receptor media. For example, the attenuation factor from the soil gas to the indoor air is used to assess vapour intrusion.
Average daily exposure	The average daily amount of a contaminant per kg bodyweight, which a critical human receptor might take in over the duration of exposure.
Averaging time	Time period over which aggregated exposure is averaged to derive a daily exposure that can be compared to a relevant Health Criteria Value. In deriving Soil Guideline Values, averaging time is equal to the exposure duration.
Background concentration	A representative ambient level for a contaminant in soil or water. Ambient concentrations may reflect natural geological variations in relatively undeveloped areas or the influence of generalised industrial or urban activity in a region.
Background sources	Sources of human exposure to a chemical other than the soil itself, either directly or indirectly. For example, ambient air, diet, and drinking water.

Bioaccessaibility	The degree to which a chemical is released from soil into solution (and thereby becomes available for absorption) when that soil is ingested and undergoes digestion.
Bioavailability	The degree to which a substance is absorbed and becomes available to the target tissue (that is, without first being metabolised). The amount of chemical available to the target tissue following exposure.
Carcinogen	A substance or agent that causes the development or increases the incidence of cancer. A carcinogen can also act upon a population to change its total frequency of cancer in terms of numbers of tumours or distribution by site and age.
Carcinogenic	Of or pertaining to the ability to cause the development of cancer.
Chemical intake/uptake rate	The daily amount of a soil contaminant expressed as an intake or an uptake from exposure to chemicals in soil, food, water and air.
Conceptual model	A representation of the characteristics of a site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.
Contaminant	Any substance present in an environmental medium at concentrations in excess of natural background concentrations.
Clean Fill	Material of certified quality and not having harmful environmental or health effects. Consists of rocks, sand or soil from the excavation of undisturbed material or derived from an acceptable source.
Detailed quantitative risk assessment	The purpose of detailed quantitative risk assessment is to establish and use more detailed site-specific information and criteria to decide whether there are unacceptable risks. It may be used as the sole method for quantitative risk assessment of risks, or it may be used to refine earlier assessments using generic assessment criteria.
Dermal absorption fraction	An empirical measure of the proportion of chemical compound in soil that is absorbed through the skin by a typical soiling event.

Dose	The amount or concentration of a substance absorbed into the body exposed to the substance.
Dose-response relationship	Relationship between the dose of a chemical taken into an organism and the response (in the form of a measured biological, systemic or physiological effect) that is detected.
Ecological receptor	A non-human organism potentially experiencing adverse effects from exposure to contaminated soil either directly (contact) or indirectly (food chain transfer).
Estimated daily intake	Total 'background' exposure to a chemical substance, arising from low levels of contamination commonly found in air, water, food, soil and consumer products.
Exposure	Contact between a chemical and the external surfaces of the human body. Quantitatively, it is the amount of a chemical that is available for intake by a target receptor/population. Exposure may be quantified as the dose or the concentration of the chemical in the medium (for example, air, water, food) integrated over the duration of exposure, expressed in terms of mass of substance per kg of soil, cubic metre of air, or litre of water.
Exposure assessment	The process of estimating or measuring the magnitude, frequency, and duration of exposure to an agent, along with the number and characteristics of the population exposed. Ideally, it describes the sources, pathways, routes, and uncertainties in the risk assessment.
Exposure duration	The specified period of exposure in years over which the chemical intake/uptake rate for a critical receptor is accumulated.
Exposure frequency	The number of days per year in which a daily exposure event is considered to occur.
Exposure pathway	The route by which an organism comes into contact with a contaminant. Direct pathways include soil ingestion, dust inhalation and dermal absorption. An indirect pathway involves migration or transport of contamination from one environmental medium to another before contact occurs. Inhalation of vapours arising from contaminated soil or groundwater is an example.

Exposure route	The mode of entry of a chemical into the body.
Fibrous Asbestos (FA)	Friable asbestos material, such as severely weathered ACM, and asbestos in the form of loose fibrous material such as insulation products.
Free-phase	Chemical present in soil or water in its natural physical form under ambient conditions, for example, solid, liquid or gas.
Guidelines	Generic numerical limits or narrative statements that are recommended to protect and maintain the quality of soil, water or sediment.
Groundwater	Subsurface water beneath the water table in fully saturated geological formations.
Hardstand Area	An area that is covered by impervious construction material such as asphalt, concrete or brick.
Index Dose	The term used in this report to refer to an estimate of the amount of a soil contaminant (expressed as daily intake) that can be experienced over a lifetime with minimal cancer risk.
Intake	Amount of a chemical entering the human body at the point of entry (that is, mouth, nose or skin) by ingestion, inhalation, or skin contact.
Long term exposure	Exposure to a contaminant in a medium lasting from several weeks to years and often includes a reproductive or life cycle of the test organism. Often referred to as a chronic exposure.
Mean daily intake	The average intake of a soil contaminant from other, non-soil sources, expressed as an amount per day. The mean daily intake is estimated for each route of exposure and arises principally from exposure to the contaminant in food, water, and air.
Multimedia exposure assessment	The quantitative estimate of total exposure to a chemical arising from all sources (air, water, soil, food, consumer products), by all routes (ingestion, inhalation, dermal absorption).
Particle Emission Factor (PEF)	The relationship between the concentration of a contaminant in soil and its concentration in air as a consequence of dust resuspension.
Partition coefficient	The experimental or calculated ratio of the concentrations of the same chemical species in two phases.

Pathway	The route or means that controls the release and migration of a contaminant to environmental media, for instance soil to water or soil to air.
Porosity	Fraction of void space within a porous media such as a rock or soil.
Receptor	The person or organism exposed to a chemical. For human health risk assessment it is common to define a critical receptor as the person expected to experience the most severe exposure (due to age, sex, diet, lifestyle) or the most severe effects (due to state of health, genetic disposition, sex, age) as a result of that exposure.
Remediation	The management of a contaminated site to prevent, minimise, or mitigate damage to human health or the environment. Remediation may include both direct physical actions (e.g. removal, destruction, and containment of contaminants) and institutional controls.
Remediation objective	A numerical limit or narrative statement that has been established to protect and maintain a specified use of soil at a particular site by taking into account site-specific conditions.
Risk assessment	A process designed to determine the qualitative aspects of hazard identification and usually a quantitative determination of the level of risk based on deterministic or probabilistic techniques.
Risk perception	An intuitive judgement about the nature and magnitude of a risk. Perceptions of risk involve the judgements people make when they characterise and evaluate hazardous substances, activities and situations.
Short term exposure	Exposure to a contaminant in a medium usually severe enough to induce an effect. Often referred to as an acute exposure.
Site-specific assessment criteria	Values for concentrations of contaminants that have been derived using detailed site-specific information on the characteristics and behaviour of contaminants, pathways and receptors, and that correspond to relevant criteria in relation to harm or pollution for deciding whether there is an unacceptable risk.

Site Use	A category for site assessment based on assumed receptor activity patterns associated with different exposure scenarios in a South African context. Includes the following: **Residential and Urban Parkland**: sites where the primary land use is residential, in formal housing, with associated public open spaces for recreational use. **Informal residential settlements**: sites without formal housing, where open ground has been settled without the construction of roads and paved areas of hard standing, and where houses may not have concrete floor slabs. **Commercial/Industrial: Commercial:** sites where the primary activity is related to commercial operations and occupancy is not for residential purposes. **Industrial:** sites where the primary activity involves the production, manufacture, construction, or assembly of goods.
Soil	Normally defined as the unconsolidated material on the immediate surface of the earth that serves as a natural medium for terrestrial plant growth.
Soil Screening Values	**Soil Screening Value 1:** soil quality values that are protective of both human health and ecotoxicological risk for multi-exposure pathways, inclusive of contaminant migration to the water resource. Soil Screening Values 1 are applicable to all land-uses, and thus represent an 'acceptable-risk' situation, with no adverse effects on human health and the aquatic environment. **Soil Screening Value 2**: soil quality values that are protective of risk to human health in the absence of a water resource. Soil Screening Values 2 are land-use specific and have been calculated for three key land-uses namely, standard residential, informal residential settlements and commercial/industrial land-uses.
Soil gas	The gaseous elements and compounds in the small spaces between particles of soil.
Soil vapour	The gaseous elements and compounds from a soil source found within the small spaces within and between the fabric and structure of buildings.
Source	Contaminant source contains a concentration of contaminant(s) – a substance that is in or on land, that has the potential to cause an impact to human health or the environment.
Threshold	The dose/concentration of a chemical below which no adverse effect is expected to occur.
Tolerable Daily Intake	Originally defined as an estimate of the amount of a soil contaminant, expressed on a body weight basis, that can be ingested daily over a lifetime without appreciable health risk, the term has been expanded to apply to exposure via inhalation and dermal contact.
Toxicity	The inherent property of a substance to cause injury or an **adverse effect** in a living organism. Defined as either cancer slope factor (SF in mg/kg/day-1) for carcinogens and reference dose (Rfd in mg/kg/day) for non carcinogens.
Uncertainty	A lack of knowledge about specific factors in a risk or exposure assessment including parameter uncertainty, model uncertainty and scenario uncertainty.
Validation	The process of demonstrating that an investigation area has been delineated or remediated successfully.
Vapour intrusion	Generic term used to describe the migration of volatile chemicals in soil gas from the subsurface into overlying buildings.
Volatilisation	The chemical process by which chemicals convert from a liquid or solid state into a gas and then disperse into the air above contaminated soil.
Volatilisation Factor	Descriptor of rate of volatisation rate of a compound from soil to air.

2 Introduction

2.1 BACKGROUND

The National Environmental Management: Waste Act of 2008 (hereafter referred to as the 'Waste Act'), clearly identifies the status and risk of contaminated sites and provides a legislative mechanism for remediation activities to be instigated and controlled. The National Framework for the Management of Contaminated Land (hereafter referred to as the 'Framework') provides national norms and standards for the practical implementation of remediation activities in compliance with Section 7 (2) (d) of the Waste Act pertaining to 'the remediation of contaminated land and soil quality'.

Due to various factors, including the high cost involved in remediation interventions, it is essential that a holistic and tiered risk-based approach be adopted that is founded on international best practice, to address remediation in a uniform manner across the country, irrespective of the sector of occurrence to safeguard both human health and the natural environment.

The Framework is based on a review of international practice in the developed countries of the world and the emergence of remediation policy from developing countries, and an assessment of alternative approaches and methodologies that may find application in the development of a South African remediation framework. The proposals have been presented and reviewed by a wide range of governmental, industry and public stakeholders. The background to this process of stakeholder engagement is included as in Appendix A to the main document.

2.2 FRAMEWORK - DECISION SUPPORT MEASURES

The following guidelines provide decision-support measures for the management of contaminated land in South Africa, and are based on the following key criteria for successful implementation:

- Nationally consistent methods and numerical values for the assessment of contaminated land that protect human health and the environment which can be implemented as guidance as part of a universal national framework to enable consistent decision making in the remediation of contaminated land.
- A consistent policy on future land use and related activity patterns for human receptors for contaminated sites based on remediation objectives conforming to the above mentioned guidelines.
- To enable the development of a contaminated land register in order to provide transparent recording of remediation activities and current land status.

The Framework consists of the following components:

Section 2: Protocol for Site Risk Assessment
Section 3: Norms and Standards for Site Assessment Reporting
Section 4: The derivation and use of Soil Screening Values

3 Protocol for Site Risk Assessment

3.1 ASSESSMENT PROTOCOL AND DECISION SUPPORT TOOL

In order to apply a multi-tired risk based methodology for the assessment of contaminated land it is necessary to construct a simple conceptual process that defines the contaminant linkage to the potential environmental receptor. There are thus three essential elements that need to be understood so that risk can be quantified and the definition of a contaminated site realised.

The concept is referred to as the source-pathway-receptor model, where;

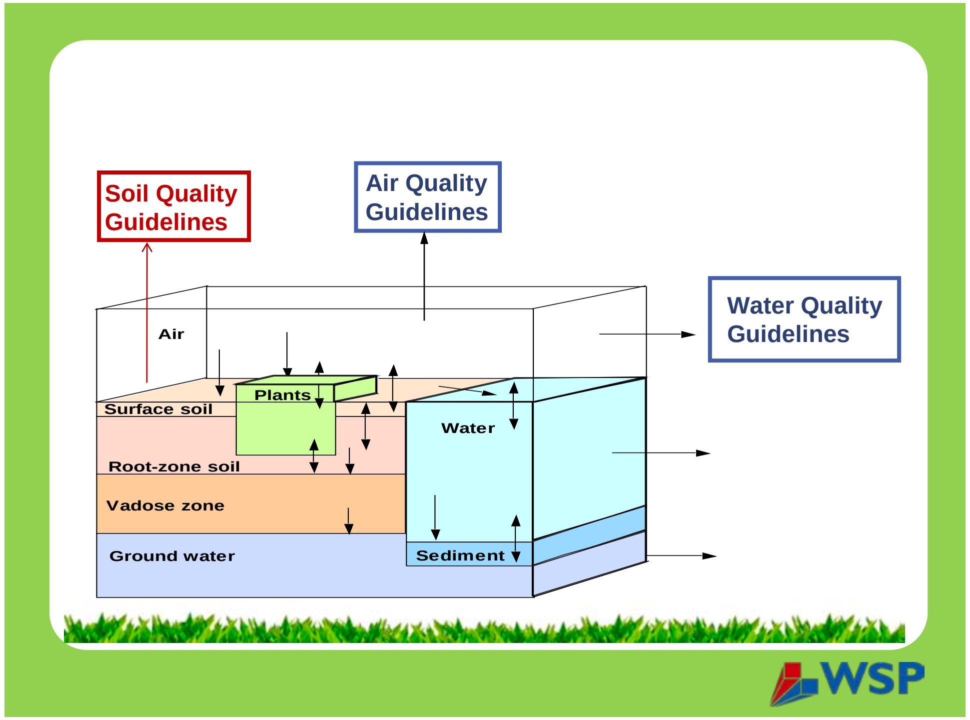
The source contains a concentration of a contaminant(s) – a substance that is in, or on land the land that has the potential to cause an impact to human health or the environment.

The pathway is the route or means that controls the release and migration of a contaminant to environmental media, for instance soil to water or soil to air.

The receptor in general terms is something that can be adversely affected by exposure to the contaminants. Receptors include humans but can also include animals and plants.

Each of the three elements can exist independent to each other and a risk only exists when the linkage is complete and the receptors are exposed to the contaminants. The risk can be assessed in either qualitative or quantitative terms and can also be expressed in terms of probability, as some pathways may pose a very low probability of risk to receptors.

Figure 1: The Interrelationship of environmental pathways associated with contaminant migration from Contaminated Land.



The protocol of Site Assessment has been developed to provide a conceptual risk-based decision-support tool for widespread use by proponent and regulator and is based on the recognition of pathway-receptor linkages. The decision tree is shown diagrammatically in Figure 1.

The conceptual model involves the derivation of a tired system of Soil Screening Values (see Section 4 for the derivation of Soil Screening Values) which can be used for comparison with soil concentrations measured for soils on the investigated site.

At the first tier for site screening Soil Screening Value 1 is a conservative concentration that is lowest of three potential source-pathway-receptor model calculations:

- Direct pathways for the protection of the child receptor taken as the most sensitive receptor in the context of potentially high exposures anticipated for informal residential settlements in South Africa.
- Indirect pathway for the protection of water resources in terms of human health based on the ingestion of drinking water. The model for contaminant transfer from soil to water is based on simplified partitioning model with allowance for finite limited dispersion, dilution and attenuation within the groundwater-surface water medium, assuming a shallow water table within a typical porous sand aquifer.
- Indirect pathway for the protection of aquatic ecosystems by applying aquatic ecotoxicology to the same assumptions used to define the soil to surface water pathway used in the calculation of the human health related water resource protection.

The lowest concentration provided by the three pathway-receptor models is selected as the Soil Screening Level 1. This is thus a multi-functional soil quality criteria that are conservative under a large number of potential exposure scenarios.

It is recognised that for a number of sites that the source-pathway-receptor is poorly developed or entirely absent. For practical reasons it is important that risk assessments do not protect receptors that do not exist and do not invoke pathways that are unrealistic. The decision on the status of contaminated land does require that the contaminant exposure risk in one environmental media does exist to the detriment of another media. The guidelines derived for water related receptors are thus an important point of departure, with often the ecologically driven Soil Screening Values (refer to Section 4) being much lower than human health based values. It thus an important step in the Site Assessment Protocol to define a conceptual model of the risk to water resources to decide on whether or not a realistic risk to water resources could exist. For a site where there is a genuine lack of knowledge on the water resource related pathways the default approach would be to assume a water resource is present and is at risk. The Soil Screening Value 1 would thus define the contaminated status of the site until proven otherwise by factual data, on soil and water quality and taking into consideration background concentrations.

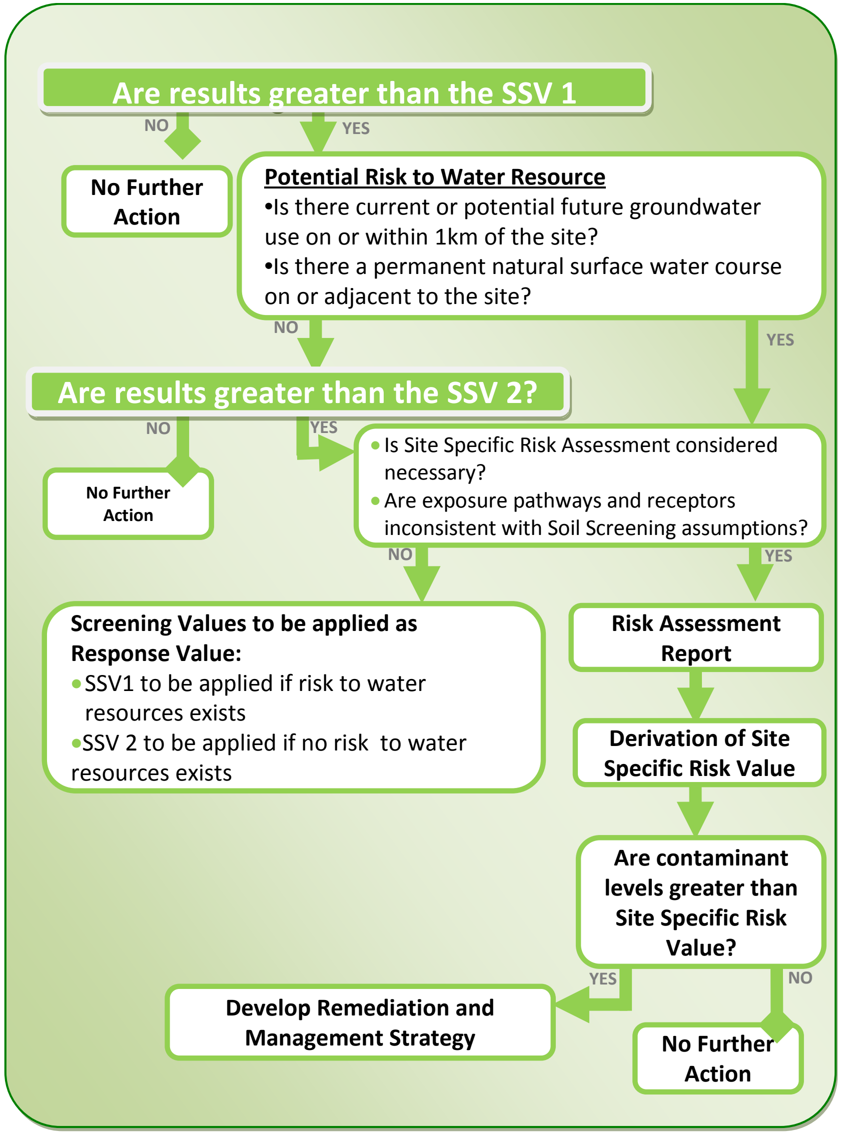
The key questions to be addressed can be summarised as follows:

- Is there risk to groundwater resource?
- Are there groundwater users with 1km of the site?
- Are there surface water bodies that could be impacted by off-site migration.

If no, then protection of human health via direct exposure criteria will apply.

The 1km radius for the influence of contaminated land on groundwater users is a default value normally requested as a minimum requirement by Department of Water Affairs for conducting hydrocensus studies on sites where groundwater contamination is suspected, it does not imply that no risk to receptors occurs outside the 1km zone, but that in general the assumption of short term acceptable risk would apply unless there was a very large and mobile source of contamination on a site

Figure 2: Diagramatic decision-tree for assessment of contaminated land



The protocol for the protection of water resources requires further comment on conceptual assumptions and this is included in Section 2.2.

If water resource protection is identified in the initial step of the protocol then the assessment criteria for groundwater protection need to applied as the remediation objective throughout the assessment protocol into the site specific risk assessment phase and the lowest of the assessment screening values shall be adopted as the target value for assessing soil quality and the requirements for remediation.

If no risk to the water resource can be identified then soil contaminants levels should be compared to Soil Screening Values 2. Soil Screening Value 2 has three sub-categories which are based on risk to receptors which are defined by activity patterns and associated exposure related to land use. There are two values derived for residential land use and development. The most sensitive is the child receptor taken as the sensitive receptor for informal settlements, the exposure levels for the child on a standard residential development define a slightly higher level of contaminant concentration. Commercial and Industrial land use is defined by exposure criteria for an adult maintenance work based on outdoor exposure criteria. If the values are less than the most appropriate of the three categories of Soil Screening Level 2 then the site is not a risk to human health and is not defined as being contaminated.

If soil contaminant concentrations are higher than the SSV2 criteria then the decision can be made to either proceed to a site specific risk assessment to define acceptable risk levels based on a detailed assessment of the linkage between source-pathway-receptor or a decision can be made to adopt the SSV2 concentrations as remediation target values for development of a remediation plan. For the either the SSV1 or SSV2 values to be promoted as remediation target values it is important that the assumptions used in their derivation are broadly consistent to the site conditions. When setting remediation target values it is also important to consider the site-specific potential for ecological and aesthetic impacts not implicit in the calculation of soil screening values and amend the risk assessment and remediation objectives accordingly.

3.2 WATER RESOURCE SENSITIVITY AND PROTECTION

The initial stage of risk assessment for contaminated land requires a decision on the sensitivity of surface water and groundwater resources with respect to land-based contamination sources. In general the groundwater pathway is most likely to be impacted by contaminants in soil particularly if the contaminants are in a liquid form or easily mobilised by infiltration and leaching processes. However there are many geological environments in South Africa where groundwater quantity or quality is not sufficient to be considered to be viable water resource, and thus the protection of water resource quality would not always be a key criteria in assessing contamination risk and setting of soil screening values, ie excessive caution and resultant costs are involved in the protection of receptors that do not exist or for pathways that are closed to contaminant migration. If the groundwater conditions on site are unknown it is advisable that a precautionary approach is followed and that the groundwater pathway is considered to be a relevant exposure route and that drinking water quality should be a point of compliance for risk assessment until proven conclusively to be otherwise.

The approach below assumes that a sound conceptual understanding of the relationship between the soil conditions and groundwater-surface water interactions is established and can be supported wherever possible with factual information from boreholes and trial pits. Key questions that need to be addressed are as follows:

- Is there current or potential groundwater use on the contaminated site or within the likely groundwater migration pathway of the site?
- Is there a surface water course on, or adjacent to the site?
- Where a water resource classification has been applied to the local area assess the qualitative sensitivity of the water resources to pollution risk.

Local user requirements and quality of life considerations together with contaminant transfer risk will determine aquifer status in terms of resource protection. The sole source aquifer is the term used to define domestic potable groundwater wells where despite low yield or marginal water quality the available groundwater resource is adequate to support the water needs of a single domestic dwelling and critically the pathway for contaminant exposure is regarded as inevitable and must be assessed in any risk assessment for protection of human health.

It should be remembered that the assessment of contamination risk to groundwater and surface water is based on establishing whether or not an exposure pathway exists and that a human or ecological receptor can be affected. It therefore does not require the application of complex resource related designations or classifications rather a broad conceptual understanding based on conservation assumptions.

4 Reporting Norms and Standards for Contaminated Land

4.1 COMPLIANCE WITH SECTION 37 OF THE WASTE ACT

Section 37 deals with the consequences of identification and notification of investigation areas. The aim is to investigate whether the land has been contaminated, and if contamination has occurred whether the contamination presents a significant risk of harm.

37 (2) (a) A site assessment report must comply with any directions that may have been published or given by the Minister or MEC in a notice contemplated in section 36 (1) or (6) and must at least include information on whether the investigation area is contaminated.

(b) Where the findings of the site assessment report are that the investigation area is contaminated, the site assessment report must at least contain information on whether-

(i) the contamination has impacted on the environment;

(ii) the substances present in or on the land are toxic, persistent or bioaccumulative or are in large quantities or high concentrations or occur in combinations;

(iii) there are exposure pathways available to the substances;

(iv) the uses of the land and land adjoining increases or is likely to increase the risk to health or the environment;

(v) the substances have migrated or are likely to migrate from the land;

(vi) the acceptable exposure for human and environmental receptors in that environment have been exceeded

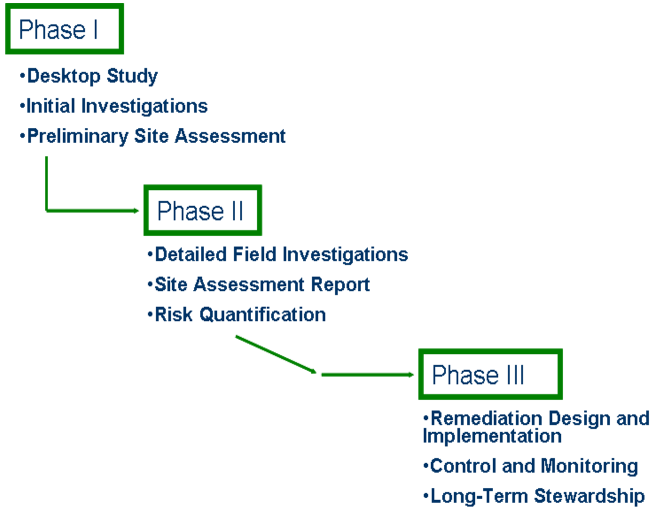
(vii) any applicable standards have been exceeded: and

(viii) the area should be remediate or any other measures should be taken to manage or neutralise the risk.

To provide a clear and consistent application of Section 37 of the Waste Act a reporting structure for contaminated land has been developed. The commonly encountered international practice consists of three distinct reporting phases and progresses from Phase 1 desktop and site walkover assessments with limited investigation and testing to a Phase 2 detailed invasive investigation and testing for site characterisation to a comprehensive Phase 3 report with a risk assessment and evaluation of remediation objectives and a proposed remediation plan.

The reporting system requires norms and standards of practice to be strictly applied but also must retain flexibility to allow for decisions on the contaminated status of sites to be made in a cost effective manner and in a reasonable timeframe. Urgent priority works may require that the phased approach to reporting has to move forward in a concurrent single report.

Figure 3: A phased approach for the assessment and remediation of contaminated land



4.2 REQUIREMENTS FOR PRELIMINARY SITE EVALUATION – PHASE 1 CONTAMINATED SITE ASSESSMENTS

A preliminary site evaluation must consider the following elements:

- Site description – location and size
- Nature and extent of contamination, contaminants of concern or historical activities that may be sources of contamination. List all past and present activities at the site that involved the storage, production, use, treatment or disposal of hazardous materials that could contaminate the site.
- Describe the current condition of the site and the contents and results of any previous assessment reports.
- Local topography and geology, drainage, surface cover, vegetation
- Status of groundwater, approximate depth to water table
- Proximity to surface water
- Proximity to drinking water supplies
- Annual rainfall and flood potential
- Land and water use for the site and nearby areas
- Any other requirements as Regulated by the Minister under Section 69 (u) and (v) of the Waste Act.

The reporting format has been developed in the form of a uniform checklist that can be used for all applications to the Department of Environmental Affairs, see Table 1.

All data may not be available, or data may vary in terms of uncertainty, it is thus important to recognise gaps in the knowledge base and to decide whether additional data must be obtained on the site characterisation. This may trigger the commencement of Phase 2 Investigations.

The Phase 1 report must make clear recommendations on the status of the contamination risk posed by the site. If a complete site history clearly demonstrates that the site activities do not pose a contamination threat then no further investigation is warranted and the site should be recommended as suitable for re-use. In most cases it is likely that some level of preliminary investigation will be required to provide the level of certainty required to enable property re-development or transfer in compliance with the Waste Act. This type of limited investigation of soil and groundwater is already common practice for certain industries in South Africa and is thus reflected in the norms and standards approach.

Table 1: Advisory Notes for Phase 1 Contaminated Land Site Assessment Reports

Site identification

- Street number, street name, suburb and town/city
- Contact details of owners and occupiers of the site.
- Legal description with lot, deposited plan and certificate of title number(s)
- Geographic co-ordinates irrespective of the size of the facility
- Current site plan with scale bar showing north direction, local water drainage and other locally significant features on-site and immediately off-site. The plan should also show the historical location of structures that may have affected the distribution of contamination (e.g. building, underground storage tanks, treatment baths, etc)
- Locality map

Site history

- Chronological list of site ownership and uses, indicating information gaps, unoccupied periods and, if relevant, proposed uses
- An outline of those contaminants commonly associated with each land use based on site-specific information
- Zoning – previous, present and, if relevant, proposed, with summary of reasons for changes to zoning that have occurred
- Details of relevant building and related permits, licences, resource consents, approvals and trade waste agreements, with records of compliance
- Local usage of ground and surface water resources, including presence, rate and location of abstractions (current and historical)
- Site layout plans showing present and past industrial processes
- Sewer and services plans identifying active and abandoned services
- Historical uses of adjacent land
- Relevant complaint history
- Local knowledge of site by staff and residents – present and former
- Summary of literature relating to the site
- Review of aerial and site photography with date and location (including direction of photography) indicated on site maps
- Description of manufacturing processes
- Inventory of materials and waste products associated with site use and their on-site storage and/or disposal locations
- Details and locations of current and former underground and aboveground storage tanks, with details of integrity testing
- Product spill and loss history
- Recorded discharges to land, water and air (authorised and unauthorised)
- On-site and off-site disposal locations
- Contaminant source areas and pathways on-site and off-site
- Assessment of the accuracy of the information

Site condition and surrounding environment

- Topography and site map
- Condition of buildings and roadways
- Presence of drums, wastes and fill materials
- Odours
- Visual or quantified details of surface water quality
- Flood potential described or mapped
- Conditions at site boundary such as type and conditioning of fencing , soil stability, erosion, and stormwater discharge
- Visible signs of contamination, such as identifiable waste products, discoloration or staining of soil, bare soil patches – on-site and at site boundary
- Visible signs of plant stress
- Details of any relevant local sensitive environments – rivers, streams, lakes, wetlands, local habitat areas, sensitive flora and fauna

Geology and hydrology

- Background groundwater and surface water quality
- Summary of local rainfall and meteorology
- Summary of all previous relevant information related to soils, geology, groundwater and hydrology of the site and neighbouring areas.
- Regional geological and hydrogeological context
- Likely soil types and depth to bedrock
- Anticipated depth to water table.
- Sensitivity of aquifers and surface water to contaminants
- Likely geological pathways for contaminant migration.

Phase 1 Preliminary Site Assessment

Reports must make clear statements with respect to the status of contamination of the site and satisfy the following requirements of the Waste Act:

- State whether or not the area should be investigated further or remediated immediately or whether any other measures should be taken to manage or neutralise the risk.
- Alternatively if all the information available in conformance with the checklist for Phase1 Reporting leads to the conclusion that the site poses no risk to human health or the environment the proponent should motivate in writing that the site is not a contaminated site and obtain approval and confirmation on the contaminated status of the site from the Department of Environmental Affairs.

4.3 SITE CHARACTERISATION – PHASE 2 CONTAMINATED SITE INVESTIGATIONS

Phase 2 investigations include the sampling and analysis of soil, sediment, groundwater and surface water. It is stressed that the adequacy of the investigation must be related to site specific conditions and is a natural progression from the Phase 1 Site Assessment. It is thus a focussed and designed programme of investigation and reporting.

The Phase 2 reporting must give information on:

- the type, extent and level of contamination anticipated on site and the issues raised in previous reports.
- the nature of samples collected, the sampling procedures followed, including field sampling quality assurance and quality control requirements.
- the analyses undertaken, methodologies used and laboratory quality assurance-quality control procedures, with laboratory certificates and appropriate accreditation listed.
- the actual extent and concentrations in all appropriate environmental media on site based on verified test data.
- any likely dispersal in air, surface water, groundwater, soil and dust from the detected contaminants
- any potential effects of contaminants on human health, the environment, or building structures and property.

Phase 2 Site Assessment Reports must list the results of chemical analyses of soils obtained against the Soil Screening Values listed in Section 4 of the Framework and clearly demonstrate that the selection of guideline values is consistent with the principles of Framework for the Management of Contaminated Land, together with all assumptions and limitations of soil screening values used.

Phase 2 Site Assessment Reports must comply with any other regulations in terms of Site Assessment Reports as Regulated by the Minister under Section 69 (u) and (v) of the Waste Act.

The report must make a clear statement regards the adequacy and completeness of all information used in the assessment and list any further studies or investigations that may be required to verify the status of the site and the risks posed.

The findings of the report must satisfy the requirements of Section 37 of the Waste Act as well as any other regulations in terms of Site Assessment Reports as Regulated by the Minister under Section 69 (u) and (v) of the Waste Act and determine and state whether or not the following triggering clauses have been breached:

A site assessment report must comply with any directions that may have been published or given by the Minister or MEC in a notice contemplated in section 36 (1) or (6) and must at least include information on whether the investigation area is contaminated.

(b) Where the findings of the site assessment report are that the investigation area is contaminated, the site assessment report must at least contain information on whether-

(i) the contamination has impacted on the environment;

(ii) the substances present in or on the land are toxic, persistent or bioaccumulative or are in large quantities or high concentrations or occur in combinations;

(iii) there are exposure pathways available to the substances;

(iv) the uses of the land and land adjoining increases or is likely to increase the risk to health or the environment;

(v) the substances have migrated or are likely to migrate from the land;

(vi) the acceptable exposure for human and environmental receptors in that environment have been exceeded

(vii) any applicable standards have been exceeded: and

(viii) the area should be remediate or any other measures should be taken to manage or neutralise the risk.

The report must reach a conclusion as to whether the site requires urgent clean-up, remediation measures over a period of time, the application of management measures, on-going monitoring or a combination thereof.

Report recommendations should be made to inform the regulatory status of contamination as required under Section 38 (1) of the Waste Act:

(a) the investigation area is contaminated, presents a risk to health or the environment, and must be remediated urgently.

(b) the investigation area is contaminated, presents a risk to health or the environment and must be remediated within a specified period:

(c) the investigation area is contaminated and does not present an immediate risk, but that measures are required to address the monitoring and management of that risk,

or

(d) the investigation area is not contaminated

Table 2: Advisory for Phase 2 Contaminated Land Site Assessment Reports

Summary of Phase 1 Reporting

Basic site information as compiled for Phase 1 should be summarised and referenced together with the conclusions of the Preliminary Site Assessment that triggered the detailed Site Characterisation.

Investigation of site geology and hydrology

- Detailed map and description of location, design and construction of on-site wells, boreholes and pits
- Site borehole / test pit logs showing stratigraphy, depth to underground water table
- Reported range of water table depths below ground surface
- Description and location of springs and wells in the vicinity
- Location, depth and extent of imported and locally derived fill
- Direction(s) and rate of groundwater flow including, where applicable, groundwater levels surveyed to a common datum
- Direction(s) of surface water run-off and identification of ponding areas
- Preferential flow paths (surface and groundwater)

Sampling and analysis plan and sampling methodology

- Sampling and analysis data quality objectives
- Rationale for the selection of:
  - sampling pattern, locations and depths (as shown on site maps)
  - sampling density, including estimated size of the residual hotspots that may remain undetected and statistical confidence in the estimate
  - which samples are/were submitted for analysis and which samples are/were not analysed
  - the analytes for each sample and the analytical methods used
- Detailed description of the sampling methods including:
  - sampling devices and equipment type
  - sampling containers and the type of seal used
  - sample preservation methods and reference to recognised protocols
  - sample handling procedures
  - equipment decontamination procedures
- Detailed description of any field-screening protocols, methods and equipment, and their calibration

Field quality assurance and quality control (QA/QC)

- Details of the sampling team, identifying unique initials for each member
- Statement of intended duplicate and blank frequency
- Records for each sample collected, including date, time and location, samplers' initials, duplicate/blank location and type, analyses to be performed, site observations and weather conditions
- Chain of custody, identifying for each sample: sampler, nature of the sample, collection date, analysis to be performed, sample preservation method, departure time from site, dispatch courier used
- Background sample, field blank, trip blank, and rinsate sample results and laboratory-prepared trip spike results for volatile analytes
- Decontamination procedures carried out between sampling events
- Sample-splitting techniques and field instrument calibrations (where used)

Laboratory QA/QC

- All samples should be sent to a properly accredited laboratory for testing
- Signed laboratory receipt of signed chain of custody form identifying date/time of receipt and identity of samples included in shipment
- Record of holding times, where not consistent with method specifications
- Analytical methods used by laboratory and laboratory accreditation for analytical methods used
- Inter-laboratory comparisons for analytical methods used (where available)
- Description of spikes and surrogates used, with percent recoveries
- Instrument, method detection and practical quantification limits
- Standard solution, reference sample and check sample (including daily) results
- Laboratory duplicate, blank and standard results
- Signed laboratory certificates of analysis

Results

- Summary of previous results (where applicable)
- Site plan(s) showing all samples and sampling locations, giving sample identification numbers and sample depth
- Summary of all results in tabular form:
  - identifying essential details such as sample identification numbers and sample depth
  - showing comparison with relevant guideline values
  - highlighting every result exceeding the guideline values
- A summary table of results containing the following statistics: minimum, maximum, arithmetic average and 95% upper confidence limit on the arithmetic average for each analyte
- Site plan showing the extent of soil and/or groundwater contamination exceeding the relevant guideline values for the medium, location and sample depth

Site characterization

- Assessment of the type of all environmental contamination, particularly in soil and groundwater
- Assessment of the extent of soil and groundwater contamination, including identifiable off-site contamination that may cause environmental effects
- Assessment of the potential for chemical degradation or interaction products
- Assessment of possible exposure routes and risk to exposed populations (human and ecological risk)

Report Recommendations – Status of Contamination Risk

The report must reach a conclusion as to whether the site requires urgent clean-up, remediation measures over a period of time, the application of management measures, on-going monitoring or a combination thereof.

Alternatively if all the information available in conformance with the checklist for Phase2 Reporting and Soil Screening Values arrived at by either comparison with the Soil Screening Values in Section 4 of the Framework, or contaminant concentrations calculated on the basis of site specific acceptable risk, leads to the conclusion that the site poses no risk to human health or the environment the proponent should motivate in writing that the site is not a contaminated site and obtain approval and confirmation on the contaminated status of the site from the Department of Environmental Affairs.

4.4 PHASE 3 REMEDIATION PLANS

The establishment of a final soil remediation objective for site clean-up must take consideration of technical feasibility, and overall risk management strategies throughout the remediation process and not simply the end point of the remediation process. All risk-based management decisions should be fully documented and justified.

The site remediation plan should be prepared as follows:

- Set remediation or management objectives that ensure the site will be suitable for its current or future proposed land-use and will pose no unacceptable risk to human health or the environment, either on-site or off-site.
- Document in detail all procedures to be adopted to achieve the remediation objective. Establish safeguards and contingency measures for safe implementation of all remediation activities.
- Establish a record of activities that ensures compliance with the approved remediation action plan.
- Obtain the relevant approvals, permits or licenses required by regulatory authorities to undertake the proposed remediation activities in terms of Section 20(b) of the Waste Act.

Table 3: Advisory for Phase 3 Contaminated Land Remediation Plans

Remedial actions

For large projects with complex remediation activities and a detailed Remediation Plan should be submitted as a stand alone document with a dedicated Operational and Environmental Management Plan. Reporting to include the following:

- Remediation objectives
- Discussion of the remedial options available, assessment of alternatives including the status quo, identifying the means of risk reduction proposed in each
- Rationale for selection of the recommended remedial option
- Discussion of the remediation required to achieve the remedial objectives
- Risk assessment of proposed remediation activities and mitigatory measures required to minimize environmental hazards and impacts during remediation.
- Identification of regulatory requirements such as permits, licences and approvals
- Proposed monitoring and testing to validate the site during and on completion of the remedial activities

Contingency plan if remedial strategy fails to reach the remediation objectives.

Remediation plans require approval under Section 20(b) of the Waste Act before any activities other than emergency activities can be instigated.

5 Determination of Preliminary Soil Screening Levels for Assessment of Contaminated Land and Protection of the Water Resource

5.1 METHODOLOGY FOR DERIVING SOIL SCREENING LEVELS

Numerical criteria for priority contaminants of concern have been determined so that they can be used to define appropriate management actions. The numerical values will serve as initial points of site assessment for authorisation of remediation activities and can be applied with discretion:

- as conservative clean-up targets
- to inform management actions to reduce the potential for adverse effects
- to trigger further investigations to determine site specific risk-based criteria

Consequences of not doing this is to have continuing uncertainty about the most appropriate criteria and method to apply in the assessment of contaminated land, and as a result conflict on the definition of a contaminated site and requirements for statutory remediation orders.

It is acknowledged that although the use of soil screening values is common in international practice, the derivation of such values is a complex process and depends on the acceptability of certain scientific assumptions used in the development of standard equations used to model risk. Although there is broad consensus internationally on the concepts of risk assessment the detailed methodology applied is based on expert judgement and is not a precise science.

The development of soil screening values to protect human health via direct exposures routes and indirect exposure routes is the key starting point. The incorporation of ecotoxicological criteria for water resource protection can be achieved. It may however be difficult to assess the ecological impact of contaminated soils at a simple generic level and this is perhaps an issue that is best resolved by site specific risk assessment.

The Waste Act and National Environmental Management Act require land to be investigated if hazardous substances are likely to have been used in or on the land. Change of land-use for future development and property transfer are triggering clauses for environmental authorisations. Investigations are thus required to assess the presence and quantify the risk posed by any hazardous substances on or in the land.

Risk assessment criteria are thus dependant on the activity patterns of human receptors associated with particular land use categories.

The land use categories for use in development of Soil Screeing Values are:

- Residential and Urban Parkland
- Informal residential settlement
- Commercial/Industrial

The land use categories are based on well documented receptor activity patterns and are not directly applicable to spatial development land use planning without applying sound judgement. For example a mixed use development would be regarded as a residential area for the purposes for determining the status of contaminated land and any remediation objectives that may be required to enable the change of land use.

Residential and Urban Parkland: sites where the primary land use is residential with formal housing and associated public open spaces for recreational use.

Informal residential settlements: sites without formal housing, where open ground has been settled without the construction of roads and paved areas of hard standing and where houses may not have concrete floor slabs.

Commercial/Industrial Commercial sites where the primary activity is related to commercial operations and occupancy is not for residential purposes. Offices and shopping malls are examples of Commercial land use. Industrial settings include sites where the primary activity involves the production, manufacture, construction, or assembly of goods.

For the purposes of deriving Soil Screening Values the receptor for commercial and industrial land use is assumed to be an adult outdoor maintenance worker. Although this receptor is likely to be a minority receptor in the population group as a whole the exposure criteria will represent a conservative scenario and can be assumed to be protective of human health except under extreme and unusual conditions. For human receptors that spend the majority of time indoors in commercial properties the values will tend to be an over-conservative assessment of exposure.

It is important to consider adjoining land use in terms of defining the appropriate soil quality guideline as the migration of contaminants may contaminate surrounding areas with more susceptible land uses. For example the off-site migration of dust from remediated commercial/industrial sites should not pose any unacceptable risk to nearby residential sites.

5.2 CONCEPTUAL APPROACH FOR DERIVATION AND USE OF SOIL SCREENING VALUES

The conceptual approach for derivation of soil screening values is based on original US EPA methodologies along with consideration of more recent derivatives, particularly the Canadian Environmental Quality Guidelines. Key assumptions for South Africa are related to the groundwater pathway with typical rainfall, infiltration and recharge considerations applied. In addition the human health exposure criteria have been revised to take into account the activity patterns and increased risk of residents of informal settlements. This sensitive population group is very significant in Southern Africa and has been previously overlooked in the application of risk-based health assessments in the past.

The use of existing published Department of Water Affairs water quality guidelines as the target for water quality used in the equations is to create internal harmonisation and is not an indication of our unequivocal acceptance of their scientific validity. As the derived screening values for protection of the water resource are based on a back calculation from a desired concentration in the receiving body of water, the soil screening values can be modified to be consistent with specific water quality objectives derived for individual catchments on the basis of an integrated water resource management approach that is flexible and adaptable to user needs.

The calculations used for derivation of Soil Screening Values are not intended to provide a stand alone series of regulatory standards for deriving clean-up targets. The use of site specific quantitative risk assessment within an overall framework of holistic risk assessment that is ethically based and takes into consideration societal values and practical implementation is advised.

The Soil Screening Values can be considered conservative under a broad range of assumptions, however, it must be accepted that there are exposure scenarios that may not be adequately addressed by these screening values. The use of the Soil Screening Values as an indication of a 'safe' or 'clean' site is thus only valid in the absence of a specific risk exposure scenario not covered in the generic equations (for example, the screening lists are not fully protective of soil biota).

Soil Screening Values are not:

- Default Remediation Standards
- Applicable to every site under all circumstances
- Absolute minimum values
- Screening values applicable to occupational exposures
- Applicable to risk of property damage
- Valid unless the assumptions inherent in the Soil Screening Values are broadly consistent with the actual site conditions
- A substitute for a thorough conceptual and qualitative understanding of a site's condition and the risks it might pose to human health and the environment.

Equations for the deriving the levels and input parameters are discussed in Section 4.3.

5.3 TECHNICAL BASIS FOR CALCULATION OF SOIL SCREENING VALUES

5.3.1 Protection of Human Health

Exposure Routes

Soil Screening Values were calculated by determining dosages associated with the following direct exposure routes:

- Soil Ingestion
- Dermal Contact
- Particulate Inhalation
- Volatile Inhalation

Exposure Parameters

Exposure parameters used for dosage calculations are summarised below.

Exposure parameters for both forms of residential land-use were based on a child as the most sensitive receptor whilst commercial/industrial land-use was based on adult exposure for an outdoor maintenance worker. Although a minority receptor within the overall population, the outdoor maintenance worker is representative of an important sensitive receptor for South Africa.

Exposures for the child receptor under informal residential land-use were modified to account for increased dermal contact, ingestion and dust inhalation. The modifications represent preliminary estimates in the absence of specific studies and data on activity patterns and exposures for informal residential land-use settings in South Africa.

Table 4: Input parameters for derivation of Soil Screening Values based on protection of human health (threshold substances)

Parameter			Standard Residential	Informal Residential	Commercial/ Industrial
Description	Symbol	Unit	child	child	adult
Body Weight	BW	kg	15	15	70
Averaging Time	AT	days	2190	2190	10950
Exposure Frequency	EF	days/yr	365	365	250
Exposure Duration	ED	yrs	6	6	30
Ingestion Rate (soil)	IR_s	mg/day	200	400	100
GI absorption factor	GI	-		chemical specific*	
Surface Area Exposed Skin	SA	cm^2	2100	4200	13110
Soil to Skin Adherence Factor	AF	$mg/cm^2/day$	0.2	0.2	0.07
Dermal Absorption Factor	ABS_i	-		chemical specific*	
Inhalation Rate (air)	IR_a	m^3/day	10	10	10.4
Particulate Emission Factor	PEF	m^3/kg	1.30E+09**	7.25E+08**	3.22E+08**
Soil to Air Volatilisation Factor	VF	m^3/kg		chemical specific*	

* Refer Appendix B for chemical specific data

** Refer Appendix B for further detail on PEF

Table 5: Input parameters for derivation of Soil Screening Values based on protection of human health (non-threshold substances)

Parameter			Standard Residential	Informal Residential	Commercial/ Industrial
Description	Symbol	Unit	adult	adult	adult
Body Weight	BW	kg	70	70	70
Averaging Time	AT	days	25550	25550	25550
Exposure Frequency	EF	days/yr	365	365	250
Exposure Duration	ED	yrs	70	70	30
Ingestion Rate (soil)	IR_s	mg/day	100	200	100
GI absorption factor	GI	-		chemical specific*	
Surface Area Exposed Skin	SA	cm^2	5800	11600	13110
Soil to Skin Adherence Factor	AF	$mg/cm^2/day$	0.07	0.07	0.07
Dermal Absorption Factor	ABS_i	-		chemical specific*	
Inhalation Rate (air)	IR_a	m^3/day	20	20	10.4
Particulate Emission Factor	PEF	m^3/kg	1.30E+09**	7.25E+08**	3.22E+08**
Soil to Air Volatilisation Factor (indoor and outdoor)	$VF_{i/o}$	m^3/kg		chemical specific**	

* Refer Appendix B for chemical specific data

** Refer Appendix B for further detail on PEF

Toxicological Parameters

Reference dosages (RfD) and Slope Factors (SF) for threshold and non-threshold effects for each exposure route were sourced from internationally reviewed databases and were considered at the time of writing to be scientifically defensible and are summarised below.

Table 6: Reference Doses and Slope Factors – Metals and Metalloids

	RfD_o (mg/kg-day)	RfD_i (mg/kg-day)	RfD_d* (mg/kg-day)	SF_o 1/(mg/kg/day)	SF_i 1/(mg/kg/day)	SF_d 1/(mg/kg/day)
As	3.00E-04	-	3.00E-04	1.50E+00	1.50E+01	-
Cd	5.00E-04	-	5.00E-04	-	6.30E+00	-
Cr(III)	1.50E+00	-	1.50E+00	-	-	-
Cr(VI)	3.00E-03	2.20E-06	3.00E-03	5.00E-01	2.90E+02	-
Co	1.00E-02	2.86E-05	1.00E-02	-	-	-
Cu	3.70E-02	-	3.70E-02	-	-	-
Pb	3.60E-03	-	3.60E-03	-	-	-
Zn	3.00E-01	-	3.00E-01	-	-	-
Ni	2.00E-02	-	2.00E-02	-	8.40E-01	-
Mn	2.40E-02	1.43E-03	2.40E-02	-	-	-
Hg	3.00E-04	8.60E-05	3.00E-04	-	-	-
V	5.04E-03	-	5.04E-03	-	-	-

Notes:

- no accepted value available.

* Note: RfDd is assumed to be same as RfDo

Table 7: Reference Doses and Slope Factors – Petroleum Organics

	RfD_o (mg/kg-day)	RfD_i (mg/kg-day)	RfD_d* (mg/kg-day)	SF_o 1/(mg/kg/day)	SF_i 1/(mg/kg/day)	SF_d 1/(mg/kg/day)
Alkanes*						
C7-C9	5	5	5	-	-	-
C10-C14	0.1	0.1	0.1	-	-	-
C15-C36	1.5	1.5	1.5	-	-	-
MAH's						
Benzene	-	-	-	0.029	0.029	0.029
Toluene	0.2	0.11	0.2	-	-	-
Ethylbenzene	0.1	0.029	0.1	-	-	-
Xylene	2	0.09	2	-	-	-
Aromatic						
Naphthalene	0.004	0.004	0.004	-	-	-
Pyrene	0.03	0.03	0.03	-	-	-
Benzo(a)pyrene	-	-	-	7.3	7.3	7.3

* Note: RfDd is set to same as RfDo
** Data sourced from TPHCWG

Table 8: Reference Doses and Slope Factors – Non Petroleum Organics

	RfD_o (mg/kg-day)	RfD_i (mg/kg-day)	RfD_d* (mg/kg-day)	SF_o 1/(mg/kg/day)	SF_i 1/(mg/kg/day)	SF_d 1/(mg/kg/day)
MTBE	-	8.57E-01	-	-	-	-
Carbon Tetrachloride	7.00E-04	-	7.00E-04	1.30E-01	5.25E-02	-
Chlorobenzene	2.00E-02	-	2.00E-02	-	-	-
Chloroform	1.00E-02	-	1.00E-02	-	8.05E-02	-
2 Chlorophenol	5.00E-03	-	5.00E-03	-	-	-
1,2 Dichlorobenzene	9.00E-02	-	9.00E-02	-	-	-
1,4-Dichlorobenzene	-	2.29E-01	-	-	-	-
1,2-Dichloroethane	-	-	-	9.10E-02	9.10E-02	-
1,1 Dichloroethene	5.00E-02	5.71E-02	5.00E-02	-	-	-
1,2 Dichloroethene	2.00E-02	-	2.00E-02	-	-	-
Trichlorobenzenes (total)	1.00E-02	-	1.00E-02	-	-	-
Nitrobenzene	2.00E-03	2.57E-03	2.00E-03	-	1.40E-01	-
1,1,2,2 Tetrachloroethane	-	-	-	2.00E01	2.03E-01	-
Trichloroethene	-		-	-	-	-
2,4,6-Trichlorophenol	-	-	-	1.10E-02	1.09E-02	-
Vinyl Chloride	3.00E-03	2.86E-02	3.00E-03	1.5E+00	3.08E-02	-

Notes:
- no accepted value available.
* RfDd is assumed to be same as RfDo

Target Risk Level

Acceptable soil values for combined direct exposure dosages were determined based on a Target Risk (TR) of $1.0x10^{-5}$ for non-threshold substances and a Target Hazard Index (THI) of 1 for threshold substances.

Calculation Method

Soil values for threshold and non-threshold effects were calculated using the equations provided below.

Equation 1: SSV Threshold Contaminants (metals and metalloids)

$$SSV(mg/kg) = \frac{THI \times BW \times AT}{\left[EF \times ED \times \left(\left(\left(\frac{1}{RfD_0}\right) \times 10^{-6} \times IR_s \times GI\right) + \left(\left(\frac{1}{RfD_i}\right) \times IR_a \times \left(\frac{1}{PEF} + \frac{1}{VF}\right)\right) + \left(\left(\frac{1}{RfD_d}\right) \times SA \times AF \times ABS \times 10^{-6}\right)\right)\right]}$$

Equation 2: SSV Threshold Contaminants (Petroleum and Non-petroleum Organics)

$$SSV(mg/kg) = \frac{THI \times BW \times AT}{\left[\left(EF \times ED \times \left(\frac{1}{RfD_0}\right) \times 10^{-6} \times IR_s \times GI\right) + \left(\left(\frac{1}{RfD_i}\right) \times \left(\left(IR_a \times \frac{1}{PEF}\right) + \left(\frac{IR_a}{2} \times \left(\frac{1}{VF_i} + \frac{1}{VF_0}\right)\right)\right)\right) + \left(\left(\frac{1}{RfD_d}\right) \times SA \times AF \times ABS \times 10^{-6}\right)\right]}$$

Equation 3: SSV Non-Threshold Contaminants (Metals and Metalloids)

$$SSV(mg/kg) = \frac{TR \times BW \times AT}{\left[EF \times ED \times \left(\left(SF_0 \times 10^{-6} \times IR_s \times GI\right) + \left(SF_a \times IR_a \times \left(\frac{1}{PEF} + \frac{1}{VF}\right)\right) + \left(SF_d \times SA \times AF \times ABS \times 10^{-6}\right)\right)\right]}$$

Equation 4: SSV Non-Threshold Contaminants (Petroleum and Non-petroleum Organics)

$$SSV(mg/kg) = \frac{TR \times BW \times AT}{\left[EF \times ED \times \left(\left(SF_0 \times 10^{-6} \times IR_s \right) + \left(SF_a \times \left(\left(IR_a \times \frac{1}{PEF} \right) + \left(\frac{IR_a}{2} \times \left(\frac{1}{VF_1} + \frac{1}{VF_0} \right) \right) \right) \right) + \left(SF_d \times SA \times AF \times ABS \times 10^{-6} \right) \right)\right]}$$

Where:

SSV	=	Soil Screening Value
THI	=	Target Hazard Index
TR	=	Target Risk
BW	=	Body Weight
AT	=	Averaging Time
EF	=	Exposure Frequency
ED	=	Exposure Duration
RfDo	=	Reference Dosage (Oral)
RfDi	=	Reference Dosage (Inhalation)
RfDd	=	Reference Dosage (Dermal)
SFo	=	Slope Factor (Oral)
SFa	=	Slope Factor (Air)
SFd	=	Slope Factor (Dermal)
IRs	=	Ingestion Rate (Soil)
IRa	=	Ingestion Rate (Air)
GI	=	GI Absorption Factor
PEF	=	Particulate Emission Factor
VF	=	Volatilisation Factor
SA	=	Surface Area of Exposed Skin
AF	=	Skin Adherence Factor
ABS	=	Dermal Absorption Factor

The lowest soil value for threshold and non-threshold effects was selected as the Soil Screening Value for each land-use and parameter as summarised below.

Table 9: Summary of Soil Screening Values for each land-use

Parameter	Units	Land Use		
		Informal Residential	Standard Residential	Commercial/ Industrial
Metals and metalloids				
Arsenic	mg/kg	20	45	150
Cadmium	mg/kg	15	30	260
Chromium (III)	mg/kg	46 000	95 000	800 000
Chromium (VI)	mg/kg	6	13	40
Cobalt	mg/kg	300	640	5000
Copper	mg/kg	1140	2400	19 500
Lead	mg/kg	110	230	1900
Manganese	mg/kg	740	1550	12 750
Mercury	mg/kg	9	19	160
Nickel	mg/kg	620	1290	10 600
Vanadium	mg/kg	155	310	2680
Zinc	mg/kg	9300	19 400	160 000
Petroleum Organics				
Alkanes				
C7-C9	mg/kg	2350	2370	23000
C10-C14	mg/kg	440	480	4400
C15-C36	mg/kg	45000	87000	700000
MAHs				
Benzene	mg/kg	1.3	1.3	10
Toluene	mg/kg	110	110	1150
Ethylbenzene	mg/kg	55	55	540
Xylenes	mg/kg	90	90	890
Aromatics	mg/kg			
Naphthalene	mg/kg	30	30	290
Pyrene	mg/kg	920	1800	15000
Benzo(a)pyrene	mg/kg	0.3	0.6	1.7

Parameter	Units	Land Use		
		Informal Residential	Standard Residential	Commercial/ Industrial
Non-Petroleum Organics				
MTBE	mg/kg	350	350	5740
Carbon Tetrachloride	mg/kg	0.26	0.26	4.0
Chlorobenzene	mg/kg	520	900	8800
Chloroform	mg/kg	0.1	0.1	1.7
2 Chlorophenol	mg/kg	125	210	2100
1,2 Dichlorobenzene	mg/kg	1890	2880	31 900
1,4-Dichlorobenzene	mg/kg	1140	1160	18 400
1,2-Dichloroethane	mg/kg	0.23	0.23	3.7
1,1 Dichloroethene	mg/kg	10	10	150
1,2 Dichloroethene	mg/kg	215	260	3570
Trichlorobenzenes (total)	mg/kg	195	290	3330
Nitrobenzene	mg/kg	2.8	2.8	45
1,1,2,2 Tetrachloroethane	mg/kg	0.3	0.3	5.0
Trichloroethene	mg/kg	710	725	11 600
2,4,6-Trichlorophenol	mg/kg	210	310	1770
Vinyl Chloride	mg/kg	0.1	0.1	1.5
PCBs	mg/kg	1.7	3.5	12
Cyanide	mg/kg	620	1240	10 500

-

5.3.2 Protection of Water Resources

Exposure Routes

Partitioning of contaminants between solid and liquid phases within soils may result in impacts to groundwater or surface water resources and thereby giving rise to potential human health risks (ingestion of contaminated water via the drinking water supply if this from natural untreated surface water or groundwater from boreholes) or the risk of adverse impacts on the aquatic ecosystem. Soil Screening Values that are protective of these potential exposure risks were calculated for protection of human health (ingestion of contaminated water) and aquatic ecosystem health based on a two phase equilibrium partitioning and dilution model.

Partition Coefficients

There is currently insufficient information available to define partition coefficients (K_d values) for specific soil types in South Africa. Partition coefficients were therefore sourced from the international literature, primarily from broad based statistical studies of K_d values undertaken in the US and Canada. The K_d values that were used for calculation purposes were selected based on professional judgement. Neutral (pH 7) soil conditions were assumed. Data used is provided in Appendix B.

Dilution Attenuation Factor

The Dilution Attenuation Factor accounts for the effects of groundwater recharge on dilution and mixing of the 'partitioned' phase. A conservative approach has been followed and thus chemical attenuation has been assumed to be 1 and the DAF simplifies to a dilution factor (DF).

An estimated DF of 20 is assumed for the protection of a drinking water borehole based on transport pathway of 50m from contaminant source to point of compliance. It should be noted that site specific DAF factors may vary from 1 to 10 000. Most commonly encountered productive aquifers tend to have DAF values between 10 and 30.

The above dilution factor does not account for attenuation of contaminants within the saturated zone. It should be noted that it was beyond the scope of these initial calculations to define generic attenuation relationships in the saturated zone. Both dilution and attenuation relationships require detailed research to define appropriate and meaningful values for South African conditions.

For calculation of DAF factors for the protection of aquatic ecosystems it is assumed that groundwater mixes as a baseflow component to a surface water body at a ratio of 1:100 (1% of the volume of the surface water body). The total DAF is thus a factor of 2000 for this pathway allowing for the dilution within the aquifer and then mixing with the surface water body.

Calculation Method

Contaminant soil concentrations were calculated using the following simple equation.

Equation 5: Calculation of Soil Values for Water Resource Protection

$$Y = C_W \times K_d \times DAF$$

$$Y = C_w \times K_d \times DAF$$

Where: Y = total contaminant concentration in soil at equilibrium with pore water at defined water quality standard

C_w = water quality standard (aquatic ecosystem / domestic drinking water use guideline)

K_d = partition coefficient

DAF or DF = dilution attenuation factor

The results of the calculations are provided below. These represent soil values required to achieve DWAF Water Quality Guideline levels for aquatic ecosystem protection and domestic water use, and are consistent both in terms of method of derivation and acceptable risk level applied in development of the existing DWAF Water Quality Guidelines.

Table 10: Summary of Soil Screening Values for protection of water resource

Parameter	Units	Water Resource Protection	
		Protection of Human Health (drinking water usage)	Protection of Ecosystem Health
Metals and metalloids			
Arsenic	mg/kg	5.8	580
Cadmium	mg/kg	8	38
Chromium (III)	mg/kg	n/a	n/a
Chromium (VI)	mg/kg	19	266
Cobalt	mg/kg	6	22 000
Copper	mg/kg	200	16
Lead	mg/kg	20	100
Manganese	mg/kg	3720	245
Mercury	mg/kg	91	1430
Nickel	mg/kg	10000	n/a
Vanadium	mg/kg	1.0	4.16
Zinc	mg/kg	2000	-
Petroleum Organics			
Alkanes			
C7-C9	mg/kg	n/a	-
C10-C14	mg/kg	n/a	-
C15-C36	mg/kg	n/a	-
MAHs			
Benzene	mg/kg	0.03	80
Toluene	mg/kg	25	175
Ethylbenzene	mg/kg	26	1745
Xylenes	mg/kg	45	265
Aromatics	mg/kg		
Naphthalene	mg/kg	-	28
Pyrene	mg/kg	-	5.3
Benzo(a)pyrene	mg/kg	-	285

Parameter	Units	Water Resource Protection	
		Protection of Human Health (drinking water usage)	Protection of Ecosystem Health
Non-Petroleum Organics			
MTBE	mg/kg	0.004	815
Carbon Tetrachloride	mg/kg	0.25	60
Chlorobenzene	mg/kg	-	965
Chloroform	mg/kg	3	11
2 Chlorophenol	mg/kg	-	145
1,2 Dichlorobenzene	mg/kg	89	1410
1,4-Dichlorobenzene	mg/kg	26	520
1,2-Dichloroethane	mg/kg	0.4	2460
1,1 Dichloroethene	mg/kg	1	-
1,2 Dichloroethene	mg/kg	-	18
Trichlorobenzenes (total)	mg/kg	0.07	0.14
Nitrobenzene	mg/kg	-	710
1,1,2,2 Tetrachloroethane	mg/kg	-	190
Trichloroethene	mg/kg	1	
2,4,6-Trichlorophenol	mg/kg	4	-
Vinyl Chloride	mg/kg	0.004	-
PCBs	mg/kg	0.62	n/a
Cyanide	mg/kg	14	20

5.3.3 Soil Screening Values

Two tiers of Soil Screening Value have been defined as follows:

- Soil Screening Value (SSV) 1 represents the lowest value calculated for each parameter from both the Human Health and Water Resource Protection pathways calculations as detailed under the preceding sections. SSV1 values are not land-use specific.
- Soil Screening Value (SSV) 2 represents the land-use specific soil value calculated following the methods as detailed under the preceding sections. SSV2 values are land-use specific and are appropriate for screening level site assessment in cases where protection of water resource is not an applicable pathway for consideration.

Soil Screening Values 1 and 2 are provided below.

Table 11: Soil Screening Values

Parameter	Units	SSV1	SSV2		
		All Land-Uses Protective of the Water Resource	Informal Residential	Standard Residential	Commercial/ Industrial
Metals and metalloids					
Arsenic	mg/kg	5.8	20	45	150
Cadmium	mg/kg	8	15	30	260
Chromium (III)	mg/kg	46 000	46 000	95 000	800 000
Chromium (VI)	mg/kg	6	6	13	40
Cobalt	mg/kg	6	300	640	5000
Copper	mg/kg	16	1140	2400	19 500
Lead	mg/kg	20	110	230	1900
Manganese	mg/kg	245	740	1550	12 750
Mercury	mg/kg	9	9	19	160
Nickel	mg/kg	620	620	1290	10 600
Vanadium	mg/kg	1.0	155	310	2680
Zinc	mg/kg	2000	9300	19 400	160 000
Petroleum Organics					
Alkanes					
C7-C9	mg/kg	2350	2350	2370	23000
C10-C14	mg/kg	440	440	480	4400
C15-C36	mg/kg	45 000	45000	87000	700000

Parameter	Units	SSV1	SSV2		
		All Land-Uses Protective of the Water Resource	Informal Residential	Standard Residential	Commercial/ Industrial
MAHs					
Benzene	mg/kg	0.03	1.3	1.3	10
Toluene	mg/kg	25	110	110	1150
Ethylbenzene	mg/kg	26	55	55	540
Xylenes	mg/kg	45	90	90	890
Aromatics	mg/kg				
Naphthalene	mg/kg	28	30	30	290
Pyrene	mg/kg	5.3	920	1800	15000
Benzo(a)pyrene	mg/kg	0.3	0.3	0.6	1.7
Non-Petroleum Organics					
MTBE	mg/kg	0.004	350	350	5740
Carbon Tetrachloride	mg/kg	0.25	0.26	0.26	4.0
Chlorobenzene	mg/kg	520	520	900	8800
Chloroform	mg/kg	0.1	0.1	0.1	1.7
2 Chlorophenol	mg/kg	125	125	210	2100
1,2 Dichlorobenzene	mg/kg	89	1890	2880	31 900
1,4-Dichlorobenzene	mg/kg	26	1140	1160	18 400
1,2-Dichloroethane	mg/kg	0.23	0.23	0.23	3.7
1,1 Dichloroethene	mg/kg	1	10	10	150
1,2 Dichloroethene	mg/kg	18	215	260	3570
Trichlorobenzenes (total)	mg/kg	0.07	195	290	3330
Nitrobenzene	mg/kg	2.8	2.8	2.8	45
1,1,2,2 Tetrachloroethane	mg/kg	0.3	0.3	0.3	5.0
Trichloroethene	mg/kg	1	710	725	11 600
2,4,6-Trichlorophenol	mg/kg	4	210	310	1770
Vinyl Chloride	mg/kg	0.004	0.1	0.1	1.5
PCBs	mg/kg	0.62	1.7	3.5	12
Cyanide	mg/kg	14	620	1240	10 500

Investigation Values for Salts

In addition to the suite of metals and organics detailed above, guidance was also requested on salts.

Commonly occurring anions are rarely encountered at concentrations that may impact on human health by direct exposure pathways, but they do however have an important influence on soil quality from an ecological and agricultural perspective. Land contaminated with excessive levels of salt is also a major cause of deterioration of water quality in South African catchments.

The soil screening values listed below should be used as investigation levels requiring the development of a site specific risk assessment where contaminant release mechanisms and migration pathways such as leaching and soil erosion and transport are evaluated in relation to on-site dilution and attenuation factors and the seasonal carrying capacity of the water resource.

Investigation values are calculated on the basis of human health considerations for drinking water for a dilution-attenuation factor of 20. Aesthetic criteria related to taste are not considered in the determination of soil screening values but could become remediation objectives for specific sites.

Anions	Soil Screening Level (mg/kg)
Chlorides	12 000
Fluorides	30
Nitrates-nitrite	120
Sulphates	4000

6 Application of Site Specific Quantitative Risk Assessment

6.1 APPROACH AND APPLICABILITY

The use of site specific forms of risk assessment is recognised as international best practice as the deficiencies of simplistic generic assumptions used at preliminary levels of assessment may provide for remediation objectives that are either unrealistic in terms of the actual identified exposure pathways or fail to allow sufficiently for the assessment of risk to sensitive or non-standard receptors, or where the contaminants of concern are complex in nature and thus excluded from preliminary screening lists.

The development of a consistent methodology for quantitative risk assessment for contaminated land together with standard equations as a guidance measure is an objective of the Framework.

Site-specific risk assessment provides a means of determining the contamination status of a site to establish whether site remediation or other action is necessary and to determine whether a tolerable level of contamination can remain in place or to enable comparison of potential impacts of various remediation techniques.

The methodology outlined below is based on the following key components:

- data collection and evaluation of the physical and chemical conditions of the site
- toxicity assessment of the contaminants of concern
- identification and exposure assessment of human and ecological receptors on or near the site
- numerical risk characterisation.

All four components are interlinked and the numerical risk models are critically dependant on the validity and appropriateness of all the input data.

Risk assessment is based on probabilities rather than absolutes and this should be reflected in the decision-making. Spurious and misleading risk assessment reports generated to motivate for minor adjustments to Soil Screening Values represent poor professional practice and will not be tolerated.

Due to complexity of site conditions it is not possible to derive a full prescriptive standard for reporting, however a checklist for assessing site specific risk assessment reports is provided for guidance purposes.

Competent persons involved in the specific components of the process should be adequately qualified and experienced and have broad understanding of health risk assessment and the practical realities of contaminated sites. Although major reports are likely to involve the input of a variety of specialists there should be a principle coordinator who takes responsibility for the overall risk assessment report.

6.2 EXPOSURE ASSESSMENT

Exposure assessment involves the determination of the frequency, extent and duration of exposures for receptors and should include the identification of exposed populations and particularly sensitive subpopulations as well as potential exposure pathways. A combination of predictive models and environmental monitoring should be used to determine the levels of exposure at particular points on the exposure pathways. The contaminant intakes from the various pathways can be estimated under a range of scenarios. Uncertainties in the models can be addressed by gathering further information or by including safety factors and other forms of conservatism by professional judgement.

Exposure assessment involves the estimation of the magnitude, frequency, extent and duration of exposure in the past, currently, and in the future.

The process involves:

- Estimate of contaminant releases
- Identification of exposed populations
- Identification of exposure concentrations for each pathway
- Estimation of exposure concentrations for each pathway
- Estimation of contaminant intakes for each pathway for a range of scenarios.

Direct measurement of the exposure of the affected population provides the best exposure data but is not always available or practicable.

The approach has strengths and weakness and the limitations of exposure assessments need to be understood and communicated.

6.2.1 Key factors for consideration in exposure assessments

- Children usually receive a higher exposure to soil contaminants per unit body weight than adults
- Soil ingestion by small children (including geophagic behaviour) is usually by far the most important exposure route.
- In South Africa exposure to soil contaminants is likely to be far higher in informal settlements than other forms of residential land use and the adoption of default exposure parameters from other countries are likely to underestimate risk for these receptor populations.
- One exposure route will normally predominate and determine the risk.
- The inhalation route will be most important for highly volatile contaminants, but if the source of volatiles is relatively small, as they rapidly evaporate and disperse in air, they will rapidly disappear from a site unless new sources are added.
- For large scale (regional) contamination assessment more exposure pathways are likely to be relevant than when dealing with localised small-scale contamination.

6.2.2 Errors in Exposure Assessments

Factors that tend to result in the false-positive overestimation of exposure include the following:

- Overlooking a significant exposure or metabolic pathway.
- Failure to evaluate all the contaminants of concern in the soil mixture
- Comparison of exposure-related data against contaminated media or exposed populations rather than appropriate background levels.
- Using insufficiently sensitive detection limits so that meaningful values ae reported as being not detected.
- Relevant individual pathways within the same exposure route may not have been summed.

Factors which can cause false-negative underestimation of exposure include the following:

- The use of unrealistically conservative exposure parameters
- Portraying hypothetical potential exposures as existing exposures
- Attributing a significant value to results that fall below an appropriate detection limit.

Factors may cause either underestimates or overestimates include:

- quality assurance/quality control problems with the field chemical data
- computational errors
- use of inappropriate input parameters for intake routes
- insufficient uncertainty assessment
- use of inappropriate number of significant figures in numeric estimates
- unthinking and uncritical use of models

6.3 TOXICITY ASSESSMENT

Toxicity assessment considers the nature of adverse effects related to exposure, the dose response relationship of the various effects, and the weight of evidence for effects such as carcinogenicity.

For specific contaminants of concern that are not included in the generic Soil Screening Values a more detailed review of relevant toxicological data is required. As a minimum requirement the following issues should be addressed.

There are two elements to toxicological assessment - hazard identification and dose response assessment.

Hazard identification examines the capacity of an agent to cause adverse health effects in humans and other animals. The key issues are :

- nature, reliability and consistency of human and animal studies
- the available information on the mechanism of toxic effect,
- the relevance of the animal studies to humans
- The dose response assessment examines the quantitative relationship between the exposure and the effects.

The following sources of toxicological assessment data are given in order of preference:

- World Health Organisation (WHO). Includes the International Programme on Chemical Safety (IPCS) which produces Environmental Health Criteria monographs and Concise International Chemical Assessment documents (CICADs). Documents detailing internationally Acceptable Daily Intakes (ADIs), Tolerable Daily Intakes (TDI) or Tolerable Weekly Intakes (TWI) may also be found in WHO/FAO Joint Meeting on Pesticide Residues and by the Joint WHO/FAO Expert Committee on Food Additives.
- International Agency for Research on Cancer (IARC) monographs.
- NICNAS Priority Existing Chemical (PEC) reports.
- US Agency for Toxic Substances and Disease Registry (ASTDR) for general toxicological reviews and Reference Doses.

At a second level the direct reference of toxicological data and opinion may be cite from peer reviewed scientific journals particularly if no guidance values are available, accompanied by an appraisal of methodology stating the level of conservatism and uncertainty.

- Integrated Risk Information System (IRIS) for cancer slope factors.

Occupational health and safety sources of information are a useful source for toxicological data and reviews but occupational exposure criteria must not be used in a general public health context without appropriate adjustment for the different durations of exposure, the inclusion of susceptible sub-populations in the general community (children) and the differences in methodology in the setting of criteria.

An advisory checklist for the compilation of Site Specific Quantitative Risk Assessment is provided below.

Advisory checklist for Site Specific Quantitative Risk Assessment Reports

Report Preparation and Review

- Has the objective and level (preliminary or detailed) of report been clearly defined?
- Is there a clear understanding of land use and site constraints?
- Is the sampling reasonably sufficient to identify, locate and demarcate any potential contamination?
- How are the results interpreted?
- Have data been analysed for the appropriate soil horizons, surface water sources and groundwater sources
- Were environmental fate and transport mechanisms understood?
- Have data been modelled to develop a spatial and time dependant understanding of the site conditions
- How were anomalous results or findings addressed?
- Were the uncertainties of the assessment identified and understood?

Contaminants of Concern

- State objectives of data collection and risk assessment
- Identify chemicals of concern (CoC)
- Identify sources of CoC
- Identify environmental fate and transport of contaminants

Integrity of Data

- Are the data collection objectives consistent with the requirements of the risk assessment?
- Note laboratories used. Are they suitably accredited to perform the chemical analyses?
- Quality Assurance/Quality Control (QA/QC):
- Has laboratory QA/QC been reported and assessed
- Has field QA/QC been reported and assessed
- Have statements of laboratory accuracy for each contaminant been made

Toxicology

- Check accuracy and currency of toxicological data
- Is the available toxicological database adequate?
- Has human health data been appraised for the relevant exposure pathways?
- Has the critical toxic effects and organ/body system been identified?
- Have synergistic and antagonistic effects of multiple contaminants been considered?
- Have uncertainties in the toxicological basis of the guidance values been discussed?
- Has the dose-response relationship for contaminants been appraised and discussed

Receptors

- Have potentially exposed populations been identified?
- Have unusually susceptible individuals been identified?
- Have estimates of chemical exposure for each significant exposure route and for each contaminant been adequately quantified and tabulated
- Has the significance of each exposure pathway been discussed on the basis of risk

Risk equations and calculations

- Have all equations used in the report been listed?
- Are all equations consistent?
- Have all parameters in each equation been clearly defined?
- Have the correct units been allocated to the parameters?
- Are the equations dimensionally correct?
- Have all unit correction factors, where applicable been included in the equations?
- Has all pertinent information been provided to enable calculations to be checked through in a stepwise manner?

Report Conclusions and Recommendations

- Have all assumptions and default data been identified and justified?
- Has the analysis been undertaken based on up-to date data and literature?
- Have all conclusions been justified?
- If toxicological data and exposure scenario lead to the conclusion that a high concentration of contaminant is permissible in terms of human health, does the result violate ecological, aesthetic, land use or other physical principles?
- Has a risk management decision been made that influences the calculation of risk?
- Has uncertainty been discussed?
- Has the information been presented coherently and in an appropriate sequence to enable efficient appraisal of the report?

7 Quality Control and Quality Assurance of Field Sampling and Laboratory Analysis

7.1 INTRODUCTION

Good data quality is essential for practical implementation of this Framework. The data used to determine risk and the status of contaminated land must be relevant, sufficient, reliable and transparent.

In general terms data quality can be judged taking into account the following factors :

- Choice of sampling points. Is it judgemental or random? How certain is it that contamination has been identified?
- Sampling method. Does it follow good practice guidance? Does it maximise the integrity of the sample?
- Sample handling and storage. Does it minimise contaminant losses or transformation.
- Sample preparation. Is it in accordance with good practice and appropriate for the accurate determination of the contaminant.
- Analytical detection limit relative to the Soil Screening Value. The analytical limit of detection (LOD) should be sufficiently below the Soil Screening Value to satisfactorily address quantification uncertainty.
- Analytical method quality assurance. Properly accredited laboratory analytical methods must be used when available.

The following section provides guidance on Quality Assurance and Quality Control (QA/QC) procedures for the investigation of potentially contaminated sites, with a focus on the sampling of soils. It is not intended to provide prescriptive comments on laboratory testing but rather to highlight measures to maintain the integrity of field samples by applying simple and consistent routines that allow discrepancies in data to traced and assessed. The primary objective is to ensure that the minimum level of QA/QC expected for the undertaking of site investigations in South Africa is clearly understood. An additional objective of this guidance is to standardise and to provide a degree of consistency with respect to QA/QC procedures for site investigation. However it is also acknowledged that these guidelines may need to be adapted for the specific conditions of a particular site investigation. Where deviations from standard QA/QC procedures occur, these must be documented in the reporting of the site investigation, so that any limitations of the investigation are clearly understood.

It is noted that total reliance cannot be placed on the results of laboratory testing. Even if one adheres to accepted test measures and uses appropriately accredited laboratories, it does not guarantee that the analytical results will be representative of the actual site conditions. It is incumbent on the proponent and appointed specialist advisors to provide control measures in order to understand any possible variance in the accuracy and precision of test results used in the assessment of a potential contaminated site. It is also worth noting that use of multiple laboratories with duplicate and sometimes triplicate testing on a large number of samples also does not necessarily result in a high level of confidence in results – particularly when simple QA/QC measures were not applied at the commencement of investigation and sampling itself. Therefore it is essential that the potential limitations of sampling and testing techniques are considered and that reasonable measures to assess variance and its consequences in the compilation and interpretation of test results are applied.

The characterisation of a contaminated site is fundamentally based on a combination of sound judgement of potential risks, identification of contaminants of concern and a clear conceptual understanding of possible exposure pathways, release mechanisms and fate and transport of contaminants in the environment. Effective QA/QC protocols do not replace a strong conceptual understanding of the site being investigated nor can they compensate for a deficient site investigation and sampling strategy, such as inappropriate drilling/excavation techniques or poorly selected sampling locations. However, provided that the other elements of a site investigation are sound, QA/QC procedures are an essential part of an effective site investigation, ensuring that scientifically defensible and validated factual data can be produced to support the findings of contaminated site assessment reports.

The QA/QC procedures outlined below are largely based upon the Australian Schedule B(2) Guidelines on Data Collection, Sample Design and Reporting (NEPC, 1999) as well as the British Standard BS10175:2001 Investigation of Potentially Contaminated Sites – Code of Practice (BSi, 2001). Should additional guidance be sought with respect to QA/QC, reference can be made to relevant sections of the above documents.

For specific guidance on groundwater sampling the following reference documents define good practice in South Africa and are adopted for the purpose of this Framework.

> Weaver JMC, Cave L, Talma, AS (2007) *Groundwater Sampling: a comprehensive guide for sampling methods. Second Edition,* Water Research Commission, Pretoria Report No TT 303.

and its precursor document

> Weaver JMC (1992) *Groundwater Sampling Manual*, Water Research Commission, Pretoria Report No TT 54/92

7.2 PRE-SAMPLING ACTIVITIES

In order to implement a cost effective and technically feasible site investigation, it is necessary to have a properly formulated sampling strategy, based upon a strong conceptual understanding of the site conditions and history, as well as a clear understanding of the objectives of the site investigation itself. Without this preparation, it is unlikely that any investigation will be successful.

7.2.1 The Sampling Plan

Sampling programmes should be designed on the basis of site history and site conditions, including geological and hydrogeological characteristics. Soil contamination is rarely homogenous, either laterally or vertically through the soil column, and may be present in differing geological strata, discontinuous lenses or within various fill horizons across a site. Professional experience and judgement should be used to ensure adequate coverage. The sampling plan and decisions regarding the number, type and location of samples need to be developed with an understanding of the potential exposure pathways and routes. The proposed use for the site will also critically affect the nature of the sampling program.

The sampling plan should consider the purpose of the investigation, such as:

- determining the nature of contamination;
- determining the concentration and distribution of contamination both laterally and vertically;
- identifying types and concentrations of contaminants, for assessing potential exposure levels and risks;
- monitoring site conditions to determine if remedial action/intervention is required;
- designing and implementing remedial action; and
- determining if clean-up has been achieved.

7.2.2 Sampling Patterns

It is the responsibility of the site investigator to formulate an appropriate sampling program based upon accurate and reliable site specific information as far as practicable, and the reasoning behind the sampling plan should be made clear within any subsequent reporting. The following sampling patterns are listed in the preferred order for determining sampling patterns:

- **Site history-based (judgemental) sampling**

Sampling is localised to known or potentially contaminated areas identified from knowledge of the site i.e. known existing or historical sources of contamination.

To undertake judgemental sampling there needs to be a high level of confidence in the reliability of information about the site. With respect to historical sources of contamination, access to reliable data can be particularly challenging.

- **Grid (systematic) sampling**

This permits the whole of the site to be covered and for sampling points to be more readily identified for further sampling. Grid sampling typically involves the use of a regular or offset grid or herringbone pattern, with the pattern selected being essentially dependant on the site size and topography. Grid sampling is useful for covering the remainder of the site once judgemental sampling has been applied to those areas of the site considered most likely to be contaminated, or if there is inadequate information regarding site history.

- **Stratified sampling**

This involves dividing the site up into different sections and applying different sampling patterns and densities in each sub-section. It is sometimes a useful technique for large and complex sites.

7.2.3 Sampling Depth and Hole Logging

Sampling of contaminated land is a forensic screening process and there is the possibility that both false positive and false negative results will occur. From a health and environmental perspective the aims of sampling are to reduce the likelihood of a false negative scenario that could result in an underestimation of contaminant concentration and hence risk that could ultimately lead to significant adverse effects. A considerable amount of expert judgement based on site history information is required to determine the density of sampling. The final amount will depend on an integrated appraisal of factors including:

- proposed use(s) and users;
- current use;
- the likely shape(s) of contamination and its distribution;
- the size of contaminated areas to be detected;
- the number of stages of sampling considered feasible;
- the size of the site and final subdivided sites if the site is to be subdivided;
- the distribution of uses on the site and the disposition of structures;
- the site history;
- potential remediation and management strategies.

If a site is to be subdivided the size of the subdivided sites should be taken into account when planning the sampling density. While predictions may be able to be made on a 'macro' scale, residents or owners may seek information about their particular area of land and the risks associated with a smaller piece of land, especially if the potential contamination on the original site was uneven in magnitude and type. The detection of ‘hot spots’ is an important issue for sites to be used for residential purposes or other sensitive uses where children have regular access to soil or where there is potential groundwater contamination. A greater sampling density is usually required for these sites. The toxicity of the contaminant, and the size and magnitude of the potential ‘hot spot(s)’ need to be considered in determining grid size. An explanation of, and justification for, the sampling density chosen should be provided.

- It is necessary to have some understanding of the following issues prior sampling:
  - Clear objectives for the sampling plan:
  - Sampling media (likely soil types)
  - Sampling locations
  - Analyses to be performed
  - Testing laboratory (and the laboratory’s requirements for QA/QC)

- The objectives of the sampling plan are usually stated in terms of:
  - Determining the presence/absence of contamination
  - Determining the extent/magnitude of contamination
  - Determining the contaminant migration pathways
  - Identifying risk to sensitive receptors within the context of a particular land-use setting

7.3 COLLECTION OF ENVIRONMENTAL SOIL SAMPLES/ INFIELD QA/QC PROCEDURES

The QA/QC sample policy has been established to provide a minimum standard of QA/QC that will allow for the evaluation of field or trip conditions and situations that may affect the results of chemical tests by the laboratory. These procedures will apply to typical projects performed by suitably qualified competent persons. These include sites having sample media consisting of soil sediment, sludge, or water.

Composite Sampling

Composite sampling is often incompatible with health risk assessment methodologies and is generally unsuitable for the definitive assessment of site contamination due to the inherent uncertainties in the resultant data. Composite sampling should not be used for site-specific health and ecological risk assessments but may be acceptable for the appraisal of stockpiled material or buried dumps characterised by the presence of non volatile contaminants. It is also the preferred choice of sampling method if leaching tests are required for waste classification or for sites where it may be desirable to leave a portion of the material in the ground in the form of an isolate-contain and monitor remediation plan. For example, a contaminated soil stockpile of say $100m^3$. The contamination may be adequately characterised for the purpose of determining a bulk chemical concentration by composite sampling. Four composite samples may be formed by partitioning the stockpile into quarters and taking 5 individual samples at surface and depth from each quarter. The five samples are thoroughly mixed and sub-sampled to form the final composite. Clustered sampling (where samples from a stratum are taken within a 1 to 5 metre diameter area and combined to represent a sampling point) may be acceptable. Clustered samples must be thoroughly mixed to ensure a true average test result is obtained. Certain contaminants are highly viscous and tend to form localised zones of high concentration, in this case the use of composite samples may be highly misleading and should not be attempted.

7.4 QA/QC SAMPLES

The following section describes the QA/QC (Quality Assurance/Quality Control) policy for environmental sampling for chemical testing. The first subsection defines QA/QC samples and is followed by the basic philosophy, a sample collection, and sample analysis policy.

7.4.1 Definitions

Field duplicate samples are samples that have been divided into two or more portions in the field collection process from project samples. Each portion is then carried through the laboratory analysis. A sample may be duplicated at other points in the analytical process; however it would not be called a field duplicate. Examples of field duplicated samples include a soil sample that has been collected and mixed before being split and placed into individual sample containers. Correctly splitting and mixing a soil sample is especially important because of its inhomogeneous nature. In cases where volatile analyses are to be performed on soil, mixing the sample will liberate the volatiles. Therefore, duplicate samples for volatile analysis should be taken from the same source without mixing and splitting. Water samples are not mixed, but poured from the same sampling device. Both soil and water duplicates should be taken from the location of expected high contamination.

Equipment blanks are defined as samples which are obtained by running analyte-free deionized water through sample collection equipment (bailer, pump, auger, split-tube, Shelby tube, spatula, etc.) after decontamination, and placing it in the appropriate sample containers, with project samples, for analysis. These samples are used to determine whether decontamination procedures have been sufficient. Deionized water is used to make equipment blanks for both water and soil samples.

Field blanks are defined as samples which are obtained in the field by pouring analyte-free deionized water into appropriate sample containers for analysis. These samples are packaged with the project samples and sent to the laboratory for analysis. Field blanks are used to determine if contamination entered the sample during field collection to laboratory analysis.

Trip blanks are prepared in actual sample containers prior to the sampling event and are kept with the project samples throughout the sampling event. They are then packaged for shipment with the project samples and sent for analysis. At no time after their preparation are the sample containers opened before they reach the laboratory.

7.4.2 Philosophy

The following standards apply to typical projects as previously defined and may be raised to higher standards by the competent person for special projects requiring more rigorous forms of quality control applied to specific contaminants.

Sample Collection

An equipment blank and field duplicate sample should be prepared for every ten project samples collected, or for every day of sampling, or for each project - whichever is more. When the number of field duplicates is controlled by the number of project days, the number of field duplicate samples shall be controlled by the one-in-ten rule, if it results in less duplicate samples. This rule will generally apply when soil borings are being drilled and converted to wells, and only a few project samples (less than ten) are being collected each day for chemical testing. The QA/QC samples will be treated in accordance with project sampling procedures, and shipped to the chemical laboratory under project chain-of-custody protocol. For projects involving the collection of one project sample, this means that two QA/QC samples will be prepared. The proportion of QA/QC samples decreases with an increase in project samples collected.

A field blank will not be required in most cases as field conditions/situations affecting the field blank will also affect the equipment blank. By having only an equipment blank, the question is only whether sampling contamination or other field conditions/situations affected the sample, if contaminants are found upon chemical testing. Field conditions requiring a field blank would be if there is a high likelihood of windblown contamination or rain affecting the sample. The need for field blanks would be decided by the competent person.

A trip blank will not be required as conditions/situations affecting the trip to the field rarely happen. If contamination occurs, the equipment blank would show those effects. Although similar to the field blank, a trip blank could not be used to differentiate between sampling contamination, field, or trip effects. Trip blanks will be required if trip conditions are unusual. An example of such conditions would be an out-of-town sampling event in which the sampler in the field has little control over time duration of sample shipments to and from the field, or where environmental conditions during the trip could potentially introduce contamination.

7.4.3 Sample Analysis

The field duplicate sample will be analyzed for the same chemical constituents as the normal project samples. This includes the same laboratory extraction procedure(s) and any clean-up that the project samples undergo.

The equipment blank for all chemical tests (including, but not limited to, metals, volatiles, semi-volatiles and pesticides) will always be prepared for analysis. Except for volatiles, the actual chemical testing will be performed only if a problem is suspected in the test results or at the discretion of the competent person. Except for volatiles, there is ample holding time for the extraction from these samples to wait for chemical tests to be performed, and the results reviewed.

The equipment blank for volatile organics will always be extracted and tested because the holding time for volatiles is only 14 days (from sampling to testing). However, if a seven day turnaround on project samples can be guaranteed, then, at the discretion of the competent person, the chemical test for volatile equipment blanks can wait until the results of the project samples have been reviewed. However, analysis of the equipment blank for volatiles, if required, must be done within the 14-day holding time.

If field and trip blanks are prepared, they shall always be prepared and analyzed for the chemical constituents tested for in the project samples

7.5 FIELD TESTING METHODS

A variety of field testing devices have been developed as field screening devices for contaminated sites. These include photoionisation detectors (PIDs), flame ionisation (FIDs), gas detectors and field portable laboratories including x-ray fluorescence (FPXRF) and field gas chromatography. These methods provide real-time or fast turnaround data to assist in rapid site characterisation. Their use as the sole source of analytical data in the assessment is however not supported by the analytical precision and detection limits available for much of this technology. When assessing the application of field testing equipment the following issues need to be addressed.

- The equipment must be capable of detecting the contaminants of concern
- Adequate understanding of the methods for use of the particular instrument and any limitations that may affect the results.
- Appropriate calibration has been recorded for the contaminants being tested.
- Wherever site conditions may effect the results (high temperatures or high moisture contents).

It is strongly recommended that laboratory validation testing is used to provide correlation with any field measurements. If good correlation exists between the results of field testing method and certified laboratory results the results of such field tests can be applied to determine extent and severity of contamination and can be used in monitoring programmes. Risk Assessment Reports and remediation objectives based solely on non-validated field test results are unacceptable.

8 References

American Society for Testing and Materials. (1998). Standard Guide for Remediation of Ground Water by Natural Attenuation at Petroleum Release Sites.

American Society for Testing and Materials (2004) Standard Guide for Risk Based Corrective Action, Designation E2081-00

ANZECC. (1992). Australian Water Quality Guidelines for Fresh and Marine Waters.

ANZECC/NHMRC (National Health and Medical Research Council). 1992. Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.

ARMCANZ/ANZECC. (2001). Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

ASTM. (1995). Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites (RBCA). E1739-95.

Australian Standard 4482.1 (2005) Guide to sampling and investigation of potentially contaminated soil. Part 1 Non-volatile and semi-volatile compounds.

Beckett G.D., and Lundegard P. (1997). Practically Impractical – The Limits of LNAP Recovery and Relationship to Risk. 1997 National Ground Water Association Proceedings for Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection and Remediation.

BP Oil Ltd. (1995). Risk Integrated Software for Clean-ups (RISC), Users Guide.

Braune, E & Xu, Y (1995) A guideline for Groundwater Protection for the Community Water Supply and Sanitation, 1st edition, DWAF, Pretoria.

Braune, E and van Zyl, FC (1997) Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme prepared by Hobbs PJ and Marais SJ under guidance of the authors (1st edition), DWAF Pretoria.

BRGM (2003) The French approach to contaminated land management Revision 1.

British Standard BS10175:2001 Investigation of Potentially Contaminated Sites – Code of Practice (BSi, 2001).

Buchman, M.F (2008) NOAA Screening Quick Reference Tables. NOAA OR&R Report 08-1. Seattle, WA, Office of Response and Restoration Division National Oceanic and Atmospheric Administration.

CCME. (1994). Final Draft: A Protocol for the Derivation of Ecological Effects-Based and Human Health-Based Soil Quality Criteria for Contaminated Sites.

CCME (1999) Summary of a Protocol for the Derivation of Environmental and Huam Health Soil Quality Guidelines.

CIEH (2006) The determination of contaminated land : deciding what is an “unacceptable risk”, Professional Practice Notice.

Cohen and Mercer. (1993). DNAPL Evaluation. CK Smoley Ltd.

CSIRO (2009) The Australian Methodology to derive Ecological Investigation Levels in Contaminated Soils .CSIRO Land and Water Sciences Report 43/09.

CSOIL. (2001). Evaluation and Revision of the CSOL Parameter Set. RIVM Report 711701021, .

Danish EPA (2002) Guidelines on Remediation of Contaminated Sites, Environmental Guidelines No7.

Defra and Environment Agency. (2002). Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans (R&D Publication CLR 9), Bristol , UK, Environment Agency.

Defra and Environmental Agency (2002) The Contaminated Land Exposure Assessment Model (CLEA) : Technical basis and algorithms, R&D Publication CLR 10, Bristol , UK, Environment Agency.

Defra and Environment Agency (2002) Soil Guideline Values for Lead Contamination, R&D Report SGV 10.

Defra (Department for Environment, Food and Rural Affairs (2006). *Assessing Risks from Land Contamination: A Proportionate Approach - Soil Guideline Values: The Way Forward.* Department for Environment, Food and Rural Affairs: London.

Department of Water Affairs and Forestry (1996) South African Water Quality Guidelines (second edition) Volume 1: Domestic Use.

Department of Water Affairs and Forestry (1996) South African Water Quality Guidelines (second edition) Volume71: Aquatic Ecosystems.

Edwards N.T. (1983). Polycyclic Aromatic Hydrocarbons (PAHs) in the Terrestrial Environment - A Review. Journal of Environmental Quality. Vol 12 No. 4, 1983 pp 427-441.

EnHealth. (2002). Environmental Health Risk Assessment, Guidelines for Assessing Human Health Risks from Environmental Hazards,

En Health (2003). Australian Exposure Assessment Handbook, Consultation Draft, December 2003, enHealth Council.

Environment Agency (2004) Update on estimating vapour intrusion into buildings Briefing Note 2 , Bristol, Environment Agency.

Environment Agency (2002) Vapour transfer of soil contaminants, Technical Report

Environment Agency (2005) Environment Agency's Science Update on the Use of Bioaccessibility Testing in Risk Assessment of Land Contamination.

EPHC (2003) Establishing Health-based Investigation Levels for benzene, toluene, ethylbenzene, xylenes, naphthalene, and aromatic and aliphatic <EC16 TPH fractions.

European Chemicals Bureau (2003) Technical Guidance Document on Risk Assessment , EUR 20418 EN/1.

Finley B., Proctor P., Scott N., Harrington D., and Price P. 1994. Recommended Distributions for Exposure Factors Frequently Used in Health Risk Assessment. Risk Analysis, Vol. 14, No. 4, pp 533-553.

Fitzgerald J. 1993. Carcinogenic Soil Contaminants: An Australian Approach. Proceedings. 2nd National. Workshop on the Health Risk Assessment and Management of Contaminated Land, Canberra.

Gilbert R.O. (1987). Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold.

GRI. (1988). The Management of Manufactured Gas Plant Sites, Vol III, Risk Assessment. Gas Research Institute, Chicago.

Hawley J.K. (1985). Assessment of Health Risk from Exposure to Contaminated Soil. Risk Analysis, 5 (4).

Herselman, JE (2006) The concentration of selected trace metals in South Africa (2006) Unpublished PhD, University of Stellenbosch.

Herselman, JE, Steyn CE and Fey MV (2005) Baseline concentrations of Cd, Co, Cr, Cu, Pb, Ni and Zn in surface soils in South Africa. South African Journal of Science 101.

Johnson P.C., and Ettinger R.A. (1991). Heuristic Model for Predicting the Intrusion of Contaminant Vapours into Buildings. Environmental Science and Technology. Vol 25 (8) pp 558-564 and 1445-1452.

Jury W.A., Spencer W.F., and Farmer W.J. (1983). Behaviour Assessment Model for Trace Organics in Soil: 1. Model Description. Journal of Environmental Quality. Vol 12, No. 4.

Jury W.A., Spencer W.F., and Farmer W.J. (1984). Behaviour Assessment Model for Trace Organics in Soil: 11. Chemical Classification and Parameter Sensitivity. J. Environ. Qual. Vol 13, No. 4.

Langley A. (1993). Refining Exposure Assessment. Proceedings 2nd National Workshop on the Health Risk Assessment and Management of Contaminated Land, Canberra.

Lenhard R.J., and Parker L.C. (1990). Estimation of Free Hydrocarbon Volume from Fluid Levels in Monitoring Wells. Ground Water. 28(1).

Lindon P. (1993). A Health Risk Assessment for Soils Contaminated with Fuel Hydrocarbons: Petrol. Proceedings 2nd National Workshop on the Health Risk Assessment and Management of Contaminated Land, Canberra.

Maryland DEP (2008) Clean-up Standards for Soil and Groundwater. Interim Final Guidelines. Maryland Department of Environmental Protection.

Massachuseetts DEP. (1994). Interim Final Petroleum Report: Development of Health-Based Alternative to the Total Petroleum Hydrocarbon Parameter. Massachusetts Department of Environmental Protection.

Massachuseetts DEP. (2002) Characterizing Risks posed by Petroleum Contaminated Sites: Implementation of MADEP VPH/EPA Approach, October 31, 2002. . Massachusetts Department of Environmental Protection

Ministry for the Environment (1995). *Discussion Document on Contaminated Sites Management.* Ministry for the Environment: Wellington.

Ministry for the Environment (1999). *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand*. Ministry for the Environment: Wellington.

Ministry for the Environment (2003). *Contaminated Land Management Guidelines No. 2: Hierarchy and Application in New Zealand of Environmental Guideline Values.* Ministry for the Environment: Wellington.

Ministry for the Environment (2004a). *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils.* Ministry for the Environment: Wellington.

Ministry for the Environment (2004b). *Contaminated Land Management Guidelines – Schedule A: Hazardous Activities and Industries List.* Ministry for the Environment: Wellington.

Ministry for the Environment (2005). *National Environmental Standard for Contaminated Land: Notes of Technical Review Workshop.* Unpublished report by the Ministry for the Environment.

Ministry for the Environment (2006a). *Contaminated Land Management Guidelines No. 4: Classification and Information Management Protocols*. Ministry for the Environment: Wellington.

Ministry for the Environment (2006b). *Contaminated Land" Review of District, Regional and Unitary Plans*. Unpublished report by the Ministry for the Environment.

Ministry for the Environment (2006c). *Working Towards a Comprehensive Policy Framework for Managing Contaminated Land in New Zealand: A Discussion Paper.* Ministry for the Environment: Wellington.

Ministry for the Environment (2007). *Working Towards a Comprehensive Policy Framework for Managing Contaminated Land in New Zealand: Report on Submissions.* Ministry for the Environment: Wellington.

Ministry for the Environment and Ministry of Health 1997. *Health and Environmental Guidelines for Selected Timber Treatment Chemicals*. Ministry for the Environment and Ministry of Health: Wellington.

Naturvardsverket (1996) Development of generic guideline values, Report 4639

NEPC. 1999. National Environment Protection Council (Assessment of Site Contamination) Measure including schedules:

Schedule B(1)	Guideline on Investigation Levels for Soil and Groundwater
Schedule B(2)	Guideline on Data Collection, Sample Design and Reporting
Schedule B(3)	Guideline on Laboratory Analysis of Potentially Contaminated Soils
Schedule B(4)	Guideline on Health Risk Assessment Methodology
Schedule B(5)	Guideline on Ecological Risk Assessment
Schedule B(6)	Guideline on Risk Based Assessment of Groundwater Contamination

Schedule B(7A) Guidelines on Health Based Investigation Levels

Schedule B(7B) Guideline on Exposure Scenarios and Exposure Settings

Schedule B(8) Guideline on Community Consultation and Risk Communication

Schedule B(9) Guideline on Protection of Health and the Environment during the Assessment of Site Contamination

Schedule B(10) Guideline on Competencies and Acceptance of Environmental Auditors and Related Professionals.

NEPC (2003) Modelling the Migration of VOCs from Soils to Dwelling Interiors, Proceedings of the Fifth National Workshop on the Assessment of Site Contamination.

New Jersey DEP (2008) Guidance for the Determination of the Dilution-Attenuation Factor for the Impact to Ground Water Pathway.

Patterson S., and Mackay D. (1989). Modelling the uptake and distribution of organic chemicals in plants, in Allen D.T. et al (eds) Intermedia Pollutant Transport: Modelling and Field Measurements, Plenum Press, New York pp 269-282

RIVM (1996) The VOLASOIL risk assessment model based on CSOIL for soils contaminated with volatile compounds. Report 715810014.

RIVM (1994) Human exposure to soil contamination : a qualitative and quantitative analysis towards proposals for human toxicological intervention values (partly revised version). Report 725201011.

RIVM (2001) Technical evaluation of the Intervention Values for soil/sediment and groundwater, Report 71170023.

Schloemann H (1994) The geochemistry of some common Western Cape Soils (South Africa) with emphasis on toxic and essential elements. Unpublished PhD University of Cape Town

SFT (1999) Guidelines for the Risk Assessment of Contaminated Sites, Report TA-1691/1999

Shell. (1994). The Concepts of HESP, Reference Manual, Human Exposure to Soil Pollutants, Version 2.10a.

Swartjes F.A., and van den Berg R. (1993). Remediation of contaminated soil and groundwater: Proposals for criteria and priority setting. Proceedings Workshop on Contaminated Soils. Stockholm. October 26-28.

USEPA. (1989a). Exposure Factors Handbook. EPA/600/8-89/043.

USEPA. (1989b). Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A. Interim Final, EPA/540/1-89/002.

USEPA. (1991). Health Effects Assessment Summary Tables, Annual FY 1991.

USEPA. (1991a). Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Supplemental Guidance, Standard Default Exposure Factors.

USEPA. (1991b). Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part B, Development of Risk-based Preliminary Remediation Goals. 9285.7-01B.

USEPA (1987). Data Quality Objectives for Remedial Responses. 540/G-87/003.

USEPA (1988). Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA. OSWER Directive 9355.3-0.

USEPA (1989). Methods for Evaluating the Attainment of Clean-up Standards. Volume 1: Soils and solid media, 230/02-89-042.

USEPA (1992). Guidance for Data Usability in Risk Assessment (Parts A and B) PB92-963356.

USEPA. (1992b). Dermal Exposure Assessment: Principles and Applications. EPA/600/8-91/011B, January 1992.

USEPA. (2003). Users Guide for Evaluating Subsurface Vapor Intrusion into Buildings, June 2003.

USEPA. (2004). Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final. EPA/540/R/99/005, July 2004.

USEPA (2004) Ecotox Database. United States Environmental Protection Authority. www.epa.gov.ecotox.

USEPA (2006) Addressing Lead at Superfund Sites, www.epa.gov/superfund/programs/lead/pbrisk.

VLAREBO (2008) Vlaams Reglement Bodemsaniering. Flemish Soil Decree.

VROM, Ministry of Housing, Spatial Planning and Environment (2000) Circular on target values and intervention values for soil remediation. Reference DBO/1999226863. Blithaven, The Netherlands.

Weaver JMC, Cave L, Talma, AS (2007) Groundwater Sampling: a comprehensive guide for sampling methods. Second Edition, Water Research Commission, Pretoria Report No TT 303.

Weaver JMC (1992) Groundwater Sampling Manual, Water Research Commission, Pretoria Report No TT 54/92

Western Australia Department of Health (2009). Guidelines for the investigation, remediation and management of asbestos contaminated sites in Western Australia.

WHO. 1993. Guidelines for Drinking Water Quality Volume 1. Geneva, Switzerland. World Health Organisation.

WHO. 1994. Assessing Human Health Risks of Chemicals: Derivation of Guidance Values for Health Based Exposure Limits (International Programme on Chemical Safety, Environmental Health Criteria, 170). Geneva, Switzerland. World Health Organisation.

WHO. 1999. Principles for the Assessment of Risks to Human Health from Exposure to Chemicals (International Programme on Chemical Safety, Environmental Health Criteria, 210). Geneva, Switzerland. World Health Organisation.

Appendix A: Synopsis of Stakeholder Engagement

Appendix B: Chemical Specific Data for Soil Screening Value calculations

Chemical Specific Data for Soil Screening Value calculations

1. Gastrointestinal and Dermal Absorption (GI and ABS)

Metals & metalloids

- Gastrointestinal absorption was assumed to be 100% for all metals and metalloids with the exception of arsenic for which a gastrointestinal absorption of 10% was applied. This modification of the arsenic value to a less conservative and more realistic assumption was deemed necessary due to the unrealistically low (below background) soil screening value derived using latest carcinogenic risk data for arsenic.
- Dermal absorption was assumed to be 10%.

Petroleum & Non-Petroleum Organics

- Gastrointestinal absorption was assumed to be 100% throughout all calculations for petroleum and non petroleum organic calculations.
- Dermal absorption was assumed to be 10%.

2. Particulate emission factors used for each land-use were as follows:

Land-Use	PEF (m^3/kg)	Key assumption
Residential (standard)	1.30E+09	Fraction vegetative cover – 50% Wind speed & diffusion height – 2.25m/s and 2m
Residential (informal)	7.25E+08	Fraction vegetative cover – 10% Wind speed & diffusion height – 2.25m/s and 2m
Commercial/Industrial	3.22E+08	Fraction vegetative cover – 10% Wind speed & diffusion height – 2m/s and 1m (semi-confined working environment)

3. Volatisation Factors (VF)

Petroleum Organics

Volatisation factors for petroleum hydrocarbons were sourced from New Zealand Ministry for the Environment. Calculations were based on a high permeability (sandy) soil using the modified Johnson and Ettinger Model. The calculations are consistent with ASTM E1739-95 (2002) as applied to the VF calculations for non-petroleum organics.

Parameter	Indoor Air		Outdoor Air
	Residential m^3/kg	Commercial/ Industrial m^3/kg	All Land-Uses m^3/kg
Alkanes			
C7-C9	1.61E+02	2.42E+02	1.31E+04
C10-C14	1.92E+03	2.87E+03	1.83E+04
C15-C36	1.16E+06	1.74E+06	4.46E+05
MAHs			
Benzene	5.85E+02	6.67E+02	5.59E+04
Toluene	3.75E+02	5.62E+02	1.31E+04
Ethylbenzene	7.09E+02	1.05E+03	1.31E+04
Xylene	3.48E+02	5.24E+02	1.31E+04
Aromatics			
Napthalene	3.42E+03	5.15E+03	2.57E+04
Pyrene	2.94E+07	4.41E+07	2.46E+06
Benzo(a)pyrene	2.32E+09	1.13E+10	4.52E+07

Non-Petroleum Organics

The VFs for non-petroleum organics were calculated following ASTM E1739-95 (2002) and are detailed below.

Parameter	Indoor Air		Outdoor Air
	Residential	Commercial/ Industrial	All Land-Uses
	m^3/kg	m^3/kg	m^3/kg
MTBE	7.14E-03	2.90E-03	7.82E-07
Carbon Tetrachloride	5.14E-03	2.09E-03	1.75E-06
Chlorobenzene	9.05E-04	3.67E-04	2.65E-07
Chloroform	8.08E-03	3.28E-03	2.49E-06
2 Chlorophenol	4.12E-03	1.67E-03	2.95E-07
1,2 Dichlorobenzene	5.04E-04	2.04E-04	1.13E-07
1,4-Dichlorobenzene	5.79E-04	2.35E-04	1.46E-07
1,2-Dichloroethane	3.29E-03	1.33E-03	5.53E-07
1,1 Dichloroethene	1.79E-02	7.26E-03	6.87E-06
1,2 Dichloroethene	9.01E-03	3.66E-03	2.33E-06
Trichlorobenzenes (total)	5.43E-03	2.20E-03	5.79E-07
Nitrobenzene	1.76E-04	7.14E-05	9.85E-09
1,1,2,2 Tetrachloroethane	1.06E-03	4.29E-04	1.01E-07
Trichloroethene	4.07E-03	1.65E-03	1.54E-06
2,4,6-Trichlorophenol	1.05E-05	4.25E-06	5.66E-10
Vinyl Chloride	2.20E-02	8.91E-03	9.66E-06

4. Soil Partition Coefficients (Kd Values)

Soil partition coefficients used in the water resource protection pathway calculations are detailed below.

Metals & Metalloids

Parameter	Kd Value (L/kg)
As	29
Cd	75
Cr(III)	1800000
Cr(VI)	19
Co	100
Copper	10
Lead	100
Zn	62
Ni	65
Mn	100
Hg	52
V	1000

Petroleum Organics

Parameter	Kd* (L/kg)
Alkanes	
C7-C9	39.8
C10-C14	2510
C15-C36	63100
MAHs	
Benzene	1.35
Toluene	1.78
Ethylbenzene	4.37
Xylene	4.47
Aromatics	
Napthalene	12.9
Pyrene	1050
Benzo(a)pyrene	10200

* Calculated from octanol-carbon coefficient assuming fraction organic carbon of 0.01

Non-petroleum Organics

Parameter	Kd* (L/kg)
MTBE	0.12
Carbon Tetrachloride	3.09
Chlorobenzene	3.72
Chloroform	0.457
2 Chlorophenol	0.15
1,2 Dichlorobenzene	4.43
1,4-Dichlorobenzene	4.34
1,2-Dichloroethane	0.617
1,1 Dichloroethene	0.59
1,2 Dichloroethene	0.36
Trichlorobenzenes (total)	0.172
Nitrobenzene	0.646
1,1,2,2 Tetrachloroethane	0.861
Trichloroethene	1.62
2,4,6-Trichlorophenol	0.89
Vinyl Chloride	0.617
Polychlorinated biphenyls	3090
Cyanide	10

* Calculated from octanol-carbon coefficient assuming fraction organic carbon of 0.01

5. Water Quality Protection Criteria

Water quality protection criteria used in the water resource protection pathway calculations are detailed below.

Metals & Metalloids

Parameter	Drinking Water		Aquatic Ecosystem Protection	
	Value (mg/l)	Source	Value (mg/l)	Source
As	0.01	DWAF TWQR	0.01	DWAF Aquatic TWQR - Medium Hardness
Cd	0.005	DWAF TWQR	0.00025	DWAF Aquatic TWQR - Medium Hardness
Cr(III)	0.05	WHO (assumes CrIV)	0.012	DWAF Aquatic TWQR - Medium Hardness
Cr(VI)	0.05	DWAF TWQR	0.007	DWAF Aquatic TWQR - Medium Hardness
Co	0.003	NOAA Squirts (chronic)	0.11	BC Aquatic
Copper	1	DWAF TWQR	0.0008	DWAF Aquatic TWQR - Medium Hardness
Lead	0.01	DWAF TWQR	0.0005	DWAF Aquatic TWQR - Medium Hardness
Zn	3	DWAF TWQR	0.002	DWAF Aquatic TWQR - Medium Hardness
Ni	0.07	WHO	0.011	ANZECC Freshwater Protection
Mn	5	DWAF TWQR	180	DWAF Aquatic TWQR - Medium Hardness
Hg	0.001	DWAF TWQR	0.00004	DWAF Aquatic TWQR - Medium Hardness
V	0.1	DWAF TWQR	-	

Petroleum Organics

Parameter	Drinking Water		Aquatic Ecosystem Protection	
	Value (mg/l)	Source	Value (mg/l)	Source
Alkanes				
C7-C9	15000	WHO (exceeds solubility)	-	
C10-C14	300	WHO	-	
C15-C36	90	WHO	-	
MAHs				
Benzene	0.001	WHO	0.03	UK Salmonid
Toluene	0.7	WHO	0.05	UK Salmonid
Ethylbenzene	0.3	WHO	0.2	BC Aquatics
Xylene	0.5	WHO	0.03	UK Salmonid
Aromatics				
Napthalene	-	-	0.0011	NOAA Squirt (chronic)
Pyrene	-	-	0.0000025	NOAA Squirt (chronic)
Benzo(a)pyrene	-	-	0.000014	NOAA Squirt (chronic)

Non-petroleum Organics

Parameter	Drinking Water		Aquatic Ecosystem Protection	
	Value (mg/l)	Source	Value (mg/l)	Source
MTBE	0.0015	WHO (odour based)	3.4	BC Aquatics
Carbon Tetrachloride	0.004	WHO	0.01	UK Salmonid
Chlorobenzene	-	-	0.13	NOAA Squirt (chronic)
Chloroform	0.3	WHO	0.012	UK Salmonid
2 Chlorophenol	-	-	0.49	NOAA Squirt (chronic)
1,2 Dichlorobenzene	1	WHO	0.16	ANZECC Freshwater Protection
1,4-Dichlorobenzene	0.3	WHO	0.06	ANZECC Freshwater Protection
1,2-Dichloroethane	0.03	WHO	2	BC Aquatics
1,1 Dichloroethene	0.05	WHO	-	-
1,2 Dichloroethene	-	-	0.025	NOAA Squirt (chronic)
Trichlorobenzenes (total)	0.02	WHO	0.0004	UK Salmonid
Nitrobenzene	-	-	0.55	NOAA Squirt (chronic)
1,1,2,2 Tetrachloroethane	-	-	0.111	NOAA Squirt (chronic)
Trichloroethene	0.02	WHO	-	-
2,4,6-Trichlorophenol	0.2	WHO	-	-
Vinyl Chloride	0.0003	WHO	-	-
Polychlorinated biphenyls	0.00001	Dutch	0.014	USEPA
Cyanide	0.07	DWAF	0.001	DWAF