BAE SYSTEMS Environmental

Risk Assessment Report for Site Pollution Investigation

Site: **Akko Steel Mills**

Client: **Enosh Systems**

Risk Assessment Report for Site Pollution Investigation

Akko Steel Mills

Enosh Systems

DOCUMENT CONTROL

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1. INTRODUCTION

1.1. INSTRUCTION

BAE Systems Environmental was appointed by ENOSH Management and Engineering Systems (ENOSH) to conduct a Phase II Environmental Assessment, comprising an intrusive site investigation, at the former Mifalei Plada Steel Works, Akko, Israel.

1.2. INVESTIGATION OBJECTIVES

The objectives of the investigation were to:

- Establish ground and groundwater conditions across the Site.
- Establish conditions and main constituents of the waste mounds in the north and west of the Site.
- Assess the potential risks posed by any contamination present on the Site taking into account both human health and the wider environment, including controlled waters.
- Collect data to enable a costed Remedial Options study to be performed

1.3. SCOPE OF WORK

The investigation comprised the following components:

- A site walkover visit on 2nd September 2003 to assist planning of the investigation and discuss Site access;
- Implementation of a Phase II combined geotechnical and geo-environmental site investigations during September 2003, comprising trial pit excavation and construction of solid stem rotary auger boreholes;
- Chemical testing of soil and groundwater samples for a standard suite of contaminants; physical testing of appropriate soil samples to determine geotechnical characteristics;
- Interpretation and reporting of data.

1.4. REPORT LAYOUT

This report provides an assessment of the potential environmental risks associated with the Akko Steel Works based on information collected by the desk study and site investigation phases.

The report includes a description of the conceptual site model, a hazard assessment, risk estimation and an evaluation of the environmental risks in relation to human health, groundwater, flora and fauna and property. Outline recommendations are given regarding further work that may be required to mitigate any identified potential risks.

1.5. DEFINITIONS

The term ‘Site’ refers to the land occupied by the former Mifalei Plada Steel Works at Akko, Israel, the boundary of which is shown in Appendix 1.

1.6. REPORTING CONDITIONS

The report refers to the conditions present at the Site at the time of the study and no liability can be accepted by BAE Systems Environmental for any future changes of Site conditions. It should be noted that BAE Systems Environmental has relied on the accuracy of the information contained in the documents consulted and is in no circumstances responsible for the accuracy of such information or data supplied.

This report has been prepared without the benefit of knowing the intentions of third parties and therefore should not be used by such organisations without prior consultation with BAE Systems Environmental.

Exploratory points only provide information on a relatively limited volume of excavated soil. In general, the ground conditions encountered may be considered representative but the possibility exists of variations in the ground conditions between exploratory points that have not been disclosed by the investigation and could not therefore be taken into account in this report.

1.7. SOURCES OF INFORMATION

Several sources of existing information have been referenced and consulted in compilation of this report, the details of which are given below: -

- ‘Stage A Report – Historical Survey and Preparation of Sampling Program - Contamination Survey, Evaluation of Risk and the Assessment of Treament Alternatives at the Acre Kiryat Haplazda Site’, ENOSH Systems Co. Ltd, February 2003

- ‘Factual Report for Site Pollution Investigation’, BAE Systems Environmental, Report No. A249-00-R2-D, December 2004.

2. RISK ASSESSMENT APPROACH

2.1. WHAT IS RISK ASSESSMENT

The term risk is widely used in different contexts and circumstances, often with slightly differing definitions. In this report, in line with UK publications about the environment, it has been given the following standard definition: - ‘Risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.’

Risk assessment is the essential starting point in managing risks. It provides a structured mechanism for identifying potential problems and making measured judgments about the consequences.

Throughout this report the approach to contaminated land risk assessment is based on good practice developed within the UK.

2.2. ASSESSING RISKS TO HUMAN HEALTH

Within the UK assessing risks to human health from land contamination is underpinned by the ‘suitable for use’ approach. The risk assessment process focuses on the question of whether there is an unacceptable risk, which will depend on the specific circumstances of the site and the exposure to contamination that humans working or living on the site have or potentially could have. This exposure will vary depending on the human activity on the site – e.g. residential use with or without gardens, open space or recreational areas and commercial or industrial use.

It is this overall approach that has been adopted in compiling this report and a more detailed discussion of the human health risk assessment approach adopted and a process flowchart is provided in Appendix 2.

2.3. ASSESSMENT CRITERIA FOR GROUNDWATER QUALITY

In the UK the method for assessing risks to groundwater is whether there is, or there is likelihood for the water body to be polluted by any poisonous, noxious or polluting matter or any solid waste matter.

In practice this assessment is typically made by a comparison of the contaminant concentration within groundwater with chemical and/or biological criteria that reflect the potential for the quality or use of the water to be impaired.

There are a variety of established water classification schemes and water quality standards in the UK that provide indicators of concentrations of substances above which there may be impairment. These classification schemes and standards are based on rigorous scientific assessment and are therefore very useful in assessing pollution, as well as the degree of pollution but are not specific standards for groundwater quality.

However, it is assumed that the most sensitive of these standards designed to protect surface water (Environmental Quality Standards - EQS) and drinking water supply (Drinking Water Standards - DWS) are protective of groundwater and it is these standards that are used to assess the quality of groundwater in terms of contaminated land.

For contaminants where there are no EQS or DWS values for comparison then reference is commonly made to the ‘Dutch List’ intervention and target values for groundwater.

If significantly elevated results are obtained as a result of the initial Tier 1screening process, a second tier, site specific assessment can be used to determine actual risk to the water environment. This Tier 2 assessment is used to derive site specific working standards using appropriate methods, with the working standard used as an assessment criteria to determine the risk to groundwater or other water body. If at this point, the actual contaminant concentration in the groundwater, soil or source material exceeds the derived working standard then there is a risk of water pollution.

2.4. ASSESSMENT CRITERIA FOR SOIL GASES

The assessment of risks from soil gas in the UK is conducted by a similar approach as that for groundwater risk assessment. Site data of soil gas concentrations are compared with accepted guideline values and exceedances above the guidance values indicates a risk is present. If a gas concentration exceeds the relevant guidance value then some form of remedial action if recommended.

Guideline trigger values for measured gas levels are set out in the UK Waste Management Paper 27 and are 1% by volume in air (% v/v) for methane and 1.5 % v/v for carbon dioxide. Above these levels gases may be considered to be potentially hazardous to building developments. This guidance is also contained within the current UK Building Regulations Approved Document C. However, the guidance is augmented and where levels of carbon dioxide exceed 5 % v/v the proposed development should include measures to protect against ingress of gas within the building fabric.

Whilst the presence of elevated soil gases may be indicative of a potential problem, conditions must exist to allow gas to actually migrate from the ground and enter buildings in sufficient quantities to allow hazardous accumulations to develop. In this regard, there has to be a mechanism and driving force to cause the gas to migrate. This potential is assessed by determining borehole pressure and flow rate. Therefore, whilst there may be elevated levels of methane and/or carbon dioxide, if the borehole pressures and flow rates are consistently low or negligible, it is unlikely that the gases will readily migrate out of the ground in sufficient volumes to present a risk to buildings.

3. REVIEW OF CONCEPTUAL SITE MODEL

3.1. INTRODUCTION

A Conceptual Site Model (CSM) is a simplified representation of the environmental conditions at the Site and its surroundings. A Conceptual Site Model is built up showing the main Sources of Site contamination, the various types of Receptors found on, under or close to the Site and the potential linkage or Pathway by which the Receptors may be exposed to the contamination Sources. A Pollutant Linkage occurs when a Receptor is exposed to a contamination Source to an extent where significant harm can be shown to be likely. The development of a CSM can highlight data gaps, identify the data which requires to be collected through site investigation. Development and refinement of the CSM is iterative as further data is collected and assessed.

In the context of land contamination, the three essential elements of the CSM, the source, receptor and pathway are defined as: -

- a source– a substance which is in, on or under the land and has the potential to cause harm or to cause pollution of controlled waters
- a receptor – in general terms, something that could be adversely affected by a contaminant, such as people, an ecological system or a water body, and
- a pathway – a means by which a receptor can be exposed to, or affected by, a contaminant.

Although each of these elements can exist independently, they only pose a potential risk where they are linked together – so that a particular source (contaminant) affects a particular receptor through a particular pathway. The term pollutant linkage is used to describe a particular combination of source-pathway-receptor for the risk assessment. If one of the three components (source-pathway or receptor) is missing then a pollutant linkage does not exist.

An initial CSM has been developed based on the findings of the Desk Study and Site Investigation and is summarized below together with the identified potential sources, pathways and receptors. A pictorial representation of the initial CSM is presented as Figure 1.

3.2. SUMMARY OF CSM

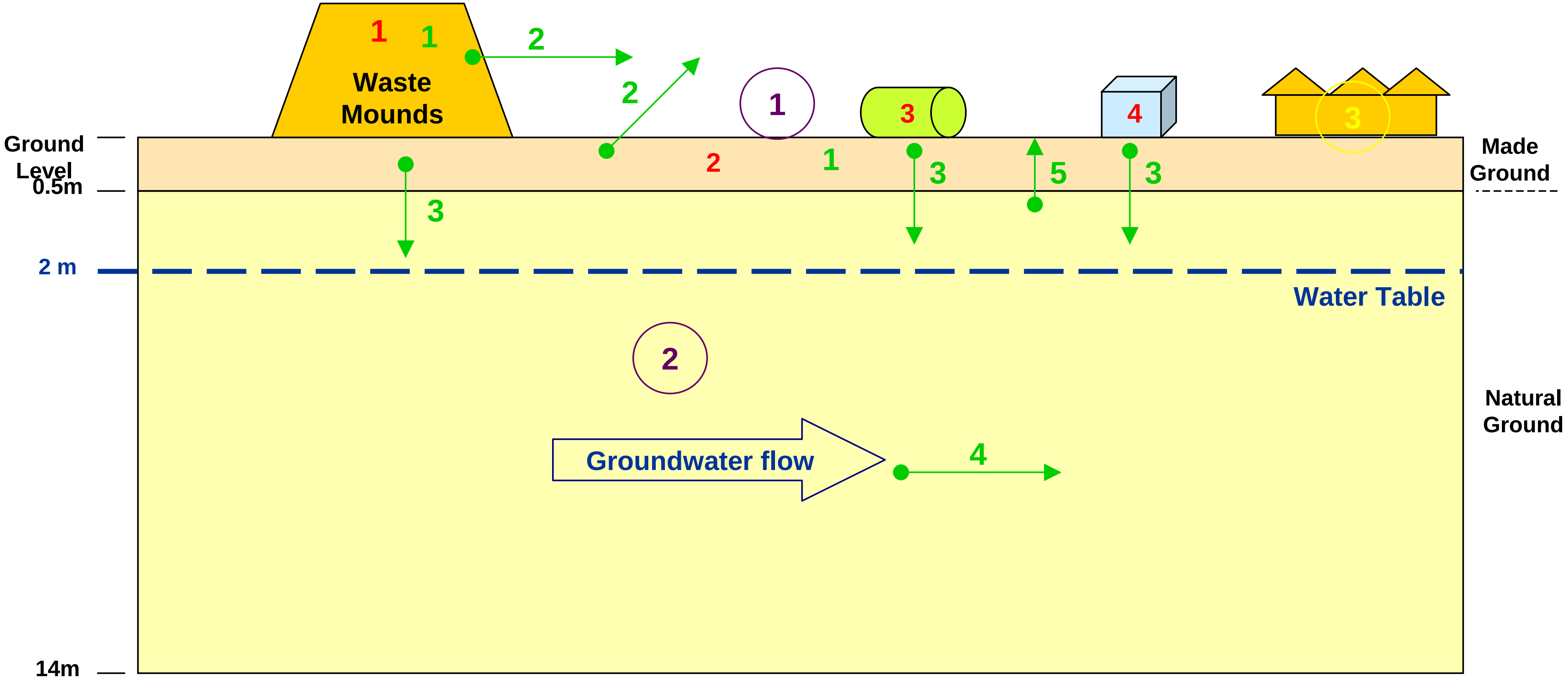
The use of the Site as a Steel Mill involving the rolling and smelting of raw and scrap materials and associated storage and waste disposal has resulted in a number of potential sources of contamination.

Contamination sources associated with the use of the Site are numerous and include most common contaminants found on steel work related sites such as, metals, oils, fuels, oxide ores, solvents, acids, PCB’s and asbestos. Many areas of visual contamination, such as surface hydrocarbon staining, were identified by the desk study.

Furthermore detailed information on the history of the site, historical operations and the type of potential contaminants are contained in the desk study report.

Although some of the buildings and services roads on Site provide some protection from potential contaminants within the sub-soil, many areas of the Site are not covered, and potentially contaminated soils are exposed at surface. This is particularly the case

Figure 1 – Initial Conceptual Site Model, Akko Steel Mills



Contamination Sources

1 Waste mounds

2 Made ground

3 Fuel storage

4 Electric substations

Pathways

1 Direct contact with contamination

2 Ingestion/inhalation of wind blown dust

3 Migration in unsaturated zone

4 Migration in shallow groundwater

5 Vapour in unsaturated zone

Receptors

1 Humans

2 Controlled water - groundwater

3 Property – building structures

around the location of the Waste Mounds and Made Ground around the Site between buildings and other infrastructure.

The unsaturated zone beneath the Site is likely to be relatively permeable due to the underlying soil type being sandy and granular in nature. This gives rise to potential risks to the groundwater which is known to exist at relatively shallow depth, generally 1m to 2m below ground level (m.bgl) beneath the Site.

Humans occupy the Site during working hours and are able to come into direct contact with underlying soils due to limited expanse of hard cover on the Site. In addition, due to numerous vehicle movements on Site and the dry climate in the area, dust generation further exposes Site users and neighbours to potential contamination.

3.3. SUMMARY OF POTENTIAL SOURCES

A summary of the potential contamination sources as identified by the desk study is listed in the table below: -

Description	**Location and geometry**	**Contaminants**
Contaminated waste materials due to historic waste storage	Extensive waste mounds around perimeter of Site	Metals, oils, fuels, oxide ores, solvents, acids, asbestos
Contaminated soil due to historical release of substances used	Across Site, mainly related to process areas although much of Site has been disturbed (by vehicle movements wind blown dusts etc.) increasing distribution of contaminants.	Metals, oils, fuels, oxide ores, solvents, acids, asbestos
Contaminated soils due to historical release of substances used	Across Site. High potential for migration through the unsaturated zone within sand strata or in shallow groundwater either dissolved or as free product where significant or prolonged releases have occurred. Also potential for off site impact.	Soluble metals in solution. Oils, fuels, solvents, may be present in dissolved phase, free product or vapours.
Contaminated soil due to historical release of oils containing PCB's.	Near transformers and rectifiers, likely to be in relatively close to surface and local to specific areas.	PCB's
Release of asbestos from insulating materials	Near transformers and rectifiers, likely to be in relatively close to surface and local to specific areas	Asbestos
Landfill gas	Potentially at multiple locations due to vapours build up in waste material or Made Ground.	Hazardous concentrations of oxygen, carbon dioxide and methane or hydrocarbon vapours etc.

Table 1 Summary of Potential Contamination Sources

At present the contaminants listed above are considered potential sources as their actual presence has not yet been determined. The following sections of this report will discuss the chemical analysis results obtained by the site investigation that will confirm or discount these as actual sources of contamination on Site based on the risk assessment process.

3.4. SUMMARY OF POTENTIAL PATHWAYS

A summary of potential contaminant pathways identified by the desk study and site investigation follows: -

Pathway	Description
Inhalation, ingestion, direct contact	Pathway for pollutant linkages involving humans. Ingestion and direct contact would only be applicable when parts of the Site where bare soil/waste are exposed or are excavated.
Inhalation, ingestion, direct contact	Potential for dust generation on Site high due to dry climate and numerous vehicle movements on un-surfaced services roads on Site.
Migration via shallow Groundwater	A pathway to surface watercourses
Contaminant migration via unsaturated zone	Potential presence of permeable sand strata. Includes contaminants in dissolved and free phase.
Vapour/gas migration in unsaturated zone	Landfill gas or vapours from build up within waste materials, underlying soils or soil gases from off site source.
Vapour/gas migration in underground services	Landfill gas or vapours from build up within waste materials, underlying soils or soil gases from off site source.
Direct contact	Pathway to building structures (potential to weaken)

Table 2 Summary of Potential Contaminant Pathways

3.5. SUMMARY OF POTENTIAL RECEPTORS

A summary of on and off site receptors identified by the desk study and site investigation follows: -

Receptor	Description
Humans	Worker, Maintenance personnel (Adults), unauthorised entry to Site (any person) Humans occupying neighbouring land
Controlled waters	Groundwater beneath Site
Controlled waters	Surface watercourses
Property	Building structures

Table 3 Summary of Potential Receptor Groups

3.6. AVERAGING AREAS

An averaging area (or area of interest) is that area (together with a consideration of depth) of soil to which a receptor is exposed or which otherwise contributes to the creation of hazardous conditions. The soil in the averaging area will contain variable concentrations of contaminants, which, when averaged across the area, will provide a representative indicator of how much contaminant the receptor is exposed to.

Defining such areas requires knowledge of the behaviour pattern of the receptor. For example, a single garden on a housing estate may be an appropriate averaging area for a child living in the house. The entire area of an abandoned industrial site that forms an informal play area for neighbourhood children could also be an appropriate averaging area to assess the risk from contaminants.

Based on the current and historical uses of the Site and the distribution soil types encountered during the site investigation, the Site has been divided into three broad averaging areas which are: -

- Waste Mounds
- Made Ground
- Natural Soils

The following sections of the report determines if sources, pathway and receptors are present at the Akko Steel Mill site based on the averaging areas described and hence determine the potential environmental risks.

4. HUMAN HEALTH HAZARD IDENTIFICATION

4.1. GENERAL

The previous sections have summarised the identified potential sources, pathways and receptors that may be present on the Site. The sampling plan was implemented to obtain data on the chemical and physical characteristics of the Site to determine if the potential sources actually exist on Site and enable an assessment of the pollutant linkages to any receptor.

Based on the laboratory test data obtained, this section of the report aims to identify those materials that may have a negative effect on the use of the Site. In summary, this section will detail those contaminants that have been identified and as such are considered a source of contamination. Where contaminants were not detected then these are not considered significant sources and are excluded from further assessment.

It should be noted then in the context of human health risk assessment, only the soils in the upper 1m of the ground mass i.e. samples from <1m below ground level (m.bgl) area a source as this is considered to be the depth to which humans are readily exposed to in normal daily activities.

Appendix 3 includes a summary of the laboratory test results together with the results of the generic screening exercise and statistical analyses that are discussed in later sections of this report

4.2. RECORDED CONTAMINATION PROFILE

The following table summarises the results of the laboratory testing on soil samples for all potential contaminants that were tested for. Where applicable the table gives details of the range of concentrations recorded for each contaminant for each differing area of the Site.

Averaging Area	Waste Mounds			Made Ground			Natural Soils		
Potential Contaminant	**Lowest**	**Highest**	**2nd Highest**	**Lowest**	**Highest**	**2nd Highest**	**Lowest**	**Highest**	**2nd Highest**
Arsenic	14	79	75	1	83	56	2	18	4
Cadmium	<0.30	208	154	<0.30	121	117	<0.30	<0.30	<0.30
Chromium	160	2230	1660	<5.00	1590	988	<5.00	40	28
Lead	43	12700	9110	<3.00	5380	5150	<3.00	42	23
Mercury	<0.20	5	2	<0.10	2	2	<0.10	1.90	0.40
Selenium	<0.30	2	2	<0.30	7	2	<0.30	<0.30	<0.30
Copper	230	1990	1960	<3.00	1590	1100	<3.00	110	29
Nickel	30	624	622	<5.00	310	300	<5.00	30	14
Zinc	57	93200	72700	<3.00	42300	38500	29	110	96
Boron	<0.30	17	10	<0.30	5	4	<0.30	0.70	0.40
Aluminium	83	28000	26500	1490	11300	10400	1690	3070	2930
Magnesium	280	60400	52500	876	106000	78300	881	16100	2050
Manganese	1920	28500	24800	77	52600	18700	84	515	280
Molybdenum	9	200	160	<4.00	84	70	<4.00	<4.00	<4.00
Titanium	180	2400	1570	44.00	880	660	60	110	99
Vanadium	<20.00	230	220	<20.00	134	113	<20.00	<20.00	<20.00
Cyanide (total)	<0.50	<0.52	<0.51	<0.50	<0.52	<0.50	<0.50	<0.50	<0.50

Averaging Area	Waste Mounds			Made Ground			Natural Soils		
Potential Contaminant	**Lowest**	**Highest**	**2nd Highest**	**Lowest**	**Highest**	**2nd Highest**	**Lowest**	**Highest**	**2nd Highest**
Cyanide (Free)	<0.50	0.61	<0.52	<0.50	<0.52	<0.50	<0.50	<0.50	<0.50
Sulphate (total)	<250	3600	3200	<250	5800	1500	<250	300.00	<250
Sulphide	<5.00	43	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
TPH	<50.00	2700	2100	<50.00	6100	1800	<50.00	200.00	<50.00
Acenaphthene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Acenaphthylene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Anthracene	<1.00	<1.00	<1.00	<1.00	2.10	<1.00	<1.00	<1.00	<1.00
Benz-g,h,i-perylene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Benz-(a)-pyrene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Benzo-a-anthracene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Benzo-b-fluoranthene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Benzo-k-fluoranthene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Chrysene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Dibenz (a,h) anthracene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Fluoranthene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Fluorene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Indeno 1,2,3-cd pyrene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Naphthalene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
2-Methylnaphthalene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Phenanthrene	<1.00	<1.00	<1.00	<1.00	2.00	<1.00	<1.00	<1.00	<1.00
Pyrene	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
PAH Total	<1.00	<1.00	<1.00	<1.00	4.10	<1.00	<1.00	<1.00	<1.00
Monohydric phenols	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
PCB	NA	NA	NA	<0.10	0.58	0.46	NA	NA	NA
Total VOCs	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphates	97	1300	1200	160	1600	830	160	250	210
Thiocyanate	<0.20	<0.20	<0.20	<0.20	1.10	0.87	0.47	0.47	0.47

NA – not analysed; Values with < figure indicate concentration below laboratory detection limit i.e. contaminant not detected
All results in mg/kg

Table 4 - Summary of Laboratory Soil Analyses

4.3. CONTAMINANTS OF CONCERN

Based on the above the following contaminants have been identified as being present on the Site at above naturally occurring levels and are therefore considered ‘contaminants of concern’ for each of the assumed averaging areas and require further assessment. Contaminants of concern are those that may have a negative effect on the use of the Site and its surroundings.

4.3.1. Identified Sources of Contamination

The following summarises the contaminants of concern identified in the sub soil at the Site based on the averaging areas assumed. Each of the contaminants listed for each of the averaging areas are considered to represent a contamination source within the conceptual site model.

Waste Mound – 20 No. potential contaminants

Arsenic, Cadmium, Chromium, Lead, Mercury, Selenium, Copper, Nickel, Zinc, Boron, Aluminium, Magnesium, Manganese, Molybdenum, Titanium, Vanadium, Sulphate (total), Sulphide, TPH, Phosphates

Made Ground – 22 No. potential contaminants

Arsenic, Cadmium, Chromium, Lead, Mercury, Selenium, Copper, Nickel, Zinc, Boron, Aluminium, Magnesium, Manganese, Molybdenum, Titanium, Vanadium, Sulphate (total), TPH, Anthracene, PCB's, Phosphates, Thiocyanate

Natural Soils – 14 No. potential contaminants

Arsenic, Chromium, Lead, Mercury, Copper, Nickel, Zinc, Boron, Aluminium, Magnesium, Manganese, Titanium, Phosphates, Thiocyanate

4.3.2. Update to Conceptual Model

Based on the review of recorded laboratory results there are numerous contamination sources present on Site. Given that several pathways and receptors have also been identified then significant pollutant linkages have been established for the Site.

As such, a Tier 1 screening exercise using generic screening criteria will assess each identified contaminant of concern further to establish the possibility of significant harm to human health occurring.

5. HUMAN HEALTH HAZARD ASSESSMENT

5.1. INTRODUCTION

This section of the report aims to determine if there are any potentially unacceptable risks arising from the previously identified contaminants of concern. Generic assessment criteria are used to compare the concentration of the contaminants of concern taking into account the actual or intended use of the site and its environmental setting. This assessment is a screening exercise to further identify any potentially significant risks.

5.2. GENERIC ASSESSMENT CRITERIA FOR SOIL CONTAMINATION

The contaminant concentrations within soils on the Site have been subjected to a screening process using, where possible, current Israeli Ministry of the Environment (MoE) guidance on assessing hazards to human health from contaminated land. These assessment criteria are known as Contaminant Threshold Values (CTV's).

Although generic guidance tables have their limitations they are considered a quick and simple method of determining the relative scale of contamination. Initial screening can be complimented, if required, by assessment using site specific assessment criteria.

This hazard assessment has been made, as far as possible, using the MoE CTV's. CTV's are available based either on land use or 'distance from ground water'.

With regards to land use, based on the assumption that the use of the Site will remain unchanged, the CTVs for industrial and commercial land uses have been selected where available. Where CTV's for industrial and commercial land uses are not available, CTV's for the other land uses have been used such as agriculture. residential, or for a distance from groundwater less than 12 m have been used as the recorded groundwater levels ranged between 1.51 and 2.55 m.bgl.

Where no CTV is available for a particular potential contaminant another source of information must be used for the screening exercise. In this case, where necessary we have compared the laboratory data with current published UK Soil Guideline Values (SGV's) derived from the Contaminated Land Exposure Model (CLEA) as detailed in the CLR series of documents published by the UK Environment Agency. Comparison with generic SGV's has been utilised as they are valid for use in a screening process in the same way as CTV's. Where published SGV's were unavailable we have used our own generic SGV's derived using the CLEA computer model for default site conditions for the industrial/commercial land use.

If no relevant CTV or CLEA SGV could be derived, other sources have been referenced such as the Dutch Serious Risk Concentration (SRC) for soil values or in the case of no reliable contaminant toxicology data etc available, values relating to potential background concentrations of contaminants have been used as indicated.

Some contaminants tested for do not have any guideline value or available data, in this case a professional judgment has been made in the report in terms of the likelihood of significant harm occurring from these contaminants.

5.3. RESULTS OF THE SCREENING EXERCISE

The table below details the results of the screening exercise for the contaminants of concern identified within the sub-soil at the Site at depths <1m below ground level.

Averaging Area		**Waste Mounds – 25 samples**	**Made Ground – 36 samples**	**Natural Soils – 7 samples**	
Potential Contaminant	**Guidance Value - G**	**No of exceedences of G**	**No of exceedences of G**	**No of exceedences of G**	**Guidance Value - Type**
Arsenic	17	24	15	1	CTV Industrial
Cadmium	30	7	5	0	CTV Industrial
Chromium	400	22	10	0	CTV Industrial
Lead	1000	12	6	0	CTV Industrial
Mercury	8	0	0	0	CTV Industrial
Selenium	100	0	0	0	CTV Industrial
Copper	190	25	18	0	CTV Industrial
Nickel	500	3	0	0	CTV Industrial
Zinc	2500	19	10	0	CTV Industrial
Boron	20	0	0	0	CTV Agriculture
Aluminium	124000	0	0	0	Generic SGV
Magnesium	9000	17	18	1	Bowen Background
Manganese	6000	21	11	0	CTV Industrial
Molybdenum	9120	0	0	0	Generic SGV
Titanium	25000	0	0	0	Bowen Background
Vanadium	12967	0	0	0	Generic SGV
Cyanide (total)	50	0	0	0	CTV Industrial
Cyanide (Free)	10	0	0	0	CTV Industrial
Sulphate (total)	6000	0	0	0	CTV Industrial
Sulphide	70	0	0	0	CTV Industrial
TPH	500	9	3	0	CTV Industrial
Acenaphthene	NA	0	0	0	NA
Acenaphthylene	NA	0	0	0	NA
Anthracene	120	0	0	0	Generic SGV
Benz-g,h,i-perylene	NA	0	0	0	NA
Benz-(a)-pyrene	9	0	0	0	Generic SGV
Benzo-a-anthracene	39	0	0	0	Generic SGV
Benzo-b-fluoranthene	63	0	0	0	Generic SGV
Benzo-k-fluoranthene	60	0	0	0	Generic SGV
Chrysene	490	0	0	0	Generic SGV
Dibenz (a,h) anthracene	10	0	0	0	Generic SGV
Fluoranthene	4843	0	0	0	Generic SGV
Fluorene	NA	0	0	0	NA
Indeno 1,2,3-cd pyrene	93	0	0	0	Generic SGV
Naphthalene	158	0	0	0	Generic SGV
2-Methylnaphthalene	NA	0	0	0	NA

Averaging Area		**Waste Mounds – 25 samples**	**Made Ground – 36 samples**	**Natural Soils – 7 samples**	
Phenanthrene	4800	0	0	0	Generic SGV
Pyrene	4559	0	0	0	Generic SGV
PAH Total	40	0	0	0	CTV Industrial
Monohydric phenols	14	0	0	0	Dutch SRC Soil
PCB	25	0	0	0	CTV Industrial
Total VOCs	NA	0	0	0	NA
Phosphate	NA	-	-	-	NA
Thiocyanate	10	0	0	0	CTV Industrial

NA – no generic screening criteria available

Table 5 Contaminants Exceeding Generic Soil Screening Values

5.3.1. Update to Conceptual Model

Based on the above screening exercise the following contaminants of concern have been identified at concentrations exceeding the generic screening criteria used. Given that the pathways and receptors identified for the Site remain unchanged it is considered that these contaminants have the potential to cause significant harm.

Waste Mound

Arsenic, Cadmium, Chromium, Lead, Copper, Nickel, Zinc, Magnesium, Manganese, and TPH.

Made Ground

Arsenic, Cadmium, Chromium, Lead, Copper, Zinc, Magnesium, Manganese, and TPH.

Natural Soils

Arsenic and Magnesium

It is noted that in the above table no assessment for phosphate has been undertaken. This is due to the being unable to derive a generic screening criteria for phosphate as no suitable and reliable toxicological data could be obtained. However, it is considered that due to the abundance in phosphate in the general environment and the fact it is relatively non-toxic, further assessment for phosphate is not required.

The screening exercise has therefore updated the conceptual model in relation to the contaminants of concern and the above list can be considered the updated list of potential sources in the conceptual site model for further assessment.

6. STATISTICAL ANALYSIS OF SOIL RESULTS

6.1. GENERAL

Statistical tests are also performed on the laboratory data for the contaminants of concern to identify the presence of any erroneously high concentrations. The statistical tests also determine whether the highest concentration for a particular contaminant is indicative of a localised ‘hotspot’ of contamination or an indication of an area of significant contamination.

6.2. TESTS OF SIGNIFICANCE

In order to determine the significance of the recorded contaminant concentrations in the soil samples it is necessary to conduct a statistical analysis of the data. Two statistical tests can be applied to a data set to determine its significance, these are the Maximum Value Test and the Mean Value Test. Examples of the mean and maximum values tests are presented in Appendix 4.

6.2.1. Maximum Value Test

For some data sets, individual concentrations may have been measured at particular locations that are much higher than the rest of the data. Decisions need to be made on whether these concentrations fall within the maximum of the range of values that can be expected from the sample population, or whether they are indicative of an area of higher contamination (in effect, a different population with a higher mean).

Data points that do not fall within the expected distribution of measurements for the sample population are termed ‘outliers’ and may be indicative of a localised hotspot of contamination. If the measured maximum concentration is found to be part of the underlying population of the data set, then the Maximum Value Test is failed. This could indicate that the maximum values recorded are representative of a widespread occurrence of contamination on the site. Professional judgment is then needed to determine whether site wide or localised hotspot remediation is required.

To use the maximum value test it is necessary to assume the form of the underlying mathematical distribution of the recorded concentrations. In the context of chemical analyses of contaminated soils, it is common practice to work with the logarithms of the measured concentrations. This log-transformation usually results in a more or less symmetric distribution that, while not strictly normal, is usually close enough to allow normal statistics to be used to analyse the chemical data.

Once the chemical data has been calculated into what are know as ‘T values’, then the results are compared with a critical value known as ‘T critical’. A comparison is then made between these values to determine if the data is an outlier or part of the underlying population of results.

6.2.2. Results of the Maximum Value Test

A Maximum Value Test has been conducted on the data sets for those contaminants exceeding the generic screening values used to decide if the elevated concentrations are representative of a contamination ‘hotspot’ or a potentially more widespread contamination issue.

Where the results indicates ‘outlier’ then that data set of concentrations can be considered an outlier from the main data population and indicative of a localised contaminant hotspot'. Where a 'part' result is shown then there is a potential that the data set of concentrations indicates widespread contamination on the Site.

From the table below it can be seen that the contaminants exceeding the generic screening values are part of the underlying population of data indicating that there is a potential widespread contamination issue in the Waste Mounds.

Similarly, for the Made Ground a potential widespread contamination issue has been identified for the contaminants shown, except for TPH and phosphate where a localised 'hotspot' of these contaminants may be present. The sample data for the Natural Soils for those concentrations elevated above the generic screening values indicate two potential 'hotspots' of contamination relating to arsenic and magnesium and a potential widespread issue with phosphate.

It should be noted that in using the maximum value test, consideration should be given to the number of samples from the relevant data sets in Table 6 that were identified exceeding the generic screening value. If the majority of the samples analysed were found to be above the screening value and the maximum value test indicated that the values were part of the underlying population, then the interpretation that there was a widespread contamination issue would be valid. Such an example, is within the samples from the Waste Mounds at the Site, particularly for arsenic, chromium, copper and zinc.

Conversely, if only a few of the total number of the sample concentrations recorded exceeded the generic screening value but the maximum value test indicated a widespread issue then judgment would be needed in interpretation. In this case it is obvious that there is not a widespread contamination issue as an insignificant number of sample concentrations exceeded the generic screening values. Such an example is seen in the sample from the Natural Soils.

In this case uncertainty is present and a further statistical test, the Mean Value Test, can be used to determine the significance of the soil results and whether a significant possibility of significant harm actually exists.

Averaging Area	**Waste Mounds – 25 samples**			**Made Ground – 36 samples**			**Natural Soils – 7 samples**		
Max Value Test	T	T critical 10%	T < T crit 10%??	T	T critical 10%	T < T crit 10%??	T	T critical 10%	T < T crit 10%??
Arsenic	1.64	2.49	PART	1.90	2.64	PART	2.14	1.94	OUTLIER
Cadmium	1.58	2.49	PART	1.93	2.64	PART	NA		
Chromium	1.49	2.49	PART	1.56	2.64	PART	NA		
Lead	1.66	2.49	PART	1.65	2.64	PART	NA		
Copper	1.12	2.49	PART	1.36	2.64	PART	NA		
Nickel	1.47	2.49	PART	NA			NA		
Zinc	1.40	2.49	PART	1.71	2.64	PART	NA		
Magnesium	1.21	2.49	PART	2.01	2.64	PART	2.16	1.94	OUTLIER
Manganese	1.58	2.49	PART	1.97	2.64	PART	NA		
TPH	1.83	2.49	PART	3.24	2.62	OUTLIER	NA		

NA – Maximum values of contaminants not assessed as concentrations did not exceed generic screening criteria

Table 6 Maximum Value Test Results

6.2.3. Mean Value Test

Contaminant concentrations in the soil can vary across a site and the calculated mean concentration may not equal the 'true' mean and will have a degree of uncertainty associated with them. A straight comparison between the calculated mean and a Generic Screening Value could be misleading. The approach of identifying the 95% confidence limit of the measured mean and using the upper 95th percentile value for comparison with the Generic Screening Value takes account of the potential uncertainty in the data set.

If the upper bound 95th percentile value is less than the Generic Screening Value, then the Mean Value Test has been passed, and the site may be considered not to present a significant possibility of significant harm to human health.

Should data fail the Mean Value Test, more comprehensive sampling where only a small number of data points exist should be considered. Alternatively, remedial action will be required where, for example, when sufficient sampling has been undertaken, further sampling is not practicable, or timescales dictate rapid action, assuming that a significant pollutant linkage has been identified. The Mean Value Test is applied to the data set for each of the averaging areas being considered.

6.2.4. Results of the Mean Value Tests

The Mean Value Test has been applied to the soil sample analyses from the Waste Mounds, Made Ground and Natural Soils, the results of which are shown in Table 7.

Averaging Area		**Waste Mounds - 25 Samples Tested**		**Made Ground - 36 Samples Tested**		**Natural Soils - 7 Samples Tested**	
Mean Value Test	**Guidance Value - G**	**Upper Bound (95th % ile)**	**Upper Bound > G ??**	**Upper Bound (95th % ile)**	**Upper Bound > G ??**	**Upper Bound (95th % ile)**	**Upper Bound > G ??**
Arsenic	17	46	FAIL	22	FAIL	9	PASS
Cadmium	30	54	FAIL	24	PASS	NA	
Chromium	400	1168	FAIL	394	PASS	NA	
Lead	1000	1584	FAIL	229	PASS	NA	
Copper	190	1337	FAIL	464	FAIL	NA	
Nickel	500	316	PASS	NA		NA	
Zinc	2500	26495	FAIL	8575	FAIL	NA	
Magnesium	9000	25007	FAIL	23861	FAIL	7615	PASS
Manganese	6000	13684	FAIL	7953	FAIL	NA	
TPH	500	830	FAIL	707	FAIL	NA	

NA – Mean values of contaminants not assessed as concentrations did not exceed generic screening criteria
NG – No guideline value available for comparison and no CLEA value could be derived due to no available suitable toxicity data
For Lead a geometric mean and log values are used for comparison, e.g. such G = log (generic screening value)

Table 7 Mean Value Test Results

In the calculated upper 95th percentile for the Waste Mounds the values for arsenic, cadmium, chromium, copper, zinc, magnesium, manganese and TPH exceed the generic screening values used. As such, under the CLEA model, the data set for these contaminants has failed the Mean Value Test and may be considered to present significant possibility of significant harm to human health.

For the soil samples from the Made Ground the 95th percentile values arsenic, copper, zinc, magnesium, manganese and TPH exceed the generic screening values used. Therefore for these contaminants the Mean Value Test has failed and there is a significant possibility of significant harm to human health from these contaminants in the Made Ground.

All other calculated 95th percentile values for soil samples in the Waste Mounds and Made Ground were below the generic screening values and have passed the mean value test. As such, it is considered that the related contaminants do not present a significant possibility of significant harm to human health based on an commercial/industrial end use for the Site and are therefore do not require further assessment.

In the natural soils, the 95th percentile values are all below the generic screening values used and therefore pass the mean value test. As such, it can be considered that the Natural Soils do not present a significant possibility of significant harm to human health and require no further assessment.

7. HUMAN HEALTH RISK EVALUTAION

7.1. CONFIRMED POLLUTANT LINKAGES

Section 3 detailed the initial conceptual site model and listed the potential pathways and pollutant linkages present on Site. Given that several sources of contamination have now been identified in the Waste Mounds and Made Ground it is considered that pollutant linkages to the identified receptors in these areas have been confirmed.

The confirmed pollutant linkages are: -

Contaminant Source	**Pathway**	**Receptors**
Contaminated materials in Waste Mounds around perimeter of the Site - arsenic, cadmium, chromium, copper, nickel, zinc, magnesium, manganese, TPH	Direct dermal contact with contamination Inhalation and/or ingestion of windblown dust	Workers, maintenance personnel (Adults), unauthorised entry to Site (adults or children)
Contaminated soil/materials in Made Ground across the Site - arsenic, copper, zinc, magnesium, manganese, TPH	Direct dermal contact with contamination Inhalation and/or ingestion of windblown dust	Workers, maintenance personnel (Adults), unauthorised entry to Site (adults or children)

Table 8 Confirmed Pollutant Linkages

The magnitude of this risk now needs to be determined to decide whether remedial action is required or further more detailed risk assessment may assist in mitigating the identified risks.

7.2. RISK EVALUATION

The results of the generic screening exercise and tests of significance have identified that the contamination exists in Waste Mounds and Made Ground on the Site in sufficient concentrations to present an unacceptable level of risk to the health of humans using the Site.

An assessment of the magnitude of this risk by comparing the amount the 95th percentile values exceeds the generic screening values can assist decision making. The results of this assessment are given in Table 9.

The results indicate that for arsenic, cadmium, chromium, lead, magnesium, manganese and TPH in the Waste Mounds, and for the all contaminants in the Made Ground, derivation of site specific assessment criteria may make it possible to mitigate the potential risks from these contaminants although remedial action would be a preferred option.

In relation to TPH, additional assessment could be conducted to further determine the level of risk. However, we consider it would be more cost and time effective to remediate the identified hotspot of TPH as it has been identified as a statistical outlier.

Further assessment is difficult due to the substances in TPH being present in the environment as complex mixtures containing many hundreds of individual compounds with differing toxicological properties. As such, we consider that the timescales to conduct this work would be undesirable for such a small hotspot occurrence of TPH and remediation is the preferred option.

Similarly, we consider further assessment for magnesium is not required as it is generally regarded as being non-toxic and due to the fact we there is no suitable and reliable toxicological data available so a generic screening criteria could not be obtained.

The magnitude of the exceedances of copper and zinc in the Waste Mounds is very high and suggests that remedial action is required to mitigate the identified risks, particularly in the Waste Mounds.

In order to more fully assess the identified risk from the contaminants listed above we have undertaken a more site specific risk assessment on these contaminants which is discussed in the following section of the report.

Averaging Area		**Waste Mounds**		**Made Ground**	
Contaminant	**Guidance Value - G**	**Upper Bound (95th % ile)**	**Magnitude of Exceedance**	**Upper Bound (95th % ile)**	**Magnitude of Exceedance**
Arsenic	17	46	x 3	22	x 1
Cadmium	30	54	x 2	NA	
Chromium	400	1168	x 3	NA	
Lead	1000	1584	x 2	NA	
Copper	190	1337	x 7	464	x 2
Nickel	500	NA		NA	
Zinc	2500	26495	x 11	8575	x 3
Magnesium	9000	25007	x 3	23861	x 3
Manganese	6000	13684	x 2	7953	x 1
TPH	500	830	x 2	707	x 1

NA – Contaminants not assessed, as concentrations did not fail the statistical tests.

Table 9 Magnitude of Exceedances

8. SITE SPECIFIC HUMAN HEALTH RISK ASSESSMENT

8.1. GENERAL

Given that several contaminants have been identified that present an unacceptable risk to continued Site use, we have undertaken a site specific risk assessment to determine if some of the identified risks can mitigated further by additional risk assessment.

For this additional assessment we have conducted a Tier 1b assessment on the contaminants in which the 95th percentile value calculated from the statistical analysis exceeds the screening value used.

8.2. SITE SPECIFIC ASSESMENT CRITERIA

The Tier 1b screening criteria have been calculated using the UK Contaminated Land Exposure Assessment (CLEA) 2002 Model. Data obtained by the site investigation has been used as input parameters for the CLEA software to derive detailed screening values for the contaminants of concern. The CLEA model has been used as it provides a probabilistic tool to assess the long term effect of contamination to human health based on toxicological data and the suitable for use approach to land use. A fact sheet detailing the CLEA model is included in Appendix 5 and details of the detail screening criteria generated are in Appendix 6.To conduct the Tier 1b assessment the 95th percentile values of the contaminants have been compared with the detailed screening values for a commercial/industrial land use to identify any exceedences. Where contaminants are found to exceed the relevant criteria then consideration should be given to the implementation of risk management actions such as remediation or a site specific risk assessment.

The table below summarises the calculated SSAC's detailed screening values and the results of the Tier 1b assessment: -

Averaging Area		**Waste Mounds**		**Made Ground**	
Contaminant	**CLEA Value (mg/kg)**	**Upper Bound (95th % ile)**	**Upper Bound (95th % ile) > SSAC**	**Upper Bound (95th % ile)**	**Upper Bound (95th % ile) > SSAC**
Arsenic	560	46	Below	22	Below
Cadmium	1400	54	Below	NA	NA
Chromium	5200	1168	Below	NA	NA
Lead	750	1584	Above	NA	NA
Copper	47128	1337	Below	464	Below
Zinc	543677	26495	Below	8575	Below
Manganese	258838	13684	Below	7953	Below

NA – Contaminants not assessed, as concentrations did not fail the statistical tests.

Table 10 Results of Detailed Screening Assessment

Based on the above, the site specific assessment has resulted in identifying only one contaminant, lead, that presents an unacceptable risk to site use.

Given that lead is a particularly toxic substance it is recommended that remediation be implemented for this contaminant within the Waste Mounds on Site.

9. GROUNDWATER RISK ASSESSMENT

9.1. GENERAL CONSIDERATIONS

Boreholes constructed during the intrusive investigation were fitted for groundwater monitoring purposes. Response zones were located in natural strata underlying Made Ground, with bentonite sealant used as required to prevent the formation of new contaminant pathways.

One groundwater monitoring visit was undertaken after the completion of the fieldwork. Soil gas concentrations and groundwater levels were monitored prior to purging and water sampling of productive boreholes.

During the sampling visit, groundwater was present in all of the nine boreholes. All boreholes were sufficiently productive to allow purging of three well volumes and subsequent sampling.

9.2. WATER ANALYSES

A total of nine groundwater samples, collected from the boreholes installed during September 2003, were sent for analysis. All samples were analysed for a standard suite of contaminants, based on the suite used for soil sample analysis. Results of chemical analyses conducted on groundwater samples are included in the Factual Report for the Site Pollution Investigation, BAE Systems Environmental Report A249-00-R2-D.

9.3. WATER QUALITY AND LEACHING POTENTIAL

9.3.1. Water Quality

A summary of contaminant concentrations elevated above the UK Drinking Water Quality Standards (DWQS) and Freshwater EQS thresholds is included as Table 11.

Metals

The results of the groundwater analysis shows that elevated levels of both aluminium and manganese were present above the DWQS in all sample locations. Concentrations of aluminium ranged between 2.2 and 7.4 mg/l (compared with DWQS of 0.2 mg/l) and manganese ranged between 0.40 and 1.51 (compared with DWQS of 0.05).

Concentrations of nickel exceeded the DWQS of 0.02 mg/l in 6 No. sample locations, with a maximum concentration of 0.032 mg/l in BH8. The EQS threshold for nickel was not exceeded.

The results show concentrations of lead to exceed the EQS (0.02 mg/l) in 5 No. locations and the DWQS (0.025 mg/l) in 4 No. locations, the concentrations of lead ranged from 0.015 to 0.083 mg/l. Results for vanadium (0.041 to 0.080 mg/l) exceeded the lower EQS threshold of 0.02 mg/l in all locations and exceeded the upper threshold of 0.6 mg/l in 6 No. locations.

In general concentrations of aluminium, manganese, nickel, lead and vanadium in groundwater increase to the north of the Site.

Concentrations of boron equalled the DWQS of 1.0 mg/l in one location (BH2), neither the DWQS or EQS for boron were exceeded. Copper exceeded the EQS of 0.028 mg/l in 7 No. locations (ranging from 0.028 to 0.064 mg/l).

In general, the potential contaminants found in elevated concentrations in the groundwater correspond strongly with those identified in the analysis of soil samples.

Hydrocarbons

Concentrations of Total Petroleum Hydrocarbons exceeded the DWQS of 10 ug/l in 8 No. of the 9 No. groundwater samples, ranging from 41 ug/l in BH4 to 511 ug/l in BH9. The recorded TPH were typically of the carbon range C_{10} to C_{24}, which are indicative of the presence of diesel fuel and light fuel oils (typically C_{10} to C_{20}), kerosene (C_{11} to C_{13}) and heavy fuel oils (C_{19} to C_{25}).

Hydrocarbons were present in both BH1 (368 ug/l) and BH2 (238 ug/l) and given the direction of groundwater flow, as determined by site data, activities off-site may be a contributing source. However, it should be noted that the highest concentration recorded was in BH9 (511 ug/l) in the centre of the Site.

PAH

Elevated concentrations of PAH were identified in BH1 (0.09 ug/l) and BH2 (0.19 ug/l). Only BH2 exceeded the DWQS of 0.1 ug/l. Of the individual PAH fractions, anthracene (0.10 ug/l) and Phenanthrene (0.09 ug/l) were present in BH2 and Phenanthrene (0.09 ug/l) was present in BH1. The ‘Dutch List’ gives threshold and target values in water of 70 ug/l and 0.1 ug/l for Anthracene and 5 ug/l and 0.02 ug/l for Phenanthrene respectively. Neither sample exceeded the respective intervention values.

VOCs

Low concentrations of VOCs were found in 3 No. of the groundwater samples. Values in italics were below the laboratory’s accredited reporting limit.

- BH1 – 25.1 ug/l Trichloroethene
  20.4 ug/l Tetrachloethene
  3.1 ug/l Cis-1,2-dichloroethene
  1.0 ug/l 1,1-Dichloroethene

- BH5 – 2.2 ug/l Trans-1,2-dichloroethene
  1.5 ug/l Cis-1,2-dichloroethene

- BH6 – 1.4 ug/l 1,2-Dichloroethane

No VOC concentrations exceeded the relevant ‘Dutch List’ Intervention values.

Sulphate

Concentrations of sulphate recorded in the groundwater samples ranged between 488 and 1530 mg/l. These values exceeded both the DWQS and the EQS values of 250 mg/l and 400 mg/l respectively. The presence of sulphate can result in significant deterioration of concrete and may have implications for the design of structures in future developments. All of the groundwater sulphate concentrations also exceed the 400 mg/l threshold for Design Class 1 as detailed in the UK BRE Special Digest No. 1, requiring maximum protection.

Sulphide

All recorded concentrations of sulphide in the groundwater (ranging between 0.09 to 0.5 mg/l) exceed the EQS threshold of 0.00025 mg/l.

Determinand	Unit	DWQS	Freshwater EQS*	BH1	BH2	BH3	BH4	BH5	BH6	BH7	BH8	BH9
Al	mg/l	0.2	-	**2.2**	**3.8**	**4.7**	**3.8**	**4.2**	**5.0**	**5.9**	**7.4**	**6.4**
As	mg/l	0.01	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	mg/l	1	2	0.3	**1.0**	0.6	0.4	0.2	0.3	0.3	0.3	0.2
Cd	mg/l	0.005	0.005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0010	<0.0005	<0.0005
Cr	mg/l	0.05	0.25	0.006	0.010	0.013	0.008	0.012	0.016	0.020	0.026	0.02
Cu	mg/l	2	0.028	0.027	0.028	0.064	0.041	0.033	0.032	-	0.056	0.037
Pb	mg/l	0.025	0.25	0.015	0.016	0.019	0.024	0.016	**0.057**	**0.074**	**0.083**	**0.048**
Mn	mg/l	0.05	-	**0.75**	**1.42**	**0.53**	**0.40**	**1.10**	**1.01**	**1.51**	**1.51**	**1.47**
Hg	mg/l	0.001	0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mo	mg/l	0.07*	-	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.005	0.021	<0.005	<0.005
Ni	mg/l	0.02	0.2	0.012	**0.024**	0.012	0.009	**0.020**	**0.023**	**0.027**	**0.032**	**0.030**
Se	mg/l	0.01	-	0.0003	0.003	<0.001	0.002	<0.001	0.002	0.002	<0.001	<0.001
V	mg/l	-	0.02 – 0.06	0.041	0.062	0.068	0.063	0.055	0.059	0.080	0.077	0.76
Zn	mg/l	5	0.5	0.033	0.11	0.15	0.037	0.11	0.076	0.32	0.095	0.12
Sulphide	mg/l	-	0.00025	0.1	0.04	0.04	0.5	0.3	0.08	0.3	0.09	0.09
Thiocyanate	mg/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.6
PH	pH units	6.5 to 10	-	7.2	7.3	7.4	7.4	7.3	7.3	7.2	7.3	7.3
Phosphate	mg/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulphate	mg/l	250	400	**992**	**1530**	**671**	**617**	**734**	**488**	**1140**	**557**	**670**
PCB	-	-	-	ND	ND	ND	ND	ND	ND	-	ND	ND
Cyanide (total)	mg/l	0.05	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Phenols	mg/l	0.0005	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hydrocarbons	ug/l	10	-	**368**	**238**	**67**	**41**	ND	**65**	**165**	**46**	**511**
PAH	ug/l	0.1	-	0.09	**0.19**	<0.05	<0.05	<0.05	<0.05	-	<0.05	<0.05

* Total Hardness for all samples is in the >250 mg/l CaCO3 group as listed in EQS Table 2b.

Exceedances

▨	EQS exceedance
1.5	DWQS exceedance

Table 11 Contaminants exceeding UK Drinking Water Standards & Freshwater EQS thresholds

9.3.2. Leaching potential

Eleven selected soil samples were submitted for leachability analysis in accordance with Environment Agency R&D Note 301, ‘Leaching Tests for the Assessment of Contaminated Land’ which details the laboratory methods to be used to conduct leaching tests on soil samples. The leachate extraction method required a mass of soil sample to be weighed and a volume of water 10 No. times the weight to be added. The sample was then shaken for 24 hours and filtered through a 0.45 um membrane filter. Chemical analysis of the leachate used the same methodology as for the groundwater samples.

Samples and determinands were selected on the basis of an initial screen of concentrations using a combination of Israeli CTV’s and CLEA SGVs. Other samples containing contaminant concentrations apparently elevated above the general background on the Site were also scheduled. Test results are presented in Table 12, which also compares them to the DWQS and Freshwater EQS.

Leachate concentrations from 4 No. samples exceeded the DWQS: concentrations of aluminium of 2070, 532 and 253 ug/l were recorded in samples TP6 – SURFACE, TP10 – 1.3 m and TP23 – 0.7 m respectively. A concentration of manganese of 11000 ug/l was recorded in TP6 – SURFACE, concentrations of lead of 832 ug/l and manganese of 60 ug/l were recorded in TP31 – 0.8 m. TP23 – 0.7 m also exceeded the Freshwater EQS threshold for lead and TP23 – 0.7 m slightly exceeded the freshwater EQS value for vanadium.

Although the concentrations of metals recorded in the leachate did not exceed either the DWQS or the Freshwater EQS in any other locations, elevated concentrations of the determinands were identified. Elevated concentrations of aluminium and magnesium were recorded in 10 No. of the samples; chromium, molybdenum and zinc in 8 No. samples tested; manganese in 7 No. samples and copper and lead in 6 No. and 5 No. samples respectively. The determinands showing the greatest number of elevated concentrations in leachate generally correspond with those found in groundwater from the Site.

The results indicate that arsenic, boron, cadmium, mercury, nickel, selenium, titanium and vanadium soil material may be present in relatively immobile forms.

				Waste Mounds			Made Ground									
Determinand	**Unit**	**DWQS**	**Freshwater EQS***	**TP6 - SURFACE**	**TP10 – 1.3m**	**TP18 – 0.1m**	**TP1 – 0.1m**	**TP15B – 0.2m**	**TP26 – 0.5m**	**TP29 – 0.3m**	**TP31 – 0.8m**	**TP37 – 0.1m**	**TP41 – 0.3m**	**TP21 – 0.2m**	**TP23 – 0.7m**
Al in filtrate	ug/l	200	-	**2070**	**532**	99	80	85	68	47	155	<20	105	83	**253**
As in filtrate	ug/l	10	50	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	N/S	<1
B in filtrate	ug/l	1000	2000	491	<100	129	<100	<100	<100	<100	<100	<100	<100	<100	<100
Cd in filtrate	ug/l	5	5	<0.5	<0.5	3.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5
Cr in filtrate	ug/l	50	250	30	6	28	<5	<5	21	15	6	<5	12	13	14
Cu in filtrate	ug/l	2000	28	11	<5	6	19	6	<5	<5	19	<5	6	21	<5
Pb in filtrate	ug/l	25	250	<5	<5	23	<5	<5	<5	16	**832**	6	6	<5	<5
Mg (soluble)	ug/l	50000	-	400	1100	6400	2900	800	6600	4200	<100	8500	4200	4300	200
Mn in filtrate	ug/l	50	-	**11000**	12	28	8	<5	6	<5	**60**	11	23	<5	<5
Hg in filtrate	ug/l	1	1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	N/S	<0.1
Mo (soluble)	ug/l	70*	-	<5	8	15	5	<5	6	9	6	<5	17	10	<5
Ni in filtrate	ug/l	20	200	<5	7	<5	<5	<5	<5	<5	<5	<5	9	<5	<5
Se in filtrate	ug/l	10	-	1	<1	5	<1	<1	1	1	<1	<1	<1	N/S	<1
Ti in filtrate	ug/l			<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
V (soluble)	ug/l	-	20 – 60	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	23
Zn in filtrate	ug/l	5000	500	12	<5	316	5	12	<5	11	169	7	87	13	<5

* Total Hardness for all samples is in the >250 mg/l CaCO3 group as listed in EQS Table 2b.

Exceedances

▨	EQS exceedance
1.5	DWQS exceedance

Table 12 Summary of Leachability Results Including Comparisons to DWQS and Freshwater EQS

Table 13 compares the elevated levels of metals recorded in the leachate analysis and those concentrations recorded in the corresponding soil analysis. In general, the table indicates that high concentrations of contaminants in the soil material increase the potential for leaching to occur. However, the levels of contaminants in the leachate are relatively low in relation to the concentrations identified in the soil samples, indicating that the majority of contaminants are present over the Site have a low leaching potential.

Location	**Al**		**Pb**		**Mg**		**Zn**	
	Soil mg/kg	Leachate mg/l	Soil mg/kg	Leachate mg/l	Soil mg/kg	Leachate mg/l	Soil mg/kg	Leachate mg/l
TP6 - SURFACE	25000	2.07	6380	<0.005	33500	0.4	72700	0.012
TP10 – 1.3m	23800	0.532	1100	<0.005	83000	1.1	4870	<0.005
TP18 – 0.1m	7400	0.099	12700	0.023	14100	6.4	93200	0.316
TP1 – 0.1m	11300	0.08	2410	<0.005	11400	2.9	4570	0.005
TP15B – 0.2m	2020	0.085	25	<0.005	106000	0.8	140	0.012
TP21 – 0.3m	8890	0.083	<3	<0.005	26100	4.3	8	0.013
TP23 – 0.7m	10400	0.253	728	<0.005	34700	0.2	4380	<0.005
TP26 – 0.5m	5650	0.068	3070	<0.005	15200	6.6	38500	<0.005
TP29 – 0.3m	2380	0.047	4880	0.016	11000	4.2	34600	0.011
TP31 – 0.8m	5790	0.155	1430	0.832	21300	<0.1	10500	0.169
TP37 – 0.1m	6840	<0.020	368	0.006	31600	8.5	3210	0.007
TP41 – 0.3m	7570	0.105	5380	0.006	14400	4.2	42300	0.087

Table 13 Comparison of Soil and Leachate Analysis for Selected Determinands

Therefore, the leachability results indicate that, in general, a number of inorganic contaminants within the soils on the Site are present in forms that have a variable water leaching potential. However, due to the granular nature of the soil material and sands underlying the Site, any contaminants that are leached from the waste mounds and Made Ground are likely to enter the groundwater system, as demonstrated by a number of groundwater test results.

10. SOIL GAS

10.1. GENERAL CONSIDERATIONS

The significance of soil borne gas relates to the presence of gases which may emanate from the ground and generate hazardous accumulations within a building development. In addition, gas may migrate from a site and impact on adjacent sites. The risks are particularly associated with methane and carbon dioxide; the presence of such gases being generally associated with biodegradation of organic rich materials. However, all types of ground may, if conducive conditions exist, generate gas and Made Ground should always be considered liable to produce gas. The presence of contaminants producing VOCs should also be considered.

Therefore, in assessing the soil-gas regime beneath the Site, the following points have been considered:

- Ground conditions and soil types;
- Gas concentrations and composition;
- The flow and pressure regime within the boreholes;
- The potential of organic materials for future degradation and subsequent gas production;
- Geological and hydrogeological aspects.

10.2. SOIL GAS REGIME

Soil gas concentrations were measured in all 9 No. boreholes during the monitoring visit undertaken on the 14th September 2003. Measurements were made using a hand held infra-red gas analyzer the results are included in the Factual Report for Site Pollution Investigation, BAE Systems Environmental Report A249-00-R2-D.

Gas concentrations in all boreholes on the Site were below detection limits or at normal ‘atmospheric’ levels, negligible flow rates were recorded in each borehole.

The soil gas regime on the Site is unlikely to pose a significant risk to current site users or constitute a development constraint.

10.3. VOCS

No elevated VOC concentrations were detected during the excavation of the trial pits and boreholes. However, subsequent monitoring in all soil samples identified slightly elevated headspace concentrations of VOCs in samples from the following locations:

- Slightly elevated concentrations, up to 0.9 parts per million (ppm) were identified in samples from TP5, TP7, TP8, TP9, TP10, TP16 and TP20, all of which were located on the waste mounds;
- Concentrations of 1.8 ppm and 1.0 ppm were identified at depths of 0.4 and 1.5 m.bgl respectively, in TP49. Both readings were from samples of natural material and were associated with a slight hydrocarbon odour. The sample location was next to a large fuel storage tank and some hydrocarbon staining was present on surrounding concrete surfaces.

- A concentration of 0.5 ppm at 2.0 m.bgl in TP13, located in the edge of a small waste mound in the northeast of the Site.

A concentration of 0.7 ppm at 0.2 m.bgl in TP2, located in the south of the Site.

The concentrations of VOCs recorded were generally negligible and are unlikely to pose a significant risk to current site users. The results of the VOC headspace monitoring are presented with the borehole and trial pit records in Appendices 2 and 3 of the Factual Report for the Site Pollution Investigation, BAE Systems Environmental Report A249-00-R2-D.

11. RADIOLOGICAL SCREENING

Four soil samples were submitted for gross alpha and beta analysis and the results are summarised below.

Exploratory Hole ID	Sample Depth (m)	Gross Alpha (Bq/g)	Gross Beta (Bq/g)
TP5	0.05	0.255	0.233
TP9	1.5	0.257	0.259
TP16	1.0	0.156	0.158
TP20	3.5	0.082	0.048

Table 14 Summary of Radiological Screening Results

The current UK guidance from the Radiological Protection Board gives a threshold value of 0.4 Bq/g for both gross alpha and gross beta radiation. All the samples were below the threshold value.

Based on these results and the results of the monitoring during site works which found no elevated levels of radiological activity, there is considered to be a negligible risk from radioactivity on the Site.

12. PHYSICAL CHARACTERISATION

12.1. LABORATORY TESTING

A programme of geotechnical laboratory testing was carried out on selected soil samples obtained from trial pits excavated on Site to assist the physical characterisation of the Waste Mound materials. Where appropriate, these tests were carried out in accordance with British Standard BS1377:1990 'Methods of Test for Soils for Civil Engineering Purposes' with the majority of tests being UKAS accredited.

A total of 22 No. soil samples from the Waste Mounds were submitted for geotechnical analysis, the results being presented in Appendix 7. The table below provides a summary of the number of tests completed and those not undertaken with reasons why.

Test Type	Test Method	Number of Test Undertaken
Natural Moisture Content	BS1377:1990, Part 2, Clause 3.2 – Oven Drying Method	22 No.
Particle Size Distribution	BS1377:1990 – Part 2, Clause 9.2 – Wet Sieving Method	8 No.
Particle Density (specific gravity)	BS1377:1990 – Part 2, Clause 8.2 – Glass Jar Method	4 No.
Bulk Density	Not applicable	None Completed – sample materials unsuitable for testing – materials too coarse for test
Slag Shrink/Swell	Not applicable	None Completed – sample materials unsuitable for testing – materials too coarse for test

Table 15 Summary of Geotechnical Laboratory Testing Completed

12.2. MATERIAL PROPERTIES

12.2.1. Particle Size Distribution

Eight samples were analysed for particle size distribution, including 2 No. composite samples made up of two samples each. The results are summarised below and show the percentage by weight passing the relative sieve aperture sizes: -

Sample	Waste Mound Location	Depth (m)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
TP7 (R20-11)	Western	0.5	None	5*	44	51
TP7 (R20-11)	Western	3.5	None	6*	31	63
TP8	Western	3.0	None	21*	29	50
TP9 (R20-7)	Western	3.0	None	8*	47	45
TP10 (R20-9)	Western	1.0	None	11*	49	40
TP16 (R20-2)	Northern	0.5	None	10*	22	68
TP18 (R20-4)	Northern	2.0 & 4.0^{+}	None	4*	34	62
TP20 (R20-1)	Northern	3.4 & 4.8^{+}	None	5*	44	51

$^{+}$ combined sample
* - Material passing 63 micron sieve

Table 16 Particle Size Distribution Results

The results show the materials present in the Waste Mounds to be predominantly granular comprising, on average; 9% of materials were <63µm (0.063mm) in size, i.e. dust particles; 38% were between 63µm and 2mm size particles; and 53% of materials were gravel between 2mm and 50mm in size. The detailed results sheets indicate that the samples of Waste Mound tested for particle size distribution contained no fragments larger than 63mm.

The particle size distribution throughout both the western and northern waste mounds was very similar. Although a number of distinct layers/types of Made Ground were recorded during the excavation of trial pits within the Waste Mounds, it is not possible to distinguish between different layers/materials from the laboratory particle size distribution testing.

Two samples tested for Particle Size Distribution were also tested for their chemical composition. The chemical analysis indicates the samples contained elevated concentrations (above generic screening criteria used) of arsenic, cadmium, chromium, lead, copper, zinc, manganese and TPH. A summary of these samples is shown in the table below: -

Sample	Waste Mound Location	Depth (m)	Contaminants Identified in the Samples
TP7 (R20-11)	Western	0.50	arsenic, cadmium, chromium, lead, copper, zinc, manganese and TPH
TP16 (R20-2)	Northern	0.50	arsenic, cadmium, chromium, lead, copper, zinc, manganese and TPH

Table 17 Chemical Composition of Samples Tested for Particle Size Distribution

An indication of which size fraction materials contained the chemical contamination was not possible as the samples were separated into their representative fractions on site prior to laboratory testing. In addition, the method of test for particle size distribution involves washing of the sample. As such, it is likely to change the chemical composition of each fraction of the sample due to either dilution or dispersion o the actual contaminants in the sample.

However, it is likely that the contamination is present mainly within the smaller size particles (sand size and smaller) as smaller size fragments have larger surface areas for contamination to be absorbed or adhere to.

12.2.2. Natural Moisture Content

The natural moisture content was determined for all 22 No. samples scheduled for testing. The moisture content ranged between 1.5 and 14 % with an average value of 5.5 %. The low moisture content reflects both the hot and dry local weather conditions and the predominantly granular nature of the waste mounds identified in the particle size distribution testing. Such soil and climate conditions reduce the ability of soils to retain moisture within the soil matrix. Granular materials are highly permeable and therefore unlikely to contain significant moisture levels. The value of 14 % was recorded in TP6 at 3.0 m and associated with a relatively high proportion of silt (21 %) sized particles.

12.2.3. Particle Density (Specific Gravity)

Particle density tests were conducted on 4 No. samples and a summary of results is given in the Table 18 below.

The recorded particle densities are much higher than those for typical soil material, ranging from 3.25 to 3.55 Mg/m3 compared with and typical soil particle density of about 2.6 Mg/m3. It is likely that the high particle densities reflect the large quantities of metallic fragments and slag material present within the waste materials.

This value of 2.65Mg/m3 for typical soil particle density is the value used in laboratory testing to British Standard 1377:1990 in the absence of actual particle density test result. This value is commonly used when calculating results for compaction testing and is considered representative of common soil particle density in a fully compacted sample that relates to the densest soil generally encountered.

Sample	Waste Mound Location	Depth (m)	Particle Density
TP 6	Western	0.50	3.37
TP 7 (R20-11)	Western	6.00	3.55
TP 10 (R20-9)	Western	3.00	3.53
TP 20 (R20-1)	Northern	0.50	3.25

Table 18 Results of Particle Density Tests

The particle densities shown are considered high due to the fact that the samples tested have much higher values of particle density (3.25 to 3.55Mg/m3) than particle densities of commonly encountered and other materials. For example, rocks such as granite has a particle density around 2.50 Mg/m3 and concrete a particle density of around 2.40 Mg/m3. As such, this gives an idea that the materials in the waste mounds contain particles of higher density suggesting that there is an elevated metal content in the mounds.

Given the actual soil conditions in the waste mounds at the Akko site being variable mix of ash, clinker and sand and gravel size materials, a value of particle density of perhaps 2.30Mg/m3 could be used. This value relates to predominantly sandy and gravel size materials and may be more representative of actual conditions in the mounds.

12.2.4. Other Testing

Samples were also submitted for bulk density and slag shrink/swell testing. However due to the relatively low proportion of slag fragments within the sample and the high proportion of coarse granular material the samples were unsuitable for the slag shrink/swell testing and the coarse granular nature of the samples also prevented bulk density testing.

12.3. VISUAL ASSESSMENT OF WASTE MOUNDS

Based on the results of the particle size distribution tests of the Waste Mounds materials tested, on average, 9% of materials were <63μm (0.063mm) in size, i.e. dust particles; 38% were between 63μm and 2mm size particles; and 53% of materials were gravel between 2mm and 50mm in size.

In real terms, the particle size distribution tests could be considered skewed data as they only provide an assessment of particle size based on the specific samples obtained and tested. As such, a visual assessment of the Waste Mounds was conducted to supplement the laboratory testing.

The field observations are based on the relatively small volume of material excavated from the Waste Mounds and the observed surface conditions. The actual distribution of particle sizes greater than 60 mm, within the waste mounds may be significantly different from the estimations based upon the field observations.

Table 19 below shows the estimated particle size distribution (percentage by estimated size) based on field observations and the particle size distribution testing results for the Waste Mounds.

It can be seen that the results of the visual assessment and particle size distribution correlate relatively closely which provides confidence in the filed observation made.

Particle Size	Distribution	Average Observed Distribution	Distribution from Lab Testing
> 60mm (Cobble/boulder size)	5 – 15 %	10%	-
2 – 60 mm (Gravel size)	35 – 65 %	50%	53%
0.063 – 2 mm (Sand size)	20 – 45 %	33%	38%
< 0.063 mm (Silt/Clay/Dust size)	5 – 20 %	12%	9%

Table 19 Particle Size Distribution of Waste Mounds Materials

Although no particles greater than 63 mm diameter were recorded in the particle size distribution tests, based upon a visual assessment undertaken on site, it is considered that approximately 10% on average of the material present in the Waste Mounds comprises particles with a diameter greater than 60 mm.

Due to their size, any contaminants present within these larger fractions (greater than 60 mm) are considered to be immobile as contamination is likely to be contained within the large particle of waste and therefore unlikely to represent a risk to either site users or groundwater. This is due to the fact that smaller particles have a much greater surface area which in turn leads to greater likelihood that particles will be inhaled or ingested and potentially be more mobile in the environment either by leaching or movement by dust.

No assessment of the relative quantities of the types of various materials in the Waste Mounds such as, wood, scrap, asbestos, plastic, wire etc, as it was considered very difficult to gain an accurate assessment of the actual content of the Waste Mounds during site investigation. This was due to the amount of waste and its extremely variable nature without conducting costly large scale screening and separating of the materials on site (it is more cost and time effective to do this at the remediation phase).

As such, only representative sampling was conducted to provide an assessment of the relative distribution of particle sizes within the mounds to assist an assessment of segregation of different waste streams during remediation.

12.4. CHEMICAL COMPOSTION OF SIEVED WASTE MOUND MATERIAL

Due to the limited number of samples of waste mound materials tested for particle size distribution, additional sitework consisting of trial scale sieving of waste mound materials was carried out. The aim of the large scale sieving trial was to segregate the waste mound materials into different size fractions for laboratory analysis to determine the chemical composition of each size fraction of material obtained.

A stockpile of waste mound material was passed through a mechanical sieve to obtain samples of 4 mm, 1.2 mm, 0.6 mm, 0.3 mm, 0.15 mm, 0.075 mm size fraction for chemical analysis.
Each sample was analysed for the same suite of metals as the other samples by both AminoLab in Israel and BAE Systems Environmental in the UK, the results of which are presented in Appendix 8.

Using the tiered approach for assessment, firstly the screening values in Section 5 and then the Site Specific Assessment Criteria (SSAC) in Section 8, only lead is shown to be a contaminant of concern in the sieved samples of waste mound materials tested.

Magnesium and boron were also recorded above the guidance values used for assessment. However, as previously stated, it is considered that magnesium is not a contaminant of concern as it generally regarded as non-toxic and is a commonly encountered substance in the environment. Similarly boron is not considered a hazardous substance to human health and is regarded as a phytotoxic (harmful to plants and vegetation) element.

It is noted that there is a significant difference between for the boron results form Aminolab and BAE Systems laboratory. It is understood that Aminolab conducted an acid extraction method to analyse for boron and BAE Systems used a water soluble method. This would explain the higher boron concentrations recorded by Aminolab when compared to the BAE Systems results.

Lead is shown to exceed the SSAC in the samples where particle size is less than 4 mm with the concentration increasing in particle sizes of finer than 0.075 mm. This suggests that the majority of lead contamination is contained within the ‘dust size’ fraction of the waste mound materials with the finest material tested possessing the highest concentrations of lead.

13. SUMMARY OF IDENTIFIED RISKS

13.1. HUMAN HEALTH

The results of the risk assessment process have indicated that the Waste Mounds and Made Ground on Site contain elevated concentrations of numerous metallic contaminants, namely arsenic, cadmium, chromium, lead, copper , zinc, magnesium, manganese. Although a site specific risk assessment discounted most of these as being a high risk it is considered that a moderate risk is present due to the existence of significant exposure pathways.

The site specific risk assessment has determined that only lead within the finer size fraction of Waste Mound material presents an unacceptably high risk to humans at the Site and there are obvious pollutant linkages between the source and receptors.

The principal pathways for exposure to the this contamination are direct dermal contact with contamination by touching or working with the contaminated materials and inhalation and/or ingestion of windblown dust which affects the Site due to the mainly dry climate. The generation of windblown dust are also of concern to persons on neighbouring sites.

For maintenance workers on the Site, a potential moderate risk exists if they are required to excavate in to or handle any of the contaminated materials in the Waste Mounds and Made Ground.

13.2. THE WATER ENVIRONMENT

13.2.1. Groundwater

A number of contaminants’ concentrations (aluminium, copper, lead, manganese, nickel, vanadium and zinc) above the selected threshold values were identified within the groundwater samples taken from the Site which correspond closely to the principal contaminants identified within the Made Ground and waste mounds. The leachate analysis indicated a variable leaching potential for inorganic contaminants. However, due to the granular nature of the soil material and sands underlying the Site, any contaminants that are leached are likely to enter the groundwater.

The calculated hydraulic gradient shows groundwater to flow towards the north over the Site and concentrations of metals in the groundwater generally appear to increase to the north of the Site. This indicates a relationship may exist between groundwater flow and contaminant concentrations, suggesting that materials from the Site may be the source of elevated levels in the underlying aquifer.

Petroleum hydrocarbons were present in 8 No. of the 9 No. groundwater samples. The highest concentration, 511 ug/l, was recorded in BH9 in the centre of the Site suggesting that activities at the Site may be the source of elevated petroleum hydrocarbons in the groundwater.

13.2.2. Groundwater Abstractions

No information was available regarding the location of any groundwater abstractions in the area surrounding the Site. However, it is understood that the aquifer has been exploited since the 1930’s and a large number of disused abstraction points are present. Currently the only active abstractions are located in the areas around the towns of Qiriat Khaim and Qiriat Mottskin located approximately 6 km to the south of the Site.

Groundwater flow under the Site is towards the north. Based on this information there is therefore considered to be a low risk to present groundwater abstractions in the area.

However, should any unrecorded groundwater abstractions be present to the north of the Site, or any groundwater abstractions reactivated, the risk would be need to be reassessed.

13.2.3. Surface Water

The closest watercourse is situated approximately 1.5 km to the east of the Site at its closest point and enters the sea 2.5 km to the north of the Site. Groundwater flow in the area is understood to be generally towards the northwest. Based on this information there is a potential pollutant linkage between elevated levels of potential contaminant at the Site and nearby watercourses but the linkage is unlikely to be significant.

13.3. FLORA AND FAUNA

The widespread elevated concentrations of both phytotoxic metals and hydrocarbons over the Site are considered to represent a significant risk to local flora. The potential pathways for fauna are likely to be similar to those for current Site users.

13.4. BUILDING MATERIALS AND SERVICES

The petroleum hydrocarbons identified on the Site could have a localised effect on underground services and building structures in the areas around hotspots. Organic contaminants are known to degrade plastic service structures such as water pipes where they exist in high concentrations.

Sulphate concentrations up to 5200 mg/kg were recorded over the Site, predominantly in the waste mounds and Made Ground. Very high concentrations of magnesium were also identified over much of the Site, with a total of 56 No. samples exceeding a threshold value of 9000 mg/kg. Groundwater sulphate concentrations exceeded the 0.4 g/l threshold for Design Class 1 in all boreholes. The presence of high concentrations of sulphate, and in some locations magnesium, can cause significant damage and degradation to concrete

13.5. SOIL GAS

Based upon the results of the gas monitoring, there is considered to be negligible risk to the Site from the presence of soil gas.

14. IMPLICATIONS TO SITE USE

The concentrations of lead within the Waste Mounds are a significant risk and it is recommended that remedial action is conducted to mitigate this risk.

In addition, remedial action should be considered to reduce the potential exposure of Site users to the contaminants identified at the generic screening stage within the Waste Mounds and Made Ground as significant exposure pathways exists, in particular the generation of wind blown dusts and the potential for direct contact.

There is considered to be a significant risk to current and Site users, visitors and site neighbours by inhalation via. The risks may increase for any Site workers engaged in manual handling of material where direct contact with soils containing elevated contaminant concentrations may be encountered.

The use of personal protective equipment (PPE) should also be considered for maintenance workers who are required to excavate or handle any contaminated Waste Mound or Made Ground materials to mitigate the current high risks.

In terms of UK Drinking Water Quality Standards or freshwater Environmental Quality Standards, the quality of groundwater encountered on the Site is poor. Concentrations of aluminium, copper, lead, manganese, nickel, vanadium and hydrocarbons all exceed one or both of the threshold values.

Assuming there are no unrecorded abstraction points close to the Site or to the north it is considered that the Site poses a low risk to groundwater abstractions. A pollutant linkage may also exist between elevated levels of potential contaminants on the Site and nearby surface watercourses although the linkage is unlikely to be significant.

Soil gas concentrations on the Site were all below detectable limits and it is therefore considered that soil gas represents a negligible risk

REFERENCES

Bowen, H.J.M, The Environmental Chemistry of the Elements, Academic Press, London, 1979.

British Drilling Association: Guidance Notes for the Safe Drilling of Landfills and Contaminated Land, 1992.

British Standard, BS1377: Methods of Test for Soils For Civil Engineering Purposes, 1990.

British Standard, BS 5930: Code of Practice for Site Investigations, 1999.

British Standards Institution, BS 10175 Code of Practice: Investigation of Potentially Contaminated Sites, 2001.

Construction Research and Information Association. Remedial Treatment for Contaminated Land: Vols I – XII. Harris MR, Herbert SM & Smith MA. 1995-6.

Department of Environment: Contaminated Land Report, Guidance on Preliminary Site Inspection of Contaminated Land. CLR No 2, Volume 1, 1994.

Department of Environment: Contaminated Land Report, Guidance on Preliminary Site Inspection of Contaminated Land. CLR No 2, Volume 2, 1994.

Department of Environment: Contaminated Land Report, Documentary Research on Industrial Sites. CLR No 3, 1994.

Department of Environment: Contaminated Land Report, Sampling Strategies for Contaminated Land. CLR No 4, 1994.

Department of Environment: Contaminated Land Report, Information Systems for Land Contamination. CLR No 5, 1994.

Department of Environment: Contaminated Land Report, Prioritisation and Categorisation Procedure for Sites which may be Contaminated. CLR No 6, 1994.

Department of Environment, Food and Rural Affairs: Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research. CLR No. 7, 2002.

Department of Environment, Food and Rural Affairs: Priority Contaminants for the Assessment of Land. CLR No. 8, 2002

Department of Environment, Food and Rural Affairs: Contaminants in soils: Collation of Toxicological Data and Intake Values for Humans. CLR No. 9, 2002

Department of Environment, Food and Rural Affairs: Collation of Toxicological Data and Intake Values for Humans (Individual contaminants). TOX No. 1 - 10, 2002.

Department of Environment, Food and Rural Affairs: Soil Guideline Values. SGV No. 1 – 10, 2002.

(CLR reports 7 – 9, TOX reports 1 – 10 and SGV reports 1 – 10 are available from www.defra.gov.uk/environment/landliability/pubs.htm)

Department of Environment: Contaminated Land Report, Model Procedures for the Management of Contaminated Land – Risk Assessment Procedure. CLR No 11, 1998. (DRAFT)

Department of Environment: Contaminated Land Report, A Quality Approach for Contaminated Land Consultancy. CLR No 12, 1997.

Department of the Environment: Derivation of Trigger Values for Hydrocarbons in Contaminated Soil, Environmental Resources Limited, 1987.

Department of the Environment: Waste Management Paper 27 Landfill Gas, 2nd Edition, 1991.

Environment Agency: R&D Note 301, ‘Leaching Tests for the Assessment of Contaminated Land.

APPENDIX 1

SITE LOCATION AND EXPLORATORY HOLE PLAN

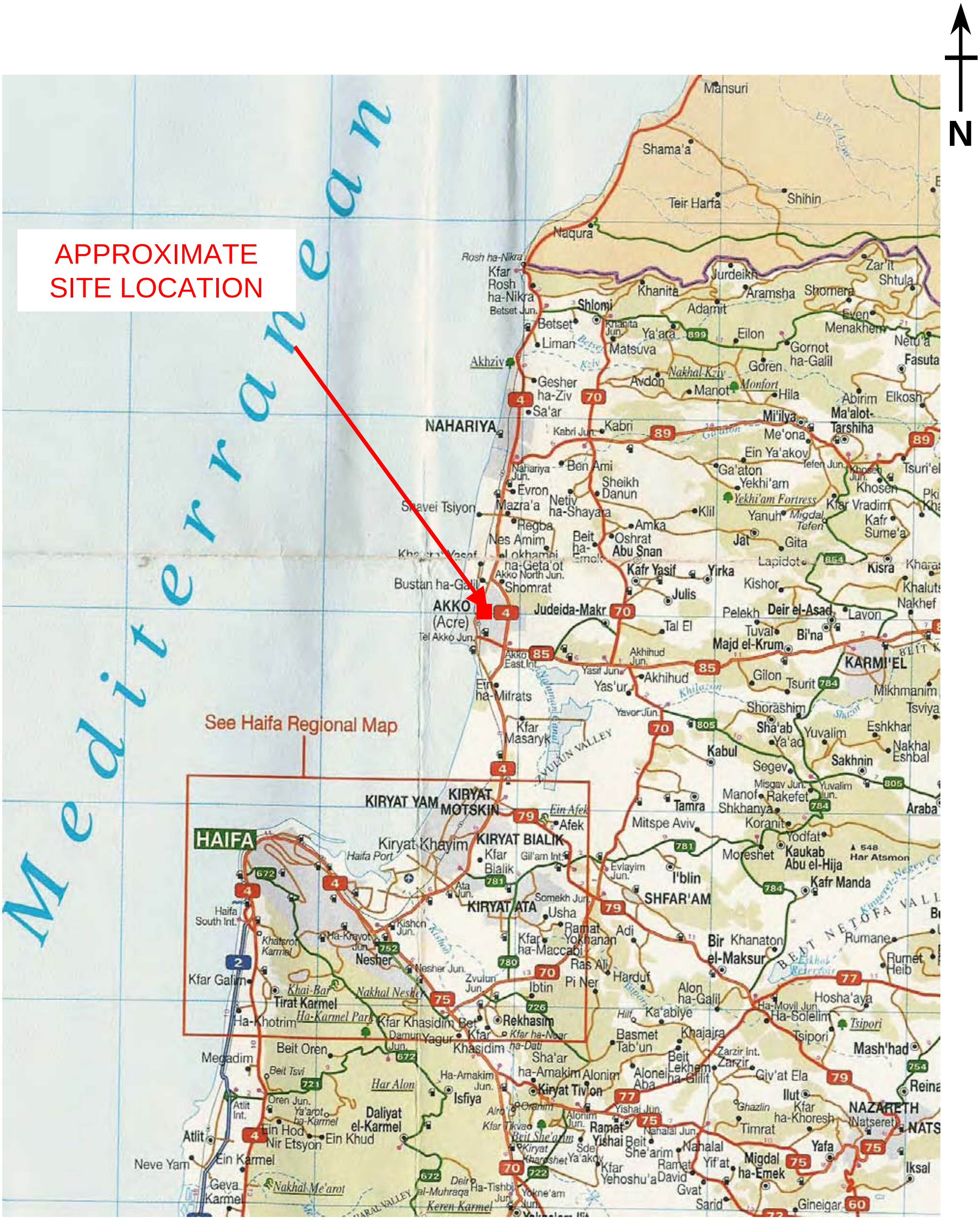


FIGURE TITLE :

SITE LOCATION PLAN

PROJECT :

AKKO, ISRAEL

REPORT NUMBER :

A249-00

BAE SYSTEMS

APPENDIX 2

OVERVIEW OF HUMAN HEALTH RISK ASSESSMENT PROCESS

1. RISK ASSESSMENT APPROACH

1.1. ASSESSING RISKS TO HUMAN HEALTH

The presence of land affected by contamination may have a direct impact on human health. For example, occupants of residential properties built on land that has not been adequately remediated in the past may be directly impacted or persons using in land in the course of their employment may also be impacted. The human receptor may also be a secondary receptor. For example contamination of groundwater, a receptor in its own right, may lead to human health effects if the groundwater is used as drinking or washing water.

1.2. DEFINITIONS

In order to provide an assessment of potential contamination the definitions of contaminated land and significant harm are needed. Significant harm is important as it is one of two reasons for land to be considered contaminated. Contaminated land is generally understood to be any land which appears to be in such a condition, by reasons of substances in, on or under the land that: _

- significant harm is being caused or there is a significant possibility of such harm being caused; or
- pollution of controlled waters is being, or is likely to be caused

Harm is defined as meaning ‘harm to the health of living organisms or other interference with the ecological systems of which they form part and, in the case of man, include harm to his property’. However we need to know what harm is to be regarded as significant and whether the possibility of significant harm being caused is significant.

In respect of or human health effects this is specified as “death, disease, serious injury, genetic mutation, birth defects or the impairment of reproductive functions”. Disease is taken to mean an unhealthy condition of the body or part of it and may include cancer, liver dysfunction or extensive skin ailments. Mental dysfunction is included only where it is attributable to the effects of a pollutant on the body of the person concerned.

Given the severity of the above human health effects, it is likely that much land could be considered contaminated on the basis of a significant possibility of significant harm, rather than the manifestation of actual harm. The conditions for possibility of significant harm generally arise from intake or direct bodily contact with a contaminant. As a result of a pathway between a human receptor and the pollutant , the pollutant would represent an unacceptable intake or exposure, assessed on the basis of relevant information on the toxicological properties of that pollutant.

As such, an assessment should take account of: -

- the likely total intake, or exposure to, the substance which forms the pollutant, from all sources including that from the pollutant linkage in question;
- the relative contribution of the pollutant linkage in question to the likely aggregate intake, or exposure to, the relevant substance or substances; and
- the duration of intake or exposure resulting from the identified pollutant linkage

1.3. DETERMINING IF SIGNIFICANT HARM IS OCCURING

To determine land as contaminated land an appropriate scientific and technical assessment of all the relevant available evidence and on the basis of this assessment be satisfied on the balance of probabilities that significant harm is being caused.

An assessor needs to be satisfied that the effects are due to the pollutant linkage and not other influencing factors, such as lifestyle or occupational exposure. In most instances, the determination of the human health effect is complex and an assessor may need to draw on the expertise within the medical profession. In practice, cases of significant harm to human health are rare and will be difficult to prove.

1.4. DETERMINING IF THE SIGNIFICANT POSSIBILITY OF SIGNIFICANT HARM IS BEING CAUSED

In determining if there is a significant possibility of significant harm to the human receptor reference is made to an unacceptable intake or exposure assessed on the basis of relevant information on the toxicological properties of a particular pollutant.

A scientific and technical assessment of the risks from the pollutant linkage according to relevant appropriate, authoritative and scientifically based guidance on risk assessments should be undertaken. In assessing the potential risks to the human receptor from the pollutant linkage(s) identified in the conceptual model, there are a number of options: -

- use relevant, appropriate, authoritative and scientifically based guideline values; and/or
- derive site specific assessment criteria using appropriate, authoritative and scientifically based methods.

In practice, a comparison of an observed concentration of contaminant on site with an appropriate, authoritative and scientifically based guideline value may be sufficient. Or the comparison of an observed concentration of contaminant on site with a site specific assessment criterion derived for the site using authoritative risk assessment tools and assumptions based on site specific conditions may be needed.

In the UK, authoritative and scientifically based guidance on undertaking risk assessments can be found in a range of documentation including the UK Contaminated Land Research series, detailed in Table A below.

CLR Document	**Outline of Content**
CLR 7 Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research (DEFRA and Environment Agency 2002a)	An introduction to the document series setting out the legal framework and the context within which the SGVs can be used.
CLR 8 Potential Contaminants for the Assessment of Land (DEFRA and Environment Agency 2002b)	Presentation of a selection of contaminants that are likely to be found on a large number of industrial sites in the UK and have the potential to cause harm to human health and the environment.
CLR 9 Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans (DEFRA and Environment Agency 2002c)	Sets out the approach for the derivation of relevant health criteria values (tolerable daily intakes and index doses) for contaminants.
CLR TOX 1-10 (DEFRA and Environment Agency 2002d-m)	Individual reports detailing the derivation of tolerable daily intakes and index doses for a number of contaminants namely arsenic, cadmium, chromium, inorganic cyanide, lead, phenol, nickel, mercury and selenium.
CLR 10 The Contaminated Land Exposure Assessment (CLEA) Model: Technical Basis and Algorithms (DEFRA and Environment Agency 2002n)	Describes the conceptual model used to derive the SGVs for each standard land use. It sets out the technical basis for exposure modelling and provides information on the default parameters and algorithms used.
CLR GV 1-10 (DEFRA and Environment Agency 2002o - u)	Individual reports setting out the derivation of the SGVs for a number of contaminants namely arsenic, cadmium, chromium,

CLR Document	Outline of Content
	inorganic mercury, nickel, selenium and lead.
CLR 11 Handbook of Model Procedures (Environment Agency in preparation)	This document will provides an overview of the risk assessment process.

Table A List of Relevant CLR Documents

It is common practice to identify and assess the risk to the critical receptor which is the receptor most likely to be at risk on the understanding that if the critical receptor is protected all other human receptors will be safe. The decision regarding the critical receptor may be: -

- dictated by policy (for example, in the residential land use CLR 10 identifies that the 0-6 year-old child as the critical receptor (DEFRA & Environment Agency, 2002); or
- made on a site specific basis (for example, in a school playing field scenario, questioning who is more at risk, the child or the school games teacher).

For a commercial/industrial site, such as the Akko Steel Mill site, the critical receptor is considered to be an adult of normal working age between 17 and 59

It may not always be obvious and a risk assessment may need to be undertaken for more than one receptor before the critical receptor can be identified.

1.5. AVERAGING AREAS

Whether a generic or a site specific assessment criterion is used, it needs to be compared against a representative contaminant concentration. The concentration needs to relate to the concentration the critical receptor is likely to be exposed to in any given scenario.

One of the factors that will influence the selection of a representative contaminant concentration is the ‘averaging area’. An averaging area defined as ‘that area (together with a consideration of depth) of soil to which a receptor is exposed to or which otherwise contributes to the creation of hazardous conditions’.

Averaging areas vary for different end uses, for example in a residential scenario the averaging area may be a single garden. In an commercial/industrial scenario a selected area of a site based on their physical characteristics may be the averaging area.

For the Akko Steel Mills site, three averaging areas have been selected based on their individual characteristics and their likelihood to cause harm or be polluted. These are the Waste Mounds, the Made Ground and the Natural Soils.

1.6. RISK ASSESSMENT

In identifying contaminated land, undertaking a risk assessment to determine whether any significant pollutant linkages are present is needed. Identifying pollutant linkages related to human health effects, is likely to establish: -

- the potential pollutant linkages through consideration of the pathways by which contaminant substances from a source can effect humans (qualitative risk assessment); and
- whether the pollutant linkages are significant by assessing whether the contaminant concentrations will result in an intake or exposure which would constitute harm (quantitative risk assessment).

1.7. IDENTIFICATION OF POLLUTANT LINKAGES

A pollutant linkage comprises three components: a contaminant (source), which has a mechanism (pathway) by which it can cause an adverse impact on a target (receptor).

In identifying possible pollutant linkages, it is important that all sources, pathways and receptors are considered. Contaminants can be dispersed in soil or be present in a discrete phase, such as oil or tar. The material in which the substances are found is important as it impacts on the pathways leading to exposure. All human beings are considered to be receptors and there are many different pathways of exposure and may include the following: -

- ingestion of soil, consumption of vegetables plant uptake/soil attached to plants, consumption other contaminated foods (e.g. fruit, dairy, meat) inhalation of windblown dust, skin contact, inhalation of vapours, consumption of contaminated food (e.g. fish)

In terms of human health effects, there are three elements that are important: -

- The identity of the substances, in particular chemical form and toxicology
- The fate and transport of the contaminant substances, with properties of the substance dictating available pathways
- The land use, as this dictates the human receptors present at the site and how they may behave (age/gender of site users, the number of visits to the site, duration of visit and activities leading to contact with and exposure to contaminants)

The critical or most sensitive receptor is selected on the basis of toxicological sensitivity and the likelihood of exposure. Children are often considered to be the critical receptor because their intakes of food, water, air and soil are greater per unit body weight than adults. For a commercial/industrial scenarios adults are the critical receptor as children generally do not inhabit this setting.

1.8. DETERMINING SIGNIFICANT POLLUTANT LINKAGES

Having identified possible pollutant linkages, the assessor has to consider whether the linkage is significant by assessing whether harm to human health is likely to result from it. All substances have the potential to cause harm to human health. Harm is established by considering: -

- the intake of the substance that the body receives from substances in/on land within the context of intake from other sources (exposure assessment); and
- health criteria values against which the intake is assessed (effects assessment)

In establishing harm, the following approach is taken whereby: -

- the effects of the substance on human health are considered
- the concentration of the substance available to the human receptor through each pathway is determined.
- the actual intake by the human receptor is determined
- the intake is assessed to decide whether it is unacceptable

Assessment criteria are typically derived to represent a concentration in soil which ensures that the tolerable intake, or health criteria value, is not exceeded for a specific exposure scenario. This concentration can then be related to the soil concentration at the site under consideration in order to make a judgement on whether there is a significant possibility of significant harm.

The majority of substances have the potential to produce adverse effects on the human body if enough of the substance is taken into the body; the intake and substance determines the effect. Some substances have a threshold above which effects can occur, whereas for other substances a threshold for health effects cannot be assumed. Effects may occur rapidly (acute) or may develop over a long period of time (chronic). Contaminated land assessments are primarily concerned with chronic effects on human health: it is normally assumed that if chronic effects are protected against, then there will be no acute effects.

Health criteria values provide an indication of the intake of a substance above which there may be an unacceptable health effect. They represent toxicological benchmarks derived from expert authoritative judgment of all relevant data, against which the health significance of exposures to substances can be assessed. Values are available for chronic human health effects associated with both threshold and non-threshold substances. Values tend to be available for individual substances, rather than mixtures.

1.9. THRESHOLD SUBSTANCES

The health criterion for substances with a threshold effect is the tolerable daily soil intake (TDSI). The TDSI is the difference between the tolerable daily intake (TDI) and the Mean Daily Intake (MDI) from other sources. Tolerable daily intake is an estimate of the amount of a substance that can be ingested daily over a lifetime without appreciable health risk.

The TDI is expressed in terms of mass per kg body weight per day. TDIs are derived by establishing a no observed effect level (NOAEL) from animal or epidemiology studies, and reducing this by application of a safety (or uncertainty) factor, typically 100, to account for intra- and inter-species variability. The aim is to provide a wide margin of safety between the TDI and harmful intakes, so whilst exceedance of a TDI is undesirable, it does not necessarily imply that harm will result. Separate TDIs may be derived for ingestion, inhalation and dermal routes, or TDIs for inhalation and dermal routes may be extrapolated from ingestion TDIs.

1.10. NON-THRESHOLD SUBSTANCES

For substances for which a threshold for health effects cannot be assumed, such as genotoxic carcinogens and mutagens, the concept of minimal risk level (termed Index Dose) is used as a toxicological benchmark.

Index doses are derived using nationally or internationally agreed exposure standards and are NOT based directly on the excess lifetime risk of developing cancer. The index dose is expressed in terms of mass per kg body weight per day and is utilised in a similar manner to the TDSI. However, it is important to note that the intake of non-threshold substances should be kept As Low As Reasonably Practicable (ALARP), so that the minimal risk is further diminished. Exceedence of the Index Dose is generally regarded as unacceptable.

1.11. EXPOSURE ASSESSMENTS

Exposure is the amount of a substance that is available for intake by a target population at a particular site. There are three exposure routes into the human body: -

- Ingestion, inhalation and dermal uptake through the skin

Exposure is quantified as the concentration of the chemical in the medium (air, soil, water, food) over the exposure duration. It is expressed in terms of the mass of substance per unit volume of air, kg of soil, litre of water or kg of food. Exposure depends on the concentration of substances in the media and how much, for how often and for how long the target population is exposed to the media, that is, the daily human exposure rate. An exposure assessment essentially calculates intake from all available pathways, as identified by the conceptual model. The intake is typically related to a corresponding soil concentration.

In the first instance, exposure to humans occurs externally; this is referred to as the intake dose. Intake dose is the amount of a substance entering or contacting the human body at the point of entry by ingestion, inhalation or skin contact. Actual intake will be a function of the chemical characteristics and the nature of the target population and their behaviour. Intake dose is expressed in terms of the mass of substance per kg body weight over a period of time. Not all the intake reaches the circulating blood having been absorbed by the body through the skin, gastrointestinal system and the pulmonary system. The fraction of the intake that can be absorbed by the body is known as the bioavailable fraction. Bioavailability depends on specific characteristics and there has been limited validation of chemical tests mimicking bioavailability or bioaccessibility. The majority of contaminated land assessments (including most of the UK SGVs) therefore consider intake rather than uptake. This intake can then be compared to the health criteria values.

When assessing exposure to establish if there is significant possibility of significant harm from threshold substances, it is important that background exposure from other non-soil sources is also taken into account. Mean daily intake (MDI) is the average background intake to which that population may be exposed. The MDI is estimated from published information on ambient air concentrations and average concentrations measured in water and food products. In taking into account background exposure, a portion of the TDI can be identified as an exposure that can be tolerated from contaminants in soil; this term is referred to as the tolerable daily soil intake (TDSI). The TDSI is normally obtained by subtracting the MDI from the TDI. However, where the MDI is similar in value to the TDI, then the TDSI is taken to be 20% of the TDI. Exposure assessments are typically concerned with deriving an equivalent soil intake for the site and comparing it to the TDSI. As risks from non-threshold substances are controlled by the ALARP principle, exposure from other (non-soil) sources of contamination is not considered for these substances.

There is a limit to the amount of medium that a target population can be exposed to, dictated by the opportunity for exposure and the amount that the receptor can ingest, breathe and absorb through the skin. Land use typically dictates the extent of exposure, with three common scenarios being used which are residential (with and without plant uptake), commercial/industrial and allotments. Residential land uses tend to present the greatest scope for exposure, as: -

- many hours per day, days per year and years per lifetime are spent on residential land;
- time is spent both indoors and outdoors;
- vegetables may be grown in the garden and consumed.

It is important that the target population is identified, as behaviour, age and gender are essential in establishing both exposure and whether the exposure is unacceptable.

A site specific assessment allows the total actual intake of the chemical (source) to the target population to be established. It is then possible to make a judgement about whether there is a risk to human health. This is done by comparing the total intake with the health criteria value. These are usually converted to soil equivalents so that it is possible to make judgements based on soil concentrations at the site.

Various models and methods are available to assist with exposure assessments and the derivation of human health assessment criteria. The assessment criteria represent a concentration of a substance in a specific medium (normally soil) above which there may be an unacceptable risk to human health. There are limitations associated with any risk assessment tool, so it is important that models and methods are used that are appropriate to the site under consideration.

1.12. THE CONCEPTUAL MODEL

The potential significant pollutant linkages requiring further assessment as part of the assessment of significant possibility of significant harm are identified from the conceptual model. The potential exposure of the receptor to the pollutant will depend on a number of factors including land use, the physico-chemical properties of the contaminant, the site conditions and the behavioural characteristics of the receptor.

1.13. USE OF GENERIC GUIDELINE VALUES

The Statutory Guidance makes reference to the use of “appropriate, authoritative, scientifically based” guideline values. If guideline values fitting these criteria are available for the site in question it is generally preferable to use these as it saves time and effort and they will have undergone extensive review. All risk based guideline values will have been derived from an assumed conceptual model of a generic site. The conceptual model is usually a reasonably worst case scenario and will incorporate a range of assumptions relating to: -

- the soil type and conditions
- the contaminant and its form and toxicity
- the location and size of the contaminated area
- the physiological and behavioural characteristics of the critical receptor
- the exposure pathways through which the critical receptor is exposed to the contaminant.

The choice of generic guideline value must always be justified with reference to the conceptual model for the site in question. For example, the assumed conceptual model underpinning the UK CLEA Soil Guideline Values is most comprehensively described in CLR 10. A determination of how authoritative and scientifically based the guideline value is requires the user to have an understanding of the source and the rationale behind the guideline value.

1.13.1. Justification of choice of guideline value used

Appropriate guideline values – the appropriateness of a guideline value is determined by comparing the conceptual model of the site in question with the conceptual model underpinning the guideline value. The guideline value can only be deemed appropriate if the conceptual models are similar and the assumptions are appropriate to the site in question.

Authoritative guideline values – in deciding if guideline values are authoritative it is necessary to establish who has produced the criteria and why. Guideline values are often produced by national government bodies to assist regulatory authorities in determining acceptable levels of contaminants in soil that are protective of human health.

Scientifically based guideline values – the basis of the guideline value needs to be understood by the user. As the assessment of contaminated land and indeed land affected by contamination is based on the principles of risk assessment any guideline values used should be risk based. Again this relates to the conceptual model from which the guideline value has been derived.

In addition, it is of vital importance that the assumptions upon which the guideline values are based are understood and shown to be relevant to the site in question before the guideline values are used. The use of the guideline values encourages a transparent and consistent approach to the assessment of risks and assists in focusing resources where they are most needed.

1.13.2. UK soil guideline values

In the UK, the authoritative guideline values for protecting human health from exposure to contaminants in soil, the Soil Guideline Values (SGVs), have been derived using the Contaminated Land Exposure Assessment Model (CLEA)

The CLEA SGVs have been derived for a number of contaminants in standard land uses. These standard land uses are residential, allotments, and commercial/industrial. They are representative of a range of generic site conditions and assumptions relating to exposure hence the SGVs can be used in a range of different circumstances

The conceptual model underpinning the SGVs for each standard land use and the technical basis and algorithms used in the CLEA model to derive the SGVs are provided in CLR10. The CLR GV 1-10 series comprises the individual reports setting out the derivation of the SGVs for the following contaminants; arsenic, cadmium, chromium, inorganic mercury, lead, nickel, and selenium. It is understood that further SGVs will be published in due course.

The UK approach to selecting appropriate toxicological data or health criteria values for contaminants is published in CLR 9. The associated series CLR TOX 1-10 are the individual reports detailing the derivation of tolerable daily intakes and index doses for the following contaminants; arsenic, cadmium, chromium, inorganic cyanide, lead, mercury, nickel, phenol and selenium.

The SGVs apply only to the assessment of direct human exposure to soil contamination. They **do not** consider:

- short term exposure (although there are eventually likely to be a number of exceptions to this);
- exposure to ionising radiation and biological agents;
- exposure of construction workers on contaminated sites, this is generally covered by health and safety legislation
- other potential receptors such as controlled waters, buildings or ecosystems

1.13.3. Basis of the CLEA Soil Guideline Values

The CLEA SGVs are intended as “intervention values” in the regulatory framework for assessing risks to human health from contaminants in the soil. An intervention value is generally used as an indicator of the concentration in soil above which land may present an ‘unacceptable’ risk. The CLEA SGVs are not intended as remediation or clean-up standards.

The CLEA SGVs are intended to meet the requirements of the assessment of human health effects arising from the intake of a contaminant or other direct bodily contact with a contaminant. The SGVs are also intended for use in the planning regime to inform judgements about unacceptable risks to intended site users and can be used to inform the selection of remediation standards or target values for individual sites.

Deriving generally applicable guideline values is a complex process. Variations in a range of influencing factors such as soil type and quality, contaminant species and the presence of contaminant mixtures make the process more difficult. Assumptions must be made to establish the relationship between the contaminant concentration in soil and the effect on human health. The use of worst case assumptions may result in overly conservative and impractical guideline values. The CLEA SGVs are based on a precautionary approach.

1.13.4. Toxicological data

Some of the most fundamental decisions in deriving guideline values and indeed site specific assessment criteria are those relating to the toxicity of the contaminant. The UK approach to the development of the health criteria values for use in assessing risks from soil contamination is detailed in CLR 9. The approach distinguishes between non-threshold and threshold substances.

For threshold substances it is assumed that there exists a level below which exposure to the substance will not cause any adverse health effects. For these substances, a certain amount of intake of a chemical can be tolerated and the term Tolerable Daily Intake (TDI) is used. The TDI is an estimate of the amount of contaminant that can be ingested daily over a lifetime without any appreciable health effects. This is usually provided in mg of contaminant per kilogram of body weight per day. Depending on the substance, the TDI may be derived from animal studies or epidemiological data, where available. From these studies it is usual to establish a No Observed Adverse Effect Level (NOAEL), which is preferable, or a Lowest Observed Adverse Effect Level (LOAEL). Depending on the degree of confidence in the data, a number of safety factors may be included to derive the TDI. Safety factors may need to be incorporated to account for extrapolation to the human species and the variation within the human species.

When dealing with a threshold substance, background exposure from other non soil sources, for example diet, water, ambient air, should also be taken into account. A fraction of the TDI, the tolerable daily soil intake (TDSI) is allocated to exposure from soil. CLR 9 provides detail on accounting for background exposure and the CLR 9 TOX series of reports presents the estimated background intake for specific substances.

For non-threshold substances, such as genotoxic carcinogens and mutagens, it is assumed that there is no threshold for health effects. In theory one molecule of the substance may interact with and damage one cell in the human body. These effects may not be directly obvious and indeed may not manifest themselves until future generations. The relevant health criteria are referred to as Index Doses. In CLR 9 the index dose is defined as the dose which can be considered to present a minimal human health risk from exposure to soil contaminants. However, additionally efforts are still needed to reduce exposures from all routes to “as low as reasonably practicable” (ALARP), so that even this minimal risk is further diminished. There is some risk at all levels of exposure to non threshold substances.

For non-threshold substances the index dose is set specifically for exposure to the soil and background exposure is not considered. It is assumed that background exposure is also kept as low as reasonably practicable.

In determining an appropriate TDI or Index Dose, the availability of authoritative contaminant specific information varies from substance to substance. CLR 9 recommends the use of source information derived (in order of priority) by authoritative UK bodies such as: the Department of Health; EU Scientific Committees; international authoritative organisations, such as the World Health Organisation; and finally other national organisations including, for example, the USEPA, which produces the commonly used IRIS database (http://www.epa.gov/iris/).

1.13.5. Using CLEA SGVs

The standard land uses for which SGVs have been developed are intended to represent a range of generic site conditions and are not intended to reflect site specific conditions. The user must determine whether it is appropriate to use the SGV for a standard land use taking into account the limitations of the conceptual model on which the guideline value is based. It is necessary to determine: -

- how significant the difference between the site and the guideline value conceptual models is; and
- whether any significant deviation from the standard land use will result in more or less conservatism in the conceptual site model.

A tiered approach should be used whereby if the application of a guideline value based on conservative assumptions provides an acceptable answer, that is, indicates that there is no unacceptable risk, then there is no need to undertake a more detailed quantitative risk assessment based on site specific assessment criteria.

1.14. IF THE SITE CONCENTRATION OF THE CONTAMINANT OF CONCERN EXCEEDS THE GUIDELINE VALUE, OR IF THERE IS NO APPROPRIATE GUIDELINE VALUE AVAILABLE

A risk assessor may in a number of situations choose to derive site specific assessment criteria for the contaminants of concern on a site. For example it may be that: -

- there is no appropriate, authoritative scientifically based guideline value available for the contaminant of concern, or
- the site concentration of the contaminant of concern exceeds the generic guideline value.

In the latter situation the assessor has two choices: -

- to introduce appropriate risk management options; or
- to undertake further site specific assessment of the potential risks and develop site specific assessment criteria.

Guideline values tend to be based on a reasonable worst case scenario and hence tend to be cautious by nature. This further assessment of the potential risks to the receptor requires a more quantitative approach and more detailed information relating to the site in order to justify the removal of some of the conservatism built into the guideline value. Risk assessment is an iterative process, thus the assessor may need to revisit the earlier hazard identification and hazard assessment stages to collate more site specific data.

It is common practice to derive site specific assessment criteria using risk assessment tools. These tools may be: -

- computer based packages such as CLEA, 2002 (DEFRA and Environment Agency, 2002v) and RBCA (GSI ,2000);
- paper based such as the SNIFFER Framework (SNIFFER, 2000); or
- in-house tools developed by the consultant.

1.14.1. Deriving site specific assessment criteria

There are many commercially available risk assessment tools (RATs) that can be used to derive site specific assessment criteria. It should be noted that tools are constantly reviewed and updated. Not all RATs are appropriate for every site.

RATs for assessing risks to human health generally work in one of two ways. Each tool contains a series of algorithms for the estimation of intake of contaminant via site specific exposure pathways. Tools such as RBCA utilise forward based calculations and estimate the risk from the representative concentration of contaminant on the site (determined from the site investigation) using site specific data and assumptions relating to the pathways and the receptor. This contaminant intake is then compared with the tolerable or acceptable level (i.e. Tolerable Daily Intake or Index Dose) for that substance.

Other tools, including the SNIFFER Framework, use a backward calculation and for the given assumptions calculate a safe concentration in soil that is protective of human health. This concentration can then be compared with the representative site concentration. Some of the tools including RBCA and Risc Human can operate in either mode.

CLEA uses a soil concentration as a starting point and iteratively determines the concentration that would give rise to the highest allowable exposure. It can be used in either a forward mode whereby an actual soil concentration is entered and exposure compared to that allowable. It can also be used in reverse mode to determine site specific assessment criteria.

1.15. THE CLEA MODEL AND SOFTWARE

CLEA 2002 is the risk assessment tool used to derive the UK Soil Guideline Values and is available for download from www.defra.gov.uk. The software has site specific functionality allowing the user to derive assessment criteria that are protective of human health. The following can be altered within the standard land uses: exposure and averaging times; choice of critical receptor; exposure pathways, buildings and soil type; background exposure; some of the physico-chemical and toxicological properties of contaminants, and new organic contaminants can be added.

The user is required to input information on the toxicity of the soil contaminants (default information is already contained within the tool for those contaminants for which SGVs have been published), the site conditions and the exposure of the receptor. The amount of contaminant to which the receptor may be exposed is predicted for a given soil concentration. This is then compared with the relevant health criteria value for the contaminant. The process is repeated until the selected percentile of daily exposure (usually the 95th percentile) equals the health criteria value. The soil concentration at which this occurs is the site specific assessment criterion.

CLEA is a probabilistic model and a number of the input parameter values e.g. body weight are selected from probability density functions (PDFs) rather than inputting single deterministic values. This allows the variability in the data set to be considered. The output is a range of predicted exposures and the user selects the most appropriate for the protection of human health, generally the 95th percentile. Probabilistic modelling provides a better understanding of the impact of parameter variability and uncertainty and allows the risk assessor to make more informed judgements about the degree of conservatism in the risk assessment. As with any other risk assessment tool all changes to the default parameters must be fully justified.

1.16. WHAT IS THE ACCEPTABLE LEVEL OF RISK?

Usually if the site concentration of a contaminant is below the generic or site specific assessment criteria derived for that contaminant the risk on the site from that contaminant is considered acceptable. This contaminant can then be excluded from any further assessment. One possible exception to this is if two or more contaminant concentrations are close to their respective site specific assessment criteria. In addition to an interpretation of the output of the risk assessment, every risk assessment report should contain an explicit statement on whether the risk to the critical receptor is acceptable.

1.16.1. If the site concentration of the contaminant of concern exceeds the site specific assessment criteria

On any site the major risk drivers will be those substances for which the representative contaminant concentration significantly exceeds the site specific assessment criterion. It is usual to consider the magnitude of the exceedance and the major sources of uncertainty and their effect on the output. If the exceedance is significant (for example, see Table B), it may be more beneficial to progress to the development of appropriate risk management options rather than spending resources in trying to reduce the uncertainty in the risk assessment.

Table B is used to help reflect on whether the exceedance is a real one in the ground requiring remedial action or an artefact of the unavoidable and desirable conservatism of the assessment criteria. If the former, then remedial action should be considered. If the latter, then additional effort should be placed on either the exposure or the assessment criteria to refine the risk assessment and determine whether the exceedance remains or has been ‘risked away’.

Where the representative site concentration is at or near the generic or site specific assessment criteria there are two options available. It may be possible to collate additional data to reduce the uncertainty and refine the risk estimate or it may be decided that a precautionary approach is adopted and some form of risk management is required. This decision will depend on the degree of confidence in the existing risk estimate and whether the risk is likely to have been over or under estimated and possibly the overall costs and benefits of implementing the risk management option.

If none of the substances exceed their site specific assessment criteria, but two or more of the contaminants are close to their site specific assessment criteria, these substances will drive the risk. Where substances are at or near their respective site specific assessment criteria, it is important to consider the impact of chemical mixtures.

Having identified the uncertainty in the process and the significance of the exceedance of the relevant criteria it may be appropriate to collect additional data to reduce this uncertainty and refine the risk estimate. This may involve returning to the earlier risk assessment stages, collating the additional data and undertaking the risk estimation stage with this further data included. Risk assessment should be viewed as an iterative process and the decision to revisit the risk assessment process can only be undertaken on a site specific basis. In practice if the site concentration greatly exceeds the assessment criteria there is little point in refining the uncertainty and revising the risk estimate as it is highly likely that risk management options will be required.

Guideline Value	Site concentration Exceedance	**Options (recommended option is in bold)**	**Comment**
Generic CLEA SGV	SGV * 10, or more	**Move to risk management selection**	Despite the conservatism in the generic SGVs, such an exceedance is unlikely to be 'risked away'
Generic CLEA SGV	SGV * 2 to 10	Develop SSAC **Move to risk management selection**	Due to the conservatism in generic SGVs, it may be possible to 'risk away' such an exceedance
Generic CLEA SGV	SGV * 1 to 2	**Develop SSAC** Move to risk management selection	Due to the conservatism in generic SGVs, it is likely that such an exceedance can be 'risked away'
CLEA SGV Modified using CLEA2002 software	SGV * 10, or more	Move to risk management selection	Despite the conservatism in the generic SGVs, such an exceedance is unlikely to be 'risked away'
CLEA SGV Modified using CLEA2002 software	SGV * 2 to 10	Develop SSAC **Move to risk management selection**	Due to the conservatism in generic SGVs, it may be possible to 'risk away' such an exceedance
CLEA SGV Modified using CLEA2002 software	SGV * 1 to 2	**Develop SSAC by carrying out appropriate bioaccessibility test** Move to risk management selection	Due to the conservatism in generic SGVs, it is likely that such an exceedance can be 'risked away'.
SSAC incorporating estimate of bioaccessibility	SSAC * 3, or more	**Develop SSAC** Move to risk management selection	
SSAC incorporating estimate of bioaccesibility and measured contaminant uptake by site grown vegetables.	SSAC * 1, or more	**Move to risk management selection**	
SGV: Soil guideline value *SSAC: Site specific assessment criterion*			

Table B Significance of exceedance of Guideline Value with respect to Human Health

1.17. EVALUATING THE RISK

Risk evaluation is the process of collating and reviewing all the risk based information relating to a site to decide whether it poses an unacceptable risk to the defined receptors.

The evaluation takes into account the nature and magnitude of any risk estimates and the technical uncertainties associated with the risk assessment. The risk evaluation information can be used as a basis for the preliminary selection of risk management options to break the pollutant linkage in question. The evaluation will have identified the main risk drivers (the contaminants and exposure pathways of concern) and it is these which need to be addressed through the selection of appropriate risk controls or remediation strategies.

A risk evaluation should accompany all risk assessments regardless of whether generic or site specific assessment criteria have been used.

If the risk evaluation concludes that unacceptable risk to human health is being posed, the land involved should be identified as contaminated land and the process of ensuring remediation should begin.

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1.18. REFERENCE MATERIAL

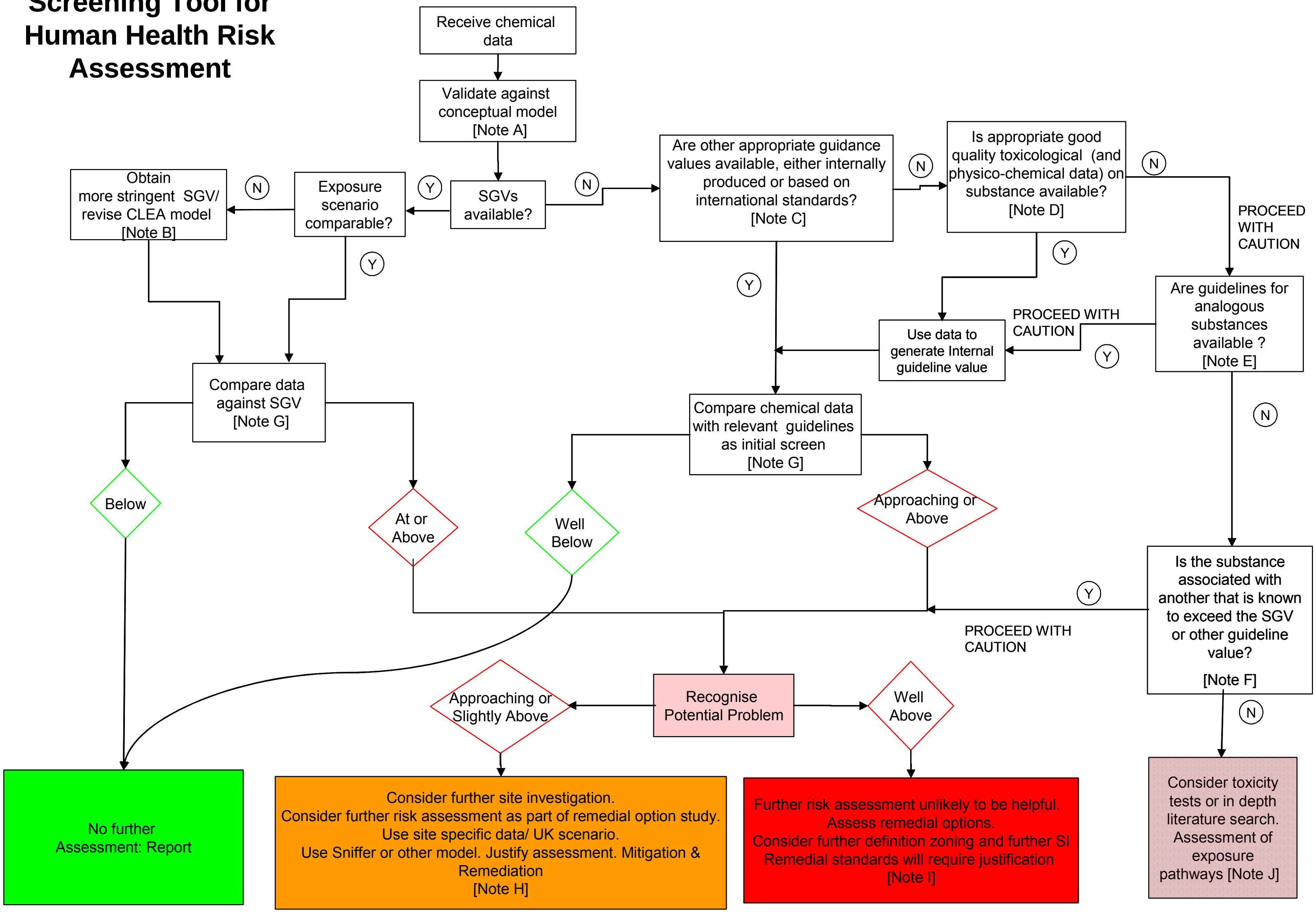
The key references in this discussion are: -

- DEFRA and Environment Agency. 2002. CLR 9 Contaminants in soils: collation of toxicological data and intake values for humans. Consolidated main report. Available from http://www.defra.gov.uk/environment/landliability/pubs.htm. Environment Agency Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF.

- DEFRA and Environment Agency. 2002. CLR 10 The Contaminated Land Exposure Assessment Model (CLEA): technical basis and algorithms. Available from http://www.defra.gov.uk/environment/landliability/pubs.htm. Environment Agency Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF.

- DEFRA and Environment Agency. 2002. CLR 9 TOX and CLR 10 SGV reports for specific substances. Available from http://www.defra.gov.uk/environment/landliability/pubs.htm. Environment Agency Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF.

Screening Tool for Human Health Risk Assessment



See Explanatory Notes A to J for additional explanations

1. EXPLANATORY NOTES FOR THE SCREENING TOOL FOR HUMAN HEALTH RISK ASSESSMENT

The Environment Agency is in the process of producing and publishing toxicological data and Soil Guideline Values (SGVs) for standardised scenarios as part of the CLEA programme. SGV and TOX reports are being prepared and issued in a staged manner and in the interim there has been some uncertainty within the contaminated land sector on how to proceed for contaminants in soils where no authoritative UK guidance has yet been published. This screening tool aims to assist decision making in the assessment of chronic risks to human health and is intended to promote consistency across the industry.

The screening tool has been devised in consultation with members of the Contaminated Land Working Groups of the Association of Geotechnical & Geoenvironmental Specialists (AGS) and the Environmental Industries Commission (EIC). The AGS and EIC shall not be held liable for any loss, damage, expense or claim of any kind sustained by any person as a result of reliance on the contents of this document or anything contained herein.

The following notes supplement the main flowchart, which is attached.

A. Validation of data.
Once the data have been received from the laboratory they should be validated against the site data including on-site observations, ground conditions, potential sources of contamination, site history, current layout, runoff and drainage, future (or on-going) site use as well as any knowledge of the likely behaviour and physical properties of the contaminant in question.

This will enable the conceptual model to be updated and the data divided appropriately considering whether zoning laterally or vertically is appropriate and relevant representative statistics generated appropriate to the distribution of this contaminant and the site end use to enable further interpretation to be carried out.

It is important that the data is accurate and has been appropriately grouped and represented prior to commencing any assessment.

B. Using a more stringent scenario.
Where a non standard scenario is under consideration, as an initial screen use of CLEA guidelines based on a more stringent scenario may allow a number of contaminants to be screened out at an early stage.

C. Other guidelines either internally produced or based on international standards.
Individual assessors can generate their own internal standards for assessment of contaminants. These may be based on models or around other international guidelines. Whatever guidelines are to be used, it is important to be sure they reflect UK conditions and approach (such as UK body weights and soil intake and the ALARP approach for non-threshold substances).

Any guidance values generated should be properly justified having regard for the approach to obtaining toxicological information set out in CLR9 and human and exposure pathway characteristics set out in CLR10 as appropriate.

D. No internal guidance but appropriate good quality data available.
Where good toxicological data and physicochemical data has been identified the assessor (following standard procedures as set out in CLR9) has already carried out the majority of the work to generate a guidance value. In this situation it is probably most straightforward to complete the assessment together with justification as an initial screen.

E and F. No appropriate good quality toxicological data can be obtained. (N.B. the order of E and F may be interchangeable.)
It should be stressed that at this stage the assessor should proceed with extreme caution and make the lack of data clear. This type of assessment should be carried out in consultation with a professional chemist and toxicologist.

E. Analogous substances
If assessment of analogous substances appears a practicable approach, the choice of analogous substance will require justification, both in terms of having similar toxicological effects and chemical and physical characteristics. Conservative choices for such substances should also be used in this initial screening stage.

F. Is the substance associated with another substance that is known to exceed the SGV or other guideline value?

If this is the case then in carrying out mitigation it may be possible to address the contamination by some form of mitigation (e.g. removal or containment) without the need for further detailed assessment. It is important to ensure that any such mitigation considers the different physicochemical characteristics of the two substances being addressed.

G. Comparison of data

When comparing the site data with the screening value, the uncertainties in the comparisons must be considered. The assessor should consider the accuracy and precision of the data, the type of contaminant (e.g. threshold or non-threshold substances) and the guidance value in making comparisons to determine if there is a potential problem.

This may be done implicitly for instance the uncertainties in analytical data are often accounted for by using statistical analysis (such as the mean value test in CLR7). Similarly internal guidelines allow for uncertainty in the base data by including uncertainty factors. The choice of uncertainty factors does depend on the judgement of the toxicological expert following best practice (such as set out in CLR 9).

H. Where the screening value is approached or slightly exceeded

Further definition of contamination by further analysis and/or investigation to reduce the uncertainty in the analytical data, or better define the pollutant characteristics (such as bioavailability and/or speciation) may be helpful.

Better definition and more detailed modelling of the exposure pathways and effects to reduce the uncertainty in the screening value may be helpful as one of the remedial options to be considered, particularly for non-standard scenarios.

I. Where the site data is well above the screening value

Further risk assessment is unlikely to be helpful while determining the presence of a problem, however if a clean-up standard is required by the remedial option being considered, this will require justification.

J. No suitable assessment data available

This situation is probably the most difficult. Options in terms of further assessment may include carrying out on-site or laboratory based toxicity tests on the soil, or detailed research. The EU technical guidance document (TGD) sets out how assessment of new and existing substances should be carried out in accordance with EU regulations.

E and F are examples of other possible approaches that might also be considered. Reference to natural background concentrations natural background levels from an accredited source, e.g. statistically assessed reviews of soil metal concentration from non-mineralised areas may also be considered. Risk assessment may not be the most cost effective solution although setting remedial targets is similarly difficult.

APPENDIX 3

SUMMARY TABLES OF CHEMICAL LABORATORY RESULTS

Summary Soil Sample Laboratory Results

Zone	Sample No.	Location	Top Depth (m)	Bottom Depth (m)	As mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	Cu mg/kg	Ni mg/kg	Zn mg/kg	B(w/s) mg/kg	Al mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Ti mg/kg	V mg/kg	Cyanide (tot) mg/kg	Cyanide (Free) mg/kg	Sulphate mg/kg	Sulphide (mg/kg)	TPH (mg/kg)	Acenaphthene mg/kg	Acenaphthylene mg/kg
Waste Mounds	**3664**	TP05	0.05		28.00	14.00	450.00	2200.00	4.60	0.80	1050.00	260.00	6840.00	10.00	10100.00	11500.00	3150.00	55.00	650.00	71.00	0.50	0.61	2200.00	5.00	2700.00		
	3665	TP05	1.00		38.00	14.00	1490.00	543.00	0.50	0.60	873.00	270.00	6760.00	5.20	18000.00	28200.00	15600.00	78.00	1140.00	88.00	0.50	0.50	1000.00	5.00	780.00	1.00	1.00
	3669	TP06	0.00		19.00	124.00	1660.00	6380.00	1.10	1.60	770.00	130.00	72700.00	5.30	25000.00	33500.00	19800.00	40.00	1460.00	106.00	0.50	0.50	1000.00	5.00	230.00		
	3670	TP06	0.50		54.00	20.00	1590.00	1240.00	0.40	0.40	1400.00	390.00	9050.00	5.10	10400.00	7700.00	15100.00	110.00	780.00	68.00	0.50	0.50	1300.00	5.00	160.00		
	3671	TP07	0.50		26.00	76.10	989.00	4280.00	2.00	1.10	1070.00	270.00	30900.00	4.20	14400.00	15800.00	8620.00	63.00	880.00	70.00	0.50	0.50	2000.00	5.00	1400.00		
	3674	TP08	0.30		28.00	32.60	933.00	1800.00	1.70	0.60	1870.00	310.00	14900.00	8.60	18000.00	15000.00	8560.00	66.00	790.00	64.00	0.50	0.50	2000.00	5.00	520.00		
	3675	TP08	1.00		27.00	154.00	790.00	9110.00	1.80	1.30	1870.00	250.00	68200.00	17.00	12400.00	9880.00	8890.00	53.00	1010.00	75.00	0.50	0.50	2700.00	5.00	2100.00		
	3676	TP09	0.20		32.00	22.00	2230.00	1290.00	0.30	1.80	480.00	75.00	10700.00	5.20	28000.00	27500.00	28500.00	46.00	2400.00	220.00	0.50	0.50	1100.00	5.00	230.00	1.00	1.00
	3678	TP10	0.50		65.00	6.20	661.00	895.00	0.70	0.40	1960.00	503.00	5780.00	4.00	3270.00	3320.00	6570.00	130.00	210.00	20.00	0.50	0.50	1000.00	5.00	300.00		
	3681	TP16	0.50		40.00	75.70	1010.00	5760.00	0.90	1.40	1290.00	260.00	49900.00	7.00	9810.00	11300.00	10000.00	65.00	660.00	46.00	0.52	0.52	3200.00	5.00	790.00	1.00	1.00
	3682	TP16	1.00		14.00	14.00	1240.00	734.00	0.40	1.00	315.00	67.00	8760.00	4.20	26500.00	50700.00	17300.00	21.00	1570.00	85.00	0.50	0.50	1000.00	5.00	330.00		
	3685	TP18	0.10		34.00	208.00	842.00	12700.00	2.00	1.90	1460.00	220.00	93200.00	7.70	7400.00	14100.00	11200.00	51.00	500.00	32.00	0.50	0.50	3600.00	5.00	140.00		
	3686	TP18	0.50		21.00	44.60	1340.00	2520.00	0.80	0.90	1320.00	92.00	24200.00	7.80	19100.00	31600.00	15700.00	30.00	1310.00	111.00	0.50	0.50	2400.00	5.00	380.00		
	3689	TP20	0.30		34.00	3.50	1240.00	553.00	0.60	0.60	1540.00	220.00	1450.00	9.60	15200.00	35600.00	12000.00	56.00	950.00	85.00	0.50	0.50	1500.00	5.00	370.00		
	3692	TP12	0.00		26.00	22.00	310.00	7050.00	1.30	0.90	980.00	200.00	11600.00	10.00	9240.00	10700.00	2450.00	33.00	630.00	21.00	0.51	0.51	900.00	5.00	760.00		
	3693	TP13	0.05		75.00	16.00	725.00	1010.00	0.30	0.30	1820.00	500.00	10000.00	1.30	375.00	857.00	8430.00	160.00	180.00	20.00	0.50	0.50	600.00	5.00	910.00		
	3694	TP13	0.15		21.00	5.00	1640.00	316.00	0.80	0.50	270.00	84.00	6110.00	2.40	12200.00	60400.00	24800.00	13.00	1140.00	162.00	0.51	0.51	1400.00	43.00	50.00		
	3695	TP14	0.00		20.00	9.00	1410.00	733.00	2.10	0.90	724.00	170.00	4050.00	2.10	15200.00	24500.00	16300.00	43.00	1130.00	142.00	0.50	0.50	1900.00	5.00	190.00		
	3696	TP15A	0.20	0.30	22.00	9.90	1450.00	714.00	2.00	1.00	622.00	190.00	3970.00	2.10	15000.00	24300.00	16400.00	50.00	1110.00	141.00	0.50	0.50	250.00	5.00	97.00		
	3697	TP36	0.00		79.00	0.30	657.00	130.00	0.20	0.30	1910.00	624.00	410.00	0.30	83.00	280.00	7140.00	200.00	190.00	20.00	0.50	0.50	700.00	5.00	1800.00		
	3698	HS03	0.00		54.00	3.20	160.00	170.00	0.40	1.30	230.00	30.00	843.00	0.90	20900.00	1990.00	1920.00	9.00	550.00	230.00	0.50	0.50	300.00	5.00	50.00		
	3699	HS04	0.00		51.00	11.00	210.00	357.00	0.70	1.20	540.00	97.00	2840.00	1.80	15100.00	3830.00	2400.00	25.00	510.00	158.00	0.50	0.50	1700.00	5.00	120.00		
	3700	HS05	0.00		75.00	0.80	591.00	43.00	0.20	0.30	1450.00	420.00	57.00	0.50	1260.00	430.00	7260.00	120.00	190.00	20.00	0.50	0.50	250.00	5.00	100.00		
	3701	HS06	0.00		72.00	0.30	661.00	43.00	0.20	0.30	1990.00	622.00	76.00	0.60	1330.00	830.00	7560.00	160.00	190.00	20.00	0.50	0.50	250.00	5.00	170.00		
	3702	HS07	0.00		32.00	0.30	410.00	130.00	0.60	0.60	713.00	220.00	76.00	2.20	21700.00	52500.00	8230.00	55.00	830.00	20.00	0.50	0.50	700.00	5.00	50.00		

	As	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**
Guidance Value -**G**	17	30	400	1000	8	100	190	500	2500	20	124000	9000	6000	9120	25000	12967	50	10	6000	70	500	NA	NA
Guidance Value - Type	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	GSAC (SGV)	Bowen BG	CTV IND	GSAC (SGV)	Bowen BG	GSAC (SGV)	CTV IND	CTV IND	CTV GW 12m	CTV IND	CTV IND		
No of exceedences of G	24	7	22	12	0	0	25	3	19	0	0	17	21	0	0	0	0	0	0	0	9	0	0
Minimum Value	14.00	0.30	160.00	43.00	0.20	0.30	230.00	30.00	57.00	0.30	83.00	280.00	1920.00	9.00	180.00	20.00	0.50	0.50	250.00	5.00	50.00	1.00	1.00
Maximum Value	79.00	208.00	2230.00	12700.00	4.60	1.90	1990.00	624.00	93200.00	17.00	28000.00	60400.00	28500.00	200.00	2400.00	230.00	0.52	0.61	3600.00	43.00	2700.00	1.00	1.00
2nd Highest	75.00	154.00	1660.00	9110.00	2.10	1.80	1960.00	622.00	72700.00	10.00	26500.00	52500.00	24800.00	160.00	1570.00	220.00	0.51	0.52	3200.00	5.00	2100.00	1.00	1.00

Mean Value Test	**As**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**
Number of samples	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	3	3
Arithemetic sample mean, x	39.48	35.46	987.56	2.96	1.06	0.88	1140.68	258.96	17734.88	5.00	13198.72	19052.68	11355.20	69.28	838.40	83.80	0.50	0.51	1398.00	6.52	589.08	1.00	1.00
Unbiased sample deviation, s	20.15	53.27	526.96	0.69	0.98	0.48	574.77	167.57	25598.04	4.00	8068.45	17400.08	6806.37	49.67	519.56	62.25	0.00	0.02	918.95	7.60	703.29	0.00	0.00
t value	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	1.711	2.920	2.920
Upper Bound (95th % ile)	46.37	53.69	1167.88	3.20	1.40	1.04	1337.37	316.30	26494.53	6.37	15959.74	25006.99	13684.34	86.28	1016.19	105.10	0.50	0.51	1712.47	9.12	829.75	1.00	1.00
Upper Bound > G ??	FAIL	FAIL	FAIL	FAIL	PASS	PASS	FAIL	PASS	FAIL	PASS	PASS	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	PASS	FAIL	PASS	PASS

Max Value Test	**As**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**
Arithemetic sample mean, y bar	1.54	1.04	2.92	2.96	-0.12	-0.12	2.99	2.31	3.70	0.53	3.91	3.97	3.97	1.73	2.83	1.79	-0.30	-0.30	3.04	0.74	2.50	0.00	0.00
Unbiased sample deviation, Sy	0.22	0.81	0.29	0.69	0.37	0.26	0.28	0.33	0.90	0.45	0.62	0.67	0.31	0.33	0.32	0.36	0.00	0.02	0.34	0.19	0.51	0.00	0.00
y max	1.90	2.32	3.35	4.10	0.66	0.28	3.30	2.80	4.97	1.23	4.45	4.78	4.45	2.30	3.38	2.36	-0.28	-0.21	3.56	1.63	3.43	0.00	0.00
T = (y max - y bar) / Sy	1.64	1.58	1.49	1.66	2.12	1.57	1.12	1.47	1.40	1.56	0.86	1.21	1.58	1.73	1.73	1.56	3.88	4.67	1.52	4.80	1.83	#DIV/0!	#DIV/0!
T crit 10%	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	2.486	1.148	1.148
T < T crit 10%??	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	PART	OUTLIER	OUTLIER	PART	OUTLIER	PART	#DIV/0!	#DIV/0!

a b c d

Zone	Sample No.	Anthracene mg/kg	Benz-g,h,i-perylene mg/kg	Benz-(a)-pyrene mg/kg	Benzo-a-anthracene mg/kg	Benzo-b-fluoranthene mg/kg	Benzo-k-fluoranthene mg/kg	Chrysene mg/kg	Dibenz (a,h) anthracene mg/kg	Fluoranthene mg/kg	Fluorene mg/kg	Indeno 1,2,3-cd pyrene mg/kg	Naphthalene mg/kg	2-Methylnaphthalene mg/kg	Phenanthrene mg/kg	Pyrene mg/kg	PAH (tot) mg/kg	Monohydric phenols mg/kg	PCB mg/kg	Total VOCs (mg/kg)	Phosphate (mg/kg)	Thiocyanate (mg/kg)
Waste Mounds	3664																				1300.00	
	3665	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50		0.05	510.00	0.20
	3669																				780.00	
	3670																				770.00	
	3671																				880.00	
	3674																				930.00	
	3675																				1100.00	
	3676	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50		0.05	1200.00	0.20
	3678																				230.00	
	3681	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50		0.05	720.00	0.20
	3682																	0.50			880.00	
	3685																				600.00	
	3686																				910.00	
	3689																				690.00	
	3692																				950.00	
	3693																				140.00	
	3694																				980.00	
	3695																				1200.00	
	3696																				130.00	
	3697																				120.00	
	3698																				1200.00	
	3699																				1200.00	
	3700																				97.00	
	3701																				270.00	
	3702																				200.00	

Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
120	NA	8.975	39.383	63.294	59.652	489.684	9.672	4842.539	NA	92.789	157.681	NA	4800.354	4558.715	40	14	25	NA	NA	10
GSAC (SGV)		GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)	CTV IND	SRC Soil	CTV IND			CTV IND
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	97.00	0.20
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	1300.00	0.20
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	1200.00	0.20

Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	0	3	25	3
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	#DIV/0!	0.05	719.48	0.20
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	0.00	401.32	0.00
2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.920	2.353		2.920	1.711	2.920
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	#DIV/0!	0.05	856.81	0.20
PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	#DIV/0!	PASS	PASS	PASS

Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene	Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	#DIV/0!	-1.30	2.75	-0.70
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#DIV/0!	0.00	0.37	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	-1.30	3.11	-0.70
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.00	0.00
1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.148	1.425	2.486	2.486	2.486	1.148
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	PART	PART

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Zone	Sample No.	Location	Top Depth (m)	Bottom Depth (m)	As mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	Cu mg/kg	Ni mg/kg	Zn mg/kg	B(w/s) mg/kg	Al mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Ti mg/kg	V mg/kg	Cyanide (tot) mg/kg	Cyanide (Free) mg/kg	Sulphate mg/kg	Sulphide (mg/kg)	TPH (mg/kg)	Acenaphthene mg/kg	Acenaphthylene mg/kg	Anthracene mg/kg	Benz-g,h,i-perylene mg/kg	Benz-(a)-pyrene mg/kg	Benzo-a-anthracene mg/kg	Benzo-b-fluoranthene mg/kg	Benzo-k-fluoranthene mg/kg	Chrysene mg/kg
Made Ground	3644	TP01	0.10	0.30	26.00	24.00	540.00	2410.00	2.40	0.90	1590.00	250.00	4570.00	4.50	11300.00	11400.00	4590.00	84.00	660.00	64.00	0.52	0.52	1400.00	5.00	1800.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3645	TP02	0.20	0.30	20.00	12.00	180.00	492.00	1.60	7.40	509.00	90.00	1570.00	2.70	7300.00	14300.00	1290.00	28.00	310.00	44.00			1400.00	5.00		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3647	TP03	0.10		3.00	3.10	180.00	76.00	1.00	0.30	33.00	89.00	305.00	0.80	2530.00	78300.00	250.00	4.00	84.00	20.00			400.00	5.00										
	3648	TP03	0.30		11.00	0.80	809.00	150.00	0.60	0.60	120.00	42.00	1480.00	1.50	7030.00	19500.00	11400.00	9.00	560.00	89.00	0.50	0.50	700.00	5.00	50.00									
	3650	TP04C	0.20	0.30	20.00	4.40	190.00	964.00	1.10	0.70	330.00	110.00	1060.00	2.60	4690.00	5020.00	918.00	23.00	140.00	35.00	0.52	0.52	1000.00	5.00	1500.00	1.00	1.00	2.10	1.00	1.00	1.00	1.00	1.00	1.00
	3652	TP15B	0.20		1.00	0.60	14.00	25.00	0.30	0.30	17.00	7.00	140.00	0.30	2020.00	106000.00	140.00	4.00	44.00	20.00	0.50	0.50	400.00	5.00	50.00									
	3654	TP24	0.40		18.00	7.90	539.00	594.00	0.90	0.30	755.00	110.00	2910.00	2.40	7330.00	20600.00	9110.00	34.00	560.00	38.00	0.50	0.50	900.00	5.00	94.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3656	TP25	0.50		11.00	6.00	190.00	353.00	0.70	0.30	230.00	77.00	1520.00	0.80	4380.00	8810.00	2130.00	15.00	230.00	20.00	0.50	0.50	600.00	5.00	50.00									
	3658	TP26	0.50		24.00	87.30	619.00	3070.00	0.90	2.00	655.00	120.00	38500.00	3.70	5650.00	15200.00	11300.00	31.00	390.00	45.00	0.50	0.50	1100.00	5.00	120.00									
	3659	TP29	0.30		50.00	117.00	512.00	4880.00	0.90	2.00	1100.00	300.00	34600.00	1.40	2380.00	11000.00	9180.00	68.00	180.00	20.00	0.50	0.50	600.00	5.00	65.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3660	TP29	1.00		22.00	6.30	200.00	318.00	0.40	0.30	560.00	100.00	1610.00	0.80	2660.00	6750.00	2150.00	20.00	160.00	20.00	0.50	0.50	400.00	5.00	76.00									
	3661	TP31	0.80		22.00	45.30	874.00	1430.00	0.50	0.50	424.00	110.00	10500.00	0.60	5790.00	21300.00	6970.00	15.00	390.00	62.00	0.50	0.50	5800.00	5.00	410.00									
	3662	TP34	0.30		3.00	0.30	37.00	19.00	0.20	0.30	17.00	8.00	83.00	0.30	2870.00	1790.00	460.00	4.00	92.00	20.00	0.50	0.50	400.00	5.00	50.00									
	3663	TP39	0.05		12.00	1.20	130.00	260.00	0.20	0.30	563.00	51.00	20.00	0.50	3370.00	4510.00	1660.00	12.00	200.00	20.00	0.50	0.50	300.00	5.00	420.00									
	3703	HS01	0.00																															
	3704	HS02	0.00																		0.50	0.50												
	3705	TP27	0.40																		0.50	0.50												
	3706	TP31	0.10																		0.50	0.50												
	3707	TP32	0.10																		0.50	0.50												
	3708	TP36	0.00																		0.50	0.50												
	3709	TP35	0.40		2.00	0.80	18.00	30.00	0.20	0.30	17.00	10.00	240.00	0.30	4600.00	64700.00	170.00	4.00	59.00	20.00	0.50	0.50	500.00	5.00	97.00									
	3710	TP35	1.00		16.00	9.50	100.00	240.00	0.20	0.30	190.00	67.00	2350.00	1.00	2610.00	6210.00	1160.00	14.00	100.00	20.00	0.50	0.50	300.00	5.00	50.00									
	3711	TP37	0.10		36.00	7.00	330.00	368.00	0.70	0.30	490.00	180.00	3210.00	0.40	6840.00	31600.00	52600.00	36.00	430.00	36.00	0.50	0.50	500.00	5.00	50.00									
	3714	TP41	0.30		36.00	67.80	988.00	5380.00	0.80	0.80	1080.00	290.00	42300.00	2.00	7570.00	14400.00	14800.00	70.00	610.00	42.00	0.50	0.50	1400.00	5.00	110.00									
	3715	TP48	0.60		4.00	0.30	17.00	14.00	0.10	0.30	60.00	10.00	38.00	0.30	2620.00	1290.00	150.00	4.00	100.00	20.00	0.50	0.50	250.00	5.00	50.00									
	3716	TP50	0.50		2.00	0.30	5.00	3.00	0.20	0.30	3.00	5.00	5.00	0.30	2070.00	876.00	84.00	4.00	61.00	20.00	0.50	0.50	250.00	5.00	50.00									
	3717	TP39	0.40		3.00	0.30	6.00	3.00	0.10	0.30	6.00	5.00	14.00	0.30	2220.00	1420.00	130.00	4.00	72.00	20.00	0.50	0.50	250.00	5.00	52.00									
	3718	TP39	0.00		5.00	0.30	10.00	9.00	0.10	0.30	8.00	5.00	61.00	0.30	1780.00	2830.00	160.00	4.00	71.00	20.00	0.50	0.50	300.00	5.00	240.00									
	3719	TP44	0.60		11.00	0.70	89.00	75.00	0.10	0.30	210.00	68.00	482.00	0.70	2140.00	33900.00	926.00	14.00	87.00	20.00	0.50	0.50	500.00	5.00	57.00									
	3721	TP45	0.50		7.00	0.30	66.00	27.00	0.10	0.30	81.00	16.00	100.00	0.30	3100.00	3660.00	1150.00	4.00	130.00	20.00	0.50	0.50	400.00	5.00	50.00									
	3723	TP43	0.15		2.00	0.30	5.00	3.00	0.10	0.30	3.00	5.00	3.00	0.30	1490.00	1110.00	77.00	4.00	60.00	20.00	0.50	0.50	300.00	5.00	100.00									
	3724	TP49	0.10		24.00	0.30	57.00	72.00	0.10	0.30	608.00	58.00	150.00	0.30	2280.00	15600.00	669.00	8.00	97.00	20.00	0.50	0.50	600.00	5.00	6100.00									
	3727	TP21	0.20		3.00	0.30	22.00	3.00	1.30	0.70	10.00	14.00	8.00	3.00	8890.00	26100.00	8180.00	48.00	650.00	51.00	0.50	0.50	1500.00	5.00	440.00									
	3728	TP22	0.20		6.00	1.10	230.00	150.00	0.20	0.30	70.00	33.00	309.00	1.20	3410.00	7560.00	1980.00	7.00	250.00	27.00	0.50	0.50	300.00	5.00	120.00									
	3729	TP23	0.70		20.00	14.00	1590.00	728.00	0.30	0.70	334.00	84.00	4380.00	2.40	10400.00	34700.00	18700.00	23.00	880.00	113.00	0.50	0.50	1000.00	5.00	160.00									
	3730	TP17	0.00		83.00	0.30	260.00	80.00	0.30	0.30	905.00	290.00	210.00	0.30	1570.00	2930.00	3210.00	61.00	130.00	20.00	0.50	0.50	300.00	5.00	470.00									
	3731	TP28	0.20		56.00	121.00	705.00	5150.00	0.90	1.70	1070.00	310.00	32800.00	1.30	2630.00	8350.00	12400.00	64.00	260.00	20.00	0.50	0.50	600.00	5.00	100.00									
	3732	TP28	1.00		28.00	11.00	240.00	516.00	2.30	0.30	376.00	120.00	3310.00	0.80	2840.00	6730.00	2870.00	23.00	170.00	20.00	0.50	0.50	400.00	5.00	66.00									
	3733	TP30	0.30		5.00	0.30	8.00	3.00	0.20	0.30	3.00	5.00	15.00	0.50	2580.00	4950.00	300.00	4.00	220.00	20.00	0.50	0.50	800.00	5.00	160.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3734	TP33	0.40		8.00	4.70	250.00	120.00	0.30	0.40	76.00	31.00	940.00	0.60	5650.00	13900.00	2860.00	4.00	340.00	63.00	0.50	0.50	400.00	5.00	50.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	3746	BH06	0.50		13.00	2.50	571.00	280.00	0.30	0.50	150.00	61.00	1430.00	0.30	7750.00	20800.00	6490.00	14.00	610.00	134.00	0.50	0.50	600.00	5.00	50.00									
	3750	BH08	0.50		3.00	0.30	10.00	8.00	0.10	0.30	7.00	5.00	48.00	0.30	3680.00	1480.00	94.00	4.00	110.00	20.00	0.50	0.50	250.00	5.00	50.00									

	As	Cd	Cr	Pb	Hg	Se	Cu	Ni	Zn	B(w/s)	Al	Mg	Mn	Mo	Ti	V	CN (tot)	CN (Free)	Sulphate	Sulphide	TPH	Acenaphthene	Acenaphthylene	Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene
Guidance Value - **G**	17	30	400	1000	8	100	190	500	2500	20	124000	9000	6000	9120	25000	12967	50	10	6000	70	500	NA	NA	120	NA	8.975	39.383	63.294	59.652	489.684
Guidance Value - Type	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	GSAC (SGV)	Bowen BG	CTV IND	GSAC (SGV)	Bowen BG	GSAC (SGV)	CTV IND	CTV IND	CTV GW 12m	CTV IND	CTV IND			GSAC (SGV)		GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)
No of exceedences of G	15	5	10	6	0	0	18	0	10	0	0	18	11	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Minimum Value	1.00	0.30	5.00	3.00	0.10	0.30	3.00	5.00	3.00	0.30	1490.00	876.00	77.00	4.00	44.00	20.00	0.50	0.50	250.00	5.00	50.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maximum Value	83.00	121.00	1590.00	5380.00	2.40	7.40	1590.00	310.00	42300.00	4.50	11300.00	106000.00	52600.00	84.00	880.00	134.00	0.52	0.52	5800.00	5.00	6100.00	1.00	1.00	2.10	1.00	1.00	1.00	1.00	1.00	1.00
2nd Highest	56.00	117.00	988.00	5150.00	2.30	2.00	1100.00	300.00	38500.00	3.70	10400.00	78300.00	18700.00	70.00	660.00	113.00	0.50	0.50	1500.00	5.00	1800.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Mean Value Test	As	Cd	Cr	Pb	Hg	Se	Cu	Ni	Zn	B(w/s)	Al	Mg	Mn	Mo	Ti	V	CN (tot)	CN (Free)	Sulphate	Sulphide	TPH	Acenaphthene	Acenaphthylene	Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene
Number of samples	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	36	39	39	36	36	34	7	7	7	7	7	7	7	7	7
Arithemetic sample mean, x	17.11	15.54	294.19	2.08	0.58	0.72	351.67	87.11	5313.08	1.11	4389.44	17488.22	5297.44	21.47	263.81	35.64	0.50	0.50	752.78	5.00	392.85	1.00	1.00	1.16	1.00	1.00	1.00	1.00	1.00	1.00
Unbiased sample deviation, s	17.64	31.75	355.74	1.00	0.59	1.23	401.76	93.14	11622.73	1.09	2625.81	22704.48	9459.86	22.60	220.30	27.59	0.00	0.00	940.82	0.00	1079.42	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
t value	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.684	1.697	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943
Upper Bound (95th % ile)	22.06	24.46	394.04	2.36	0.74	1.06	464.43	113.25	8575.19	1.42	5126.42	23860.61	7952.51	27.81	325.64	43.38	0.50	0.50	1016.83	5.00	707.00	1.00	1.00	1.46	1.00	1.00	1.00	1.00	1.00	1.00
Upper Bound > G ??	FAIL	PASS	PASS	PASS	PASS	PASS	FAIL	PASS	FAIL	PASS	PASS	FAIL	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	PASS	FAIL	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

Max Value Test	As	Cd	Cr	Pb	Hg	Se	Cu	Ni	Zn	B(w/s)	Al	Mg	Mn	Mo	Ti	V	CN (tot)	CN (Free)	Sulphate	Sulphide	TPH	Acenaphthene	Acenaphthylene	Anthracene	Benz-g,h,i-perylene	Benz-(a)-pyrene	Benzo-a-anthracene	Benzo-b-fluoranthene	Benzo-k-fluoranthene	Chrysene
Arithemetic sample mean, y bar	1.01	0.39	2.04	2.08	-0.44	-0.34	2.05	1.62	2.69	-0.13	3.57	3.95	3.18	1.10	2.28	1.47	-0.30	-0.30	2.74	0.70	2.09	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Unbiased sample deviation, Sy	0.48	0.88	0.75	1.00	0.43	0.32	0.85	0.61	1.14	0.39	0.25	0.53	0.78	0.46	0.37	0.25	0.00	0.00	0.30	0.00	0.52	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00
y max	1.92	2.08	3.20	3.73	0.38	0.87	3.20	2.49	4.63	0.65	4.05	5.03	4.72	1.92	2.94	2.13	-0.28	-0.28	3.76	0.70	3.79	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
T = (y max - y bar) / Sy	1.90	1.93	1.56	1.65	1.92	3.74	1.36	1.43	1.71	2.02	1.95	2.01	1.97	1.79	1.83	2.67	4.25	4.25	3.44	0.00	3.24	#DIV/0!	#DIV/0!	2.27	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
T crit 10%	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.639	2.671	2.671	2.639	2.639	2.616	1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.828
T < T crit 10%??	PART	PART	PART	PART	PART	OUTLIER	PART	PART	PART	PART	PART	PART	PART	PART	PART	OUTLIER	OUTLIER	OUTLIER	OUTLIER	PART	OUTLIER	#DIV/0!	#DIV/0!	OUTLIER	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

a b c d

Zone	Sample No.	Dibenz (a,h) anthracene mg/kg	Fluoranthene mg/kg	Fluorene mg/kg	Indeno 1,2,3-cd pyrene mg/kg	Naphthalene mg/kg	2-Methylnaphthalene mg/kg	Phenanthrene mg/kg	Pyrene mg/kg	PAH (tot) mg/kg	Monohydric phenols mg/kg	PCB mg/kg	Total VOCs (mg/kg)	Phosphate (mg/kg)	Thiocyanate (mg/kg)
Made Ground	3644	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00			0.05	1600.00	0.20
	3645	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50			640.00	0.20
	3647										0.50			280.00	
	3648													410.00	
	3650	1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	4.10	0.50		0.05	640.00	0.20
	3652													160.00	
	3654	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50			470.00	0.20
	3656													720.00	
	3658													640.00	
	3659	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50			340.00	0.20
	3660													180.00	
	3661													330.00	
	3662													210.00	
	3663													250.00	
	3703														
	3704											0.10			
	3705											0.58			
	3706											0.46			
	3707											0.11			
	3708											0.11			
	3709													170.00	
	3710													220.00	
	3711													330.00	
	3714													540.00	
	3715													200.00	
	3716													220.00	
	3717													160.00	
	3718													170.00	
	3719													260.00	
	3721													220.00	
	3723													180.00	
	3724													260.00	
	3727													830.00	
	3728													290.00	
	3729													700.00	
	3730													240.00	
	3731													270.00	
	3732													380.00	
	3733	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50		0.05	270.00	0.87
	3734	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50		0.05	160.00	1.10
	3746													290.00	
	3750													210.00	

Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
9.672	4842.539	NA	92.789	157.681	NA	4800.354	4558.715	40	14	25	NA	NA	10
GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)	CTV IND	SRC Soil	CTV IND			CTV IND
0	0	0	0	0	0	0	0	0	0	0	0		0
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.10	0.05	160.00	0.20
1.00	1.00	1.00	1.00	1.00	1.00	2.00	1.00	4.10	0.50	0.58	0.05	1600.00	1.10
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.46	0.05	830.00	0.87

Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
7	7	7	7	7	7	7	7	7	7	5	4	36	7
1.00	1.00	1.00	1.00	1.00	1.00	1.14	1.00	1.44	0.50	0.27	0.05	373.33	0.42
0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	1.17	0.00	0.23	0.00	280.17	0.39
1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	2.132	2.353	1.684	1.943
1.00	1.00	1.00	1.00	1.00	1.00	1.42	1.00	2.30	0.50	0.49	0.05	451.97	0.71
PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

Dibenz (a,h) anthracene	Fluoranthene	Fluorene	Indeno 1,2,3-cd pyrene	Naphthalene	2-Methylnaphthalene	Phenanthrene	Pyrene	PAH (tot)	Monohydric phenols	PCB	Total VOCs	Phosphate	Thiocyanate
0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.09	-0.30	-0.70	-1.30	2.49	-0.50
0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.23	0.00	0.38	0.00	0.24	0.34
0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.61	-0.30	-0.24	-1.30	3.20	0.04
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	2.27	#DIV/0!	2.27	#DIV/0!	1.22	#DIV/0!	2.92	1.61
1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.828	1.602	1.425	2.639	1.828
#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	OUTLIER	#DIV/0!	OUTLIER	#DIV/0!	PART	#DIV/0!	OUTLIER	PART

a b c d

Zone	Sample No.	Location	Top Depth (m)	Bottom Depth (m)	As mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	Cu mg/kg	Ni mg/kg	Zn mg/kg	B(w/s) mg/kg	Al mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Ti mg/kg	V mg/kg	Cyanide (tot) mg/kg	Cyanide (Free) mg/kg	Sulphate mg/kg	Sulphide (mg/kg)	TPH (mg/kg)	Acenaphthene mg/kg	Acenaphthylene mg/kg	Anthracene mg/kg
Natural Soils	**3646**	TP02	0.90		2.00	0.30	6.00	6.00	0.40	0.30	3.00	5.00	30.00	0.40	1690.00	1450.00	84.00	4.00	60.00	20.00	0.50	0.50	300.00	5.00	50.00			
	3712	TP38	0.90		3.00	0.30	12.00	5.00	1.90	0.30	17.00	6.00	48.00	0.30	2050.00	2050.00	280.00	4.00	76.00	20.00	0.50	0.50	300.00	5.00	50.00	1.00	1.00	1.00
	3725	TP49	0.40		2.00	0.30	5.00	3.00	0.10	0.30	8.00	5.00	29.00	0.30	1950.00	1220.00	87.00	4.00	62.00	20.00	0.50	0.50	250.00	5.00	200.00			
	3740	BH03	1.00		2.00	0.30	12.00	42.00	0.30	0.30	19.00	7.00	87.00	0.70	2930.00	1140.00	110.00	4.00	95.00	20.00	0.50	0.50	250.00	5.00	50.00			
	3744	BH05	1.00		4.00	0.30	28.00	20.00	0.10	0.30	29.00	14.00	110.00	0.30	2880.00	1900.00	200.00	4.00	96.00	20.00	0.50	0.50	250.00	5.00	50.00			
	3748	BH07	1.00		2.00	0.30	13.00	16.00	0.10	0.30	6.00	5.00	96.00	0.30	3070.00	881.00	150.00	4.00	99.00	20.00	0.50	0.50	250.00	5.00	50.00			
	3752	BH09	1.00		18.00	0.30	40.00	23.00	0.10	0.30	110.00	30.00	81.00	0.30	2450.00	16100.00	515.00	4.00	110.00	20.00								

	As	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**	**Anthracene**
Guidance Value -**G**	17	30	400	1000	8	100	190	500	2500	20	124000	9000	6000	9120	25000	12967	50	10	6000	70	500	NA	NA	120
Guidance Value - Type	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	CTV IND	GSAC (SGV)	Bowen BG	CTV IND	GSAC (SGV)	Bowen BG	GSAC (SGV)	CTV IND	CTV IND	CTV GW 12m	CTV IND	CTV IND			GSAC (SGV)
No of exceedences of G	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Value	2.00	0.30	5.00	3.00	0.10	0.30	3.00	5.00	29.00	0.30	1690.00	881.00	84.00	4.00	60.00	20.00	0.50	0.50	250.00	5.00	50.00	1.00	1.00	1.00
Maximum Value	18.00	0.30	40.00	42.00	1.90	0.30	110.00	30.00	110.00	0.70	3070.00	16100.00	515.00	4.00	110.00	20.00	0.50	0.50	300.00	5.00	200.00	1.00	1.00	1.00
2nd Highest	4.00	0.30	28.00	23.00	0.40	0.30	29.00	14.00	96.00	0.40	2930.00	2050.00	280.00	4.00	99.00	20.00	0.50	0.50	250.00	5.00	50.00	1.00	1.00	1.00

Mean Value Test	**As**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**	**Anthracene**
Number of samples	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	6	6	6	6	6	1	1	1
Arithemetic sample mean, x	4.71	0.30	16.57	16.43	0.43	0.30	27.43	10.29	68.71	0.37	2431.43	3534.43	203.71	4.00	85.43	20.00	0.50	0.50	266.67	5.00	75.00	1.00	1.00	1.00
Unbiased sample deviation, s	5.91	0.00	12.78	13.72	0.66	0.00	37.49	9.27	32.76	0.15	545.42	5556.44	154.03	0.00	19.48	0.00	0.00	0.00	25.82	0.00	61.24	#DIV/0!	#DIV/0!	#DIV/0!
t value	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	2.015	2.015	2.015	2.015	2.015	6.314	6.314	6.314
Upper Bound (95th % ile)	9.05	0.30	25.96	26.51	0.91	0.30	54.96	17.09	92.77	0.48	2831.98	7614.99	316.83	4.00	99.73	20.00	0.50	0.50	287.91	5.00	125.38	#DIV/0!	#DIV/0!	#DIV/0!
Upper Bound > G ??	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	#DIV/0!	#DIV/0!	#DIV/0!

Max Value Test	**As**	**Cd**	**Cr**	**Pb**	**Hg**	**Se**	**Cu**	**Ni**	**Zn**	**B(w/s)**	**Al**	**Mg**	**Mn**	**Mo**	**Ti**	**V**	**CN (tot)**	**CN (Free)**	**Sulphate**	**Sulphide**	**TPH**	**Acenaphthene**	**Acenaphthylene**	**Anthracene**
Arithemetic sample mean, y bar	0.51	-0.52	1.11	1.06	-0.66	-0.52	1.17	0.91	1.78	-0.45	3.38	3.29	2.22	0.60	1.92	1.30	-0.30	-0.30	2.42	0.70	1.80	0.00	0.00	0.00
Unbiased sample deviation, Sy	0.35	0.00	0.33	0.42	0.49	0.00	0.51	0.30	0.24	0.14	0.10	0.42	0.29	0.00	0.10	0.00	0.00	0.00	0.04	0.00	0.25	#DIV/0!	#DIV/0!	#DIV/0!
y max	1.26	-0.52	1.60	1.62	0.28	-0.52	2.04	1.48	2.04	-0.15	3.49	4.21	2.71	0.60	2.04	1.30	-0.30	-0.30	2.48	0.70	2.30	0.00	0.00	0.00
T = (y max - y bar) / Sy	2.14	0.00	1.50	1.35	1.93	0.00	1.71	1.92	1.06	2.14	1.10	2.16	1.70	#DIV/0!	1.15	0.00	#DIV/0!	#DIV/0!	1.29	#DIV/0!	2.04	#DIV/0!	#DIV/0!	#DIV/0!
T crit 10%	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.828	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943
T < T crit 10%??	OUTLIER	PART	PART	PART	PART	PART	PART	PART	PART	OUTLIER	PART	OUTLIER	PART	#DIV/0!	PART	PART	#DIV/0!	#DIV/0!	PART	#DIV/0!	OUTLIER	#DIV/0!	#DIV/0!	#DIV/0!

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Zone	Sample No.	Location	Top Depth (m)	Bottom Depth (m)	Benz-g,h,i-perylene mg/kg	Benz-(a)-pyrene mg/kg	Benzo-a-anthracene mg/kg	Benzo-b-fluoranthene mg/kg	Benzo-k-fluoranthene mg/kg	Chrysene mg/kg	Dibenz (a,h) anthracene mg/kg	Fluoranthene mg/kg	Fluorene mg/kg	Indeno 1,2,3-cd pyrene mg/kg	Naphthalene mg/kg	2-Methylnaphthalene mg/kg	Phenanthrene mg/kg	Pyrene mg/kg	PAH (tot) mg/kg	Monohydric phenols mg/kg	PCB mg/kg	Total VOCs (mg/kg)	Phosphate (mg/kg)	Thiocyanate (mg/kg)
Natural Soils	**3646**	TP02	0.90																				180.00	
	3712	TP38	0.90		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50			200.00	0.47
	3725	TP49	0.40																				170.00	
	3740	BH03	1.00																				210.00	
	3744	BH05	1.00																				160.00	
	3748	BH07	1.00																				250.00	
	3752	BH09	1.00																			0.05		

	Benz-g,h,i-perylene	**Benz-(a)-pyrene**	**Benzo-a-anthracene**	**Benzo-b-fluoranthene**	**Benzo-k-fluoranthene**	**Chrysene**	**Dibenz (a,h) anthracene**	**Fluoranthene**	**Fluorene**	**Indeno 1,2,3-cd pyrene**	**Naphthalene**	**2-Methylnaphthalene**	**Phenanthrene**	**Pyrene**	**PAH (tot)**	**Monohydric phenols**	**PCB**	**Total VOCs**	**Phosphate**	**Thiocyanate**
Guidance Value -**G**	NA	8.975	39.383	63.294	59.652	489.684	9.672	4842.539	NA	92.789	157.681	NA	4800.354	4558.715	40	14	25	NA	NA	10
Guidance Value - Type		GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)		GSAC (SGV)	GSAC (SGV)	CTV IND	SRC Soil	CTV IND			CTV IND
No of exceedences of G	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Minimum Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	160.00	0.47
Maximum Value	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	250.00	0.47
2nd Highest	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.00	0.05	210.00	0.47

Mean Value Test	**Benz-g,h,i-perylene**	**Benz-(a)-pyrene**	**Benzo-a-anthracene**	**Benzo-b-fluoranthene**	**Benzo-k-fluoranthene**	**Chrysene**	**Dibenz (a,h) anthracene**	**Fluoranthene**	**Fluorene**	**Indeno 1,2,3-cd pyrene**	**Naphthalene**	**2-Methylnaphthalene**	**Phenanthrene**	**Pyrene**	**PAH (tot)**	**Monohydric phenols**	**PCB**	**Total VOCs**	**Phosphate**	**Thiocyanate**
Number of samples	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	6	1
Arithemetic sample mean, x	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	#DIV/0!	0.05	195.00	0.47
Unbiased sample deviation, s	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	32.71	#DIV/0!
t value	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	6.314	1.684	6.314	2.015	6.314
Upper Bound (95th % ile)	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	221.91	#DIV/0!
Upper Bound > G ??	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	PASS	#DIV/0!

Max Value Test	**Benz-g,h,i-perylene**	**Benz-(a)-pyrene**	**Benzo-a-anthracene**	**Benzo-b-fluoranthene**	**Benzo-k-fluoranthene**	**Chrysene**	**Dibenz (a,h) anthracene**	**Fluoranthene**	**Fluorene**	**Indeno 1,2,3-cd pyrene**	**Naphthalene**	**2-Methylnaphthalene**	**Phenanthrene**	**Pyrene**	**PAH (tot)**	**Monohydric phenols**	**PCB**	**Total VOCs**	**Phosphate**	**Thiocyanate**
Arithemetic sample mean, y bar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	#DIV/0!	-1.30	2.29	-0.33
Unbiased sample deviation, Sy	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.07	#DIV/0!
y max	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.30	0.00	-1.30	2.40	-0.33
T = (y max - y bar) / Sy	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1.60	#DIV/0!
T crit 10%	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943	1.943
T < T crit 10%??	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	PART	#DIV/0!

a b c d

APPENDIX 4

EXAMPLE MEAN AND MAXIMUM VALUE TESTS

APPENDIX A

Statistical tests for contaminated soils relative to Soil Guideline Values

This appendix is based upon work by the late Professor Colin Ferguson of Nottingham University.

Introduction

A1 Human health risk assessments of contaminated sites rely on sampling and chemical analysis of soil samples. Advice on developing site sampling strategies is provided in Sampling Strategies for Contaminated Land (Department of the Environment, 1994) and Development of Appropriate Soil Sampling Strategies for Land Contamination (Environment Agency, 2001b).

A2 Once a checked set of chemical data on levels of contaminants in the test area is available, a decision can be made about how these levels compare to the appropriate Soil Guideline Value or a comparable value derived from site-specific study. Whatever values are used for this comparison, it is essential to ensure that the conceptual model and other conditions assumed in the derivation of the Soil Guideline Values are all appropriate to the site under investigation.

A3 If soils were uniformly contaminated at concentration x, acceptance (or otherwise) with respect to a Soil Guideline Value $\underline{G}$ would simply depend on whether x was less than or greater than $\underline{G}$. In reality, contaminant concentrations vary across a site, and the measured mean concentration, derived from a limited number of samples, may not equal the "true" mean; and in any event it will have uncertainty associated with it. Because of this, simple comparisons of the measured mean value with the Soil Guideline Value could be misleading. The approach here is to identify the 95% confidence limits of the measured mean and to compare the upper 95th percentile with the Soil Guideline Value using the mean value test described below.

A4 To determine whether the maximum value in a sample set classifies as an outlier, the maximum value test should be applied. This appendix describes how to conduct statistical tests for each relevant contaminant using the following information collected over a suitable averaging area:

- The arithmetic sample mean
- The standard deviation
- The maximum value

The Mean Value Test

A5 The sample mean value, x, based on only a few samples may be a poor estimate of the true (population) mean. Therefore, a no remedial action decision based on x less than G may not be adequately health protective when x is computed from only a small number of samples. Clearly it is desirable to state with a given level on confidence (say 95th percentile) that the population mean is less than the Soil Guideline Value G.

A6 The necessary calculation involves five simple steps as follows:

(i) calculate the arithmetic sample mean, x.

(ii) calculate the (unbiased) sample standard deviation, s.

(iii) select an appropriate t value from standard tables. Table A 1.1 gives t values for a 95th percentile confidence limit. t values for other confidence limits are given in Table A 1.2. It should be noted that when using Table A 1.2, the number of degrees of freedom (v) is one less than the number of samples, i.e. for $n = 8$, $\nu = 7$.

(iv) calculate the upper 95th percentile bound of sample as:

$$US_{95} = \bar{x} + \frac{t.s}{\sqrt{n}}$$

(v) compare the upper bound value, (US_{95}) with the Soil Guideline Value (G). If the upper bound value is less than G, then the mean value test has been passed, and the site may be considered not to present a significant possibility of significant harm to human health in the context of Part IIA. Conversely, if the test is failed, then the assessor should consider whether it is appropriate to take more samples (because the number on which the test has been based is very low), or to make a determination as contaminated land under Part IIA, taking into account the other requirements of the regime such as the presence of a significant pollutant linkage.

A7 The correct value to use for t (for 95th percentile confidence) depends on the sample size n as shown in Table A 1.1. A worked example of application of the mean value test is given in Annex 1.

A8 Some analytical data sets will include samples recorded as below the analytical detection limit (or quantitation limit). The simplest way of handling such data is to include "non detects" but, for calculation purposes, to assign a value equal to the detection limit. Thus if a laboratory reports a substance as <1mg kg^{-1} in soil, a value of 1.0 mg kg^{-1} would be used for calculation.

Table A 1.1 Relationship between sample size (n) and t

n	t	n	t	n	t
-	-	11	1.812	21	1.725
2	6.314	12	1.796	22	1.721
3	2.920	13	1.782	23	1.717
4	2.353	14	1.771	24	1.714
5	2.132	15	1.761	25	1.711
6	2.015	16	1.753	26	1.708
7	1.943	17	1.746	27	1.706
8	1.895	18	1.740	28	1.703
9	1.860	19	1.734	29	1.701
10	1.833	20	1.729	30	1.699

The Maximum Value Test

A9 Values that exceed Soil Guideline Values will invariably warrant some further consideration even when the mean value test has been passed. The problem of acceptance or rejection of maximum values that exceed Soil Guideline Values is not straightforward. This is because there is a need to balance the primary goal of health protection with the recognition that contaminants in soil often have high sampling and analytical variability. This is especially so for contaminants occurring at low concentrations.

A10 In forming a view on whether extra sampling and analysis may be required, a useful question to ask is whether the maximum value in a set of measurements is likely to have come from the same population as the other measurements, or whether it is a statistical outlier.

A11 To make progress with this question it is necessary to assume the form of the underlying distribution; the vast bulk of the relevant literature on outliers relates to an underlying Normal distribution . In the context of chemical analyses of contaminated soils, it is common practice to work with the logarithms of the measured values. This log-transformation usually results in a more or less symmetric distribution which, while not strictly Normal, is usually close enough to allow Normal statistics to be used with some confidence.

A12 Thus the raw measurements x_1, x_2,.....,x_n are first log-transformed ($y_1 = \log x_1$ etc); and the sample mean $\bar{y}$ and unbiased sample standard deviation S_y are then calculated from the log transformed values.

A13 An appropriate test is then:

$$T = \frac{y_{max} - \bar{y}}{S_y}$$

If the value of T is smaller than some critical value, the maximum value may be accepted (at the prescribed level of confidence) as a member of the underlying population from which the other measurements were drawn. If T is greater than the critical value the maximum value is treated as an outlier, which may indicate a localised area of contamination. Of course, the outlier might instead be the result of a measurement or recording error; but in any event it flags up the need for further investigation. A worked example is given in Annex 2.

Annex 1

Worked example of the mean value test

A1.1 Consider, an averaging area in which $n = 8$ samples are taken with contaminant concentrations as follows:

$x_1 = 80$ $x_5 = 160$

$x_2 = 130$ $x_6 = 90$

$x_3 = 210$ $x_7 = 120$

$x_4 = 350$ $x_8 = 150$

Let the Soil Guideline Value for the contaminant be $G = 230$.

A.1.2 Compute the following statistics:

(i) arithmetic sample mean $\overline{X} = 161.25$

(ii) unbiased standard deviation $s = 86.59$

(iii) t value from Table A1.1 selected for n=8, $t = 1.895$

(iv) calculate normalised upper bound

(for 95th percentile confidence)

$$US_{95} = \bar{x} + \frac{t.s}{\sqrt{n}}$$

$$= 161.25 + \frac{(1.895).(86.59)}{\sqrt{8}}$$

$$= 219.26$$

Note that the t value used in this calculation is $t = 1.895$, which is derived from Table A1.1 for single-tailed t tests. For confidence intervals other than the 95 %, refer to Table A1.2.

A.1.3 The upper bound value (US_{95}) of 219 is less than the Soil Guideline Value (G) of 230, and thus it can be concluded that no action is warranted in the averaging area based on the mean value test.

A.1.4 Now consider the situation if only the following 5 samples were available:

$x_1 = 80$

$x_4 = 350$

$x_5 = 160$

$x_6 = 90$

$$x_7 = 120$$

The arithmetic sample mean, $\overline{x} = 160$, is slightly smaller than before but the standard deviation (= 110.68) is much larger and the sample size is smaller.

A recalculation gives the upper bound value as 265.5, which is greater than the Soil Guideline Value of 230, and thus the data do not pass the mean value test. In this circumstance, the assessor should consider taking further samples to gain a more representative picture of the site. Alternatively, they may take remedial action where, for example, further sampling is not practicable, or timescales dictate rapid action.

Annex 2

Worked example of the Maximum Value Test

A2.1 The contaminant concentrations listed in paragraph A 1.2 are repeated below together with their common logarithms.

i	x_i	$y_i = \log(x_i)$
1	80	1.903
2	130	2.114
3	210	2.322
4	350	2.544
5	160	2.204
6	90	1.954
7	120	2.079
8	150	2.176

A.2.2 The objective is to decide whether the maximum value $x_4 = 350$ (therefore $y_{max} = 2.544$) should be treated as an outlier, or whether it can reasonably be considered as coming from the same underlying population as the other samples.

A.2.3 Compute the following statistics:

(i) arithmetic sample mean of y values $\bar{y} = 2.162$

(ii) unbiased standard deviation of y values $Sy = 0.2046$

(iii) outlier test statistic $T = \dfrac{y_{max} - \bar{y}}{S_y} = 1.87$

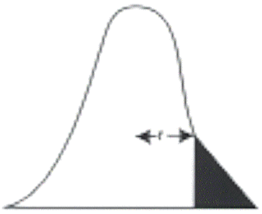
This value, $T = 1.87$, is to be compared with a critical value, T_{crit}, taken from Table A1.3 .

A2.4 The critical values relate to the chance of wrongly classifying a maximum value as an outlier when it is actually from the same underlying population as the other values. In the context of contaminated soil analyses, we are more concerned with wrongly accepting a value, which should properly be treated as an outlier. Therefore 10% critical values are more stringent (i.e. health protective) than 5% critical values, and will usually be most appropriate.

A2.5. The maximum value statistic calculated above ($T = 1.87$) is less than the 10% critical value of 1.91. Therefore it is reasonable to treat the maximum value as belonging to the same underlying distribution as the other values. Note that a maximum value of 370ppm would have been rejected as an outlier using the same test.

A.2.6 It needs to be emphasised that passing an outlier test (i.e. $T < T_{crit}$ does not **prove** that a maximum value is not an outlier possibly representing a (largely undiscovered) area of contamination. It merely demonstrates that the maximum value is reasonably consistent with belonging to the same underlying distribution as the other measurements. As always, statistical tests are an aid to decision making, but are not a substitute for professional judgement.

Table A1.2 – Probability points of the *t* distribution with *v* degrees of freedom



V (degree of freedom) = n-1

Note: this uses degrees of freedom not sample numbers

	Tail area probability, α									
V	0.4	0.25	0.1	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	127.32	318.31	636.62
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	14.089	22.326	31.598
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	7.453	10.213	12.924
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	4.773	5.893	6.869
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.029	4.785	5.408
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.796	2.201	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.197	3.610	3.922
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845	3.153	3.552	3.850
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831	3.135	3.527	3.819

22	0.256	0.686	1.321	1.717	2.074	2.508	2.819	3.119	3.505	3.792
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807	3.104	3.485	3.767
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797	3.091	3.467	3.745
25	0.256	0.684	1.316	1.708	2.060	2.485	2.787	3.078	3.450	3.725
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779	3.067	3.435	3.707
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771	3.057	3.421	3.690
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763	3.047	3.408	3.674
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756	3.038	3.396	3.659
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750	3.030	3.385	3.646
40	0.255	0.681	1.303	1.684	2.021	2.423	2.704	2.971	3.307	3.551
60	0.254	0.679	1.296	1.671	2.000	2.390	2.660	2.915	3.232	3.460
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617	2.860	3.160	3.373
∞	0.253	0.674	1.282	1.645	1.960	2.326	2.576	2.807	3.090	3.291

Table A1.3 – Critical Values to test for the presence of outliers.

N	5%	10%
4	1.46	1.42
5	1.67	1.60
6	1.82	1.73
7	1.94	1.83
8	2.03	1.91
9	2.11	1.98
10	2.18	2.04
12	2.29	2.13
14	2.37	2.21
16	2.44	2.28
18	2.50	2.33
20	2.56	2.38

APPENDIX 5

FACT SHEET FOR CLEA MODEL

www.environment-agency.gov.uk

Contaminated Land Assessment Model fact sheet for the Contaminated Land Exposure Assessment (CLEA) 2002 model

Basic model information

Model name:	Contaminated Land Exposure Assessment (CLEA 2002) v 1.3.0.1 model
Available from:	Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF. As accompaniment to CLR 10 or Can be downloaded from DEFRA's website (defra.gov.uk)
Cost:	Freely downloadable from DEFRA website.
Developed by:	The Environment Agency
Hardware:	PC with Intel Pentium II Processor or higher, running Windows 9x (95, 98, ME), Windows 2000 or XP.

Brief model description

CLEA 2002 v 1.3.0.1 is the first authorised, externally released version of the CLEA model. It is a probabilistic computer tool that has been used to derive the first suite of UK long-term human health generic assessment criteria for contaminated soil (Soil Guideline Values (SGVs)). Future versions of the model will be produced, as it is updated for the derivation of further suites of SGVs. CLEA 2002 has been issued as an accompaniment to CLR 10, which provides the technical and scientific basis and algorithms that underpin it. Receptors other than humans are not considered. The model does not estimate human exposure via contaminated surface water or groundwater.

Contaminants and contaminated media

The CLEA 2002 model has a database of nine contaminants. These are all toxic metals and metalloids with the exception of benzo(a)pyrene and phenol (although the toxicological data is incomplete for benzo(a)pyrene and phenol). Only media concentrations in soil (not air or water) can be entered directly into the model. Users can modify existing substances or add new organic substances to the database.

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Receptor types

Only on-site human receptors are considered. The receptor types included in the model are defined by age classes. The first 16 years of life are each treated as a separate age class numbered 1-16. The 'working life' from 16-59 (43 years) is treated as age class 17 and the period from age 59 to age 70 (11 years) is treated as age class 18. The default age classes are selected by the model according to the land use scenario selected. However, a receptor can be defined by choosing any combination of consecutive age classes. A child receptor of 0-6 years of age is the default for all land use scenarios except the commercial/industrial scenario where the default age class is 17 (working adult).

Land use and exposure scenarios

The land use scenarios defined within CLEA 2002 are as follows:

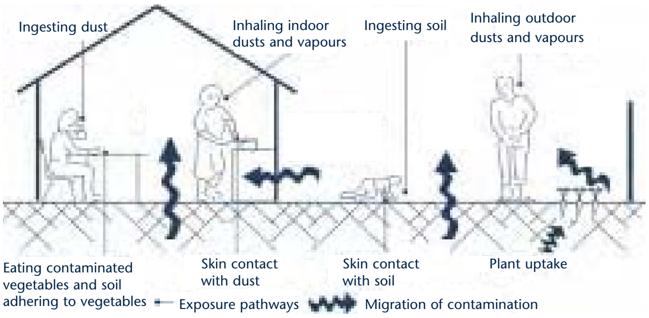
- residential (with plant uptake)
- residential (without plant uptake)
- allotments; and
- commercial and industrial.

The following pathways are available:

- direct ingestion of soil and dust
- ingestion of soil attached to garden vegetables
- consumption of contaminated home-grown garden vegetables
- dermal contact with soil outdoors
- dermal contact with soil derived dust indoors
- inhalation of soil-derived dust outdoors
- inhalation of soil-derived dust indoors
- inhalation of soil vapours outdoors; and
- inhalation of soil vapours indoors.

Some of the pathways are automatically switched on and off depending on the contaminant, land use and available toxicological data. However the user can switch additional pathways on and off on the land use selection screen.

Figure 1. Conceptual Model within CLEA Model



Key features of the model

What the model is supposed to do (model utility)

CLEA 2002 was developed for the derivation of the UK Soil Guideline Values (SGVs) which are intended for use within the context of Part IIA of EPA 1990 and development under the Town and Country Planning Act. This version of the model allows users to replicate the technical process used to derive the SGVs. CLR 7 describes the full context within which SGVs should be used.

CLEA 2002 also has limited functionality to enable users to alter site conditions such as soil type, pH and percentage soil organic matter. The model allows users to add new organic substances to the database. However, users should note that site-specific assessment criteria produced for new substances using the model are **not** SGVs. This is due to a number of reasons including: the fact that toxicological data may not have been reviewed for the UK context; the algorithms within the model may not be the most appropriate for the substance; and the absence of consultation with the relevant government agencies and departments.

CLEA 2002 is a probabilistic model. This means that, for a limited number of parameters, a value is selected from a family or range of values for a given parameter rather than using only a single number. This family of values is prescribed a shape, referred to as a probability density function (PDF) which acts as a guide to the random selection process, ensuring that values are selected within certain limits and according to likely probability. CLR 10 provides detailed information about which parameters are treated probabilistically and the applicable PDFs.

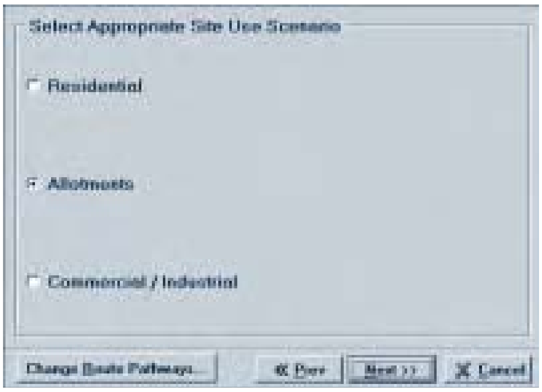
There are different levels of user that can be assigned to an individual or organisation for use of the model. The 'admin' and 'super' grades can change information in the contaminant database; other users can not. The 'admin' user can assign grades to others and edit their databases.

Model usability

In order to understand the principles of CLEA 2002 and its operation, it is strongly recommended that the user reads CLR 10 and the user manual. Without this background information, the user will not be able to understand the limited functionality of the model.

CLEA 2002 consists of two primary parts: data collection **(See Figure 2 for an example)** and Monte Carlo simulation. A 'roadmap' guides the user through each step of the data collection process and once each step has been completed, the colour changes. It is possible to go back through the data collection process if there is a need to revisit one of the previous data collection screens. The data collection process saves the previous selections until the simulation is closed. Therefore, if the initial Average Daily Exposure / Tolerable Daily Soil Intake (ADE/TDSI) or ADE: Index Dose ratio is too high or too low, the user may simply enter a new soil concentration seed value and re-run the Monte Carlo process. There is no need to repeat the data collection process.

Figure 2. Example of data collection screen


Select Appropriate Site Use Scenario

○ Residential

● Allotments

○ Commercial / Industrial

Each simulation can be saved with a unique simulation filename within the user's area. The user needs to take care to change the simulation filename; otherwise a new simulation can be saved over a previous simulation fairly easily.

Toxicological information

The database currently contains default toxicological information for the contaminants for which SGVs were issued in March 2002 (inorganic arsenic, cadmium, chromium, lead, nickel, inorganic mercury and selenium) and an oral Index Dose for benzo(a)pyrene. The toxicological information within the database is taken from the individual TOX reports. For threshold substances, separate Tolerable Daily Intakes (TDIs) and adult Mean Daily Intake (MDIs) are required for the oral and inhalation exposure routes. Where only oral toxicological data is available, the approach prescribed in CLR 9 and CLR 10 should be followed when applying it to other routes of exposure.

For non-threshold substances (including genotoxic carcinogens) a separate Index Dose is used rather than a TDI for the oral and inhalation exposure routes. Where only oral toxicological data is available, the approach prescribed in CLR 9 and CLR 10 should be followed when applying it to other routes of exposure. An MDI is not required for non-threshold substances.

Toxicological information for existing substances can either be edited permanently within the global database or changed for an individual simulation during data collection on the contaminant selection screen. When new substances are added, the toxicological data is input at the same time.

Contaminants and contact media

Only contaminant concentrations in soil can be entered directly into CLEA 2002 (the concentrations in air and plants are calculated internally). CLEA 2002 allows the calculation of contaminant exposure via direct soil contact, plant uptake and/or via vapours generated from soil sources. Vapours are evaluated only for organic contaminants. Therefore, soil vapours of inorganic contaminants, such as elemental mercury, cannot be included within the assessment.

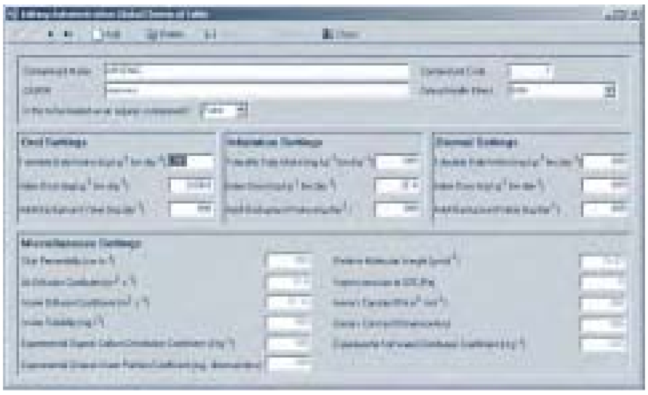
Of the nine contaminants included within the database of the current version of the model, seven are metals or metalloids.

The user should note that if lead is selected from the contaminant database, it is modelled in a different way from the other contaminants. This is because a target blood lead concentration is used, rather than a TDSI or Index Dose. TOX 6 details the UK toxicological approach to lead and SGV 10 describes the derivation of SGVs for lead.

Users can alter the toxicological and physico-chemical properties of existing substances, either within an individual simulation, or by altering the global database. In both cases a justification is requested for any changes.

New substances can be entered into the global database **(See Figure 3)** provided that all required data is entered. Users should note that although new metals may be entered, it is not possible to enter information about soil:plant concentration ratios; and therefore the plant uptake pathway cannot be modelled.

Figure 3. Contaminant properties screen



Receptor characterisation

Full information about physiological receptor characterisation (e.g. body weights, heights, skin areas) for all age classes is contained within CLR 10. CLR 10 also contains information about exposure factors for the standard land uses.

These include:

- exposure frequency
- time spent on site (inside and outside)
- proportion of time spent in active or passive inhalation
- soil ingestion rates
- vegetable consumption rates
- home-grown vegetable fraction
- exposed skin areas; and
- soiled skin areas.

The choice of critical receptor depends on the land use, the young child between 0-6 is selected for residential and allotments land-use scenarios, and the working adult (between 16 and 59) is taken as the critical receptor for the commercial and industrial scenario. Exposure is always averaged over its duration for both threshold and non-threshold substances.

Although the default critical receptor for the residential and allotments scenarios is the 0-6 year old child, appropriate exposure characteristics for the land use scenarios for the other age classes are included within the model. However for the commercial/industrial scenario, only the characteristics for age class 17 (working life) are within the model.

Some receptor characteristics differ for a number or all of the age classes depending on the land-use scenario.

These include:

- exposure frequency for pathways (days per year)
- numbers of hours of exposure for inhalation pathways
- proportion of time spent inside and outside; and
- proportion of time spent in active and passive inhalation.

Land use

The default land use within CLEA 2002 is the residential (with plant uptake) scenario. The user may also select one of the following standard land use scenarios during data collection.

- allotments; and
- commercial and industrial.

In order to select the residential (without plant uptake) scenario, the pathways pertaining to plant uptake need to be switched off when the residential land use is selected.

A full description of each land use scenario is included in CLR 10.

Pathway characterisation

The following section provides a summary of some relevant information about the pathways within CLEA 2002. Users should consult CLR 10 for detailed pathway information.

Direct ingestion of soil and dust

- contamination is within top 0-0.1 m of soil
- no distinction is made between soil and soil-derived dust; and
- bioaccessibility is assumed to be 100%.

Consumption of vegetables that have taken up contamination

- contamination is within top 0.5m
- Briggs Ryan algorithm used for organic contaminants (may not be suitable for substances with high Kow); and
- algorithms for metal uptake are contaminant specific. The user is advised to consult individual SGV reports for details.

Ingestion of soil attached to garden vegetables

- contamination is assumed to be present in top 0.5 m of soil; and
- mass of soil attached to vegetables is vegetable-specific.

Dermal contact with soil outdoors and soil-derived dust indoors

- contamination is assumed to be present in top 0-0.1m of soil
- no dermal contact is assumed for any of the metals currently included within CLEA 2002
- soil-specific Enrichment Factors for benzo(a)pyrene are currently included within the model. The default for all other organic contaminants within the model is 1
- dermal contact time is assumed to be 8 hours
- dermal soiling rates are assumed to be 1 mg/cm2; and
- not all exposed skin is assumed to be soiled.

Inhalation of soil-derived dust outdoors and indoors

- contamination is assumed to be present in top 0-0.1m of soil
- flux is assumed to be slowly due to perturbation - movement of vehicles across the site is not considered
- soil-specific Enrichment Factors for benzo(a)pyrene are currently included within the model. The default for all other organic contaminants within the model is 1; and
- only a proportion of inside dust is assumed to be derived from soil on the site. This is land use specific. CLR 10 should be consulted for further detail.

Inhalation of soil vapours outdoors

- contamination is assumed to be at 1m depth
- contaminant source zone in prevailing wind direction is assumed to be 15m
- contaminant is assumed to be in equilibrium between solid, aqueous and vapour phases of soil (i.e. transport of free product cannot be modelled)
- wind speed is assumed to be 3m/sec
- constant source is assumed (i.e. degradation cannot be modelled, and mass balance to adjust concentration for loss with volatilisation is not carried out).

Inhalation of soil vapours indoors

- contamination is assumed to be directly beneath the house
- the user has the option to select a ground-bearing slab foundation or a timber suspended floor
- the user has the option to select no pressure driven flow, pressure driven flow in winter only, or pressure driven flow all year round; and
- constant source is assumed (i.e. degradation cannot be modelled, and mass balance to adjust concentration for loss with volatilisation is not carried out).

Model outputs

The following outputs are available:

a report that can be printed out **(See Figure 4)**. This provides the following information:

- summary of results including contaminant, soil concentration and health criteria value used, background and whether substance has been treated as a threshold or non-threshold substance
- model parameters including which entry routes toxicological data has been applied to, critical receptor and soil parameters
- routes applied
- average contribution of each route to total exposure
- percentiles of average daily exposure in mg kg^{-1} bw day^{-1} for each age class; and
- list of contaminant parameters that have been changed from the default together with a justification.

Figure 4. Example report generated by CLEA model

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

- Graph showing the ratio of exposure over the TDSI or Index Dose at different percentiles **(See Figure 5)**.

Model interpretation

What does the output mean?

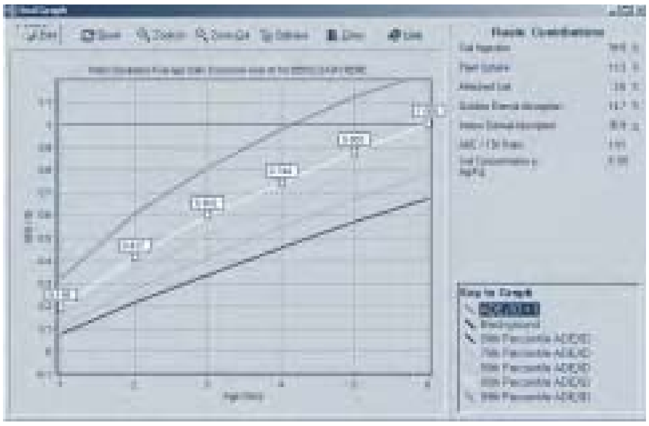
Report

When the ADE:TDSI or ADE:Index Dose ratio is equal to 1, this signifies that the 95th percentile of Average Daily Exposure is equal to the TDSI or Index Dose. This is the site-specific assessment criterion.

The Exposure Routes Analysis section allows a reviewer to check that appropriate pathways have been switched off (depends on contaminant, land use scenario, and toxicological data).

The section on the Average Contribution of each Exposure Route to ADE indicates which routes are the risk drivers.

Figure 5. Example graph generated from CLEA model



The graph shows the cumulative 50th, 75th, 90th and 95th percentiles of ADE compared to the TDSI or Index Dose. Where applicable, the contribution of background is also shown. This provides risk management information on the contribution of background exposure from other sources, and information for risk evaluation on whether the percentiles of exposure are far apart (showing that there is considerable variation in the exposure calculated by the Monte Carlo process) or close together.

Supporting information required to use the model appropriately (input data requirements)

- soil type (or information on particle size to enable appropriate soil type to be selected). This will have little effect on assessment criteria generated for metals (unless inhalation of dust is the risk driver) but may be highly significant for organic contaminants
- total, air-filled and water filled porosities (these cannot be changed within CLEA 2002 but should be consulted to verify that the conceptual model within it is appropriate for the site)
- pH, currently only explicitly used within the model for cadmium but also necessary to determine whether it is appropriate to use the model for other metal contamination
- depth of contamination (to verify that the conceptual model is appropriate)
- width of source zone (to verify that the conceptual model is appropriate)
- proportion soil organic matter (SOM). NB if laboratory analysis gives a fraction of organic carbon this will need to be converted into an organic matter content.

Common problems with the model

Use of the model is still in its infancy. The following are some mistakes that have been noted to date:

- the model report does not always present all the physico-chemical properties, especially for newly added contaminants. This makes QA/QC difficult
- the radio labels for 'Pressure Driven Flow All Year Round' and 'Pressure Driven Flow in Winter Only' are the wrong way round
- it is not possible to obtain absolute information about the exposures from each pathway at the 95th percentile from the report. This is due to the mean contribution of each simulation being reported.

Common mistakes made when using the model

The following are some mistakes that have been noted to date:

- failure to check that the conceptual model within CLEA 2002 is appropriate for the site in question
- failure to convert units from literature into units required by CLEA 2002. This is particularly common with diffusivities in air and water; and
- selection of 'lifetime' exposure and averaging, rather than elapsed time (which automatically selects the appropriate critical receptor for each land use scenario).

Model limitations - what the model does not do

The following summarises the model limitations:

- CLEA 2002 does not consider short term risks
- it does not consider risks to construction workers
- it is not possible to change information about the source term, such as depth of contamination, width of source zone
- it is not possible to change certain site information such as wind speed
- it is not possible to model free product (e.g. from a fresh spill or a layer floating on groundwater)
- it is not possible to input measured concentrations for contaminated media e.g. vegetables, indoor air directly into the model (some manipulation of the outputs is possible but is difficult because of the probabilistic nature of the model).

CLEA 2002 does not model the following pathways:

- consumption of fruit that has taken up contamination from soil
- consumption of contaminated meat or poultry
- consumption of contaminated dairy products and eggs
- use of on-site water for drinking/bathing/showering (either through direct use of an on-site source or permeation of plastic pipes).

It is not possible to alter exposure factors within CLEA 2002 (e.g. physiological characteristics such as body weight, exposure frequencies, and behaviour patterns such as soil ingestion rate, proportion exposed skin, and proportion of time engaged in active/passive respiration). It is therefore not possible to adapt the model for non-standard land uses where there is a need to alter these exposure factors.

Sensitive model parameters

Few of the defaults within CLEA 2002 can be changed at present. The following is a brief summary of some of the parameters which may be changed and are sensitive in certain situations. The Agency is in the process of producing an R&D report, which is a full sensitivity analysis of the non-compiled version of the CLEA model (i.e. all parameters can be changed).

- exposure and averaging periods
- choice of toxicological data when entering new substances
- physico-chemical parameter choice for new substances
- selection of building type for vapour intrusion pathway (ground bearing slab results in a higher exposure, and thus lower site-specific assessment criterion)
- selection of flow type for vapour intrusion pathway (the higher the proportion of pressure-driven flow, the lower the site-specific assessment criterion)
- soil type (coarser grained soils are more permeable to organic contaminant flux and have a higher soil Enrichment Factor than finer grained soils)
- percent soil organic matter (relevant for organic contaminants and plant uptake, vapour and dermal uptake pathways, also relevant for plant uptake of inorganic mercury. The higher the proportion of soil organic matter, the greater the capacity of the soil to bind contaminant, and the less that is available); and
- pH (relevant for cadmium contamination and the plant uptake pathway).

References and further information

1. DEFRA and the Environment Agency (2002) Assessment of Risks to Human Health from Land Contamination: An Overview of the Development of Soil Guideline Values and Related Research. Report CLR7. Available from: Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

2. DEFRA and the Environment Agency (2002) Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans. Report CLR9. Available from: Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

3. DEFRA and the Environment Agency (2002) The Contaminated Land Exposure Assessment Model (CLEA): Technical basis and algorithms. CLR10 Available from: Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

4. DEFRA and the Environment Agency (2002) Soil Guideline Value Reports for Individual Soil Contaminants R&D SGV series. Available from: Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

5. DEFRA and the Environment Agency (2002) Toxicological Reports for Individual Soil Contaminants. Report R&D TOX 1-10. Available from: Environment Agency R&D Dissemination Centre, c/o WRc, Frankland Road, Swindon, Wilts SN5 8YF

Further information

Further details on the application of this model and other risk assessment tools can be obtained from:

Environment Agency
National Groundwater and Contaminated Land Centre
Olton Court
10 Warwick Road
Olton
Solihull, B92 7HX
Tel: 0121 711 5885
Fax: 0121 711 5925

Acknowledgments

The National Groundwater & Contaminated Land Centre would like to thank internal and external colleagues for their comments when developing this fact sheet.

ENVIRONMENT AGENCY

APPENDIX 6

CLEA MODEL RESULTS

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

		User Name:	**Super User**	*Report Date:*	**26/04/2004**
Contaminant :	**LEAD**			*Simulation Date:*	**26/04/2004**
Soil Concentration (mg/Kg):	**750.000**	*Chemical Type :*	**Inorganic / Threshold**		
Health Criteria Value:	**N/A**	*Details:*	**New Simulation**		
(mg/Kg bw / day):	**N/A**				
Background (micro.g/dL):	**2.3**				

Model Parameters

Entry Route:	**Oral**		
Applied Dose Data To:	**Oral Route Only**		
No. of Iterations:	**1**		
Scenario Type :	**Commercial / Industrial**		
Receptor Used :	**Female height / weight database**	*Age Class:*	**17 To 17**
Averaging Method :	**Elapsed exposure time**	*Soil Ingestion rate (g/day):*	**0.04**
Exposure (days/year):	**230**	*Soil PH :*	**N/A**
S.D. for B-L concentration:	**2**	*Soil Organic Matter (%):*	**N/A**
Confidence limit:	**95th Percentile**	*Molecular Weight (g) :*	**N/A**
Period of soil contact (days):	**365**	*Air Diffusivity (m2 /s) :*	**N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date	Reason
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004	calculation mistake
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004	calculation mistake
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004	data input error
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003	Index dose from TOX report
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003	TOX data from database
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003	convert mg/m3 to mg/kgbw/day

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Report Date:	**26/04/2004**
Simulation Date:	**26/04/2004**

Contaminant **LEAD**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**4E-6**
Air Diffusion Coefficient (m2.s-1)	**1E-6**
Water Diffusion Coefficient (m2.s-1)	**1E-10**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**207.19**
Vapour Pressure at 20'C (Pa)	**0**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**200**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

		User Name:	**Super User**	*Report Date:*	**26/04/2004**
Contaminant :	**Zinc**			*Simulation Date:*	**26/04/2004**
Soil Concentration (mg/Kg):	**543677.573**	*Chemical Type :*	**Inorganic / Threshold**		
Health Criteria Value:	**TDI**	*Details:*	**New Simulation**		
(mg/Kg bw / day):	**0.3**				
Background (mg/day):	**0.3**				

Model Parameters

		Mean Daily Intakes:	
Entry Route:	**Oral**	*Oral:*	**0.3**
Applied Dose Data To:	**All Routes**	*Dermal*	**N/A**
No. of Iterations:	**5000**	*Inhalation:*	**N/A**
Scenario Type :	**Commercial / Industrial**		
Receptor Used :	**Female height / weight database**	*Age Class:*	**17 To 17**
Averaging Method :	**Lifetime**	*Soil Type :*	**Sandy**
Dermal Uptake Routine :	**N/A**	*Soil PH :*	**7**
Plant Uptake Routine :	**N/A**	*Soil Organic Matter (%):*	**5**
Building Type :	**N/A**	*Molecular Weight (g) :*	**N/A**
Flow Type:	**N/A**	*Air Diffusivity (m2 /s) :*	**N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust
Route 5 : Outdoor exposure to soil through skin contact pathway
Route 6 : Indoor exposure to dust through skin contact pathway
Route 7 : Outdoor inhalation of fugitive dust pathway
Route 8 : Indoor inhalation of fugitive dust pathway
Route 9 : Outdoor inhalation of soil vapour pathway
Route 10 : Indoor inhalation of soil vapour pathway

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*
1	**100.0**	**0.0**	**100.0**	**100.0**
7	**0.0**	**0.0**	**0.0**	**0.0**
8	**0.0**	**0.0**	**0.0**	**0.0**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant : **Zinc**

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Total Average Daily Exposure (mg/Kg bodyweight / day)

Ratio of ADE/TDI at 95th percentile : **0.981**

Ageclass	*Percentiles*			
	99 th	*95 th*	*90 th*	*50 th*
17	**3.53E-1**	**2.94E-1**	**2.68E-1**	**2.01E-1**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date	Reason
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004	calculation mistake
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004	calculation mistake
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004	data input error
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003	Index dose from TOX report
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003	TOX data from database
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003	convert mg/m3 to mg/kgbw/day

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Contaminant Zinc

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**0.3**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**0.3**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**N/A**
Air Diffusion Coefficient (m2.s-1)	**1E-10**
Water Diffusion Coefficient (m2.s-1)	**1E-6**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**65.4**
Vapour Pressure at 20'C (Pa)	**N/A**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**40**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

		User Name:	**Super User**	*Report Date:*	**26/04/2004**
Contaminant :	**ARSENIC**			*Simulation Date:*	**26/04/2004**
Soil Concentration (mg/Kg):	**559.951**	*Chemical Type :*	**Inorganic / Non-Threshold**		
Health Criteria Value:	**Index Dose**	*Details:*	**New Simulation**		
(mg/Kg bw / day):	**0.0003**				
Background (mg/day):	**Not Applicable**				

Model Parameters

Entry Route:	**Oral**		
Applied Dose Data To:	**All Routes**		
No. of Iterations:	**5000**		
Scenario Type :	**Commercial / Industrial**		
Receptor Used :	**Female height / weight database**	*Age Class:*	**17 To 17**
Averaging Method :	**Lifetime**	*Soil Type :*	**Sandy**
Dermal Uptake Routine :	**N/A**	*Soil PH :*	**7**
Plant Uptake Routine :	**N/A**	*Soil Organic Matter (%):*	**5**
Building Type :	**N/A**	*Molecular Weight (g) :*	**N/A**
Flow Type:	**N/A**	*Air Diffusivity (m2 /s) :*	**N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust
Route 5 : Outdoor exposure to soil through skin contact pathway
Route 6 : Indoor exposure to dust through skin contact pathway
Route 7 : Outdoor inhalation of fugitive dust pathway
Route 8 : Indoor inhalation of fugitive dust pathway
Route 9 : Outdoor inhalation of soil vapour pathway
Route 10 : Indoor inhalation of soil vapour pathway

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*
1	100.0	0.0	100.0	100.0
7	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Contaminant : **ARSENIC**

Total Average Daily Exposure (mg/Kg bodyweight / day)

Ratio of ADE/TDI at 95th percentile : **1.000**

Ageclass	*Percentiles* *99 th*	*95 th*	*90 th*	*50 th*
17	**3.54E-4**	**3.00E-4**	**2.73E-4**	**2.06E-4**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date	Reason
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004	calculation mistake
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004	calculation mistake
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004	data input error
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003	Index dose from TOX report
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003	TOX data from database
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003	convert mg/m3 to mg/kgbw/day

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Contaminant **ARSENIC**

Report Date:	**26/04/2004**
Simulation Date:	**26/04/2004**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**0.0003**
Adult Background Value (mg.day-1)	**N/A**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**7E-8**
Adult Background Value (mg.day-1)	**N/A**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**N/A**
Air Diffusion Coefficient (m2.s-1)	**1E-6**
Water Diffusion Coefficient (m2.s-1)	**1E-10**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**74.92**
Vapour Pressure at 20'C (Pa)	**0**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**200**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

User Name: **Super User**
Report Date: **26/04/2004**
Simulation Date: **26/04/2004**
Contaminant : **Copper**
Soil Concentration (mg/Kg): **47128.228**
Chemical Type : **Inorganic / Threshold**
Health Criteria Value: **TDI**
Details: **New Simulation**
(mg/Kg bw / day): **0.026**
Background (mg/day): **Not Applicable**

Model Parameters

Entry Route: **Oral**
Applied Dose Data To: **All Routes**
No. of Iterations: **5000**
Scenario Type : **Commercial / Industrial**
Receptor Used : **Female height / weight database**
Averaging Method : **Lifetime**
Dermal Uptake Routine : **N/A**
Plant Uptake Routine : **N/A**
Building Type : **N/A**
Flow Type: **N/A**

Age Class: **17 To 17**
Soil Type : **Sandy**
Soil PH : **7**
Soil Organic Matter (%): **5**
Molecular Weight (g) : **N/A**
Air Diffusivity (m2 /s) : **N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust
Route 5 : Outdoor exposure to soil through skin contact pathway
Route 6 : Indoor exposure to dust through skin contact pathway
Route 7 : Outdoor inhalation of fugitive dust pathway
Route 8 : Indoor inhalation of fugitive dust pathway
Route 9 : Outdoor inhalation of soil vapour pathway
Route 10 : Indoor inhalation of soil vapour pathway

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*
1	**100.0**	**0.0**	**100.0**	**100.0**
7	**0.0**	**0.0**	**0.0**	**0.0**
8	**0.0**	**0.0**	**0.0**	**0.0**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant : **Copper**

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Total Average Daily Exposure (mg/Kg bodyweight / day)

Ratio of ADE/TDI at 95th percentile : **1.007**

Ageclass	*Percentiles*			
	99 th	*95 th*	*90 th*	*50 th*
17	**3.08E-2**	**2.62E-2**	**2.35E-2**	**1.75E-2**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date	Reason
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004	calculation mistake
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004	calculation mistake
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004	data input error
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003	Index dose from TOX report
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003	TOX data from database
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003	convert mg/m3 to mg/kgbw/day

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Report Date:	**26/04/2004**
Simulation Date:	**26/04/2004**

Contaminant **Copper**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**0.026**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**N/A**
Air Diffusion Coefficient (m2.s-1)	**N/A**
Water Diffusion Coefficient (m2.s-1)	**N/A**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**63.5**
Vapour Pressure at 20'C (Pa)	**N/A**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**2120**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant :	**Manganese**	*User Name:*	**Super User**	*Report Date:*	**26/04/2004**
Soil Concentration (mg/Kg):	**258838.359**			*Simulation Date:*	**26/04/2004**
Health Criteria Value:	**TDI**	*Chemical Type :*	**Inorganic / Threshold**		
(mg/Kg bw / day):	**0.14**	*Details:*	**New Simulation**		
Background (mg/day):	**0.004**				

Model Parameters

		Mean Daily Intakes:	
Entry Route:	**Oral**	*Oral:*	**N/A**
Applied Dose Data To:	**All Routes**	*Dermal*	**N/A**
No. of Iterations:	**5000**	*Inhalation:*	**0.004**
Scenario Type :	**Commercial / Industrial**		
Receptor Used :	**Female height / weight database**	*Age Class:*	**17 To 17**
Averaging Method :	**Elapsed exposure time**	*Soil Type :*	**Sandy**
Dermal Uptake Routine :	**N/A**	*Soil PH :*	**7**
Plant Uptake Routine :	**N/A**	*Soil Organic Matter (%):*	**5**
Building Type :	**N/A**	*Molecular Weight (g) :*	**N/A**
Flow Type:	**N/A**	*Air Diffusivity (m2 /s) :*	**N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust
Route 5 : Outdoor exposure to soil through skin contact pathway
Route 6 : Indoor exposure to dust through skin contact pathway
Route 7 : Outdoor inhalation of fugitive dust pathway
Route 8 : Indoor inhalation of fugitive dust pathway
Route 9 : Outdoor inhalation of soil vapour pathway
Route 10 : Indoor inhalation of soil vapour pathway

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*
1	**100.0**	**0.0**	**100.0**	**100.0**
7	**0.0**	**0.0**	**0.0**	**0.0**
8	**0.0**	**0.0**	**0.0**	**0.0**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant : **Manganese**

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Total Average Daily Exposure (mg/Kg bodyweight / day)

Ratio of ADE/TDI at 95th percentile : **0.985**

Ageclass	*Percentiles* *99 th*	 *95 th*	 *90 th*	 *50 th*
17	**1.66E-1**	**1.38E-1**	**1.26E-1**	**9.37E-2**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date
Reason						
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004
calculation mistake						
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004
calculation mistake						
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004
data input error						
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003
Index dose from TOX report						
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003
TOX data from database						
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003
convert mg/m3 to mg/kgbw/day						

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Contaminant **Manganese**

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**0.14**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**0.009**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**0.004**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**N/A**
Air Diffusion Coefficient (m2.s-1)	**N/A**
Water Diffusion Coefficient (m2.s-1)	**N/A**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**54.94**
Vapour Pressure at 20'C (Pa)	**N/A**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**200**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant :	**CHROMIUM**	*User Name:*	**Super User**	*Report Date:*	**26/04/2004**
Soil Concentration (mg/Kg):	**5191.215**			*Simulation Date:*	**26/04/2004**
Health Criteria Value:	**TDI**	*Chemical Type :*	**Inorganic / Threshold**		
(mg/Kg bw / day):	**0.003**	*Details:*	**New Simulation**		
Background (mg/day):	**0.013**				

Model Parameters

		Mean Daily Intakes:	
Entry Route:	**Oral**	*Oral:*	**0.013**
Applied Dose Data To:	**All Routes**	*Dermal*	**N/A**
No. of Iterations:	**5000**	*Inhalation:*	**N/A**
Scenario Type :	**Commercial / Industrial**		
Receptor Used :	**Female height / weight database**	*Age Class:*	**17 To 17**
Averaging Method :	**Lifetime**	*Soil Type :*	**Sandy**
Dermal Uptake Routine :	**N/A**	*Soil PH :*	**7**
Plant Uptake Routine :	**N/A**	*Soil Organic Matter (%):*	**5**
Building Type :	**N/A**	*Molecular Weight (g) :*	**N/A**
Flow Type:	**N/A**	*Air Diffusivity (m2 /s) :*	**N/A**

Exposure Routes Analysis

Route 1 : Soil ingestion pathway
Route 2 : Ingestion of indoor dust
Route 5 : Outdoor exposure to soil through skin contact pathway
Route 6 : Indoor exposure to dust through skin contact pathway
Route 7 : Outdoor inhalation of fugitive dust pathway
Route 8 : Indoor inhalation of fugitive dust pathway
Route 9 : Outdoor inhalation of soil vapour pathway
Route 10 : Indoor inhalation of soil vapour pathway

Average Contribution of Each Exposure Route to ADE

Exposure route	*Contributions for each exposure route*			
	Mean (%)	*Standard Dev (%)*	*Minimum (%)*	*Maximum (%)*
1	**100.0**	**0.0**	**100.0**	**100.0**
7	**0.0**	**0.0**	**0.0**	**0.0**
8	**0.0**	**0.0**	**0.0**	**0.0**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Summary of Results

Contaminant : **CHROMIUM**

Report Date: **26/04/2004**
Simulation Date: **26/04/2004**

Total Average Daily Exposure (mg/Kg bodyweight / day)

Ratio of ADE/TDI at 95th percentile : **0.998**

Ageclass	*Percentiles*			
	99 th	*95 th*	*90 th*	*50 th*
17	**3.50E-3**	**2.99E-3**	**2.73E-3**	**2.10E-3**

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment For the Environment Agency 1993 - 2000.

Table	Record	Field	Initial Value	New Value	User	Date	Reason
Chemical	1,2-Dichloroeth	Dair	0.104	**1.04E-5**		14/04/2004	calculation mistake
Chemical	1,2-Dichloroeth	Dwater	1.05E-5	**1.05E-9**		14/04/2004	calculation mistake
Chemical	Acnaphthylene	OralCPS	7E-6	**0.002**		16/03/2004	data input error
Chemical	ARSENIC	InhalCPS	2E-6	**7E-8**		04/11/2003	Index dose from TOX report
Chemical	BENZO(A)PYRENE	InhalCPS	-999	**7E-8**		04/11/2003	TOX data from database
Chemical	NAPHTHALENE	InhalTDI	0.003	**0.000857**		04/11/2003	convert mg/m3 to mg/kgbw/day

CONTAMINATED LAND EXPOSURE ASSESSMENT MODEL 2002

Prepared by the Centre for Research into the Built Environment, for the Environment Agency (1993 - 2002)

Report Date:	**26/04/2004**
Simulation Date:	**26/04/2004**

Contaminant **CHROMIUM**

Oral Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**0.003**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**0.013**

Inhalation Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**1E-6**
Adult Background Value (mg.day-1)	**N/A**

Dermal Settings

Tolerable Daily Intake (mg.kg-1.bw.day-1)	**N/A**
Index Dose (mg.kg-1.bw.day-1)	**N/A**
Adult Background Value (mg.day-1)	**N/A**

Miscellaneous Settings

Skin Permeability (cm.hr-1)	**0.002**
Air Diffusion Coefficient (m2.s-1)	**1E-6**
Water Diffusion Coefficient (m2.s-1)	**1E-10**
Water Solubility (mg.l-1)	**N/A**
Experimental Organic Carbon Distribution Coefficient (l.kg-1)	**N/A**
Experimental Octanol-Water Partition Coefficient (log, dimensionless)	**N/A**
Relative Molecular Weight (g.mol-1)	**51.996**
Vapour Pressure at 20'C (Pa)	**0**
Henry's Constant (Pa.m3.mol-1)	**N/A**
Henry's Constant (Dimensionless)	**N/A**
Experimental Soil Water Distribution Coefficient (l.kg-1)	**200**

APPENDIX 7

GEOTECHNICAL LABORATORY RESULTS

Summary of Geotechnical Laboratory Test Results

Project: - A249-00 Akko Steel Mill

Sample Details					Classification										Chemical				Density		Compaction			C.B.R		Triaxial Compression						Consolidation		
											Particle size distribution					SO_4																		
Trial Pit	Waste Mound Location	Ref.	Depth (m)	Description	W %	L.L %	P.L %	P.I. & CODE	425µ (%)	SG	Clay	Silt	Sand	Gravel	pH	Water Sol g/l	Acid Sol %	Org %	Bulk γ Mg/m^3	Dry γd Mg/m^3	Test Code	Max γd Mg/m^3	Opt m/c %	Top Base	m/c %	Test Code	σ_3 kN/m^2	σ_1-σ_3 kN/m^2	C_u kN/m^2	c Ø	Mode of Fail	Pressure Range kN/m^2	M_v (m^2/MN)	C_v (m^2/Year)
TP 06	Western		0.50		3.3					3.37																								
TP 06	Western		1.50		5.1																													
TP 07	Western	R20-11	Surface		6.5																													
TP 07	Western	R20-11	0.50		1.7							5*	44	51																				
TP 07	Western	R20-11	3.50		4.8							6*	31	63																				
TP 07	Western	R20-11	6.00		4.8					3.55																								
TP 08	Western		0.50		8.4																													
TP 08	Western		3.00		14							21	29	50																				
TP 09	Western	R20-7	0.00		1.5																													
TP 09	Western	R20-7	1.00		9.3																													
TP 09	Western	R20-7	3.00		4.0							8*	47	45																				
TP 10	Western	R20-9	1.00		8.9							11*	49	40																				
TP 10	Western	R20-9	3.00		4.0					3.53																								
TP 16	Northern	R20-2	0.50		1.5							10*	22	68																				
TP 16	Northern	R20-2	1.50		7.3																													
TP 18	Northern	R20-4	1.00		2.8																													
TP 18	Northern	R20-4	1.50		7.8																													
TP 18	Northern	R20-4	2.00	Sample combined with sample from R20-4 at 4m for particle size distribution test	10							4*	34	62																				
TP 18	Northern	R20-4	4.00		3.6																													
TP 20	Northern	R20-1	0.50		2.4					3.25																								
TP 20	Northern	R20-1	4.00	Sample combined with sample from R20-1 at 5m for particle size distribution test	3.4							5*	44	51																				
TP 20	Northern	R20-1	5.00		4.8																													

KEY:

U = Undisturbed
B = Bulk
J = Jar
W = Water

W =Natural Moisture Content
L.L = Liquid Limit
P.L = Plastic Limit
P.I = Plasticity Index
Code = Casagrande Classification

* passing 63µm

H = 4.5 kg hammer
L = 2.5 kg hammer
V = Vibrating hammer
m/c = Moisture Content

M = Multistage
U = Undrained
F = Functional Drained
R = Remoulded
E = Effective Stress
C_u = Shear Strength
σ_3 = Lateral Cell Pressure

B = Brittle
C = Compound
P = Plastic
$Ø_u$ = Angle of Internal Friction
σ_1-σ_3 = Deviator Stress

M_v = Coefficient of Compressibility
C_v = Coefficient of Consolidation

APPENDIX 8

ANALYTICAL RESULTS FOR SIEVED WASTE MOUND SAMPLES

Soil Analysis Results - Sieved Fractions of Waste Mound Material

BAE Systems Environmental Laboraotry Results

Sample Reference	Sample Particle Size	Type	As mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	Cu mg/kg	Ni mg/kg	Zn mg/kg	B mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Ti mg/kg	V mg/kg
36974 Waste Mound Dust	<75um	D/G	18.00	42.40	470.00	3070.00	1.20	1.40	1130.00	210.00	0.02	8.00	39800.00	6490.00	42.00	1180.00	51.00
36975 Waste Mound Dust	75-150um	D/G	17.00	24.00	551.00	1880.00	0.70	2.10	938.00	250.00	0.01	8.10	34800.00	6210.00	54.00	840.00	38.00
36976 Waste Mound Dust	150-300um	D/G	13.00	16.00	533.00	1370.00	0.30	0.50	1140.00	210.00	6980.00	6.20	16800.00	5720.00	47.00	740.00	34.00
36977 Waste Mound Dust	300-600um	D/G	15.00	11.00	953.00	1450.00	0.40	0.70	1360.00	260.00	6940.00	5.90	22000.00	10600.00	57.00	1230.00	64.00
36978 Waste Mound Dust	600-1180um	D/G	11.00	6.20	1250.00	1090.00	0.20	0.60	594.00	180.00	5360.00	6.10	27000.00	13700.00	52.00	1520.00	96.00
36979 Waste Mound Dust	1180-4000um	D/G	9.00	4.20	1330.00	1610.00	0.10	0.60	446.00	140.00	3270.00	5.30	33900.00	15300.00	38.00	1730.00	116.00
36980 Waste Mound Dust	>4000um	D/G	13.00	2.10	1750.00	210.00	0.10	0.70	240.00	61.00	992.00	3.00	29800.00	20800.00	28.00	2350.00	180.00
36974 Waste Mound Dust	<75um	A/R	18.00	42.80	470.00	3120.00	1.20	1.30	1100.00	200.00	0.02	8.90	40200.00	6310.00	42.00	1090.00	54.00
36974 Waste Mound Dust	75-150um	A/R	17.00	27.00	557.00	1950.00	0.60	0.60	925.00	240.00	0.01	8.60	34000.00	6590.00	52.00	900.00	40.00
36974 Waste Mound Dust	150-300um	A/R	16.00	14.00	573.00	1410.00	0.50	4.50	944.00	230.00	7300.00	7.70	18800.00	6160.00	49.00	770.00	38.00
36974 Waste Mound Dust	300-600um	A/R	14.00	11.00	914.00	1890.00	0.30	0.40	918.00	230.00	6340.00	6.60	21400.00	10000.00	54.00	1130.00	69.00
36974 Waste Mound Dust	600-1180um	A/R	12.00	8.40	1350.00	1330.00	0.20	0.60	856.00	190.00	4760.00	4.80	23500.00	14000.00	48.00	1380.00	104.00
36974 Waste Mound Dust	1180-4000um	A/R	15.00	0.70	2110.00	240.00	0.10	0.60	326.00	87.00	928.00	2.10	24700.00	20600.00	90.00	2090.00	240.00
36974 Waste Mound Dust	>4000um	A/R	13.00	0.30	1740.00	52.00	0.10	0.60	270.00	79.00	329.00	0.80	21600.00	30900.00	28.00	2340.00	240.00

Notes Type D/G = sample analysed was dried and ground Type A/R = sample analysed was as recevied

	As	Cd	Cr	Pb	Hg	Se	Cu	Ni	Zn	B	Mg	Mn	Mo	Ti	V
Guidance Value - **G**	500	1400	5000	750	480	800	48000	4897	548025	20	9000	258838	9120	25000	12967
Guidance Value - Type	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CTV IND	Bowen BG	CLEA SSAC	GSAC (SGV)	Bowen BG	GSAC (SGV)
No of samples	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
No of exceedences of G	0	0	0	11	0	0	0	0	0	0	14	0	0	0	0
Minimum Value	9.00	0.30	470.00	52.00	0.10	0.40	240.00	61.00	0.01	0.80	16800.00	5720.00	28.00	740.00	34.00
Maximum Value	18.00	42.80	2110.00	3120.00	1.20	4.50	1360.00	260.00	7300.00	8.90	40200.00	30900.00	90.00	2350.00	240.00
2nd Highest	18.00	42.40	1750.00	3070.00	0.70	2.10	1140.00	250.00	6980.00	8.60	101000.00	208000.00	57.00	2340.00	180.00

Aminolab Laboraotry Results

Sample Reference	Sample Particle Size	As mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Hg mg/kg	Se mg/kg	Cu mg/kg	Ni mg/kg	Zn mg/kg	B mg/kg	Mg mg/kg	Mn mg/kg	Mo mg/kg	Ti mg/kg	V mg/kg
36974 Waste mountain dust	Combined Sample All Sizes	5.00	13.00	937.00	2262.00	2.00	5.00	979.00	148.00	8680.00	162.00	27101.00	8842.00	32.00	872.00	76.00
36974 Waste mountain dust	<75um	9.00	36.00	516.00	4019.00	2.00	5.00	1126.00	197.00	17889.00	122.00	34823.00	5545.00	34.00	724.00	53.00
36974 Waste mountain dust	75-150um	7.00	21.00	616.00	2720.00	2.00	5.00	930.00	242.00	10695.00	122.00	33152.00	5825.00	44.00	684.00	47.00
36974 Waste mountain dust	150-300um	8.00	12.00	568.00	1865.00	2.00	5.00	884.00	179.00	7024.00	96.00	18043.00	5093.00	36.00	584.00	41.00
36975 Waste mountain dust	300-600um	7.00	8.00	927.00	2163.00	2.00	5.00	929.00	184.00	7129.00	101.00	20455.00	8239.00	40.00	851.00	70.00
36976 Waste mountain dust	600-1180um	5.00	3.00	1680.00	6544.00	2.00	5.00	838.00	224.00	5234.00	117.00	25773.00	13661.00	38.00	1313.00	126.00
36977 Waste mountain dust	1180-4000um	5.00	5.00	1699.00	317.00	2.00	5.00	247.00	35.00	1092.00	496.00	24576.00	14578.00	45.00	906.00	221.00
36978 Waste mountain dust	>4000um	5.00	2.00	872.00	192.00	2.00	5.00	103.00	17.00	792.00	40.00	12244.00	9605.00	10.00	377.00	65.00

	As	Cd	Cr	Pb	Hg	Se	Cu	Ni	Zn	B	Mg	Mn	Mo	Ti	V
Guidance Value - **G**	500	1400	5000	750	480	800	48000	4897	548025	20	9000	258838	9120	25000	12967
Guidance Value - Type	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CLEA SSAC	CTV IND	Bowen BG	CLEA SSAC	GSAC (SGV)	Bowen BG	GSAC (SGV)
No of samples	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
No of exceedences of G	0	0	0	6	0	0	0	0	0	8	8	0	0	0	0
Minimum Value	5.00	2.00	516.00	192.00	2.00	5.00	103.00	17.00	792.00	40.00	12244.00	5093.00	10.00	377.00	41.00
Maximum Value	9.00	36.00	1699.00	6544.00	2.00	5.00	1126.00	242.00	17889.00	496.00	34823.00	14578.00	45.00	1313.00	221.00
2nd Highest	10.00	21.00	1680.00	4019.00	2.00	5.00	979.00	224.00	10695.00	162.00	44925.00	13661.00	44.00	906.00	126.00