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Remediation Strategy Report

On

The Former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire

For

Kier Partnership Homes

Report J9619
February 2007
Revision 1.02

Remediation Strategy Report

Job Title: Former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire

Client: Kier Partnership Homes

CONTROL DOCUMENT

SOILS LIMITED DOCUMENT REFERENCE NUMBER: J9619

DOCUMENT TYPE: INTERPRETATIVE REPORT

DOCUMENT STATUS: Final Revision: 1.02

DATE: February 2007

Note: This is not a valid document for use in the design of the project unless it is titled **Final** in the Document Status box.

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Remediation Strategy Report

For

The Former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire

For

Kier Partnership Homes

Commission

In June 2005 Soils Limited were commissioned by Martlet Development Consultants, on behalf of Kier Partnership Homes, to undertake a Desk Study and Phase II Ground Investigation for a potential redevelopment site at the former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire. The results of the initial investigation into the potential for contamination were issued within the Soils Limited Ground Investigation Report, ref: J8930 issued in September 2005.

This report presents the results of our additional investigation on the site, and incorporates the results of the initial investigation into formulating a remediation strategy for soil contamination for the site of a proposed redevelopment located at the former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire.

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The field investigation was performed in accordance with the recommended practices set out in BS 5930:1999 and BS1377:1990 Part 9.

The chemical analyses were undertaken by Alcontrol Technichem in accordance with their UKAS & MCERTS accredited test methods or their documented in-house testing procedures.

This investigation did not comprise an environmental audit of the site or its environs.

Trial hole is a generic term used to describe a method of direct investigation. The term trial pit or borehole implies the specific technique used to produce a trial hole.

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1.0 Introduction

1.1 Aims of the Investigation

The overall objective was understood to be to supply the client and local authority information regarding remediation strategies for contamination conditions associated with the site identified in the original Soils Limited Ground Investigation Report, ref: J8930 issued in September 2005.

This report must be read in conjunction with the original Soils Limited Ground Investigation Report, J8930, September 2005.

1.2 Site Location

The site lies off the main A3024 Northam Road, Southampton, south of the River Itchen. The approximate O.S. National Grid Reference at the centre of the site was 442980, 112760. The general site location is given on Figure 1. The approximate locations of the trial holes are shown on Figure 2.

1.3 Proposed Redevelopment

The proposed construction was understood to comprise the erection of ten private residential houses and one block of residential flats with ancillary structures, access roads, car parking areas and private and communal garden soft-landscaped areas.

1.4 Legislative Background

Part IIA of the Environment Act 1995 provides powers in relation to the identification, remediation and apportionment of liability for contaminated land.

Local Authorities are required to identify contaminated land and serve on every person who is an appropriate person a remediation notice setting out what is to be done by way of remediation and the period within which it must be done.

If the person who caused, or knowingly permitted the contaminating substance cannot be found, the owner and/or occupier for the time being of the property can be the appropriate person.

For the first time in the United Kingdom there is a legal meaning to the term Contaminated Land as: -

> *"Land which is in such a condition by reason of substances in, on or under the land that significant harm is being caused or that there is a significant possibility of such harm being caused or that pollution of controlled waters is being, or is likely to be caused".*

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Where the Act defines harm as: -

> *"harm to the health of living organisms or other interference with the ecological systems of which they form a part and, in the case of man, includes harm to his property".*

and pollution of controlled waters is defined as: -

> *"the entry into controlled waters of any poisonous, noxious or polluting matter or any solid waste matter".*

With regard to contaminated waters the Environment Act 1995 amends the Water Resources Act 1991 and provides the Environment Agency with the power to force clean-up of historical contamination by issuing a "Works Notice", with remediation paid for by the responsible parties.

In addition, the Groundwater Regulations (1998) state that entry of List 1 substances into groundwater must be prevented and List II substances must be controlled. Petroleum hydrocarbons, pesticides and some herbicides are List I substances.

Interpretation of the new legislation in respect of determining the need for remedial action is based on the use of risk assessment principles with investigation and assessment activities consistent with a tiered risk-based corrective action approach.

1.5 Limitations and Disclaimers

The ground is a product of continuing natural and artificial processes. As a result, the ground will exhibit a variety of characteristics that vary from place to place across a site, and also with time. Whilst a ground investigation will mitigate to a greater or lesser degree against the resulting risk from variation, the risks cannot be eliminated.

The investigation, interpretations and recommendations given in this report were prepared for the sole benefit of the client in accordance with their brief as described in Section 1.0 of this report. As such these do not necessarily address all aspects of ground behaviour at the site. It should be noted that the investigation was made for the form of redevelopment described in Section 1.3 and may be inappropriate to another form of development or scheme.

The analyses, conclusions and recommendations relate to the proposed redevelopment of a site located on the former North Allotment Gardens, Radcliffe Road, Southampton, Hampshire. Attention is drawn to the fact that these analyses are based on data obtained from the trial holes and associated laboratory and *in-situ* testing. The possibility of variation in ground conditions around the trial holes should not be overlooked. Any opinion or diagram of a possible configuration of strata beyond the trial holes or extrapolated to greater depth is conjectural and given for guidance only. No liability can be accepted for such variations.

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The depth to roots and/or of desiccation may vary from that found during the investigation. The client is responsible for establishing the depth to roots and/or of desiccation on a plot by plot basis prior to the construction of foundations.

Current regulations and good practice were used in the preparation of this report. The recommendations given in this report must be reviewed by an appropriately qualified person at the time of preparation of the scheme design to ensure that any recommendations given remain valid in light of changes in regulation and practice, or additional information obtained regarding the site.

There may be other sources of information not included in those listed in Section 1.0 that hold data relevant to the desk study undertaken at the site that could materially affect the conclusions made in this report.

Ownership of land brings with it onerous legal liabilities in respect of harm to the environment. "Contaminated Land" is defined in Section 57 of the Environment Act 1995 as *"Land which is in such a condition by reason of substances in, on or under the land that significant harm is being caused or that there is a significant possibility of such harm being caused or that pollution of controlled waters is being, or is likely to be caused".*

The investigation, analysis or recommendations in respect of contamination are made solely in respect of the prevention of harm to vulnerable receptors, using where possible best practice at the date of preparation of the report. The investigation and report do not address, define or make recommendations in respect of environmental liabilities. A separate environmental audit and liaison with statutory authorities is required to address these issues.

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2.0 Conceptual Site Model and Contaminant Linkages

2.1 General

The results of the Desk Study were used to formulate plausible pollutant linkages, which in turn were used to construct a Conceptual Site Model. The results of the Desk Study can be seen within the Ground Investigation Report, J8930, issued September 2005.

2.2 Plausible Pollutant Linkages

The results of the targeted contamination assessment of risks to human health and groundwater were used to test the source-pathway and receptor model, constructed in Section 3.0 of the original Ground Investigation Report, ref: J8930. A quantitative risk assessment was carried out in order to determine which sources could be discounted.

The summarised Conceptual Site Model, which was reproduced in Section 8.0 of the original Ground Investigation Report ref: J8930, is presented overleaf with the non plausible items struck out. Following intrusive works and determination of the groundwater flow direction, sources to the north of the site were discounted as groundwater flow was towards the north/north-east.

Following the Environment Agency's comments, the Conceptual Site Model was amended to include the River Itchen as a potential receptor.

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Tabulated Conceptual Site Model					
Source	*Explanation*	**Migration Pathway**	**Exposure Pathway**	*Explanation*	**Receptor**
Bio-gas generation from:- - Possible putrescible fill used on site to infill brick field - Alluvium from River Itchen - Putrescible fill in site's environs (fill material used north of site for reclaiming land) - Putrescible fill used to infill gravel pit north-west of site		~~Via porous ground and anthropogenic pathways (services) accumulating in new buildings~~	~~Inhalation from the ground surface, excavations or confined spaces~~	*Installation of a suitable gas resistance membrane + associated gas protection measures would prevent ingress of bio-gases* *Further bio-gas monitoring required to comply with current UK best practice (CIRIA 149)*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers/buildings Public within airborne range
Contaminants associated with historic brick works/ brick firing processes on-site:- - PAHs - Metals (arsenic, lead)	*Elevated levels of arsenic, lead and PAHs were identified in the Made Ground samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil contaminants carried through porous ground or granular backfill to service trenches by groundwater • Soil contaminants exposed at surface then carried by run-off • Airborne dust fibres or volatile contaminants	Dermal exposure, ingestion or inhalation of contaminants generated during removal Leachates migrating via porous soils to groundwater	*Chemical analysis has indicated elevated levels of metals and PAHs in soil are leachable. R&D20 Groundwater Risk Assessment to be carried out to assess risk posed to controlled waters.*	Construction workers Service and maintenance operatives Site occupiers Aquifer groundwater/River Itchen General public
Contaminants associated with Bomb Damage that may have occurred on the site:- - Combustion products (e.g. PAHs)	*Elevated levels of benzo (a) pyrene and other PAHs identified in Made Ground samples tested during the investigation*				

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Source	*Explanation*	Migration Pathway	Exposure Pathway	*Explanation*	Receptor
Construction Materials used for Previous Residential Properties On-site:- - ~~Insulation Materials (asbestos)~~ - Metal-based paints - ~~Preservatives & Pesticides -Aggressive sulphates from plaster~~	*No asbestos-like material was visually recorded from trial hole excavations or in samples recovered during the investigation* *No elevated concentrations of pesticides or sulphates identified in soil samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil contaminants carried through porous ground or granular backfill to service trenches by groundwater • Soil contaminants exposed at surface then carried by run-off • Airborne dust fibres or volatile contaminants	Dermal exposure, ingestion or inhalation of contaminants generated during removal of Made Ground Leachates migrating via porous soils to groundwater	*Chemical analysis has indicated elevated levels of metals and PAHs in soil are leachable. R&D20 Groundwater Risk Assessment to be carried out to assess risk posed to controlled waters.*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range Aquifer groundwater/River Itchen
~~Pesticide and herbicide contamination from site's land use as allotment gardens~~	*No elevated concentrations of pesticides or acid herbicides identified in soil samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil Contaminants carried through porous ground or granular backfill to service trenches by groundwater • Airborne dust fibres or volatile contaminants • Soil contaminants exposed at surface then carried by run-off	Dermal exposure, ingestion or inhalation of contaminants from the ground surface or excavation Leachates migrating via porous soils to groundwater		Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range Aquifer groundwater/River Itchen

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Source	*Explanation*	Migration Pathway	Exposure Pathway	*Explanation*	Receptor
Contaminated Made Ground introduced onto the site as fill taken from site's environs:- - Metals ~~- Inorganic compounds (solvents, lubricants)~~ ~~- Organic compounds~~ (PAHs~~, fuel oils, ash, tar)~~ ~~- Paints~~ - ~~Pesticides~~ ~~- Asbestos~~	*No elevated levels of pesticides or heavy fraction petroleum hydrocarbons identified in soil samples tested during the investigation.* *No Asbestos-like material visually recorded from trial hole excavations or in samples recovered during the investigation.*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil Contaminants carried through porous ground or granular backfill to service trenches by groundwater • Airborne dust fibres or volatile contaminants • Soil contaminants exposed at surface then carried by run-off	Dermal exposure, ingestion or inhalation of contaminants from the ground surface or excavation Leachates migrating via porous soils to groundwater	*Chemical analysis has indicated elevated levels of metals and PAHs in soil are leachable. R&D20 Groundwater Risk Assessment to be carried out to assess risk posed to controlled waters.* *Given the numerous industrial works in site's environs, the background concentration of metals in the groundwater are likely to be the same or greater than those encountered on-site. Therefore no groundwater remediation required.*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range Aquifer groundwater/River Itchen
General Industrial Contaminants migrating from Industrial Works (~~north &~~ east of site) & Railway Tracks (west of site) in Site's Environs:- ~~- Metals (e.g. cadmium, chromium,~~ lead, arsenic) - Organic compounds (~~fuel oils~~ & PAHs, ~~ash, tar)~~ ~~- Inorganic compounds (solvents, lubricants)~~ ~~- Asbestos~~ ~~- Pesticides~~ ~~- Preservatives~~	*No elevated levels of chromium or cadmium identified in soil samples tested during the investigation.* *No elevated levels of pesticides or heavy fraction petroleum hydrocarbons identified in soil samples tested during the investigation. No Asbestos-like material visually recorded from trial hole excavations or in samples recovered during the investigation.*				Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Aquifer groundwater/River Itchen

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2.3 Plausible Sources and Pathways

After removing the disproved contaminant sources and pathways from the Conceptual Site Model it appears there are two pollutant linkages that could be assumed to be present and require further assessment and possible remediation to mitigate the risks posed to human health and/or groundwater.

The remaining sources and pathways have been listed below. Each of the sources identified will require further risk assessment to aid the formulation of the remediation strategy in order to permit safe redevelopment of the site with respect to end users, maintenance and construction workers, aquifer groundwater, River Itchen and the public within air borne range.

- Metallic (arsenic and lead) and benzo (a) pyrene contamination was identified in some of the Made Ground samples tested during the original investigation. These elevated levels of determinands were also found to be leachable and therefore could impact aquifer groundwater via migration through porous soils. Remediation recommendations in the original Ground Investigation Report ref: J8930 included the removal of Made Ground in all soft-landscaped areas. This recommendation is also extended to any potential soakaway locations. In order to assess the risk of leachable metals and PAHs in the shallow surface soils, which are proposed to be left under area of permanent hardstanding, impacting groundwater and the River Itchen, an R&D20 Groundwater Risk Assessment will be carried out.

- The bio-gas risk assessment carried out during the original investigation, report ref: J8930, indicated that the site fell into Characteristic Situation 3 in accordance with CIRIA 149 Report. An additional two months of bio-gas monitoring was recommended to comply with current UK best practice. Additional bio-gas monitoring was carried out between September and December 2006, the results of which are discussed in Section 3.0 of this report.

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3.0 Bio-Gas Risk Assessment

3.1 General

The original Soils Limited Ground Investigation Report ref: J8930 highlighted a potential land gas risk. This determination of risk was based on the land use changing to a proposed development made up of private houses and flats. A bio-gas risk assessment was carried out for the site to solely satisfy the planning regime.

The Soils Limited Ground Investigation Report ref: J8930 classified the site as falling within a Characteristic Situation 3 in accordance with the CIRIA 149 Report; however, further bio-gas monitoring was recommended to comply with current UK best practice and in order to fully verify the gassing regime on the site.

3.2 Bio-Gas Risk Assessment

Bio-gas monitoring has been carried out on ten occasions in total and included periods of low and falling atmospheric pressure and different weather conditions. The results from the original and additional monitoring are presented in the table below and overleaf.

Bio-Gas Monitoring from Wells

Date	Trial Hole	O_2 (%)	LEL (%)	CH_4 (%)	CO_2 (%)	H2S (ppm)	CO (ppm)	Flow Rate (litre/hr)	Groundwater (m BGL)
18.07.2005	Atmosphere (1008mb)	21.1	0	0	0	0	0	0	-
	BH1	20.2	0	0	0	0	0	0.2	2.46
	BH2	20.2	0	0	0	0	0	0	2.41
	BH3	20.0	0	0	0	0	0	0	2.24
09.08.2005	Atmosphere (1015mb)	21.0	0	0	0	0	0	0	-
	BH1	16.5	0	0	3.5	0	0	0	2.38
	BH2	17.2	0	0	2.8	0	0	0	2.33
	BH3	17.9	0	0	1.9	0	0	0	2.17
17.08.2005	Atmosphere (1019mb)	20.6	0	0	0	0	0	0	-
	BH1	18.8	1.8	0	1.5	0	0	0	2.41
	BH2	17.7	0	0	2.9	0	0	0	2.36
	BH3	17.8	0	0	1.7	0	0	0	2.20
07.09.2005	Atmosphere (1010mb)	20.8	0	0	0	0	0	0	-
	BH1	18.2	0	0	2.2	0	0	0	2.40
	BH2	20.0	0	0	0.3	0	0	0	2.35
	BH3	18.9	0	0	1.7	0	0	0	2.19
21.09.2006	Atmosphere (993mb)	20.7	0	0	0	0	0	0	-
	BH1	18.5	0	0	2.4	0	0	0	2.22
	BH2	20.6	0	0	0.2	0	0	0	2.11
Could not find BH3, site very overgrown									
10.10.2006	Atmosphere (1000mb)	20.9	0	0	0	0	0	0	-
	BH1	17.4	0	0	2.6	0	0	0	2.20
	BH2	20.4	0	0	0.1	0	0	0	2.10
Could not find BH3, site very overgrown									

Continued on page overleaf

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07.11.2006	Atmosphere (1013mb)	21.0	0	0	0	0	0	0	-
	BH1	18.8	0	0	1.3	0	0	0	2.18
	BH2	18.5	0	0	1.9	0	0	0	2.03
Could not find BH3, site very overgrown									
21.11.2006	Atmosphere (993mb)	21.7	0	0	0	0	0	0	-
	BH1	21.2	0	0	0.1	0	0	0.1	1.91
	BH2	21.3	0	0	0.1	0	0	0.1	1.78
Could not find BH3, site very overgrown									
29.11.2006	Atmosphere (1023mb)	21.1	0	0	0	0	0	0	-
	BH1	21.5	0	0	0.1	0	0	0.1	1.86
	BH2	21.1	0.1	0	0.1	0	0	0.1	1.73
Could not find BH3, site very overgrown									
07.12.2006	Atmosphere (982mb)	21.4	0	0	0	0	0	0	-
	BH1	20.9	0	0	0.2	0	0	0.4	1.84
	BH2	21.0	0	0	0.1	0	0	-0.2	1.70
Could not find BH3, site very overgrown									

Note: reading of 0 = not detected (below detection limit)

3.2.1 Measured Bio-Gas Concentrations

The table below summarises the bio-gas data collected on a total of ten occasions between July 2005 and December 2006. The table indicates the highest bio-gas concentrations detected, highest positive flow rates and most depleted oxygen concentrations.

Summary of Bio-Gas Results from BH1, BH2 & BH3								
Bio-Gases	**O_2 (%)**	**LEL (%)**	**CH_4 (%)**	**CO_2 (%)**	**H_2S (ppm)**	**CO (ppm)**	**Flow Rate (litre/hr)**	**Groundwater (m bgl)**
Monitoring period between July 2005 & December 2006	Oxygen conc. ranged bet. **16.5% -** 21.5%	LEL detected on two occasions, with conc. of 0.1% & **1.8%**	No methane detected during any monitoring visit	Carbon dioxide conc. ranged bet. 0.1% - **3.5%**	No hydrogen sulphide detected during any monitoring visit	No carbon monoxide detected during any monitoring visit	Positive flow rates ranged bet. 0.1- **0.4 litre/hr**	Groundwater depth ranged bet. 1.70m - 2.46m bgl.

The bio-gas data has shown that carbon dioxide was detected during every monitoring visit. The highest concentration of carbon dioxide of 3.5% by volume was detected in BH1 on the 9th August 2005.

The LEL (Lower Explosive Limit) is the lower limit concentration in air that is required for a gas to be in a potentially explosive concentration and has a value of 5% i.e. 100% LEL is equal to 5% total methane.

LEL was detected on two occasions. An LEL concentration of 1.8% by volume was detected in BH1 on the 17th August 2005, which equates to 0.09% methane. This methane concentration of 0.09% was within the limit concentration allowed for a Characteristic Situation 1 where no precautionary measures are required; therefore the LEL concentration of 1.8% was not considered a risk. LEL was

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detected on a second occasion on the 29th November 2006, when a concentration of 0.1% by volume was recorded, which equates to 0.005% methane. Again, this concentration of methane was significantly below the limit concentration allowed for a Characteristic Situation 1 where no precautionary measures are required.

The most depleted oxygen concentration was recorded at 16.5% by volume in BH1 on the 9th August 2005. The highest positive flow rate was recorded at 0.4 litres/hour in BH1 on the 7th December 2006. The bio-gas data overleaf shows that no methane, hydrogen sulphide or carbon monoxide was detected in any of the boreholes during the monitoring visits.

3.2.2 Gas Protection Measures

A combination of Desk Study, intrusive investigation and five months of bio-gas monitoring has demonstrated that the site falls within Characteristic Situation 3 (CS3) in accordance with CIRIA 149 Report and Wilson and Card 1999.

The following measures are typically recommended for CS3 to prevent the ingress of bio-gases:

- Well constructed suspended or ground slab;
- Gas resistant membrane (carbon dioxide), lapped at joints and passing beneath internal walls;
- Passively ventilated underfloor sub-space;
- Ventilation of confined spaces within building;
- Minimum penetration of ground slab by services (Service entry points should be kept to a minimum and the void surrounding the services should be sealed).

All details for gas protection measures are given in the BRE 414, *Protective Measures for Housing on Gas-Contaminated Land* and all gas protection measures should be installed in accordance with the BRE Report: *Construction of buildings on Gas Contaminated land.*

We have carried out a data quality review to assess the robustness and reliability of the bio-gas data we have collated.

3.2.3 Data Quality

A review was made of the quality of the available data for the site, which can be viewed in the table overleaf. Both CIRIA 149 (1999) and Wilson and Card (1999) stress the need for risk assessments to be based on good quality data and give guidance as to best practice in this respect.

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Review of Data Quality			
Data Type	Current Situation	UK Practice	Recommendation
Geological and hydro-geological conditions	With regard to landfill gas risk assessment the data from Desk Study and logged trial holes is good.	CIRA 152 and Wilson and Card (1999) recommend that geology and hydrogeology be fully understood	No further action required
Monitoring period	The monitoring has been undertaken for a total of five months. Monitoring has been undertaken over a range of seasons and weather conditions including falling, low (982mb) and high (1023mb) atmospheric pressures.	CIRIA 152 recommends a minimum of 3 month monitoring over a range of weather conditions. Wilson and Card (1999) recommend that for less than 12 months monitoring the protective measures should be made more conservative.	Monitoring over a 5 month period has shown maximum carbon dioxide concentration of 3.5% by volume. LEL detected on two occasions, showing max. concentration of 1.8% by volume, which equates to 0.09% methane, therefore protection measures installed to a CS3. No hydrogen sulphide, methane or carbon monoxide detected during monitoring visits. No further action required
Gas data sets	Borehole flow velocity has been measured on each monitoring occasion.	Borehole flow velocity and borehole gas volume (carbon dioxide) required for gas flux categorisation. Wilson and Card (1999) Table 4.	No further action required

Data quality is good, covering a wide range of atmospheric pressure trends and measurements of positive flow rates. Geological and hydrogeological conditions have been investigated and fully understood.

3.3 Conclusions

A combination of Desk Study, intrusive investigation and bio-gas monitoring has demonstrated that the site falls within CS3 (Wilson and Card 1999).

Given that bio-gas monitoring has been carried out over a five month period, including low and falling atmospheric pressure, our data has allowed for an accurate and robust bio-gas risk assessment to be made for the site.

On the basis that a CS3 Situation is adopted for the site, this will ensure that end users and buildings are safely protected from any bio-gas hazards.

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4.0 Contamination Analysis

4.1 General

A Tier 1 quantitative soil and groundwater risk assessment was carried out for the site within the Soils Limited Ground Investigation Report ref: J8930. A précis of the results are given in Sections 4.2 to 4.4 below. The trial hole locations can be viewed in Figure 2 of this report.

4.2 Determination of Representative Contamination Concentration for Soil Samples

Descriptive statistics to establish representative contaminant concentrations were given in CLR 7 (DOE 2002) though this was not appropriate as the Tier 1 was not based on an averaging area. The results of the comparison of the representative contaminants concentration for human health receptor to the Soil Guideline Values and General Assessment Criteria Values are presented in the table below and are assessed against the *'Residential with plant-uptake'* land-use scenario.

Soil Guideline Values and General Acceptance Criteria Results			
Substance	SGV/GAC (mg/kg)	Max Concentration Recorded	Where SGV or GAC were exceeded
Arsenic	**20**	**27**	**TP1/0.15, TP8/0.15, BH3/0.30-0.50**
Cadmium	1 to 8	1.3	None
Chromium	130	25	None
Lead	**450**	**1400**	**TP1/0.15, TP4/0.15, TP8/0.15**
Mercury (inorganic)	8	7.9	None
Nickel	50	35	None
Selenium	35	1.0	None
Benzo (a) pyrene	**1.3**	**1.8**	**TP8/0.15**
TPH	250	180	None
Zinc	1000	770	None
Copper	250	140	None
Organophosphate Pesticides	-	<0. 2	None
Organochlorine Pesticides	-	<0.1	None
Acid Herbicides	-	<0.1	None

The results of the contamination testing summarised in the table above are based on the results reviewed from report references: B05005245 and B05005241, both of which are presented in Appendix B.

The guideline values used to compare the chemical results can be viewed in Section 7.0 of the Soils Limited Ground Investigation Report ref: J8930. The derivation of Soil Assessment Values for toxicity to humans of Petroleum Hydrocarbons can be seen in Appendix C.

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4.3 Tier 1 Quantitative Risk Assessment on Soils

Elevated levels of determinands above the guideline values were noted within four Made Ground samples.

Elevated concentrations of arsenic ranging between 21mg/kg to 27mg/kg were identified in shallow Made Ground samples within three trial holes. Elevated concentrations of lead ranging between 730mg/kg to 1400mg/kg were also identified in the Made Ground samples tested at shallow depth. Maximum and mean value tests were carried out on these analytical results, which are presented in Appendix D. The statistical tests showed that the maximum value passed, indicating that the highest concentrations of arsenic and lead identified were not isolated results or hotpots and fell into the general distribution of results within the sample population. The mean tests failed, indicating that the actual mean present in the soil may exceed the calculated mean value and hence the Made Ground across the site could be considered as contaminated with arsenic and lead.

One elevated concentration of benzo (a) pyrene of 1.8mg/kg was detected in trial hole TP8 at a depth of 0.15m bgl. Statistical tests carried out for benzo (a) pyrene concentrations in the Made Ground showed that the maximum value test passed, indicating that the highest concentration of benzo (a) pyrene identified was not an isolated result or hotpot and fell into the general distribution of results within the sample population. The mean tests failed, indicating that the actual mean present in the soil may exceed the calculated mean value and hence the Made Ground across the site could be considered as contaminated with benzo (a) pyrene.

The arsenic, lead and benzo (a) pyrene concentrations on the site do therefore pose a potential risk to human health. An appropriate remediation strategy will be formulated and discussed in Section 6.0 of this report to address the arsenic, lead and benzo (a) pyrene contamination in the shallow Made Ground.

The interpretation of the soils in Sections 4.2 and 4.3 indicated that arsenic, lead and benzo (a) pyrene concentrations within the Made Ground presented a potential risk. Although this health protective assessment is suitable for the purposes of planning it does not necessarily meet the requirements of Part IIA where it has to be demonstrated that significant harm is being caused or there is a significant possibility of such harm being caused.

4.4 Groundwater Risk Assessment

The Desk Study showed that groundwater encountered within the River Terrace Deposits was a potential receptor for contamination. As the site was situated on a minor aquifer with soils of high leaching potential, a Tier 1 quantitative risk assessment was carried out on the groundwater.

The groundwater results were presented and discussed within the Soils Limited Ground Investigation Report J8930. A précis of the results is presented in the table overleaf.

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For Tier 1 risk assessment the results were compared with EQS's taken as those for the United Kingdom Drinking Water Standards (DWS), protection of aquatic life – freshwater (SPAL) and World Health Organisation (WHO).

Tabulated Results For Groundwater Samples

Determinand	Units	EQS Source	EQS Level	Samples where EQS level was exceeded
Arsenic	**µg/l**	**DWS**	**10**	**BH2 (13µg/l)**
Cadmium	µg/l	DWS	5	None
Chromium	µg/l	DWS	50	None
Copper	µg/l	DWS	2000	None
Nickel	**µg/l**	**DWS**	**20**	**BH1 (39µg/l)**
Lead	µg/l	DWS	10	None
Mercury	µg/l	DWS	1	None
Selenium	µg/l	DWS	10	None
Zinc	µg/l	DWS	5000	None
Boron	µg/l	DWS	1000	None
Sulphate	mg/l	DWS	250	None
Total Cyanide	µg/l	DWS	50	None
Phenol (1)	µg/l	SPAL	300	None
Benzo (a) pyrene	µg/l	WHO	0.7	None
Naphthalene	µg/l	SPAL	10	None
Polycyclic Aromatic Hydrocarbon (2)	µg/l	DWS	0.1	None

Notes
DWS = UK Drinking Water Standards
SPAL = EA Standard for Protection of Aquatic Life (Freshwater)
(1) Taken as Maximum Allowable Concentration
(2) Sum of fluoranthene, benzo 3.4 fluoranthene (*benzo (b) flouranthene)*, benzo 11.12 fluoranthene (*benzo (k) flouranthene)*, benzo 3.4 pyrene (*benzo (a) pyrene)* and indeno (1,2,3-cd) pyrene
WHO = World Health Organisation Guidelines for Drinking Water Quality, 1984

Groundwater results showed one elevated concentration of arsenic in the groundwater in BH2 at a concentration of 13µg/l and one elevated concentration of nickel in the groundwater in BH1 at a concentration of 39µg/l. No other elevated levels of determinands were identified in any of the groundwater samples analysed. The groundwater chemical results are presented in report ref: B05005366, within Appendix B of this report.

The majority of the results have been compared with Environmental Quality Standards (EQS's) taken as UK Drinking Water Standards, which are the most onerous published standards applicable to UK control of potable water sources. If the results were compared against EQS saltwater or EQS freshwater standards, the arsenic and nickel levels would not be elevated.

On this basis, it is considered that these slightly elevated levels of metals found in the groundwater do not pose a significant risk to human health or controlled waters. In addition, there are no groundwater abstractions within a 700m radius of the site and the background concentration of metals in the groundwater in this area of Southampton is considered to be fairly significant given the numerous industrial works that exist. The elevated levels of arsenic and nickel in the groundwater may also have been sourced from off-site industrial works.

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Arsenic, lead and speciated PAH leachate tests were ordered from a sample of Made Ground from TP8 at a depth of 0.15m bgl as elevated levels of these determinands were identified in the Made Ground. A Tier 1 Risk Assessment was carried out on the eluate results and a précis of the results is presented in the table below.

Tabulated Results For Eluate Results

Determinand	Units	EQS Source	EQS Level	Results of leachate analysis on sample from TP8 at 0.15m bgl
Arsenic	**µg/l**	**DWS**	**10**	**16**
Lead	**µg/l**	**DWS**	**10**	**16**
Benzo (a) pyrene	µg/l	WHO	0.7	0.16
Naphthalene	µg/l	SPAL	10	0.1
Polycyclic Aromatic Hydrocarbon (1)	**µg/l**	**DWS**	**0.1**	**0.8**

Notes
DWS = UK Drinking Water Standards
SPAL = EA Standard for Protection of Aquatic Life (Freshwater)
(1) Sum of fluoranthene, benzo 3.4 fluoranthene (*benzo (b) flouranthene)*, benzo 11.12 fluoranthene (*benzo (k) flouranthene)*, benzo 3.4 pyrene (*benzo (a) pyrene)* and indeno (1,2,3-cd) pyrene
WHO = World Health Organisation Guidelines for Drinking Water Quality, 1984

The World Health Organisation Health data has been used to assess the benzo (a) pyrene eluate. This is due to the site's environmental setting. The site is situated within a built up area and is located approximately 150m to the south of the nearest surface water feature. The nearest groundwater abstraction point was located 767m to the south of the site and was used for mineral washing. Therefore the UK Drinking Water Standards were thought to be too conservative given the site's environmental setting.

No elevated levels of naphthalene or benzo (a) pyrene were noted within the eluate sample tested. This indicates that the concentrations of naphthalene or benzo (a) pyrene present in the Made Ground does not pose a risk to the groundwater receptor.

The results showed slightly elevated levels of lead and arsenic above the DWS guideline value of 10µg/l. An elevated Total PAH concentration of 0.8µg/l was detected in the sample tested, which exceeded the DWS guideline value of 0.1µg/l. Given the site's environmental setting, the DWS guideline value of 0.1µg/l was considered too conservative; however, as there were no other guideline values available for comparing Total PAH concentrations, the DWS guidelines were used. The results of the eluate testing can be seen within report ref: B05006372, Appendix B.

The arsenic, lead and Total PAH concentrations in the Made Ground were found to be leachable and therefore could impact groundwater over the longer term.

The assessment of risk to groundwater from the levels of arsenic, lead and Total PAH present in the Made Ground soil on-site was undertaken using the Environment Agency Research and Development 20 Spreadsheet (R&D20 or P20) from laboratory measured eluate concentrations.

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Groundwater remedial targets were derived using UK Drinking Water Standards and others sources, which are tabulated on the previous page.

The groundwater remedial targets are tabulated below. The derivation of all groundwater remedial targets can be seen within Appendix E. All assumptions and parameters used in the derivation of these groundwater remedial targets can be seen within Appendix E.

R&D20 Groundwater Remedial Targets	
Determinand	**Tier 3 Soil Target (mg/kg)**
Arsenic	915
Lead	24,600
Total PAH	34.3

The most elevated concentrations of arsenic (27mg/kg), lead (1400mg/kg) and Total PAH (9.77mg/kg) identified in the Made Ground soil samples tested during the original investigation have all been demonstrated to be below the Tier 3 soil target levels listed in the table above.

This indicates that there is no risk to the groundwater receptor from the concentrations of arsenic, lead and Total PAH identified in the shallow surface soils on the site.

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5.0 Qualitative Risk Assessment – Revised Conceptual Site Model & Contaminative Linkages

5.1 Revised Conceptual Site Model

Following further investigations in the form of bio-gas monitoring and a review of the quantitative risk assessment, including the completion of an R&D20 Tier 2 and 3 Groundwater Risk Assessment, the Conceptual Site Model has been revised and is presented overleaf. Non-plausible items have been struck out. The remaining plausible pollutant linkages will be addressed in Section 6.0 of the report.

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Tabulated Conceptual Site Model					
Source	*Explanation*	**Migration Pathway**	**Exposure Pathway**	*Explanation*	**Receptor**
Bio-gas generation from:- - Possible putrescible fill used on site to infill brick field - Alluvium from River Itchen - Putrescible fill in site's environs (fill material used north of site for reclaiming land) - Putrescible fill used to infill gravel pit north-west of site		~~Via porous ground and anthropogenic pathways (services) accumulating in new buildings~~	~~Inhalation from the ground surface, excavations or confined spaces~~	*Bio-gas monitoring indicated the site to fall within a Characteristic Situation 3.* *On the basis that gas protection measures are installed to a CS3, construction workers, end users and buildings will be protected from the ingress of bio-gases.*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers/buildings Public within airborne range
Contaminants associated with historic brick works/ brick firing processes on-site:- - PAHs - Metals (arsenic, lead)	*Elevated levels of arsenic, lead and PAHs were identified in the Made Ground samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil contaminants carried through porous ground or granular backfill to service trenches by groundwater • Soil contaminants exposed at surface then carried by run-off • Airborne dust fibres or volatile contaminants	Dermal exposure, ingestion or inhalation of contaminants generated during removal Leachates migrating via porous soils to groundwater	*Elevated concentrations of metals and PAHs in soil not a risk to controlled waters following completion of R&D20 Groundwater Risk Assessment; therefore can be left under areas of hardstanding.* *Metallic and benzo (a) pyrene contaminated Made Ground cannot be left in areas of soft landscaping and in proposed soakaway locations. Remediation necessary.*	Construction workers Service and maintenance operatives Site occupiers ~~Aquifer groundwater/River Itchen~~ General public
Contaminants associated with Bomb Damage that may have occurred on the site:- - Combustion products (e.g. PAHs)	*Elevated levels of benzo (a) pyrene and other PAHs identified in Made Ground samples tested during the investigation*				

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Source	*Explanation*	Migration Pathway	Exposure Pathway	*Explanation*	Receptor
Construction Materials used for Previous Residential Properties On-site:- - ~~Insulation Materials (asbestos)~~ - Metal-based paints - ~~Preservatives & Pesticides -Aggressive sulphates from plaster~~	*No asbestos-like material was visually recorded from trial hole excavations or in samples recovered during the investigation* *No elevated concentrations of pesticides or sulphates identified in soil samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil contaminants carried through porous ground or granular backfill to service trenches by groundwater • Soil contaminants exposed at surface then carried by run-off • Airborne dust fibres or volatile contaminants	Dermal exposure, ingestion or inhalation of contaminants generated during removal of Made Ground Leachates migrating via porous soils to groundwater	*Elevated concentrations of metals and PAHs in soil not a risk to controlled waters following completion of R&D20 Groundwater Risk Assessment; therefore can be left under areas of hardstanding.* *Metallic and benzo (a) pyrene contaminated Made Ground cannot be left in areas of soft landscaping and in proposed soakaway locations. Remediation necessary.*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range ~~Aquifer groundwater/River Itchen~~
~~Pesticide and herbicide contamination from site's land use as allotment gardens~~	*No elevated concentrations of pesticides or acid herbicides identified in soil samples tested during the investigation*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil Contaminants carried through porous ground or granular backfill to service trenches by groundwater • Airborne dust fibres or volatile contaminants • Soil contaminants exposed at surface then carried by run-off	Dermal exposure, ingestion or inhalation of contaminants from the ground surface or excavation Leachates migrating via porous soils to groundwater		Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range Aquifer groundwater/River Itchen

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Source	*Explanation*	Migration Pathway	Exposure Pathway	*Explanation*	Receptor
Contaminated Made Ground introduced onto the site as fill taken from site's environs:- - Metals ~~- Inorganic compounds (solvents, lubricants)~~ ~~- Organic compounds~~ (PAHs~~, fuel oils, ash, tar)~~ ~~- Paints~~ - ~~Pesticides~~ ~~- Asbestos~~	*No elevated levels of pesticides or heavy fraction petroleum hydrocarbons identified in soil samples tested during the investigation.* *No Asbestos-like material visually recorded from trial hole excavations or in samples recovered during the investigation.*	• Direct migration of soil contaminants through porous ground or granular backfill to service trenches (volatiles or gases) • Soil Contaminants carried through porous ground or granular backfill to service trenches by groundwater • Airborne dust fibres or volatile contaminants • Soil contaminants exposed at surface then carried by run-off	Dermal exposure, ingestion or inhalation of contaminants from the ground surface or excavation Leachates migrating via porous soils to groundwater	*Elevated concentrations of metals and PAHs in soil not a risk to controlled waters following completion of R&D20 Groundwater Risk Assessment; therefore can be left under areas of hardstanding.* *Metallic and benzo (a) pyrene contaminated Made Ground cannot be left in areas of soft landscaping and in proposed soakaway locations. Remediation necessary.* *Given the numerous industrial works in site's environs, the background concentration of metals in the groundwater are likely to be the same or greater than those encountered on-site. Therefore no groundwater remediation required.*	Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers Public exposed to migrated contaminants off-site from ground surface Public within airborne range ~~Aquifer groundwater/River Itchen~~
General Industrial Contaminants migrating from Industrial Works (~~north &~~ east of site) & Railway Tracks (west of site) in Site's Environs:- ~~- Metals (e.g. cadmium, chromium,~~ lead, arsenic) - Organic compounds (~~fuel oils~~ & PAHs, ~~ash, tar)~~ ~~- Inorganic compounds (solvents, lubricants)~~ ~~- Asbestos~~ ~~- Pesticides~~ ~~- Preservatives~~	*No elevated levels of chromium or cadmium identified in soil samples tested during the investigation.* *No elevated levels of pesticides or heavy fraction petroleum hydrocarbons identified in soil samples tested during the investigation. No Asbestos-like material visually recorded from trial hole excavations or in samples recovered during the investigation.*				Construction workers (particularly during foundation construction) Service and maintenance operatives Site occupiers ~~Aquifer groundwater/River Itchen~~

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5.2 Plausible Sources and Pathways

Re-evaluation of the conceptual site model has revealed that plausible pollutant linkages remain after the risk assessment and that remediation is required.

In terms of human health, the investigation and assessment revealed the following:

- Elevated concentrations of lead, arsenic and benzo (a) pyrene were identified within the Made Ground. CLEA mean and maximum value tests demonstrated that the concentrations of lead, arsenic and benzo (a) pyrene did pose an unacceptable risk to end users.
- Bio-gas risk assessment indicated the site to fall within a Characteristic Situation 3.

In terms of groundwater, the investigation along with the R&D P20 Tier 3 Risk Assessment demonstrated that the slightly elevated arsenic, lead and Total PAH eluate concentrations measured in the Made Ground did not pose a risk to the groundwater receptor.

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6.0 Remediation Strategy

6.1 Remedial Objective

The objective of the remediation for the site is to ensure site clean-up removes any unacceptable risk to the identified receptors of demolition/construction workers, service maintenance workers, the public, and future site occupiers, i.e. home owners.

The preceding assessment was achieved using a risk-based approach that considered the circumstances of the site, such as its location and intended use, engineering considerations and the need to ensure suitable amenities for any development.

In essence the remedial objective should be to sever any source-pathway-target pollutant linkages that have been established for the site in Section 2.2 of this report. Once this has been achieved, by whatever means, there can theoretically be no risk.

The advice and recommendations presented below are made on the basis of the chemical analyses results obtained to date.

6.2 Development of a Remediation Scheme

The table below shows the contamination identified on-site from the investigation works which has been deemed to be a risk to end-users. The R&D20 Tier 3 Groundwater Risk Assessment demonstrated that the elevated determinands listed in the table below did not pose a risk to aquifer groundwater or the River Itchen if left under areas of permanent hardstanding.

Trial Hole	Depth (m)	Human Health
TP1	0.15	Arsenic & Lead
TP4	0.15	Lead
TP8	0.15	Arsenic, Lead & Benzo (a) Pyrene
BH3	0.30-0.50	Arsenic

6.2.1 Metallic (Arsenic & Lead) & Benzo (a) Pyrene Contamination in Made Ground

Elevated levels of arsenic (21-27mg/kg), lead (730-1400mg/kg) and benzo (a) pyrene (1.8mg/kg) were found in the Made Ground that mantled the site at various depths to a maximum test depth of 0.35m. The Made Ground was of similar type and appearance both laterally and vertically across the site, accordingly it was concluded that the Made Ground could be treated as a homogenous mass with regard to the risk assessment and remediation. This conclusion was supported by statistical tests made on the test data. As the levels of contaminants present in the Made Ground failed the CLEA mean test and were demonstrated by the maximum test not to be an outlier, the Made Ground across the whole site was classified as being contaminated with arsenic, lead and benzo (a) pyrene.

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Made Ground was observed to range in thickness from 0.40m bgl to 1.00m bgl from the trial holes carried out across the site and to an average depth of 0.60m.

In order to eliminate any risk to end users, Made Ground must be excavated from all private garden and communal soft landscaped areas. This will be extended to all proposed patio areas within the gardens as future home owners could remove the patios, which would create an unacceptable risk to the human health receptor if the area beneath patios were not remediated.

The depth of excavation required will vary across the private garden and communal garden soft landscaped areas and if the trial pits are representative of the thickness of Made Ground over the whole site, the excavation depth will vary from 0.40m bgl to 1.00m bgl, with an average thickness removed of 0.60m.

If Made Ground is encountered greater than 1.00m in depth within **private garden areas**, then it must be removed to a depth of 1.00m below finished ground level and the Made Ground must then be re-tested to assess the risk to the groundwater receptor. Determinands to be tested will include arsenic, lead and Total PAH. If the testing indicates that there is no risk to the groundwater receptor, a 250mm crushed coarse concrete anti-capillarity barrier must be placed in the 1.00m reduced dig, which must then be raised by certified clean subsoil and topsoil. If the testing indicates that there is a risk to the groundwater receptor, all of the Made Ground must be removed from the excavation and a validation sample taken from the base.

If Made Ground is encountered greater than 0.60m in depth within **communal garden areas**, then it must be removed to a depth of 0.60m below finished ground level and the Made Ground must then be re-tested to assess the risk to the groundwater receptor. Determinands to be tested will include arsenic, lead and Total PAH. If the testing indicates that there is no risk to the groundwater receptor, a 100mm crushed coarse concrete anti-capillarity barrier must be placed in the 0.60m reduced dig, which must then be raised by certified clean subsoil and topsoil. If the testing indicates that there is a risk to the groundwater receptor, all of the Made Ground must be removed from the excavation and a validation sample taken from the base.

After stripping, the formation level will need to be inspected by a Soils Limited engineer to ensure complete removal of the Made Ground. Once the excavations have been undertaken, validation samples will need to be recovered to verify the removal of Made Ground in all soft landscaped areas. One validation sample will be recovered from the base of the excavation from each private house and two validation samples from the communal garden soft-landscaped areas.

Levels must be re-established to finished ground level using clean certified material. The topsoil must be of sufficient thickness to sustain plant growth, at

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least 300mm of topsoil grade soil, to be placed in all areas of private gardens and communal soft landscaping.

To avoid mixing any clean imported soils, which will be used to backfill garden areas, with any Made Ground which will still be remaining under areas of permanent hardstanding, a barrier must be installed against the side of the excavations, possibly in the form of a polyethylene sheet or something similar.

Where garden areas border the edge of the houses, there will already be a barrier present in the form of the concrete foundations, therefore Made Ground will be prevented from mixing with any clean soils. Where the garden areas border car parks and footpaths, a barrier must be installed along the side of the excavation to prevent mixing of soils.

The Made Ground material excavated from garden areas must either be classified and removed from site to a suitably licensed facility or alternatively, can be used to raise ground levels under areas of permanent hardstanding.

Made Ground excavated from foundation excavations and service excavations must be dealt with using the same method of disposal or re-use under areas of hardstanding. Service excavations will be over-dug and must be backfilled with certified clean material.

Excavated Made Ground material must be stockpiled on a waterproof polythene sheet to avoid mixing with clean soils and to prevent leachate run-off.

All proposed soakaway locations must also be excavated through the Made Ground into the natural ground. Figure 3 of this report shows the four proposed soakaway locations and the intended depths for each of the soakaways, which vary in depth between 1.66m and 2.29m bgl.

The base levels for all soakaway locations will be inspected by a Soils Limited engineer upon completion to verify the complete removal of Made Ground. A validation sample will be recovered by the Soils Limited engineer from the base of each of the soakaway excavations and sent off for chemical laboratory analysis to undertake leachate testing.

All remedial works must be inspected and validated by a Soils Limited Engineer.

6.2.2 Bio-gases

The bio-gas risk assessment indicated that the site falls into a Characteristic Situation 3. It is proposed to install the following remedial measures within all plots developed on-site:

- Well constructed suspended floor;
- Low permeability (minimum 1200 gauge polyethylene) gas membrane resistant to carbon dioxide;
- Minimum penetration of the ground slab by services;
- Passively ventilated under floor space.

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6.3 Validation Strategy

All remedial works will need to be inspected and validated by a Soils Limited Engineer.

Validation samples within all private garden and communal garden soft-landscaped area reduced-digs will need to be recovered and sent off for chemical laboratory analysis. All remedial excavations will need to be inspected and photographed.

The imported subsoil and/or topsoil will need to be certified as clean material prior to placement.

Base levels for soakaway locations will require inspection, during which the excavations will be measured and photographed. One validation sample will be recovered from each of the base levels and sent off for leachate testing to assess the risks posed to the groundwater receptor.

The installation of gas (carbon dioxide) resistant membranes will need to inspected, photographed and verified by a Soils Limited Geo-environmental Engineer.

Individual plot specific validation certificates can be issued as and when remedial and validation works have been completed for each plot.

6.4 Construction & Remediation Timetable

The proposed construction sequence and time periods are as follows:

Construction & Remediation Timetable	
Actions	**Periods**
Site Clearance	Week 1 - week commencing 8th Jan 2007
Soakaway SA2 to be excavated and installed and road built up around SA2	Week 2 & 3 - week commencing 15th Jan 2007
Foundations placed and oversites built to slab level for Plots 1-10 & for block of flats	Week 2 to 7. Week commencing 15th Jan 2007. Should be completed by 23rd Feb 2007
Remediation to be carried out for garden areas to Plots 1-10 and installation of soakaways SA3 and SA4. All private gardens will be backfilled with clean certified subsoil material.	Week 7 & 8 - should commence 19th Feb 2007
Haul road to be laid across proposed private garden areas. Haul road will be made up of crushed concrete material and will have a barrier installed to prevent any of the underlying remediated garden areas to become impacted from any construction works.	Week 8 (26th Feb 2007) – will commence once garden areas remediated for Plots 1-10
Gas membranes installed to all plots (plots 1-10 and block of flats) & inspected by Soils Limited Engineer	Weeks 7 to 9
Remediation to be carried out for communal garden areas to flats and installation of soakaway SA1. All communal gardens will be backfilled with clean certified subsoil material.	Week 9 - commencing 5th March 2007

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Construction & Remediation Timetable Cont'd	
Actions	**Periods**
Construction of houses (plots 1-10) and block of flats above slab level	Commencing week 8 to 9. Estimated to be watertight by end of May 2007
Haul road taken up once scaffolding removed	Estimated between September and December 2007
Clean certified topsoil to be placed in all garden areas. Topsoil will be tested and approved prior to placement	Estimated between September and December 2007
Site completed and validation and closure report issued	Completion date of Feb 2008 given for final site finish. Validation and closure report will be submitted prior to this date for review.

The timescales given are estimated and therefore may overrun or be completed faster than listed in the table dependent on factors such as weather conditions and number of groundworkers on-site. All remedial works should be completed by end of week 9.

6.5 Duty of Care

Groundworkers must maintain a good standard of personal hygiene including the wearing of overalls, boots, gloves and eye protectors and the use of dust masks during periods of dry weather.

To prevent exposure to airborne dust by both the general public and construction personnel the site must be kept damp during dry weather and at other times when dust were generated as a result of construction activities.

The site must be securely fenced at all times to prevent unauthorised access.

Washing facilities must be provided and eating and smoking restricted to mess huts.

6.6 Waste Disposal

The new landfill directive came into force in 16 July 2001 and was implemented by the European Union. The Landfill Regulations came into effect on the 15 June 2002 in England and Wales. The directive aims to enforce higher standards for landfills which ban co-disposal of anything alongside domestic waste, and the disposal of liquids and tyres. The directive also re-classifies landfills and encourages pre-treatment, recycling/recovery.

All materials will have to be characterised in accordance with the Waste Acceptance Criteria (WAC) before the materials can be disposed to landfill.

The contamination analysis included in this report was undertaken solely to assess the risk to human health and/or groundwater. The sample preparation, testing method and determinands and the method of reporting, is different for WAC testing and specific sampling and analysis will be required for this purpose.

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Three classifications are available: inert waste; stable non-reactive hazardous waste and hazardous waste. The cost of off-site disposal has significantly increased after 15th July 2005 and disposal to landfill may cease to be an economic option for some sites.

6.7 Imported Material

Any soil which is to be imported onto the site must undergo chemical analysis to permit classification prior to its importation and placement in order to ascertain its status with specific regard to contamination, i.e. to prove that it is suitable for the purpose for which it is intended.

Topsoil must come from a reputable source, i.e. established wholesaler or Greenfield site and must conform to BS 3882.

For each source of topsoil, one sample per $50m^3$ will be required. Samples will be tested for a range of determinands using MCERTS accredited methodology, using Soil Guideline Values/Generic Assessment Criteria values *for Residential with Plant Uptake Scenarios.* These guideline values are presented in the table below.

General Suite of Determinands	Soil Guideline Values/General Acceptance Criteria Values (mg/kg) for ***Residential with Plant Uptake Scenarios***
Arsenic	20
Cadmium	1 to 8
Chromium	130
Lead	450
Mercury	8
Nickel	50
Selenium	35
Copper	250
Zinc	1000
Benzo (a) Pyrene	1.3
TPH	250

6.8 Validation and Closure Report

On completion of the development, a Validation and Closure Report must be supplied to both the Local Authority and the NHBC. Details of the requirements of the report are listed in NHBC Standards Chapter 2.1 *Managing Land Conditions.* The essential requirements are for inspection and certification of remedial works, records of materials taken off and onto site; copies of Test Certificates as described in the preceding section and correspondence with the Local Authority and Environment Agency as appropriate.

A 'Completion Statement' form should also be completed by the developer upon completion of all validation works and submitted to the Environmental Health Officer at Southampton City Council.

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The following figures and appendices complete this report:

Figure 1	Site Location Plan
Figure 2	Trial Hole Location Plan
Figure 3	Proposed Development Plan showing Soakaway Locations

Appendix A	Trial Hole Logs
Appendix B	Chemical Laboratory Results Certificates
Appendix C	The Derivation of Soil Assessment Values for Toxicity to Humans of Petroleum Hydrocarbons
Appendix D	CLEA Mean & Maximum Value Tests
Appendix E	R&D P20 Groundwater Risk Assessment Worksheets & Model Parameters, Assumptions and Limitations

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Eur Ing. R. B. Higginson B.Sc., PG. Dip., C.Eng., MICE., FGS.
Geotechnical Advisor

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Geo-Environmental Engineer

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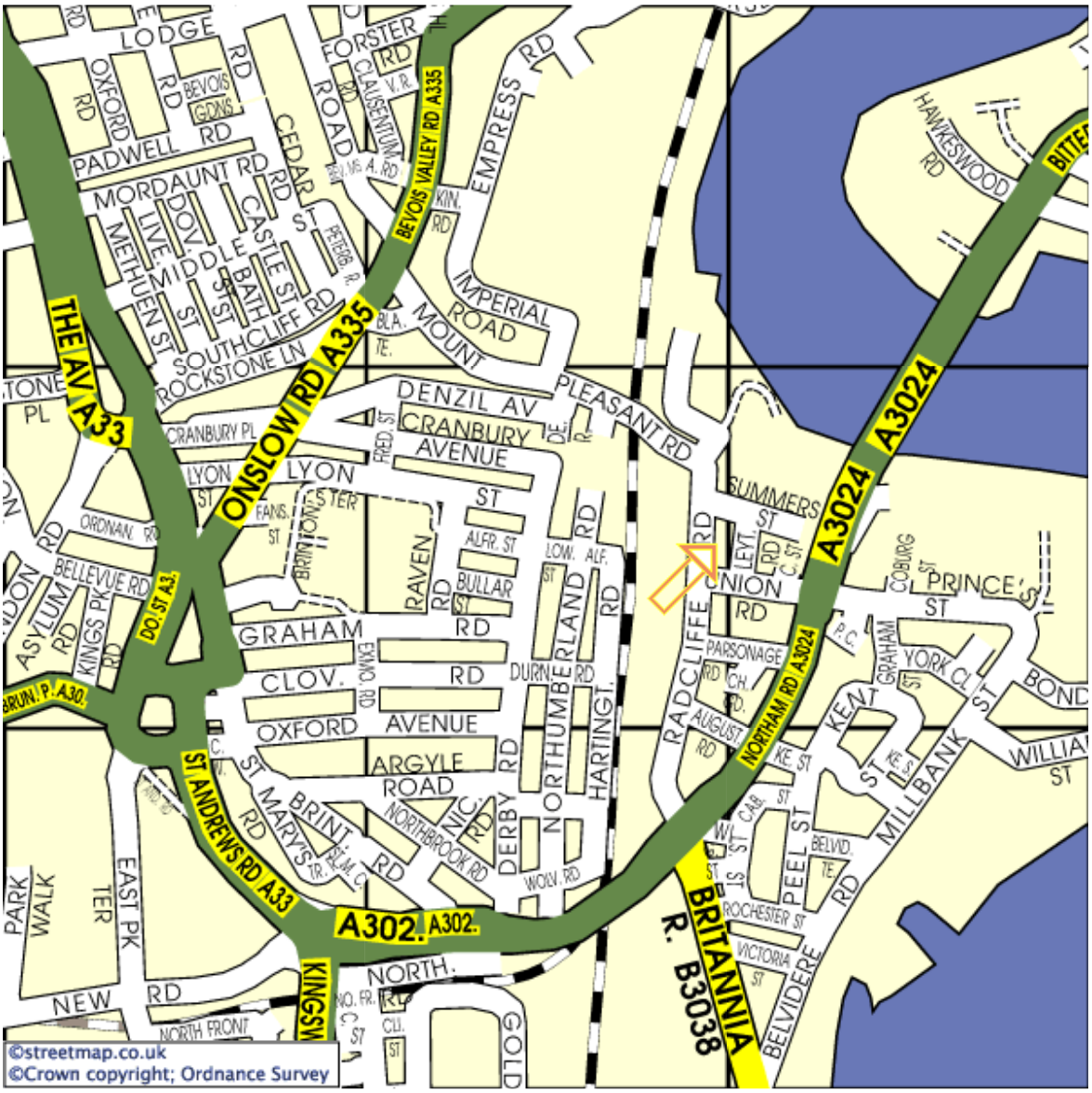

Project: **Allotment Gardens, Radcliffe Road, Southampton, Hampshire**	**Fig No. 1**
Client **Kier Partnership Homes**	Date: **December 2006**
Site Location Plan	Ref: **J9619**

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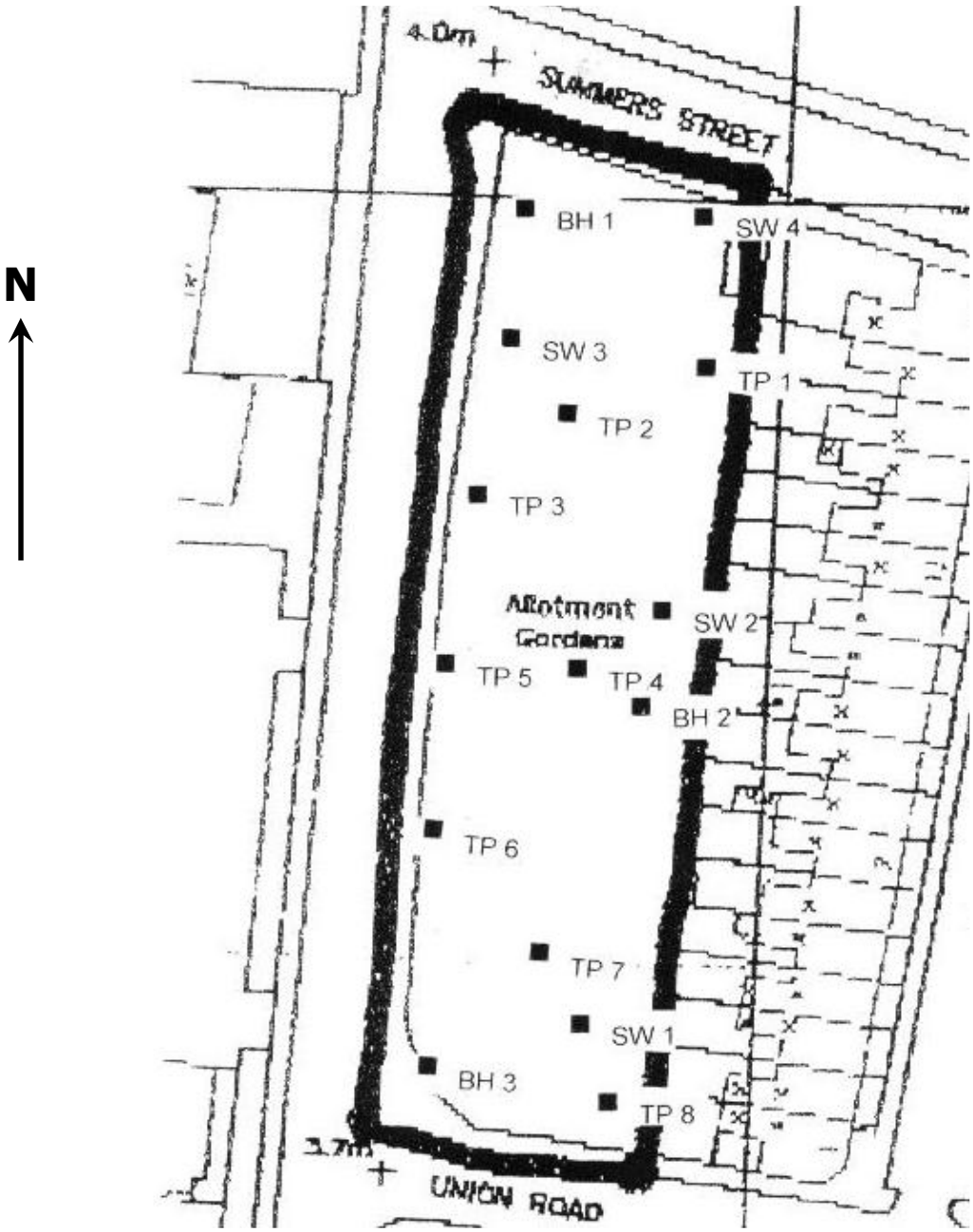

Project: **Allotment Gardens, Radcliffe Road, Southampton, Hampshire**	**Fig No. 2**
Client **Kier Partnership Homes**	Date: **December 2006**
Trial Hole Location Plan	Ref: **J9619**

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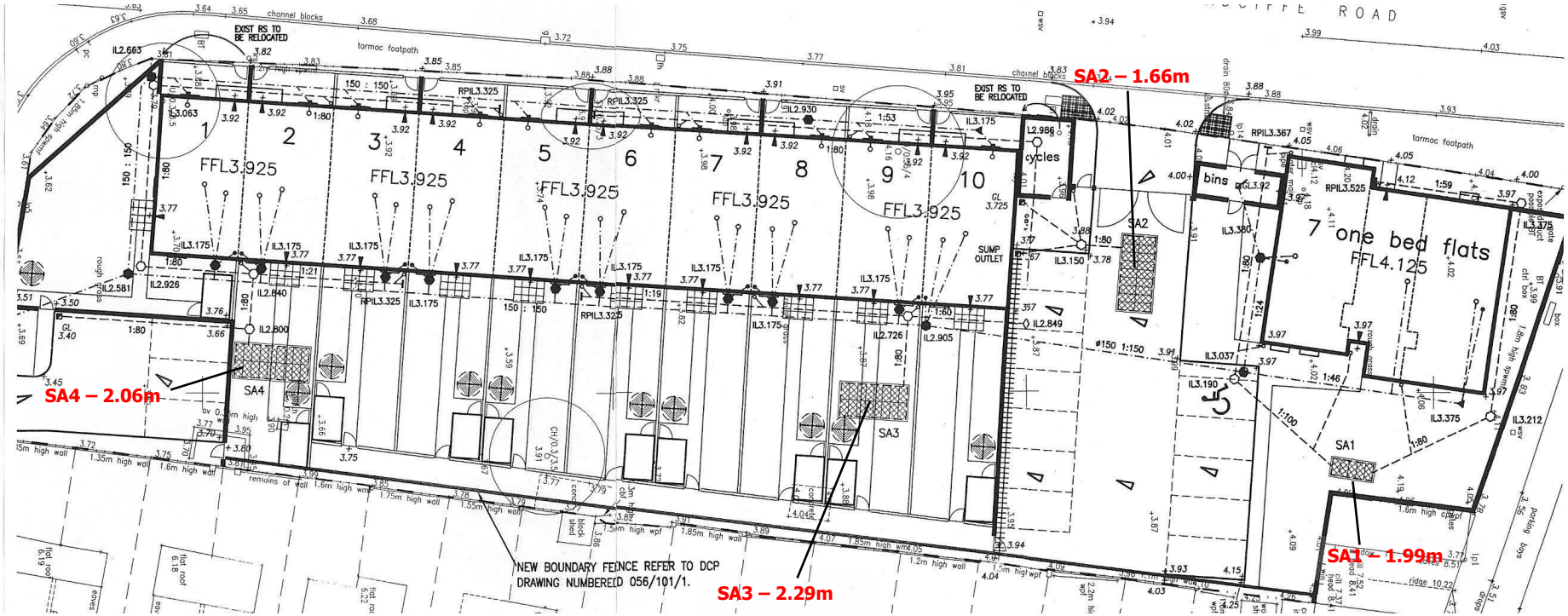

PROJECT North Allotment Gardens, Radcliffe Road, Southampton	**DATE** December 2006	
CLIENT Kier Partnership Homes		
Proposed Development Plan showing Soakaway Locations & Depths	**REF:** J9619	**Figure No. 3**

Appendix A
Trial Hole Logs

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 1

Start Date:	08/07/2005	**Ground Level:**	-
End Date:	08/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations

Strata

Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
0.20-0.40	B					0.10 (0.10)	TURF and TOPSOIL
0.60	D					0.40 (0.30)	MADE GROUND Dark brown slightly sandy clay with compacted brick earth fill, abundant gravel and fine to medium roots
0.90-1.10	B					0.90 (0.50)	RIVER TERRACE DEPOSITS Firm orange brown sandy CLAY with fine roots. Sand is fine to medium rounded quartz
1.20	B	S N=14 (3,2/1,2,4,7)				1.60 (0.70)	RIVER TERRACE DEPOSITS Medium-dense, orange-brown, slightly clayey, sandy GRAVEL. Gravel is fine to medium, sub-angular to sub-rounded flint.
1.90	D						
2.20	B	S N=12 (3,3/2,3,4,3)					RIVER TERRACE DEPOSITS Medium-dense, orange-brown, sandy GRAVEL. Gravel is fine to medium, angular to sub-angular flint and sand is fine to medium rounded quartz.
3.10	B	S N=11 (2,3/2,3,3,3)				2.40	
4.10	B	S N=30 (4,6/5,6,9,10)				4.00 (1.00)	PORTSMOUTH SAND FORMATION (lower member of London Clay Formation) Medium-dense, olive-brown and grey-brown, clayey SAND with occasional small sub-angular to angular flint gravel.
5.10	D	S N=28 (1,2/4,6,8,10)				5.00	PORTSMOUTH SAND FORMATION (Lower member of London Clay Formation) Loose to medium-dense, becoming dense, grey-brown, fine rounded quartz SAND with frequent lenses of soft to firm, dark grey clay.
5.90-6.30	B						
6.50	D	S N=9 (1,2/2,2,2,3)					
7.50	D						
8.00	D	S N=29 (1,2/2,6,11,10)				6.50	
9.00	D						
9.50	D	S N=50 (4,7/11,14,15,10)					
10.00	D						

Continued next sheet

Daily Progress

Date	Time	Hole	Depth	Water Depth

Water Strikes

Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed
No Groundwater Encountered						

Chiselling

Start Depth	End Depth	Hours

Hole Diameter		**Casing Diameter**	
Depth	Diam. (mm)	Depth	Diam. (mm)

General Remarks:
Roots observed to approximately 0.9m bgl

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 1

Start Date:	08/07/2005	**Ground Level:**	-
End Date:	08/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations

Strata

Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
11.00	D	S N=50 (5,9/13,13,17,7)				11.50	PORTSMOUTH SAND FORMATION (Lower member of London Clay Formation) Loose to medium-dense, becoming dense, grey-brown, fine rounded quartz SAND with frequent lenses of soft to firm, dark grey clay.
12.00	D						LONDON CLAY FORMATION Stiff to very stiff, dark grey, slightly sandy CLAY with rare, small black pebbles. Sand is fine to medium rounded quartz.
12.50-12.90	U						
12.90	D					3.50	
13.50	D						
14.00-14.45	U						
14.45	D	S N=50 (4,5/11,15,15,9)				15.00	End of Borehole at 15.00 m
14.50	D						

Daily Progress					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole	Depth	Water Depth	Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed	Start Depth	End Depth	Hours	Depth	Diam. (mm)	Depth	Diam. (mm)
					No Groundwater Encountered													

General Remarks:
Roots observed to approximately 0.9m bgl

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 2

Start Date:	09/07/2005	**Ground Level:**	-
End Date:	11/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations / Strata

Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
						0.10 (0.10)	Turf and TOPSOIL
0.30-0.50	B					(0.90)	MADE GROUND Dark brown sandy clay with brick earth fill, occasional small to medium sub-angular gravel and fine roots
0.80-1.00	B						
1.00	D					1.00 (0.10)	
1.20	B	S N=40 (1,2/5,9,11,15)				1.10	RIVER TERRACE DEPOSITS Soft to firm, orange-brown CLAY with occasional fine roots.
						(0.90)	RIVER TERRACE DEPOSITS Dense, orange-brown, clayey sandy GRAVEL. Gravel is fine to medium angular to sub-rounded flint and sand is fine rounded quartz.
2.10	B	S N=41 (4,6/8,9,11,13)				2.00	
2.40	W						RIVER TERRACE DEPOSITS Medium-dense to dense, orange-brown sandy GRAVEL. Gravel is fine to medium, angular to rounded flint and sand is fine to medium rounded quartz.
3.10	B	S N=28 (10,7/8,8,7,5)				(2.00)	
4.00	D					4.00	
4.10	D	S 50 (5,9/15,24,11)				(1.00)	PORTSMOUTH SAND FORMATION (Lower member of London Clay Formation) Dense, orange-brown slightly clayey fine rounded quartz SAND with occasional small sub-angular gravel. Clay content decreasing with depth.
5.10	D	S N=44 (4,4/8,8,14,14)				5.00	PORTSMOUTH SAND FORMATION (Lower member of London Clay Formation) Dense, grey-brown, fine rounded quartz SAND with frequent lenses of soft to firm dark grey clay.
6.30-6.50	B						
6.60	D	S 50 (3,10/15,21,14)					
7.50	D					(5.00)	
8.00	D	S N=46 (4,7/9,10,12,15)					
9.00	D						
9.50	D	S N=37 (3,5/9,10,10,8)					
10.00	D					10.00	LONDON CLAY FORMATION Stiff to very stiff, dark grey, thinly laminated, slightly sandy CLAY with rare, small sub-angular to sub-rounded gravel. Sand is fine to medium rounded quartz.

Continued next sheet

Daily Progress

Date	Time	Hole	Depth	Water Depth

Water Strikes

Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed
3.80	0.00	11/07/2005		2.40	20	-
3.80	-	11/07/2005		-	-	-

Chiselling

Start Depth	End Depth	Hours

Hole Diameter		**Casing Diameter**	
Depth	Diam. (mm)	Depth	Diam. (mm)

General Remarks:
Roots observed to approximately 1.10m bgl

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 2

Start Date:	09/07/2005	**Ground Level:**	-
End Date:	11/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations				Strata			
Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
11.00-11.45	U						LONDON CLAY FORMATION Stiff to very stiff, dark grey, thinly laminated, slightly sandy CLAY with rare, small sub-angular to sub-rounded gravel. Sand is fine to medium rounded quartz.
11.45	D						
12.00	D						
12.50-12.95	U					5.00	
12.95	D						
13.50	D						
14.00-14.45	U						
14.50	D	S N=31 (4,5/7,8,8,8)				15.00	End of Borehole at 15.00 m

Daily Progress					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole	Depth	Water Depth	Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed	Start Depth	End Depth	Hours	Depth	Diam. (mm)	Depth	Diam. (mm)

General Remarks:
Roots observed to approximately 1.10m bgl

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 3

Start Date:	11/07/2005	**Ground Level:**	-
End Date:	11/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations

Strata

Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
0.30-0.50	B					0.10 (0.10)	Turf and TOPSOIL
0.70	D					0.70 (0.60)	MADE GROUND Dark brown, slightly sandy clay with occasional sub-angular to sub-rounded gravel,small brick fragments and fine to medium roots.
1.20	D	S N=9 (1,2/3,2,2,2)				1.00	RIVER TERRACE DEPOSITS Firm, orange-brown slightly sandy CLAY with occasional fine roots.
1.80	D					1.70 (0.30)	RIVER TERRACE DEPOSITS Soft to firm, orange-brown CLAY with fine to medium sub-angular to rounded gravel and occasional fine roots.
2.10	B	S N=16 (4,4/4,4,4,4)				2.00	
2.40	W					1.00	RIVER TERRACE DEPOSITS Medium-dense, orange-brown to dark brown, slightly clayey, sandy GRAVEL. Gravel is fine to medium, angular to sub-angular and sand is fine to medium rounded quartz.
3.10	B	S N=28 (3,4/7,7,8,6)				3.00 (1.00)	RIVER TERRACE DEPOSITS Medium-dense, orange-brown, sandy GRAVEL. Gravel is fine to medium, angular to sub-rounded flint and sand is fine to medium rounded quartz.
4.10	B	S N=50 (2,4/8,12,21,9)				4.00 (0.60)	PORTSMOUTH SAND FORMATION (lower member of the London Clay Formation) Dense, brown, slightly clayey SAND with occasional small sub-angular gravel. Sand is fine to medium rounded quartz.
4.70	D					4.60 (0.30)	
5.20	D	S N=38 (1,4/6,9,11,12)				4.90	PORTSMOUTH SAND FORMATION (lower member of the London Clay Formation) Soft to firm, orange-brown and grey-brown CLAY with occasional small to medium, sub-angular to rounded gravel and partings of fine rounded quartz sand.
5.90-6.30	B						PORTSMOUTH SAND FORMATION (lower member of the London Clay Formation) Medium-dense to very dense, fine rounded quartz SAND with frequent lenses of soft to firm dark grey clay.
6.60	D	S N=36 (3,3/6,12,11,7)					
7.50	D						
8.00	D	S N=50 (2,4/7,13,23,7)				6.20	
9.00	D						
9.50	D	S 52 (3,5/9,16,27)					

Continued next sheet

Daily Progress

Date	Time	Hole	Depth	Water Depth

Water Strikes

Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed
No Groundwater Encountered						

Chiselling

Start Depth	End Depth	Hours

Hole Diameter

Depth	Diam. (mm)

Casing Diameter

Depth	Diam. (mm)

General Remarks:

Soils Limited
Newton House
Cross Road
Tadworth
Surrey KT20 5SR
Tel: 01737 814221
Fax: 01737 812557

Record of Borehole BH 3

Start Date:	11/07/2005	**Ground Level:**	-
End Date:	11/07/2005	**Easting:**	-
Logged By:	D Johnson	**Northing:**	-

Site: Radcliffe Road, Southampton
Client: Kier Partnership Homes
Project No: J8930

Boring Method: CP
Weather:
Driller:

Samples, In-situ Tests & Installations

Strata

Depth	Type	Result	S/Pipe	Elev	Legend	Depth/(Thk)	Description
11.00	D	S N=24 (2,3/4,6,6,8)				11.10	PORTSMOUTH SAND FORMATION (lower member of the London Clay Formation) Medium-dense to very dense, fine rounded quartz SAND with frequent lenses of soft to firm dark grey clay.
11.80-12.20	B						LONDON CLAY FORMATION Stiff, dark grey sandy CLAY. Sand is fine to medium rounded quartz.
12.50-12.95	U						
12.95	D					3.90	
13.50	D						
14.00-14.45	U						
14.45 14.50	D D	S N=28 (3,4/5,7,7,9)				15.00	End of Borehole at 15.00 m

Daily Progress					Water Strikes							Chiselling			Hole Diameter		Casing Diameter	
Date	Time	Hole	Depth	Water Depth	Strike Depth	Casing Depth	Date	Time	Post Depth	Elapsed Minutes	Depth Sealed	Start Depth	End Depth	Hours	Depth	Diam. (mm)	Depth	Diam. (mm)
					No Groundwater Encountered													

General Remarks:

soils LIMITED

Soils Ltd
Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 1
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.15	D					MADE GROUND Grass over brown slightly silty desiccated fine to medium sand with occasional fine to medium mixed gravel, fine roots, very occasional ash and brick fragments
			0.40			
0.50	D					MADE GROUND Brown fine sandy silty clay with pockets of topsoil, occasional fine to medium gravel and small brick fragments
			0.60			Trialpit Complete at 0.60 m

Remarks: Roots observed to 0.4m

Groundwater: Dry

AGS

HoleBASE III (Bid 338) Standard Trialpit Log v1 dated 26th Mar 03

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Soils Ltd
Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 2
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.15	D					MADE GROUND Grass over brown desiccated silty clay with occasional fine to medium mixed gravel, fine roots, brick and ash fragments
			0.30			
0.50	D					MADE GROUND Brown desiccated silty clay with occasional fine to medium gravels and very occasional brick fragments
			0.60			Trialpit Complete at 0.60 m

Remarks: Roots observed to 0.3m

Groundwater: Dry

AGS

HoleBASE III (Bd 338) Standard Trialpit Log v1 dated 26th Mar 03

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Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 3
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.10	D					MADE GROUND Grass over brown desiccated silty clay with occasional fine to medium gravel and brick rubble
			0.25			MADE GROUND Brown desiccated silty clay with occasional brick fragments in top 100mm
0.60	D		0.60			Trialpit Complete at 0.60 m

Remarks: No roots observed

Groundwater: Dry

AGS

HoleBASE III (Bld 338) Standard Trialpit Log v1 dated 26th Mar 03

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Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 4
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.15	D					MADE GROUND Grass over brown fine silty clay with occasional fine to medium gravel, timber, brick and ash fragments
0.50	D		0.45			MADE GROUND Brown silty clay with very occasional fine gravel, small brick and ash fragments
			0.60			Trialpit Complete at 0.60 m

Remarks: No roots observed

Groundwater: Dry

AGS

HoleBASE III (Bid 338) Standard Trialpit Log v1 dated 26th Mar 03

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Soils Ltd
Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 5
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.10	D					MADE GROUND Grass over brown desiccated sandy clay with occasional fine to medium gravel, fine roots, brick, ash and very occasional pottery fragments
			0.40			
0.50	D					MADE GROUND Brown desiccated fine sandy clay / clayey sand with very occasional small brick and ash fragments and fine roots
			0.60			Trialpit Complete at 0.60 m

Remarks: Roots observed to 0.6m

Groundwater: Dry

AGS

HoleBASE III (Bid 338) Standard Trialpit Log v1 dated 26th Mar 03

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Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 6
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.50m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.10	D					MADE GROUND Grass over brown desiccated fine sandy clay with occasional fine to medium mixed gravel, brick, ash and fine gravel
			0.30			MADE GROUND Brown desiccated fine sandy clay with very occasional ash fragments
0.50	D		0.50			Trialpit Complete at 0.50 m

Remarks: Roots observed to 0.3m

Groundwater: Dry

AGS

HoleBASE III (Bid 338) Standard Trialpit Log v1 dated 26th Mar 03

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Soils Ltd
Brunel House
Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 7
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.10	D					MADE GROUND Grass over brown silty clay with occasional fine to medium mixed gravel, brick and ash fragments
			0.30			
0.50	D					MADE GROUND Brown desiccated fine sandy clay with brick and ash fragments
			0.60			Trialpit Complete at 0.60 m

Remarks: Roots observed to 0.3m

Groundwater: Dry

AGS

HoleBASE III (Bd 338) Standard Trialpit Log v1 dated 26th Mar 03

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Chalcroft Distribution Park
Southampton
SO30 2PA
Tel: 02380 696456

Trialpit No
TP 8
Sheet 1 of 1

Project Name	Project No.	Co-ords: -	Date
Radcliffe Road, Southampton	J8930	Level: -	08/07/2005
Location: Radcliffe Road, Southampton		Dimensions: -	Scale 1:25
Client: Kier Partnership Homes		Depth 0.60m	Logged By S N

Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
Depth (m)	Type	Results				
0.15	D					MADE GROUND Grass over brown sandy clay with occasional fine to medium mixed gravel, brick and ash fragments and fine roots
			0.40			
0.50	D					MADE GROUND Brown fine sandy clay with brick, and ash fragments
			0.60			Trialpit Complete at 0.60 m

Remarks: Roots observed to 0.4m

Groundwater: Dry

AGS

HoleBASE III (Bd 338) Standard Trialpit Log v1 dated 26th Mar 03

Appendix B
Chemical Laboratory Results Certificates

Dipalee Patel
Soils Ltd
Brunel House
Chalcroft Distibution Park
Burnetts Lane
Southampton
Hampshire
SO30 2PA

29th July 2005

TEST REPORT

Our Report No: B05005245

Your Order No: Instns. of 14.07.2005

5 no. soil samples submitted for analysis on 14.07.2005

Project Name: Radcliffe Road, Southampton

Project Code: J8930

Results enclosed: Pages 2-4

Laboratory analysis started on 14.07.2005
All laboratory analysis completed by 29th July 2005

Rexona Rahman
Project Co-ordinator
ALCONTROL TECHNICHEM

Peter Morley
Site Manager
ALCONTROL TECHNICHEM

Test Methods are Documented In House Procedures or where appropriate Standard Methods.
Non accredited tests (if applicable) are identified on each page. Procedures for sampling are outside the scope of the laboratory UKAS accreditation. Opinions and interpretations expressed herein are outside the scope of our UKAS accreditation.
All samples connected with this report, including any 'on hold', will be stored and disposed of according to Company policy. A copy of this policy is available on request.

TEST REPORT

SOIL ANALYTICAL RESULTS

Our Report No: B05005245

Your Order No: Instns. of 14.07.2005 CLIENT: Soils Ltd

5 no. soil samples submitted for analysis on 14.07.2005 DATE OF ISSUE: 29th July 2005

Project Name: Radcliffe Road, Southampton Project Code: J8930

Lab Ref No:	**S05035611**	**S05035612**	**S05035613**	**S05035614**	**S05035615**					
Sampling Date:	**08/07/2005**	**08/07/2005**	**08/07/2005**	**11/07/2005**	**11/07/2005**					
Location:	**TP1**	**TP4**	**TP8**	**BH3**	**BH3**					
Depth (m)	**0.15**	**0.15**	**0.15**	**0.3-0.5**	**1.20**					
Sample Type:	**S**	**S**	**S**	**S**	**S**					
009 pH	7.6	7.7	7.7	8.0	8.0					
011 2:1 Water Soluble Sulphate SO_4 (g/l)	<0.01	<0.01	<0.01	<0.01	<0.01					
008 Sulphide	<10	<10	<10	<10	<10					
014 Monohydric Phenol	<3	<3	<3	<3	<3					
061 Total Cyanide	<5	<5	5.3	<5	<5					
016 Water Soluble Boron	1.1	0.8	1.1	0.8	0.6					
016 Arsenic	22	12	27	21	8					
016 Cadmium	1.3	<0.5	0.6	<0.5	<0.5					
016 Chromium	23	19	25	18	21					
016 Lead	730	830	1400	440	18					
016 Mercury	7.9	0.5	1.5	0.5	<0.3					
016 Selenium	1.0	<0.5	0.7	<0.5	<0.5					
016 Copper	120	75	140	91	10					
016 Nickel	29	16	35	24	16					
016 Zinc	660	420	770	250	46					

All results expressed in mg/kg dry weight basis except for pH, unless stated.

ALcontrol Technichem

TEST REPORT

SOIL ANALYTICAL RESULTS - 022 PAH SPECIATED BY GC

Our Report No: B05005245 — Page 3 of 4 pages

Your Order No: Instns. of 14.07.2005 — CLIENT: Soils Ltd

5 no. soil samples submitted for analysis on 14.07.2005 — DATE OF ISSUE: 29th July 2005

Project Name: Radcliffe Road, Southampton — Project Code: J8930

Lab Ref No:	**S05035611**	**S05035612**	**S05035613**	**S05035614**	**S05035615**					
Sampling Date:	**08/07/2005**	**08/07/2005**	**08/07/2005**	**11/07/2005**	**11/07/2005**					
Location:	**TP1**	**TP4**	**TP8**	**BH3**	**BH3**					
Depth (m)	**0.15**	**0.15**	**0.15**	**0.3-0.5**	**1.2**					
Sample Type:	**S**	**S**	**S**	**S**	**S**					
Naphthalene	<0.1	<0.1	<0.1	<0.1	<0.1					
Acenaphthylene	0.13	<0.1	0.11	<0.1	<0.1					
Acenaphthene	<0.1	<0.1	<0.1	<0.1	<0.1					
Fluorene	<0.1	0.15	<0.1	<0.1	<0.1					
Phenanthrene	1.4	0.64	1.5	0.65	<0.1					
Anthracene	0.30	0.62	0.38	0.15	<0.1					
Fluoranthene	2.8	0.92	4.1	1.6	<0.1					
Pyrene	2.2	0.73	3.5	1.3	<0.1					
Benzo (a) anthracene	1.1	0.40	1.6	0.54	<0.1					
Chrysene	1.5	0.77	2.0	0.76	<0.1					
Benzo (b) fluoranthene	1.2	0.46	1.5	0.43	<0.1					
Benzo (k) fluoranthene	1.3	0.46	1.5	0.58	<0.1					
Benzo (a) pyrene	1.3	0.35	1.8	0.52	<0.1					
Indeno (1,2,3-cd) pyrene	0.78	0.20	0.87	0.28	<0.1					
Dibenzo (a,h) anthracene	0.23	<0.1	0.25	0.11	<0.1					
Benzo (g,h,i) perylene	0.78	0.18	0.85	0.28	<0.1					
Total PAH	15.02	5.88	19.96	7.20	ND					

All results expressed in mg/kg dry weight basis — ND denotes Not Detected

Total PAH = Sum of 16 identified components

ALcontrol Technichem

TEST REPORT

Your Order No: Instns. of 14.07.2005 CLIENT: Soils Ltd

5 no. soil samples submitted for analysis on 14.07.2005 DATE OF ISSUE: 29th July 2005

Project Name: Radcliffe Road, Southampton Project Code: J8930

SOIL - RESULTS

Lab Ref No:	Sampling Date:	Location:	Depth (m)	Sample Type:	070 EPH by GC-FID (C_{10}-C_{40})	Description
S05035611	**08/07/2005**	**TP1**	**0.15**	**S**	180	The sample chromatogram exhibits a hump of unresolved complex material eluting from C_{12} to beyond C_{40}, overlain by a series of peaks consistent with PAHs.
S05035613	**08/07/2005**	**TP8**	**0.15**	**S**	150	The sample chromatogram exhibits a hump of unresolved complex material eluting from C_{12} to beyond C_{40}, overlain by a series of peaks consistent with PAHs.
S05035614	**11/07/2005**	**BH3**	**0.3-0.5**	**S**	98	The sample chromatogram exhibits a hump of unresolved complex material eluting from C_{12} to beyond C_{40}, overlain by a series of peaks consistent with PAHs.

NOTE:

(i) The method provides information only on Gas Chromatograph (GC) amenable material with elutions ranging between 40^{o}C and 325^{o}C.

(ii) The results are expressed as mg/kg dry weight soil sample after correction for moisture content.

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28th July 2005

TEST REPORT

Our Report No: B05005241

Your Order No: Instns. of 14.07.2005

2 no. soil samples submitted for analysis on 14.07.2004

Results enclosed: Pages 2-4

Laboratory analysis started on 14.07.2004
All in-house laboratory analysis completed by 28th July 2005

Leigh Barker
Project Co-ordinator
ALCONTROL TECHNICHEM

Peter Morley
Site Manager
ALCONTROL TECHNICHEM

Test Methods are Documented In House Procedures or where appropriate Standard Methods.
All samples connected with this report, including any 'on hold', will be stored and disposed of according to Company policy. A copy of this policy is available on request.

TEST REPORT

SOIL ANALYTICAL RESULTS - Acid Herbicides (mg/kg)

Our Report No: B05005241

Your Order No: Instns. of 14.07.2005 CLIENT: Soils Ltd

2 no. soil samples submitted for analysis on 14.07.2004 DATE OF ISSUE: 28th July 2005

Lab Ref No:	**S05035595**	**S05035596**								
Sample Ref :	**TP3**	**TP7**								
Date of Sampling:	**08/07/2005**	**08/07/2005**								
Depth(m)	**0.1**	**0.1**								
Sample Type:	**S**	**S**								
Clopyralid	<0.1	<0.1								
Picloram	<0.1	<0.1								
2,3,6-TBA	<0.1	<0.1								
Dicamba	<0.1	<0.1								
Benazolin	<0.1	<0.1								
4-CPA	<0.1	<0.1								
Bentazone	<0.1	<0.1								
2,4-D	<0.1	<0.1								
MCPA	<0.1	<0.1								
Bromoxynil	<0.1	<0.1								
Triclopyr	<0.1	<0.1								
2,4,5-T	<0.1	<0.1								
Dichlorprop	<0.1	<0.1								
Mecoprop	<0.1	<0.1								
Ioxynil	<0.1	<0.1								
Flamprop	<0.1	<0.1								
Fenoprop	<0.1	<0.1								
2,4-DB	<0.1	<0.1								
MCPB	<0.1	<0.1								
Diclofop	<0.1	<0.1								
PCP	<0.1	<0.1								
Flamprop-Isopropyl	<0.1	<0.1								

Note: Method awaiting accreditation

TEST REPORT

SOIL ANALYTICAL RESULTS - Organophosphate Pesticides (mg/kg)

Our Report No: B05005241

Your Order No: Instns. of 14.07.2005 CLIENT: Soils Ltd

2 no. soil samples submitted for analysis on 14.07.2004 DATE OF ISSUE: 28th July 2005

Lab Ref No:	**S05035595**	**S05035596**								
Sample Ref :	**TP3**	**TP7**								
Date of Sampling:	**08/07/2005**	**08/07/2005**								
Depth(m)	**0.1**	**0.1**								
Sample Type:	**S**	**S**								
Azinphos-ethyl	<0.2	<0.2								
Azinphos-methyl	<0.2	<0.2								
Carbophenothion	<0.1	<0.1								
Chlorfenvinphos	<0.2	<0.2								
Chlorpyriphos	<0.1	<0.1								
Chlorpyriphos-methyl	<0.1	<0.1								
Coumaphos	<0.2	<0.2								
Diazinon	<0.1	<0.1								
Dichlorvos	<0.1	<0.1								
Dimethoate	<0.1	<0.1								
Disulfoton	<0.1	<0.1								
EPN	<0.1	<0.1								
Ethion	<0.1	<0.1								
Fenitrothion	<0.1	<0.1								
Fenthion	<0.1	<0.1								
Fonofos	<0.1	<0.1								
Heptenophos	<0.1	<0.1								
Malathion	<0.2	<0.2								
Methacriphos	<0.1	<0.1								
Methyl-Parathion	<0.1	<0.1								
Mevinphos	<0.1	<0.1								
Parathion	<0.1	<0.1								
Phorate	<0.1	<0.1								
Phosalone	<0.2	<0.2								
Phosmet	<0.2	<0.2								
Phosphamidon I	<0.1	<0.1								
Phosphamidon II	<0.1	<0.1								
Pirimiphos-methyl	<0.1	<0.1								
Propetamphos	<0.1	<0.1								
Sulfotep	<0.1	<0.1								
Triazophos	<0.2	<0.2								
Tributylphosphate	<0.1	<0.1								
Triphenylphosphate	<0.1	<0.1								

Note: Method awaiting accreditation

TEST REPORT

SOIL ANALYTICAL RESULTS - Organochlorine Pesticides (mg/kg)

Our Report No: B05005241

Your Order No: Instns. of 14.07.2005 CLIENT: Soils Ltd

2 no. soil samples submitted for analysis on 14.07.2004 DATE OF ISSUE: 28th July 2005

Lab Ref No:	**S05035595**	**S05035596**				
Sample Ref :	**TP3**	**TP7**				
Date of Sampling:	**08/07/2005**	**08/07/2005**				
Depth(m)	**0.1**	**0.1**				
Sample Type:	**S**	**S**				
1,2,3-trichlorobenzene	<0.1	<0.1				
1,2,4,5-tetrachlorobenzene	<0.1	<0.1				
1,2,4-trichlorobenzene	<0.1	<0.1				
1,3,5-trichlorobenzene	<0.1	<0.1				
Aldrin	<0.1	<0.1				
alpha-Chlordane (cis)	<0.1	<0.1				
alpha-Endosulphan	<0.1	<0.1				
alpha-HCH	<0.1	<0.1				
beta-Endosulphan	<0.1	<0.1				
beta-HCH	<0.1	<0.1				
Chlorothalonil	<0.1	<0.1				
Cis-Heptachlor Epoxide	<0.1	<0.1				
delta-HCH	<0.1	<0.1				
Dichlobenil	<0.1	<0.1				
Dieldrin	<0.1	<0.1				
Endosulphan sulphate	<0.1	<0.1				
Endrin	<0.1	<0.1				
Fluroxypyr	<0.1	<0.1				
gamma-Chlordane (trans)	<0.1	<0.1				
gamma-HCH (lindane)	<0.1	<0.1				
Heptachlor	<0.1	<0.1				
Hexachlorobenzene	<0.1	<0.1				
Hexachlorobutadiene	<0.1	<0.1				
Hexachloroethane	<0.1	<0.1				
Iprodione	<0.1	<0.1				
Isodrin	<0.1	<0.1				
o,p-DDE	<0.1	<0.1				
o,p-DDT	<0.1	<0.1				
o,p-Methoxychlor	<0.1	<0.1				
o,p-TDE	<0.1	<0.1				
p,p-DDE	<0.1	<0.1				
p,p-DDT	<0.1	<0.1				
p,p-Methoxychlor	<0.1	<0.1				
p,p-TDE	<0.1	<0.1				
Pentachlorobenzene	<0.1	<0.1				
Pentachloroethane	<0.1	<0.1				
Permethrin I	<0.1	<0.1				
Permethrin II	<0.1	<0.1				
Propiconazole I	<0.1	<0.1				
Propiconazole II	<0.1	<0.1				
Propyzamide	<0.1	<0.1				
Quintozene	<0.1	<0.1				
Tecnazene	<0.1	<0.1				
Triadimefon	<0.1	<0.1				
Triallate	<0.1	<0.1				
Trifluralin	<0.1	<0.1				

Note: Method awaiting accreditation

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1st August 2005

TEST REPORT

Our Report No: B05005366

Your Order No: Instns. of 19.07.2005

3 no. water samples submitted for analysis on 19.07.2005

Project Name: Radcliffe Road, Southampton

Project Code: J8930

Results enclosed: Pages 2-3

Laboratory analysis started on 19.07.2005
All laboratory analysis completed by 1st August 2005

Rexona Rahman
Project Co-ordinator
ALCONTROL TECHNICHEM

Leigh Barker
Project Co-ordinator
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Test Methods are Documented In House Procedures or where appropriate Standard Methods.
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TEST REPORT

WATER ANALYTICAL RESULTS

Our Report No: B05005366

Your Order No: Instns. of 19.07.2005 CLIENT: Soils Ltd

3 no. water samples submitted for analysis on 19.07.2005 DATE OF ISSUE: 1st August 2005

Project Name: Radcliffe Road, Southampton Project Code: J8930

Lab Ref No:	**S05036418**	**S05036419**	**S05036420**							
Location:	**BH1**	**BH2**	**BH3**							
Sample Type:	**W**	**W**	**W**							
009 pH	6.8	7.2	7.0							
016 Sulphate as SO_4	48	61	48							
055 Sulphide	<0.05	<0.05	<0.05							
020 Phenol by HPLC	<0.01	<0.01	<0.01							
020 Total Monohydric Phenols by HPLC	<0.01	<0.01	<0.01							
061 Total Cyanide	<0.03	<0.03	<0.03							
016 Dissolved Boron	0.14	0.077	0.14							
016 Dissolved Arsenic	0.010	0.013	0.008							
016 Dissolved Cadmium	<0.001	<0.001	<0.001							
016 Dissolved Chromium	<0.01	<0.01	<0.01							
016 Dissolved Lead	<0.01	<0.01	<0.01							
028 Dissolved Mercury	<0.00005	<0.00005	<0.00005							
016 Dissolved Selenium	<0.01	<0.01	<0.01							
016 Dissolved Copper	<0.005	<0.005	<0.005							
016 Dissolved Nickel	0.039	0.005	<0.005							
016 Dissolved Zinc	0.016	<0.005	<0.005							

All results expressed in mg/l except for pH unless stated

TEST REPORT

WATER ANALYTICAL RESULTS - 022 PAH SPECIATED

Our Report No: B05005366 — Page 3 of 3 pages

Your Order No: Instns. of 19.07.2005 — CLIENT: Soils Ltd

3 no. water samples submitted for analysis on 19.07.2005 — DATE OF ISSUE: 1st August 2005

Project Name: Radcliffe Road, Southampton — Project Code: J8930

Lab Ref No:	**S05036418**	**S05036419**	**S05036420**							
Location:	**BH1**	**BH2**	**BH3**							
Sample Type:	**W**	**W**	**W**							
Naphthalene	<0.0001	<0.0001	<0.0001							
Acenaphthylene	<0.0001	<0.0001	<0.0001							
Acenaphthene	<0.0001	<0.0001	<0.0001							
Fluorene	<0.0001	<0.0001	<0.0001							
Phenanthrene	<0.0001	<0.0001	<0.0001							
Anthracene	<0.0001	<0.0001	<0.0001							
Fluoranthene	<0.0001	<0.0001	<0.0001							
Pyrene	<0.0001	<0.0001	<0.0001							
Benzo (a) anthracene	<0.0001	<0.0001	<0.0001							
Chrysene	<0.0001	<0.0001	<0.0001							
Benzo (b) fluoranthene	<0.0001	<0.0001	<0.0001							
Benzo (k) fluoranthene	<0.0001	<0.0001	<0.0001							
Benzo (a) pyrene	<0.0001	<0.0001	<0.0001							
Indeno (1,2,3-cd) pyrene	<0.0001	<0.0001	<0.0001							
Dibenzo (a,h) anthracene	<0.0001	<0.0001	<0.0001							
Benzo (g,h,i) perylene	<0.0001	<0.0001	<0.0001							
Total PAH	ND	ND	ND							

All results expressed in mg/l — ND denotes Not Detected — Total PAH = Sum of 16 identified components

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30th August 2005

TEST REPORT

Our Report No: B05006372 (Previous Report B05005245) **Re Issue No. 1 (dated 07.09.05**

Your Order No: Instns. of 22.08.2005

1 no. soil sample submitted for additional analysis on 22.08.2005

Project Name: Radcliffe Road, Southampton

Project Code: J8930

Results enclosed: Pages 2-3

Laboratory analysis started on 22.08.2005
All laboratory analysis completed by 30th August 2005

Rexona Rahman
Project Co-ordinator
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Leigh Barker
Project Co-ordinator
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TEST REPORT

LEACHATE ANALYTICAL RESULTS - 022 PAH SPECIATED BY GC

Our Report No: B05006372 (Previous Report B05005245) Re Issue No. 1 (dated 07.09.05)

Your Order No: Instns. of 22.08.2005 CLIENT: Soils Ltd

1 no. soil sample submitted for additional analysis on 22.08.2005 DATE OF ISSUE: 30th August 2005

Project Name: Radcliffe Road, Southampton Project Code: J8930

Lab Ref No:	**S05042748**									
Previous Lab Ref No:	**S05035613**									
Location:	**TP8**									
Depth (m)	**0.15**									
Sample Type:	**L**									
Naphthalene	<0.0001									
Acenaphthylene	<0.0001									
Acenaphthene	<0.0001									
Fluorene	<0.0001									
Phenanthrene	<0.0001									
Anthracene	<0.0001									
Fluoranthene	0.00018									
Pyrene	0.00017									
Benzo (a) anthracene	0.00011									
Chrysene	0.00013									
Benzo (b) fluoranthene	0.00019									
Benzo (k) fluoranthene	0.00013									
Benzo (a) pyrene	0.00016									
Indeno (1,2,3-cd) pyrene	0.00014									
Dibenzo (a,h) anthracene	<0.0001									
Benzo (g,h,i) perylene	0.00019									
Total PAH	0.00140									

All results expressed in mg/l.

Total PAH = Sum of 16 identified components

Method 004: NRA Leaching Test, Single Cycle, 24 hours; 10 parts water to one part soil.

TEST REPORT

LEACHATE ANALYTICAL RESULTS

Our Report No: B05006372 (Previous Report B05005245) Re Issue No. 1 (dated 07.09.05)

Your Order No: Instns. of 22.08.2005

CLIENT: Soils Ltd

1 no. soil sample submitted for additional analysis on 22.08.2005

DATE OF ISSUE: 30th August 2005

Project Name: Radcliffe Road, Southampton

Project Code: J8930

Lab Ref No:	**S05042748**									
Sample Ref :	**S05035613**									
Sample No:	**TP8**									
Depth(m)	**0.15**									
Sample Type:	**L**									
016 Dissolved Arsenic	0.016									
016 Dissolved Lead	0.016									

All results expressed in mg/l

Method 004: NRA Leaching Test, Single Cycle, 24 hours; 10 parts water to one part soil.

ALcontrol Technichem

Appendix C
The Derivation of Soil Assessment Values for Toxicity to Humans of Petroleum Hydrocarbons

The use of Total Petroleum Hydrocarbon screening tests in human health risk assessment for the residential with plant uptake land-use

Introduction

A particular problem arising at Brownfield redevelopment sites is the prevalence of relic petroleum hydrocarbon contamination. Typically the petroleum hydrocarbons are of the diesel and higher carbon chain lengths and the product is weathered.

The assessment of human health risk from petroleum hydrocarbon lies within the Contaminated Land Exposure Assessment (CLEA) framework as enacted by the CLR reports. Detailed recommendations are given in Science Report P5-080/TR3 *The UK Approach to Evaluating Human Health Risks from Petroleum Hydrocarbons in Soil.* Environment Agency, February 2005.

For petroleum hydrocarbons a combined indicator and fraction approach has been adopted by the EA for human health risk assessment within a tiered risk-based framework.

With regard to indicators a GAC may be determined for benzo(a)prene (non-threshold diesel range indicator) using the CLEA UK software implementation of CLR10. An SGV is published for both ethylbenzene and for toluene (threshold petrol range indicators). SGV for other indicators are reported by the EA as being under development.

No SGV for fractions have been published or are currently under development by the EA though these will eventually be based on updated US TPHCWG research.

Current Practice

In the interim period before SGV are published for the remaining indicator compounds and fractions, the CLEA framework allows the assessor to undertake a human health risk assessment using a combined indicator and fraction approach in the following manner:

Indicator approach

1. SGV Ethylbenzene for petrol release sites
2. SGV Toluene for petrol release sites
3. GAC derived from TOX reports for benzo(a)pyrene for diesel release sites.

Fraction Approach

1. Site Specific Assessment Criteria (SSAC) derived from modified TPHWG (1997) toxicity values (Table 4.1 Environment Agency (2005).

Assessment for fractions was made RBCA Toolkit for Chemical Releases Toolkit with exposure defaults modified to CLR10 values and CLEA Briefing Note 3 amendments for building parameters. The RBCA Toolkit uses a deterministic model and details of the method are given in Environment Agency Fact Sheet FS-02 (2003).

At each stage in the assessment conservatism was adopted as follows:

a) The measured soil concentration was taken to be wholly within EC8 to EC16 giving the lowest tolerable daily intake values for oral ingestion and inhalations.
b) The proportion of aliphatic to aromatic compounds was taken as 70% aromatic and 30% aliphatic. This was conservative as the proportion of aromatic compounds in diesel rarely exceeds 30%.
c) The Soil Organic Matter was taken as 1% whilst the field value would be expected to be greater than 2%, this introduces a further element of conservatism.

In addition the following were assumed:

Soil type sandy silt
Soil pH 6.8

Summary Petroleum Hydrocarbon Risk Assessment

Weathered diesel and heating oil – residential with plant uptake land-use

The applicability is assessed from the GC-FID TPH analysis chromatogram that identifies:

- The appropriateness of the carbon range
- The degree of weathering of the petroleum hydrocarbons

Non-threshold indicators	
Benzo(a)pyrene	1.3mg/kg

TPH fractions	
TPH EC8-EC16. 70% aromatic. 30% aliphatic.	250mg/kg

Note:
Benzo(a)pyrene is included in Soils Limited Brownfield Screening Suite.
TPH by GC-FID EC10-EC40 used as screening tool with entire fraction taken to lie within higher toxicity EC8-EC16 range. This approach introduces conservatism as the toxicity of the compound will be over-estimated.

Output from RBCA Toolkit for Chemical Releases

Main Screen

RBCA Tool Kit for Chemical Releases
Version 1.3a © 2000

1. Project Information

Site Name:	TPH AROMATIC 70% ALIPHATIC 30% C10-C12		
Location:	CLEA Briefing Note 3 building modifications		
Compl. By:	NJL		
Date:	16-11-05	Job ID:	Gen

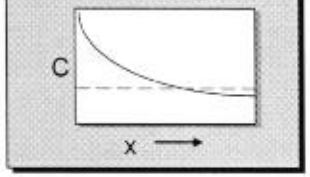
2. Which Type of RBCA Analysis?

(?)

◉ **Tier 1**

Generic Values
On-Site
Exposure

○ **Tier 2**



Site-Specific Values
On- or Off-Site Exposure

3. Calculation Options

(?)

Affects which input data are required

☑ ***Baseline Risks (Forward mode)***

☑ ***RBCA Cleanup Standards (Backward mode)***

4. RBCA Evaluation Process

Prepare Input Data

Data Complete? (■ yes, ■ no)

- ■ □ Exposure Pathways
- ↓
- ■ □ Constituents of Concern (COCs)
- ↓
- ■ □ Transport Models
- ↓
- ■ □ Soil Parameters
- ↓
- **GW Parameters**
- ↓
- ■ □ Air Parameters

Review Output

- Exposure Flowchart
- COC Chem. Parameters
- Input Data Summary
- User-Spec. COC Data...
- Transient Domenico Analysis...
- Baseline Risks...
- Cleanup Standards...

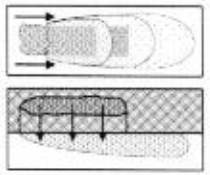
5. Commands and Options

New Site	Load Data...	Save Data As...	Quit
Print Sheet	Set Units	Custom Chem. Data...	*Help*

Exposure Pathway Identification

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12
Location: CLEA Briefing Note 3 building modifications
Compl. By: NJL
Job ID: Gen Date: 16-11-05

1. Groundwater Exposure



Groundwater Ingestion/ Surface Water Impact

	Receptor Type:	On-site	Off-site1	Off-site2
		None		

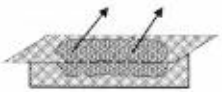
Source Media:

	Distance to GW receptors	On-site	Off-site1	Off-site2	
☐ Affected Groundwater		0			(m)
☐ Affected Soils Leaching to Groundwater		0			(m)

GW Discharge to Surface Water Exposure

☐ Swimming
☐ Fish Consumption
☐ Aquatic Life Protection
Enter ALP Criteria

2. Surface Soil Exposure

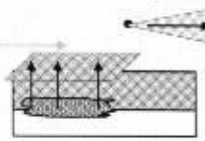


Direct Ingestion and Dermal Contact

Receptor Type:	Res.	No off-site receptors	
	On-site		

Construction Worker ☐

3. Air Exposure

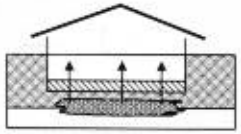


Volatilization and Particulates to Outdoor Air Inhalation

	On-site	Off-site1	Off-site2	
Receptor Type:	Res.			
	0			(m)

Construction worker ☐

☑ Affected Soils--Volatilization to Ambient Outdoor Air
☐ Affected Groundwater--Volatilization to Ambient Outdoor Air
☑ Affected Surface Soils--Particulates to Ambient Outdoor Air



Volatilization to Indoor Air Inhalation

Receptor Type:	Res.	No off-site receptors
	On-site	

☑ Affected Soils--Volatilization to Enclosed Space
☐ Affected Groundwater--Volatilization to Enclosed Space

4. Commands and Options

Main Screen | Print Sheet | Set Units | *Help*

■ □ Exposure Factors & Target Risks | Exposure Flowchart

Exposure Factors and Target Risk Limits

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12
Location: CLEA Briefing Note 3 building modifications
Compl. By: NJL
Job ID: Gen Date: 16-11-05

1. Exposure Parameters

	Age Adjustment?	Residential			Commercial	
		Adult	(Age 0-6)	(Age 0-16)	Chronic	Construc.
Averaging time, carcinogens (yr)		70				
Averaging time, non-carcinogens (yr)		30			25	1
Body weight (kg)		70	15	35	70	
Exposure duration (yr)		30	6	16	25	1
Exposure frequency (days/yr)		350			250	180
Dermal exposure frequency (days/yr)		350			250	
Skin surface area, soil contact (cm^2)	☐	5800		2023	5800	5800
Soil dermal adherence factor ($mg/cm^2/day$)		1				
Water ingestion rate (L/day)		2			1	
Soil ingestion rate (mg/day)	☐	100	200		50	100
Swimming exposure time (hr/event)		3				
Swimming event frequency (events/yr)		12	12	12		
Swimming water ingestion rate (L/hr)	☐	0.05	0.5			
Skin surface area, swimming (cm^2)	☐	23000		8100		
Fish consumption rate (kg/day)		0.025				
Contaminated fish fraction (unitless)		1				

2. Risk Goal Calculation Options

- ○ Individual Constitiuent Risk Goals Only
- ◉ Individual and Cumulative Risk Goals

3. Target Health Risk Limits

	Individual	Cumulative
Target Risk (Class A/B carcins.)	1.0E-6	1.0E-5
Target Risk (Class C carcinogens)	1.0E-5	
Target Hazard Quotient	1.0E+0	
Target Hazard Index		1.0E+0

4. Commands and Options

Return to Exposure Pathways

Use Default Values

Print Sheet

Help

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C | Job ID: Gen
Location: CLEA Briefing Note 3 building modifications | Date: 16-11-05
Compl. By: NJL

Commands and Options

Main Screen | Print Sheet | *Help*

Source Media Constituents of Concern (COCs)

Apply Raoult's Law ?

Selected COCs

COC Select: | *Sort List:* ?

Add/Insert | Top | MoveUp
Delete | Bottom | MoveDown

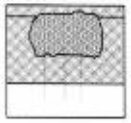
Representative COC Concentration ?

Selected COCs	Groundwater Source Zone		Soil Source Zone		Mole Fraction in Source Material
	Calculate	Enter Site Data	Calculate	Enter Site Data	
	(mg/L)	note	*(mg/kg)*	note	*(-)*
TPH - Arom >C10-C12			7.0E+1		
TPH - Aliph >C10-C12			3.0E+1		

Transport Modeling Options

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C1 Job ID: Gen
Location: CLEA Briefing Note 3 building modifications Date: 16-11-05
Compl. By: NJL

1. Vertical Transport, Surface Soil Column



Outdoor Air Volatilization Factors ?

- (●) Surface soil volatilization model only
- ( ) Combination surface soil/Johnson & Ettinger models
  - Thickness of surface soil zone: 1 *(m)*
- ( ) User-specified VF from other model — Enter VF Values

Indoor Air Volatilization Factors ?

- (●) Johnson & Ettinger model
- ( ) User-specified VF from other model — Enter VF Values

Soil-to-Groundwater Leaching Factor

- ( ) ASTM Model ?
  - [ ] Apply Soil Attenuation Model (SAM)
  - [ ] Allow first-order biodecay — Enter Decay Rates
- ( ) User-specified LF from other model — Enter LF Values

2. Lateral Air Dispersion Factor

?

	Off-site 1	Off-site 2	
( ) 3-D Gaussian dispersion model			
( ) User-Specified ADF	1.00E+0	1.00E+0	*(-)*

3. Groundwater Dilution Attenuation Factor

Calculate DAF using Domenico Model ?

- ( ) Domenico equation with dispersion only (no biodegradation)
- ( ) Domenico equation first-order decay — Enter Decay Rates
- ( ) Modified Domenico equation using electron acceptor superposition — Enter Site Data
  - Enter Directly — Biodegradation Capacity: NC *(mg/L)*

— or —

User-Specified DAF Values

- ( ) DAF values from other model or site data — Enter DAF Values

n o

4. Commands and Options

Main Screen | **Print Sheet** | ***Help***

Site-Specific Soil Parameters

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12 Job ID: Gen
Location: CLEA Briefing Note 3 building modifications Date: 16-11-05
Compl. By: NJL

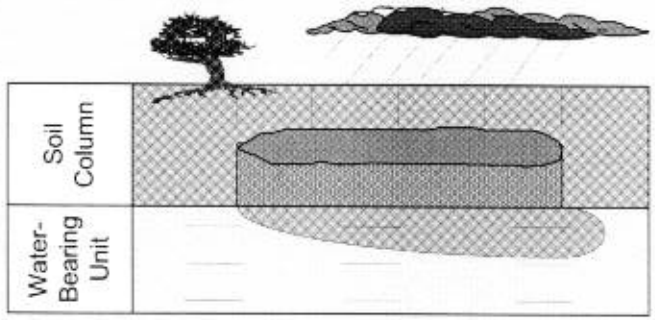
1. Soil Source Zone Characteristics

Hydrogeology

	General Case	Construction	
Depth to water-bearing unit	3		(m)
Capillary zone thickness	0.09		(m)
Soil column thickness	2.91		(m)

Affected Soil Zone

Depth to top of affected soils	0		(m)
Depth to base of affected soils	3		(m)
Affected soil area	2025	2025	(m^2)
Length of affected soil parallel to assumed wind direction	45	45	(m)
Length of affected soil parallel to assumed GW flow direction			(m)



2. Surface Soil Column

Vadose Zone Capillary Fringe

Predominant USCS Soil Type

SM: Silty Sand

or Enter Directly

↓ or

Total porosity	0.41		(-)
Volumetric water content	0.12	0.369	(-)
Volumetric air content	0.29	0.041	(-)
Dry bulk density	1.7		(kg/L)
Vertical hydraulic conductivity	8.6E+1		(cm/d)
Vapor permeability	1.0E-13		(m^2)
Capillary zone thickness	9.0E-2		(m)

Net Rainfall Infiltration

Net infiltration estimate (cm/yr)

or NA

↑ or

Average annual precipitation (cm/yr)

Partitioning Parameters

Fraction organic carbon	0.01	(-)
Soil/water pH	6.8	(-)

3. Commands and Options

Main Screen | Use Default Values | Print Sheet

Set Units | | Help

Site-Specific Air Parameters

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10- Job ID: Gen
Location: CLEA Briefing Note 3 building modifications Date: 16-11-05
Compl. By: NJL

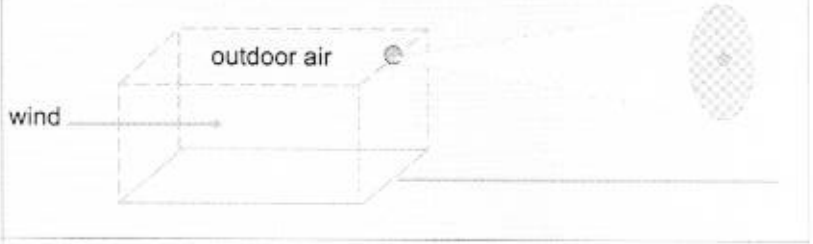
1. Outdoor Air Pathway

Dispersion in Air

	Off-site 1	Off-site 2	
Distance to offsite air receptor			(m)
or NA		or	
Horizontal dispersivity			(m)
Vertical dispersivity			(m)

Air Source Zone

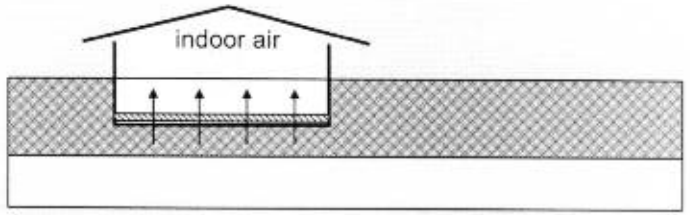
Air mixing zone height	2	(m)
Ambient air velocity in mixing zone	2.25	(m/s)
Areal particulate emission flux	6.9E-14	(g/cm^2/s)



2. Indoor Air Pathway

Building Parameters

	Residential	Commercial	
Building volume/area ratio	2	3	(m)
Foundation area	41	70	(m^2)
Foundation perimeter	25.6	34	(m)
Building air exchange rate	1.4E-4	2.3E-4	(1/s)
Depth to bottom of foundation slab	0.15	0.15	(m)
Convective air flow through cracks	9.1E-7	1.3E-6	(m^3/s)
Foundation thickness	0.15		(m)
Foundation crack fraction	0.01		(-)
Volumetric water content of cracks	0.12		(-)
Volumetric air content of cracks	0.26		(-)
Indoor/Outdoor differential pressure	30		(g/cm/s^2)

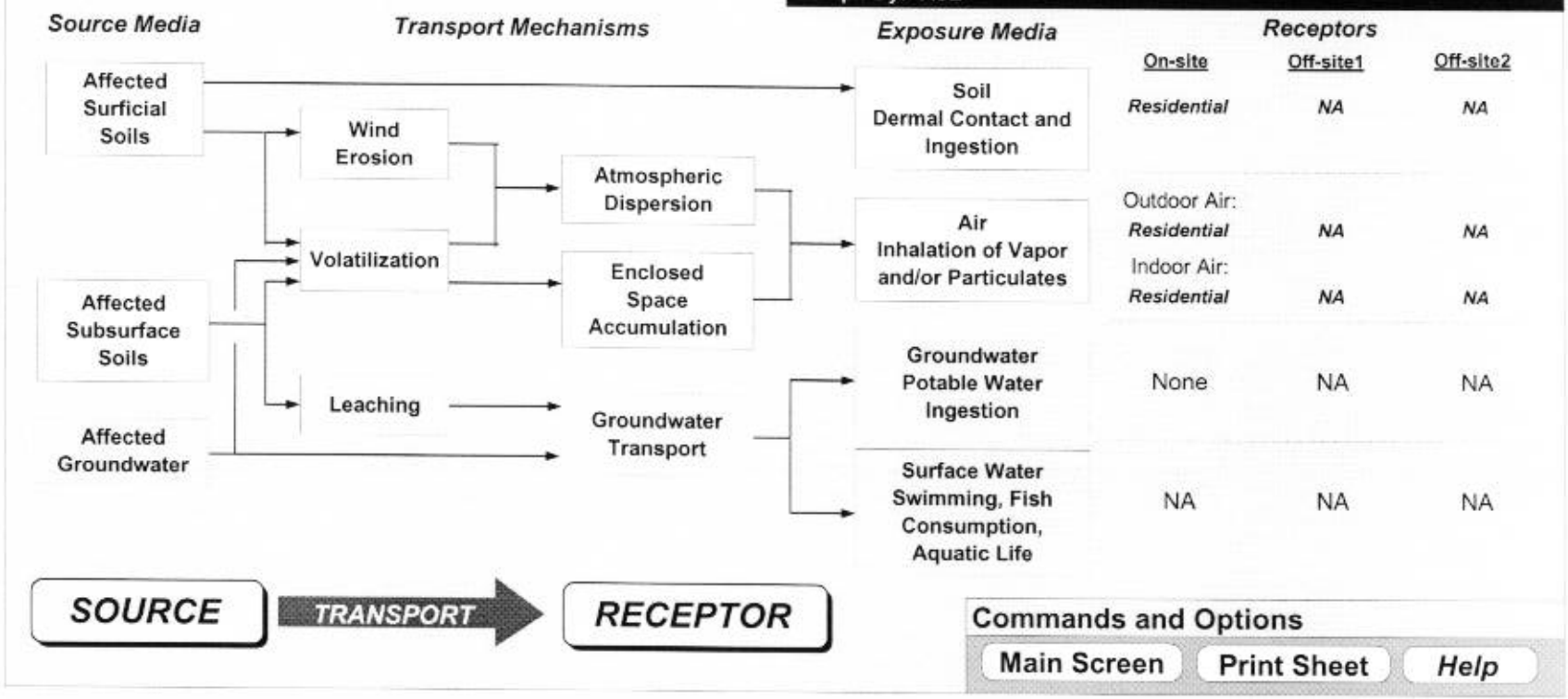


3. Commands and Options

Main Screen | Use Default Values | Print Sheet
Set Units | | *Help*

Exposure Pathway Flowchart

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12 Job ID: Gen
Location: CLEA Briefing Note 3 building modifications Date: 16-11-05
Compl. By: NJL



Commands and Options

Main Screen | Print Sheet | Help

CHEMICAL DATA FOR SELECTED COCs

Physical Property Data

Constituent	CAS Number	type	Molecular Weight (g/mole) MW	ref	Diffusion Coefficients in air (cm2/s) Dair	ref	in water (cm2/s) Dwat	ref	log (Koc) or log(Kd) (@ 20 - 25 C) log(L/kg) partition		ref	Henry's Law Constant (@ 20 - 25 C) (atm-m3/mol)	(unitless)	ref	Vapor Pressure (@ 20 - 25 C) (mm Hg)	ref	Solubility (@ 20 - 25 C) (mg/L)	ref	acid pKa	base pKb	ref
TPH - Arom >C10-C12	0-00-0	T	130	T	1.00E-01	T	1.00E-05	T	5.40	Koc	T	3.28E-03	1.35E-01	T	4.79E-01	-	2.50E+01	T	-	-	-
TPH - Aliph >C10-C12	0-00-0	T	160	T	1.00E-01	T	1.00E-05	T	5.40	Koc	T	2.96E+00	1.22E+02	T	4.79E-01	-	3.40E-02	T	-	-	-

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12
Site Location: CLEA Briefing Note 3 building modifications

Completed By: NJL
Date Completed: 16-11-05

Job ID: Gen

CHEMICAL DATA FOR SELECTED COCs

Toxicity Data

	Reference Dose (mg/kg/day)				Reference Conc. (mg/m3)		Slope Factors 1/(mg/kg/day)				Unit Risk Factor 1/(µg/m3)			
Constituent	Oral RfD_oral	ref	Dermal (mg/kg/day) RfD_dermal	ref	Inhalation RfC_inhal	ref	Oral SF_oral	ref	Dermal 1/(mg/kg/day) SF_dermal	ref	Inhalation URF_inhal	ref	EPA Weight of Evidence	Is Constituent Carcinogenic ?
TPH - Arom >C10-C12	4.00E-02	T	-	-	2.00E-01	T	-	-	-	-	-	-	D	FALSE
TPH - Aliph >C10-C12	1.00E-01	T	-	-	1.00E+00	T	-	-	-	-	-	-	D	FALSE

Site Name: TPH AROMATIC 70

Site Location: CLEA Briefing

Miscellaneous Chemical Data

Constituent	Maximum Contaminant Level MCL (mg/L)	ref	Time-Weighted Average Workplace Criteria TWA (mg/m3)	ref	Aquatic Life Prot. Criteria AQL (mg/L)	ref	Biocon-centration Factor (L-wat/kg-fish)
TPH - Arom >C10-C12	-	-	-	-	-	-	1
TPH - Aliph >C10-C12	-	-	-	-	-	-	1

Site Name: TPH AROMATIC 70

Site Location: CLEA Briefing

CHEMICAL DATA FOR SELECTED COCs

Miscellaneous Chemical Data

Constituent	Dermal Relative Absorp. Factor (unitless)	Water Dermal Permeability Data: Dermal Permeability Coeff. (cm/hr)	Lag time for Dermal Exposure (hr)	Critical Exposure Time (hr)	Relative Contr of Derm Perm Coeff (unitless)	Water/Skin Derm Adsorp Factor (cm/event)	ref	Detection Limits: Groundwater (mg/L)	ref	Soil (mg/kg)	ref	Half Life (First-Order Decay) (days): Saturated	Unsaturated	ref
TPH - Arom >C10-C12	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
TPH - Aliph >C10-C12	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-

Site Name: TPH AROMATIC 70

Site Location: CLEA Briefing

RBCA SITE ASSESSMENT

Input Parameter Summary

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12
Site Location: CLEA Briefing Note 3 building modifications

Completed By: NJL
Date Completed: 16-11-05

Job ID: Gen

Exposure Parameters		Residential			Commercial/Industrial	
		Adult	(1-6yrs)	(1-16 yrs)	Chronic	Construc.
AT_c	Averaging time for carcinogens (yr)	70				
AT_n	Averaging time for non-carcinogens (yr)	30			25	1
BW	Body weight (kg)	70	15	35	70	
ED	Exposure duration (yr)	30	6	16	25	1
τ	Averaging time for vapor flux (yr)	30			25	1
EF	Exposure frequency (days/yr)	350			250	180
EF_D	Exposure frequency for dermal exposure	350			250	
IR_w	Ingestion rate of water (L/day)	2			1	
IR_s	Ingestion rate of soil (mg/day)	100	200		50	100
SA	Skin surface area (dermal) (cm^2)	5800		2023	5800	5800
M	Soil to skin adherence factor	1				
ET_{swim}	Swimming exposure time (hr/event)	3				
EV_{swim}	Swimming event frequency (events/yr)	12	12	12		
IR_{swim}	Water ingestion while swimming (L/hr)	0.05	0.5			
SA_{swim}	Skin surface area for swimming (cm^2)	23000		8100		
IR_{fish}	Ingestion rate of fish (kg/yr)	0.025				
FI_{fish}	Contaminated fish fraction (unitless)	1				

Complete Exposure Pathways and Receptors	On-site	Off-site 1	Off-site 2
Groundwater:			
Groundwater Ingestion	None	NA	NA
Soil Leaching to Groundwater Ingestion	None	NA	NA
Applicable Surface Water Exposure Routes:			
Swimming			NA
Fish Consumption			NA
Aquatic Life Protection			NA
Soil:			
Direct Ingestion and Dermal Contact	Residential		
Outdoor Air:			
Particulates from Surface Soils	Residential	NA	NA
Volatilization from Soils	Residential	NA	NA
Volatilization from Groundwater	None	NA	NA
Indoor Air:			
Volatilization from Subsurface Soils	Residential	NA	NA
Volatilization from Groundwater	None	NA	NA

Receptor Distance from Source Media	On-site	Off-site 1	Off-site 2	(Units)
Groundwater receptor	NA	NA	NA	(m)
Soil leaching to groundwater receptor	NA	NA	NA	(m)
Outdoor air inhalation receptor	0	NA	NA	(m)

Target Health Risk Values		Individual	Cumulative
TR_{ac}	Target Risk (class A&B carcinogens)	1.0E-6	1.0E-5
TR_c	Target Risk (class C carcinogens)	1.0E-5	
THQ	Target Hazard Quotient (non-carcinogenic risk)	1.0E+0	1.0E+0

Modeling Options	
RBCA tier	Tier 1
Outdoor air volatilization model	Surface model only
Indoor air volatilization model	Johnson & Ettinger model
Soil leaching model	NA
Use soil attenuation model (SAM) for leachate?	NA
Air dilution factor	NA
Groundwater dilution-attenuation factor	NA

NOTE: NA = Not applicable

Surface Parameters		General	Construction	(Units)
A	Source zone area	2.0E+3	NA	(m^2)
W	Length of source-zone area parallel to wind	4.5E+1	NA	(m)
W_{gw}	Length of source-zone area parallel to GW flow	NA		(m)
U_{air}	Ambient air velocity in mixing zone	2.3E+0		(m/s)
δ_{air}	Air mixing zone height	2.0E+0		(m)
P_e	Areal particulate emission rate	6.9E-14		(g/cm^2/s)
L_{ss}	Thickness of affected surface soils	NA		(m)

Surface Soil Column Parameters		Value			(Units)
h_{cap}	Capillary zone thickness	NA			(m)
h_v	Vadose zone thickness	NA			(m)
ρ_b	Soil bulk density	1.7E+0			(g/cm^3)
f_{oc}	Fraction organic carbon	1.0E-2			(-)
θ_T	Soil total porosity	4.1E-1			(-)
K_{vs}	Vertical hydraulic conductivity	8.6E+1			(cm/d)
k_v	Vapor permeability	1.0E-13			(m^2)
L_{gw}	Depth to groundwater	NA			(m)
L_s	Depth to top of affected soils	0.0E+0			(m)
L_{base}	Depth to base of affected soils	3.0E+0			(m)
L_{subs}	Thickness of affected soils	3.0E+0			(m)
pH	Soil/groundwater pH	6.8E+0			(-)
		capillary	vadose	foundation	
θ_w	Volumetric water content	0.369	0.12	0.12	(-)
θ_a	Volumetric air content	0.041	0.29	0.28	(-)

Building Parameters		Residential	Commercial	(Units)
L_b	Building volume/area ratio	2.00E+0	NA	(m)
A_b	Foundation area	4.10E+1	NA	(m^2)
X_{crack}	Foundation perimeter	2.56E+1	NA	(m)
ER	Building air exchange rate	1.40E-4	NA	(1/s)
L_{crack}	Foundation thickness	1.50E-1	NA	(m)
Z_{crack}	Depth to bottom of foundation slab	1.50E-1	NA	(m)
η	Foundation crack fraction	1.00E-2	NA	(-)
dP	Indoor/outdoor differential pressure	3.00E+1	NA	(g/cm/s^2)
Q_s	Convective air flow through slab	9.10E-7	NA	(m^3/s)

Groundwater Parameters		Value	(Units)
δ_{gw}	Groundwater mixing zone depth	NA	(m)
I	Net groundwater infiltration rate	NA	(cm/yr)
U_{gw}	Groundwater Darcy velocity	NA	(cm/d)
V_{gw}	Groundwater seepage velocity	NA	(cm/d)
K_s	Saturated hydraulic conductivity	NA	(cm/d)
i	Groundwater gradient	NA	(-)
S_w	Width of groundwater source zone	NA	(m)
S_d	Depth of groundwater source zone	NA	(m)
θ_{ef}	Effective porosity in water-bearing unit	NA	(-)
f_{oc-sat}	Fraction organic carbon in water-bearing unit	NA	(-)
pH_{sat}	Groundwater pH	NA	(-)
	Biodegradation considered?	NA	

Transport Parameters		Off-site 1	Off-site 2	Off-site 1	Off-site 2	(Units)
	Lateral Groundwater Transport	Groundwater Ingestion		Soil Leaching to GW		
α_x	Longitudinal dispersivity	NA	NA	NA	NA	(m)
α_y	Transverse dispersivity	NA	NA	NA	NA	(m)
α_z	Vertical dispersivity	NA	NA	NA	NA	(m)
	Lateral Outdoor Air Transport	Soil to Outdoor Air Inhal.		GW to Outdoor Air Inhal.		
σ_y	Transverse dispersion coefficient	NA	NA	NA	NA	(m)
σ_z	Vertical dispersion coefficient	NA	NA	NA	NA	(m)
ADF	Air dispersion factor	NA	NA	NA	NA	(-)

Surface Water Parameters		Off-site 2	(Units)
Q_{sw}	Surface water flowrate	NA	(m^3/s)
W_{sw}	Width of GW plume at SW discharge	NA	(m)
δ_p	Thickness of GW plume at SW discharge	NA	(m)
DF_{sw}	Groundwater-to-surface water dilution factor	NA	(-)

RBCA SITE ASSESSMENT | TPH Criteria RBSL Worksheet

Site Name: TPH AROMATIC 70% ALIPHATIC 30% C10-C12 | Completed By: NJL | Job ID: Gen

Site Location: CLEA Briefing Note 3 building modifications | Date Completed: 16-11-05

CALCULATION OF RBSL VALUES FOR TPH

		Mass Fractions		Representative Concentrations		Calculated Concentration Limits		Appilcable SSTL Values	
CONSTITUENTS OF CONCERN		Soil	Groundwater	Soil	Groundwater	Residual Soil Concentration	Solubility	Soils (0 - 3 m)	Groundwater
CAS No.	Name	(-)	(-)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)
0-00-0	TPH - Arom >C10-C12	7.0E-1		7.0E+1		6.3E+2		1.7E+2	
0-00-0	TPH - Aliph >C10-C12	3.0E-1		3.0E+1		8.6E+1		2.2E+3	
	Total	1.0E+0	0.0E+0	1.0E+2	0.0E+0		Total TPH SSTL value	2.5E+2	

">" indicates risk-based target concentration greater than constituent residual saturation value. NC = Not calculated.

EA Factsheet for RBCA Toolkit for Chemical Releases

Fact sheet for the RBCA Tool Kit for Chemical Releases

Basic model information

Model name:	Risk-Based Corrective Action (RBCA) Tool Kit for Chemical Releases (Version 1.3)
Available from:	Groundwater Services, Inc., 2211 Norfolk, Suite 1000, Houston, Texas 77098-4044, USA www.gsi-net.com
Cost:	$795 (USA)
Developed by:	RBCA Framework (American Society for Testing and Materials) RBCA Tool Kit (Groundwater Services Inc., USA)
Hardware:	Minimum of 32 MB RAM and 25 MB free disk space Microsoft Excel v7.0 or Excel 97

Brief model description

The RBCA Tool Kit for Chemical Releases consists of a series of linked workbooks programmed in Microsoft® Excel version 7.0 or 97 [1]. This tool can be used to calculate risk levels (i.e. 1 in a million) and/or "cleanup standards"[1] for soil and groundwater (e.g. 10 mg/kg for soil or 10 mg/L for groundwater). These values are calculated based on information provided by the user. The RBCA Tool Kit is designed to be protective of human health and the environment.

The Tool Kit was specifically designed to complete all calculations required for Tier 1 and Tier 2 of the RBCA planning process, as defined in the ASTM (American Society for Testing and Material) E2081-00 Standard Guide for Risk-Based Corrective Action [2]. This includes the calculation of exposure concentrations and average daily intake of contaminants by humans.

The Tool Kit includes analytical fate and transport models for air, groundwater and soil exposure pathways. The user can enter suitable site-specific soil, groundwater and air parameters.

1 It must be emphasised that "cleanup standards" may not be the same as remedial objectives or remedial standards within the context of UK regulation.

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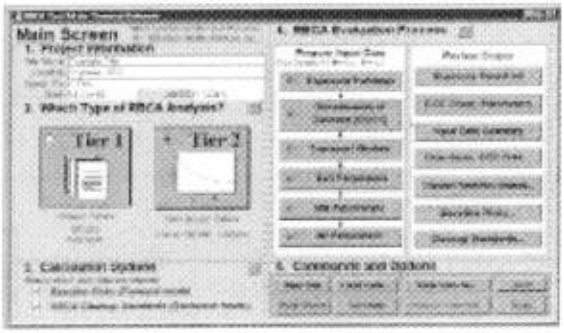
The user selects the level of assessment required as follows:

- Tier 1 assessment involves the generation of generic risk-based screening level (RBSL) for on-site exposure only, assuming default exposure and site parameters
- Tier 2 allows the user to evaluate risk levels and/or site-specific target levels (SSTLs) for both on-site and off-site receptor locations based on site-specific soil, groundwater and air parameters. In a Tier 2 assessment the user may implement the fate and transport models included in the Tool Kit to evaluate off-site receptors

Figure 1 provides an example of the RBCA Tool Kit main screen and illustrates the options presented in the Tool Kit Main Screen.

Figure 1 RBCA Tool Kit main screen
Reproduced with permission from GSI



The forward mode option is used to calculate risk levels, based on measured concentrations of the contaminant of concern in soils and groundwater. The back-calculating mode of the programme can be utilised to back-calculate "cleanup standards". This tool was specifically designed for use in the USA based within the US regulatory context. However, the default parameters can be modified to evaluate sites within the UK.

Contaminants and contaminated media

An integrated toxicological and physico-chemical parameter database of 115 chemicals is provided in the Tool Kit. These include metals and organic parameters, and also, aliphatic and aromatic carbon chain lengths specified in the TPH Criteria Working Group (TPHCWG) methodology.

The Tool Kit can evaluate surface soil, subsurface soil, air, groundwater and surface water. However, contaminant concentrations can only be specified for soil and groundwater.

Lead is not included in the database. The user can customise the database to alter the parameters or add new chemicals.

Receptor types

Both on-site and off-site receptors can be considered. In RBCA on-site refers to a receptor directly above the source area, and off-site to a receptor at any point away from the source area (i.e. not related to the site boundary, see Figure 3). The receptor types included in the model are:

- groundwater
- surface water
- adult residential
- child residential
- adult commercial
- construction worker

Land-use and exposure scenarios

There is no default land-use scenario in the RBCA Tool Kit. The user has to select the receptor type, which can be either a residential receptor or a commercial / construction worker. The following exposure pathways and scenarios are included in the software:

Groundwater/surface water exposure:

- ingestion of groundwater
- inhalation of groundwater vapour
- discharge of contaminated groundwater to surface water
- ingestion/dermal contact via swimming
- ingestion via fish consumption
- aquatic life protection

Surface soil exposure (0 to <1 m):

- inhalation of vapour and particulates
- direct dermal contact
- ingestion of soil and dust (incidental)
- leaching to groundwater

Subsurface soil exposure (>1 m):

- inhalation of vapours
- leaching to groundwater

Air exposures are all included in the media specific exposures listed above.

The RBCA Tool Kit does not include the consumption of garden vegetables, dairy products, eggs, meat, fish or shellfish.

Key features of the model

What the model is supposed to do (model utility)

The RBCA Tool Kit was developed for use in the USA, taking into consideration the US regulatory context. Therefore, if it is used for sites in the UK it needs to be applied by considering the UK regulatory context. The RBCA Tool Kit can be used to derive generic and site-specific target levels that can be used to support risk management actions. The model can be used to simulate fate and transport of contaminants both on-site and off-site. The RBCA Tool Kit for Chemical Releases is a deterministic model (i.e. it uses a single value for each exposure parameter).

The default target risk levels are those for a residential land use. If another land use is evaluated, then the target risk input parameters must be altered to reflect this change.

Although the Tool Kit is a deterministic model, simple statistics may be applied to source area concentration data to calculate a representative value. The available statistical options are:

- maximum values
- arithmetic and/or geometric means
- confidence levels (e.g. 95% confidence levels)

The user must also note that the model assumes a constant source with no declining source options (i.e. the source concentration will never decrease during the assessment period).

Model usability

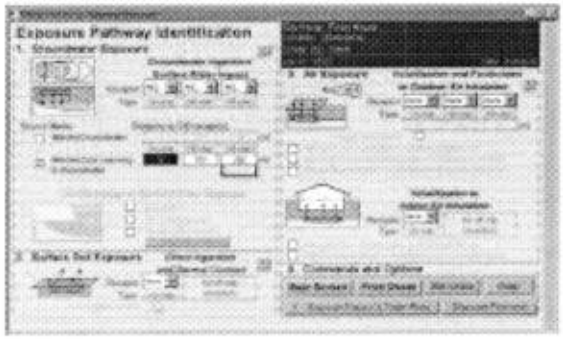
The RBCA Tool Kit has a good user interface, and can be described as user friendly. However, it must be noted that it is a complex model; for it to be used appropriately and effectively, considerable technical skill in risk assessment is required.

The operation of the programme is within Excel and data is entered onto Excel spreadsheets. There is a Main Screen that displays the risk assessment process (see Figure 1). The Main Screen is automatically displayed whenever the RBCA Tool Kit is opened, and it serves as the hub of the user interface. Most of the input and output screens are accessed from and returned to this screen. Here the user enters or selects:

- general project information (e.g. site name, site location)
- the type of RBCA analysis (e.g. Tier 1 or 2)
- calculations to be performed (e.g. calculation of risk values or "cleanup standards")

The user then progresses through the RBCA evaluation process by navigating to the appropriate input and output screens (e.g. Figure 2). Input and output options become successively available as individual steps of the process are completed. In addition, the user may create, load and save user-input data files.

Figure 2 Exposure Pathway Identification screen
Reproduced with permission from GSI



There are also help files within each screen that can help the user identify what information is required. Although the help files do not contain the equations, the manual does include the full equations for many of the fate and transport modelling methods used in the spreadsheets. In addition, there is a unit conversion feature that can be used if the available data needs to be input with different units.

Finally, it is important to note that in order for this tool to be used appropriately, it must be used in conjunction with the manual and the ASTM standards [1 and 2].

Toxicological information

The software contains a database of 115 chemicals. The user can alter the default toxicological and physico-chemical information within the database. Any alteration from the default values is highlighted in the output. The toxicological information found in the database has been compiled from several sources including the USEPA Integrated Risk Information System (IRIS) and the USEPA Health Effects Assessment Summary Tables (HEAST). The toxicological parameters listed in these databases are classified as carcinogens and non-carcinogens, and therefore the derivation and resulting units are different. Reference doses (RfD) and slope factors are the toxicological entities used when evaluating non-carcinogens and carcinogens respectively. Table 1 contains examples of three contaminants and their associated carcinogenic and non-carcinogenic toxicological values.

Table 1 Example of toxicological information in the Tool Kit

Contaminant	RfD (mg/kg/day)	Slope factors $(mg/kg/day)^{-1}$
Arsenic	3.0 E-04	1.5
Trichloroethene	6.0 E-03	1.1 E-02
Benzo (a) Pyrene	NA	7.3

The user must ensure that any toxicological information used in the risk assessment complies with the UK regulatory context [3]. It is worth noting that the RBCA Tox database was compiled when the software was written and is not regularly updated. DEFRA and the Environment Agency have produced a number of contaminant toxicological reports [4], and the data within these should be used when conducting risk assessments within the UK.

Contaminants and contact media

Clicking "Constituents of Concern (COCs)" on the Main Screen accesses the Contaminant Selection screen. During this step the user must identify the constituents of concern (COCs) present at the site. Identified concentrations for COCs do not need to be input if "cleanup levels" (i.e. RBSLs or SSTLs) are only required. However, if risk levels are to be calculated, the user must also provide representative concentrations of the COCs in the relevant media. If only "cleanup levels" are required and the user includes representative site contaminant levels then the programme will highlight the exceeded "cleanup levels" automatically.

For Tier 1 evaluations using RBCA, any constituent associated with the source and consistently detected above natural background levels can be considered a possible COC. Only those constituents present above Tier 1 RBSLs are typically considered as COCs for a Tier 2 assessment.

The user must input the COC concentrations into the soil and groundwater columns, if these media have been identified as affected during the exposure pathway selection stage (Forward mode only). If this is not done then the user cannot continue into the next step of the assessment.

The Tool Kit can assess free product contamination through the use of Raoult's Law. The programme assesses the transport of dissolved phase but not free product.

Receptor characterisation

The human receptors evaluated in this software are:

- adult residential
- child residential
- commercial
- construction worker

The averaging time used for carcinogens and for all receptors is 70 years. The default averaging time for non-carcinogens and for the identified receptors are:

- 30 years for the adult residential receptor
- 25 years for the commercial receptor
- 1 year for the construction worker

The child receptor is evaluated into 0 to 6 or 0 to 16 age classes.

Table 2 Reasonable maximum exposure parameters

Parameter	Adult	Child (0–6)	Child (0–16)	Commercial	Construction
Body weight (kg)	70	15	35	70	70
Exposure duration (yr)	30	6	16	25	1
Exposure frequency (d/yr)	350	350	350	250	180
Dermal exposure frequency (d/yr)	350	350	350	250	250
Skin surface area (cm^2)	5,800		2,023	5,800	5,800
Water ingestion rate (L/d)	2	2	2	1	1
Soil ingestion rate (mg/d)	100	200	-	50	100
Swimming exposure time (hr/event)	3	3	3	NA	NA
Swimming exposure frequency (event/yr)	12	12	12	NA	NA
Swimming water ingestion rate (L/hr)	0.05	0.5	-	NA	NA
Skin surface area, swimming (cm^2)	23,000	-	8,100	NA	NA
Fish consumption rate (kg/d)	0.025	0.025	0.025	NA	NA

Table 2 contains the other default exposure parameters used in the assessment for each receptor. These parameters are all based on the reasonable maximum exposure (RME) concept, where the highest exposure that is reasonably expected to occur at a site is used.

These parameters are based on conservative US statistics. Therefore, when using this model these parameters need to be considered within the UK context.

Land use

There is no explicit land use in the software. However, from the description of the receptors the user can see that the land use can be identified as:

- residential (adult and child)
- recreational (adult and child)
- commercial/construction.

Pathway characterisation

During the Tier 1 assessment only on-site exposure pathways for both human health and groundwater can be evaluated. Therefore, all other receptors and off-site exposure pathways are greyed out so that the user cannot select them. These only become available if the Tier 2 assessment is conducted.

The exposure and migration pathways that can be evaluated during a Tier 1 assessment for the on-site receptors are:

- groundwater ingestion (on-site)
  - commercial
  - residential
  - maximum contaminant levels (MCLs)
- surface soil (direct ingestion and dermal contact on-site)
  - residential
  - commercial
  - construction worker
- air (volatilisation and particulates to outdoor air and volatilisation to indoor air, on-site)
  - residential
  - commercial
  - construction worker (no indoor air volatilisation)
  - time-weighted average (TWA)

The MCLs listed in the software are a drinking water standard established by USEPA under the Safe Drinking Water Act. They are the maximum permissible levels of chemicals of concern in water that is to be delivered to any user of a public water supply. These values are different from the UK drinking water standards, and the user should ensure that the appropriate values are entered if necessary.

The construction worker pathway can only be evaluated if either the residential or commercial receptors have been selected first. Therefore, this receptor cannot be evaluated separately. Additionally, the US Occupational Safety and Health Administration (OSHA) have published permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances. These limits are based on an 8 hour time weighted average (TWA) exposure. Should this option be used in the UK, then the values published by the Health and Safety Executive (HSE) in EH40 [5] should be used instead of the OSHA PELs.

It is also important to note that the term 'on-site receptor' refers to an on-source receptor (i.e. a receptor immediately on the source area). Figure 3 illustrates this concept. The off-site receptor does not necessarily need to be outside the site boundary, nor does the on-site receptor need to be located inside the boundary. In this figure the receptors are represented by the house/building structure.

Figure 3a | Example of an on-site receptor

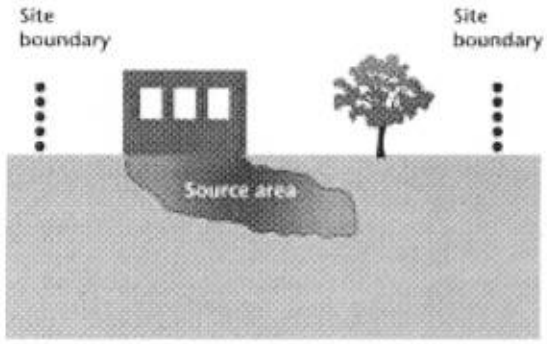
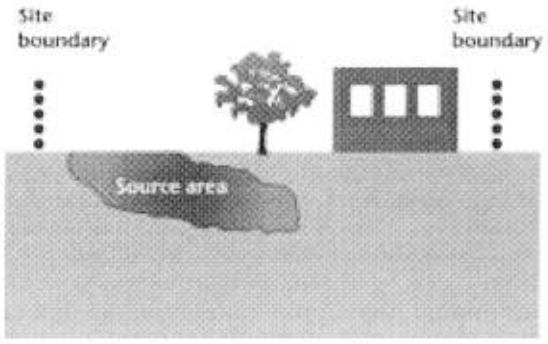


Figure 3b | Example of an off-site receptor



In addition to the exposure pathways listed above for the on-site receptor, the following exposure pathways can be selected for the off-site receptors during a Tier 2 assessment:

- groundwater (a maximum of two off-site receptors can be selected in which surface water may be one)
  - residential
  - commercial
  - MCLs
  - surface water impacts
  - surface water (ingestion of fish)
- air (two off-site receptors can be selected)
  - residential
  - commercial
  - TWA.

Model outputs

One of the most important outputs from the model is the input summary sheet. This sheet contains all the exposure parameters and migration models selected. It is extremely important that this sheet accompanies any risk assessment conducted with this model.

Outputs are in the form of tables in Microsoft Excel. As the user works through the RBCA model each individual screen can be printed. The output details the exposure routes, the toxicological data and, where the source zone concentration data has been input, whether or not the "target levels" have been exceeded. Alternatively, the user can print a single summary sheet detailing all the input parameters.

The output highlights chemical-specific parameters that have been altered from the default by the user. If any values have been altered from those contained in the chemical database, the user should include a justification for the change as part of the final report together with a printout of the project-specific chemical database.

The output tables in the software are:

- A table of human health risks for individual pathways and a table of cumulative risk (note that the UK Department of Health does not accept cumulative assessment of risk unless the contaminants are acting on the same target organ)
- A table of steady-state contaminant concentrations at the exposure point (if analytical groundwater modelling has been conducted)
- A table of "cleanup standards" for each contaminant and each media evaluated (i.e. soil and groundwater)

In addition, for the risk value calculation mode the software also provides the following outputs:

- **Risks by individual pathway**. These tables present the average daily intake and baseline risk calculations for each complete exposure pathway and associated receptors (on-site, off-site1 and off-site2):
  - outdoor air
  - indoor air
  - soil
  - groundwater
  - surface water
- **Risks by all pathways.** This table presents a summary of baseline risks for all selected pathways. A solid red box indicates pathways for which target risk limits are exceeded. The user can later assess the target risk limits depending on the context within which the risk assessment is conducted

For the "cleanup standards" mode the following types of tables can be selected:

- **Result summary by individual COC**. This is a summary of RBSL or SSTL values together with the chemical, toxicological and natural attenuation parameters used in their calculation. Applicable media "cleanup standards" are identified by values displayed in bold italics
- **Individual constituents by affected media.** This output screen presents a summary of calculated Tier 1 RBSLs or Tier 2 SSTLs for all COCs, organised by affected source medium (soil and groundwater)
- **Multiple constituents.** In order to compute SSTLs based on cumulative risk effects, RBCA provides an interactive calculator for adjusting individual constituent target levels to meet cumulative risk goals (i.e. total risks from all contaminant exposure not to exceed 1 in a million). The cumulative risk worksheet only applies if the affected soil or groundwater zone must be remediated to meet a cumulative risk limit (i.e. an upper bound carcinogenic risk or hazard index for the combined effects of multiple constituents). The worksheet lists all COCs and displays individual and cumulative risk values for each applicable exposure medium and receptor. If the applicable cumulative risk limit is exceeded for a given exposure medium, the user may then adjust constituent reduction factors (CRFs) (i.e. the representative COC concentration divided by the applicable target concentration) until the desired cumulative risk level is achieved.

Model interpretation

What does the output mean?

From the Tier 1 and Tier 2 assessment two primary types of outputs are derived using this model:

- risk values
- cleanup levels

The Tier 1 values are screening values and should not be used as remediation values. These values are non-site-specific and are based on conservative exposure factors, and fate and transport parameters.

The Tier 2 assessment can generate both risk values and "cleanup levels". These levels are based on site-specific information and parameters. As part of the Tier 2 assessment a constituent reduction factor (CRF) is generated which indicates what level of contaminant reduction would be required to ensure that the contaminant levels do not exceed a specified cumulative "target risk level".

As noted earlier, the Department of Health does not support cumulative risk levels unless the COCs are acting on the same target organ. The RBCA toolkit does not make a distinction as to which target organs are being impacted. Therefore, the user should be aware that although the software may highlight risk levels or SSTLs as being exceeded, it does not necessarily mean that the site is causing unacceptable levels of risk. In order to determine if in fact this is the case, the user should seek an expert toxicologist's advice.

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

The following is a list of information required to conduct a comprehensive risk assessment using the RBCA Tool Kit. Some of the parameters can be obtained from published literature. However, to conduct a site-specific assessment the following data should be collected from the site:

- source area
- soil porosity
- depth of contamination (top to bottom)
- depth to groundwater
- groundwater gradient
- groundwater flow direction
- hydraulic conductivity
- potentially affected receptor types
- distance to off-site human receptor
- distance to surface water / groundwater receptor
- impacted media
- contaminant concentrations in each impacted media.

Common problems with the model

- The programme sometimes crashes due to changes made in the chemical database while running a simulation
- The chemical database for each project has to be saved separately from the rest of the programme and recopied into the programme folder every time the project file needs to be altered
- Sometimes the programme does not recognise that all the appropriate boxes have been checked on the screen and does not allow the user to move onto the next step
- Calculations for the inhalation exposure result in different values when comparing the forward and backward modes due to the use of, and conversion of, the inhalation unit risk concentrations
- Sometimes the unit conversion is not saved when the user changes it.

Common mistakes made when using the model

- The RBCA Tool Kit conceptual model and the site-specific conceptual model do not match and therefore the assessment would be incorrect (e.g. site grows vegetables but RBCA does not evaluate vegetable uptake and subsequent human consumption)
- The NC abbreviation is sometimes found in the output tables, indicating contaminants for which RBSLs or SSTLs could not be calculated. This is usually due to a lack of toxicological or physico-chemical data. This does not mean that the particular contaminant and exposure pathway can be ignored, but indicates that there are uncertainties with the assessment due to the lack of data
- The ">Csat" symbol is sometimes part of the results table generated by the RBCA Tool Kit. This symbol is usually generated by the software to indicate that risk levels are not exceeded at a concentration above the saturation level for soil or groundwater. This means that even if free product was encountered it would not cause adverse effects via that particular exposure pathway
- Using an erroneous soil porosity
- Using the default values provided within the programme for soil types, which are based on US soils and not UK soils
- Not adopting the UK context for exposure parameters, drinking water standards and toxicological data
- Using inappropriate "target risk" levels
- Confusing the on-site and off-site receptors
- Not including all the input and output data as part of the report.

Model limitations – what the model does not do

The following list summarises the model limitations:

- The model is not capable of simulating contaminant concentrations down-gradient of a discharge point for surface water
- The model does not allow probabilistic human health risk evaluation
- The Tool Kit only addresses indoor air exposure for the on-site receptor. Therefore, this model cannot be used to migrate volatiles to an off-site receptor and the subsequent intrusion of volatiles to off-site buildings

- The model is a US-based model and must be adapted to the UK context
- The UK considers surface soils to consist of the first 0.5 metres, while RBCA uses 0–1 metre [6]
- The "target risk" levels used in RBCA is a maximum excess cancer risk of $1x10^{-4}$ which equates to an annual risk level of $1x10^{-6}$. However, it is important to note that this differs from the UK approach [3].

Sensitive model parameters

- Source area – The source area is an important parameter because it is this area that determines the amount of vapours available for indoor and outdoor receptors
- Soil porosity – Use of a small soil porosity value will retard the contaminant migration in soils
- Hydraulic gradient – This is important in determining how fast a contaminant plume may be moving to an off-site receptor
- Hydraulic conductivity
- Degradation factors – These will influence how quickly a contaminant is transformed or degraded
- Toxicological parameters such as reference doses (RfD) and slope factors (SF)
- Building-crack factor – This has a major impact on the vapour regimes for the indoor receptor

Other parameters which will influence the model results are the exposure parameters used for the different exposure pathways. These should be in line with current site use and/or UK statistical values. Some of these parameters have been summarised as part of the Contaminated Land Exposure Assessment (CLEA) model [4].

References and further information

[1] American Society for Testing and Materials (ASTM) (1995) Risk-Based Corrective Action (RBCA) E1739-95 Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites.

[2] American Society for Testing and Materials (ASTM) (2001) *Risk-Based Corrective Action (RBCA) (E2081-00) Standard Guide for Risk-Based Corrective Action.*

[3] Defra and the Environment Agency (2002) *Contaminants in Soil: Collation of Toxicological Data and Intake Values for Humans.* Report CLR9. Published by Defra and the Environment Agency. Available from WRc, Frankland Road, Swindon, Wilts SN5 8YF. Also downloadable from the Defra website – www.defra.gov.uk.

[4] Defra and the Environment Agency (2002) *Toxicological Reports for Individual Soil Contaminants.* Report TOX1-10. Published by Defra and the Environment Agency. Available from WRc, Frankland Road, Swindon, Wilts SN5 8YF. Also downloadable from the Defra website – www.defra.gov.uk.

[5] Health and Safety Executive. *EH40/02 Occupational Exposure Limits 2002.* Health and Safety Executive. ISBN 0 7176 14743.

[6] Defra and Environment Agency (2002) *The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms.* Report CLR10. Published by Defra and the Environment Agency. Available from WRc, Frankland Road, Swindon, Wilts SN5 8YF. Also downloadable from the Defra website – www.defra.gov.uk.

Further information

Further details on the application of this model and other risk assessment models can be obtained from: Environment Agency, National Groundwater and Contaminated Land Centre (NGWCLC), Olton Court, 10 Warwick Road, Olton, Solihull, B92 7HX (Tel: 0121 708 4714, Fax: 0121 708 4637).

Acknowledgements

The National Groundwater and Contaminated Land Centre would like to acknowledge and thank those individuals who reviewed and commented on drafts of this fact sheet. These reviewers included the model developer, the Environment Agency and environmental consultants.

ISBN 1844320987

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Appendix D
CLEA Mean & Maximum Value Tests

Job: Radcliffe Road

Arsenic	SGV=	**20**	**US95% =**	**28**	(This would be the concentration at any given point on the site with 95% probability
Test Value					If greater than the SGV then cleanup or more sampling. If less than SGV then OK)
22	1.3424				
12	1.0792	Notes: Only enter data in green cells			
27	1.4314				
21	1.3222				

	Results
Maximum Value Test	***Value is unlikely to be an outlier***
Mean Value Test	***More samples or remediate***

Job: Radcliffe Road

Lead SGV= **450** **US95% = 1323** (This would be the concentration at any given point on the site with 95% probability

If greater than the SGV then cleanup or more sampling. If less than SGV then OK)

Test Value	
730	2.8633
830	2.9191
1400	3.1461
440	2.6435

Notes: Only enter data in green cells

	Results
Maximum Value Test	***Value is unlikely to be an outlier***
Mean Value Test	***More samples or remediate***

Job: Radcliffe Road

B (a) P	SGV=	1.3	US95% =	2	(This would be the concentration at any given point on the site with 95% probability
Test Value					If greater than the SGV then cleanup or more sampling. If less than SGV then OK)
1.3	0.1139				
0.35	-0.4559	Notes: Only enter data in green cells			
1.8	0.2553				
0.52	-0.2840				

	Results
Maximum Value Test	***Value is unlikely to be an outlier***
Mean Value Test	***More samples or remediate***

Appendix E
R&D P20 Groundwater Risk Assessment Worksheets & Model Parameters, Assumptions and Limitations

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Date of Workbook Issue: April 2002

This worksheet has been produced in combination with the document 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources' - Environment Agency R&D Publication 20, (1999).

Users of this worksheet should always refer to the User Manual, to R&D Publication 20 and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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This calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the NGWCLC.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error f

Details to be completed for each assessment				
Site Name:	Radcliffe Road			
Site Address:				
Completed by:	Dipalee Patel			
Date:	01-Nov-06		Version:	1
Contaminant	Lead			
Target Concentration (C_T)	0.01	mg/l	Origin of C_T:	UK Drinking Water Standards

This worksheet can be used to determine remedial targets for soils (Worksheets Tier 1 Soil, Tier 2 Soil and Tier 3 Soil) or to determine remedial targets for groundwater (Tier 3 Groundwater). For Tier 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Tier 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menu or require a "0", "1" or "2" to be entered. Data entry are identified as blue backgı
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The worksheet also calculates a number of frequently used hydrogeological equations.

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 1 - Soil

Select the Method of calculating the soil water Partition Co-efficient by using the Pull down menu below

User specified value for partition coefficient

Contaminant		**Lead**		
Target concentration	**C_T**	**0.01**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	1.20E-01	fraction	Literature
Air filled soil porosity	θa	2.90E-01	fraction	Literature
Bulk density of soil zone material	ρ	1.70E+00	g/cm^3	Literature
Henry's Law constant	H	1.86E-05	dimensionless	*Literature*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	8.75E+04	l/kg	*Measured*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Soil water partition coefficient used in Tier Assessment	**Kd**	**8.75E+04**	**l/kg**	*Specified value*

This sheet calculates the Tier 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Tier 1 remedial target to determine the need for further action.

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

Calculated Parameters

Tier 1 Remedial Target		**8.75E+02**	**mg/kg**	(for comparison with soil analyses)
	LTC1	**0.01**	**mg/l**	(for comparison with leachate test results)

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 2 - Soil

Contaminant		**Lead**		from Tier 1
Target concentration	C_T	**0.01**	**mg/l**	from Tier 1

This sheet calculates the Tier 2 remedial target for soils (mg/kg) or for pore water (mg/l). Three options are included dependent on the identified in receptor (groundwater, surface water, or groundwater abstraction). In general the assessment should be for groundwater below the site.

Select Target for Tier 2 Soil Assessment (click on brown cell below, then on pull-down menu)

Groundwater flow below site

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 2 remedial target to determine the need for further action. Equations presented in R&D Pub. 20

Input Parameters	Variable	Value	Unit	Source of parameter value
Standard entry				
Infiltration	Inf	2.12E-05	m/d	**alculated based on average raifall and 99.9% hard cov**
Area of contaminant source	A		m^2	
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	3.39E+01	m	**Hotspot area measured from scaled plan**
Saturated aquifer thickness	da	8.54E+00	m	**tic Surface to impermeable strata (based on data fron**
Hydraulic Conductivity of aquifer in which dilution occurs	K	6.66E+00	m/d	**Calculated using average soakage rate over site**
Hydraulic gradient of water table	i	0	fraction	
Width of contaminant source perpendicular to groundwater flow	w	33 9/10	m	**Hotspot area measured from scaled plan**
Background concentration of contaminant in groundwater beneath site	Cu	9.00E-03	mg/l	**Assumed (<0.01mg/l)**
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**		
Enter mixing zone depth	Mz		m	*used in tier assessment*
Calculated mixing zone depth	Mz	3.61E+00	m	*used in tier assessment* (Equation presented in Table 4.5, R&D Pub. 20)
Entry for groundwater abstraction				
Abstraction rate	Q		m^3/d	
Background concentration of contaminant in groundwater entering borehole	Cu		mg/l	
Entry for receiving stream				
Surface water flow upstream of discharge points under low flow conditions	Qu		m^3/d	
Background concentration of contaminant in receiving watercourse	Cu		mg/l	

Calculated Parameters

Dilution Factor	**DF**	**1.44E+01**		
Tier 2 Remedial Target	**LTC2**	**1.44E-01**	**mg/l**	For comparison with measured pore water concentration. This assumes Tier 1 Remedial Target is based on Target Concentration.
Groundwater flow below site		**or**		
		1.26E+04	**mg/kg**	For comparison with measured soil concentration. This assumes Tier 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	Groundwater flow below site

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 3 - Soil

ENVIRONMENT AGENCY

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Lead		from Tier 1
Target Concentration	C_T	0.01	mg/l	from Tier 1
Dilution Factor	DF	1.44E+01		from Tier 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in R&D Pub. 20

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Enter '1' if biodegradation rate is for the substance in water, '0' if rate is for decay in field conditions (i.e. field data from aquifer): 1

	Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	*No 1st order decay*
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source	Sz	3.39E+01	m	*Same as contaminant source (Tier 2)*
Plume thickness in aquifer at source	Sy		m	
Bulk density of aquifer materials	ρ	1.70E+00	g/cm^3	*Literature*
Effective porosity of aquifer	n	1.20E-01	fraction	*Literature*
Hydraulic gradient	i		fraction	
Hydraulic conductivity of saturated aquifer	K		m/d	
Distance to compliance point	x	1.50E+02	m	*Measured*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	9.90E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	8.75E+04	l/kg	*see options*
Longitudinal dispersivity	ax	5.42E+00	m	*see options*
Transverse dispersivity	az	5.42E-01	m	*see options*
Vertical dispersivity	ay	5.42E-02	m	*see options*

Parameter values should be checked against Tier 1 and 2

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.39E-01	m/d
Retardation factor	Rf	1.24E+06	fraction
Decay rate used	λ	6.21E-107	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	4.30E-03	fraction
Rate of contaminant flow due to retardation	u	1.92E-07	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	5.14E-01	fraction
Attenuation factor (C_O/C_{ED})	AF	1.95E+00	fraction

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Note: For Non-polar, Calculates Kd as: Kd = Koc . foc

Calculates Kd as: Kd = Koc,n(1 + 10pH-pKa)-1 + Koc,i[1-(1 + 10pH-pKa)-1]

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — 8.75E+04 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer — foc — fraction

Organic carbon partition coefficient — Koc — l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species — $K_{oc,n}$ — l/kg

Sorption coefficient for ionised species — $K_{oc,i}$ — l/kg

pH value — pH

Acid dissociation constant — pKa

Soil water partition coefficient — Kd — 8.75E+04 l/kg

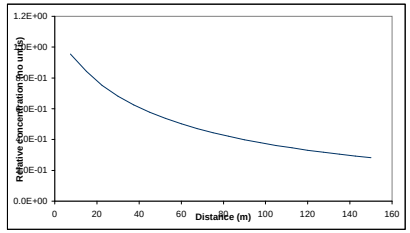
Define dispersivity (click brown cell and use pull down list)

Calculate dependant on distance to compliance point (0), specify dispersivity (1), or calc after Xu & Eckstein (2) ? 2

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	ax	0.00	15.00	5.42	m
Transverse dispersivity	az	0.00	1.50	0.54	m
Vertical dispersivity	ay	0.00	0.15	0.05	m

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Tier3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.E+99.

Calculated (relative) concentrations distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration (No units)
7.5	9.5E-01
15.0	8.4E-01
22.5	7.5E-01
30.0	6.8E-01
37.5	6.2E-01
45.0	5.8E-01
52.5	5.4E-01
60.0	5.0E-01
67.5	4.7E-01
75.0	4.5E-01
82.5	4.2E-01
90.0	4.0E-01
97.5	3.8E-01
105.0	3.6E-01
112.5	3.5E-01
120.0	3.3E-01
127.5	3.2E-01
135.0	3.0E-01
142.5	2.9E-01
150.0	2.8E-01

Remedial Targets

Remedial Target	**LTC3**	**2.81E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Tier 1 Remedial Target is based on Target Concentration.
		2.46E+04	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**150**	**m**	assumes Tier 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**5.14E-01**	**fraction**	Ogata Banks
after		**9.9E+99**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	########
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Date of Workbook Issue: April 2002

This worksheet has been produced in combination with the document 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources' - Environment Agency R&D Publication 20, (1999).

Users of this worksheet should always refer to the User Manual, to R&D Publication 20 and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error f

Details to be completed for each assessment				
Site Name:	Radcliffe Road			
Site Address:				
Completed by:	Dipalee Patel			
Date:	01-Nov-06		Version:	1
Contaminant	Arsenic			
Target Concentration (C_T)	0.01	mg/l	Origin of C_T:	UK Drinking Water Standards

This worksheet can be used to determine remedial targets for soils (Worksheets Tier 1 Soil, Tier 2 Soil and Tier 3 Soil) or to determine remedial targets for groundwater (Tier 3 Groundwater). For Tier 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Tier 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menu or require a "0", "1" or "2" to be entered. Data entry are identified as blue backgı
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The worksheet also calculates a number of frequently used hydrogeological equations.

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 1 - Soil

Select the Method of calculating the soil water Partition Co-efficient by using the Pull down menu below

User specified value for partition coefficient

Contaminant		**Arsenic**	
Target concentration	**C_T**	**0.01**	**mg/l**

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	1.20E-01	fraction	Literature
Air filled soil porosity	θa	2.90E-01	fraction	Literature
Bulk density of soil zone material	ρ	1.70E+00	g/cm^3	Literature
Henry's Law constant	H	1.86E-05	dimensionless	*Literature*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.69E+03	l/kg	*Measured*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Soil water partition coefficient used in Tier Assessment	**Kd**	**1.69E+03**	**l/kg**	*Specified value*

This sheet calculates the Tier 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Tier 1 remedial target to determine the need for further action.

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

Calculated Parameters

Tier 1 Remedial Target		**1.69E+01**	**mg/kg**	(for comparison with soil analyses)
	LTC1	**0.01**	**mg/l**	(for comparison with leachate test results)

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 2 - Soil

Contaminant		**Arsenic**		from Tier 1
Target concentration	C_T	**0.01**	**mg/l**	from Tier 1

This sheet calculates the Tier 2 remedial target for soils (mg/kg) or for pore water (mg/l). Three options are included dependent on the identified in receptor (groundwater, surface water, or groundwater abstraction). In general the assessment should be for groundwater below the site.

Select Target for Tier 2 Soil Assessment (click on brown cell below, then on pull-down menu)

Groundwater flow below site

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 2 remedial target to determine the need for further action. Equations presented in R&D Pub. 20

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**	
Standard entry					
Infiltration	Inf	2.12E-05	m/d	**lculated based on average rainfall and 99.9% hard cov**	
Area of contaminant source	A		m^2		
Entry for groundwater flow below site					
Length of contaminant source in direction of groundwater flow	L	3.39E+01	m	**Hotspot area measured from scaled plan**	
Saturated aquifer thickness	da	8.54E+00	m	**tic Surface to impermeable strata (based on data fron**	
Hydraulic Conductivity of aquifer in which dilution occurs	K	6.66E+00	m/d	**Calculated using average soakage rate over site**	
Hydraulic gradient of water table	i	0	fraction		
Width of contaminant source perpendicular to groundwater flow	w	33 9/10	m	**Hotspot area measured from scaled plan**	
Background concentration of contaminant in groundwater beneath site	Cu	8.00E-03	mg/l	**Measured from BH3**	
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**			
Enter mixing zone depth	Mz		m		*used in tier assessment*
Calculated mixing zone depth	Mz	3.61E+00	m	*used in tier assessment*	(Equation presented in Table 4.5, R&D Pub. 20)
Entry for groundwater abstraction					
Abstraction rate	Q		m^3/d		
Background concentration of contaminant in groundwater entering borehole	Cu		mg/l		
Entry for receiving stream					
Surface water flow upstream of discharge points under low flow conditions	Qu		m^3/d		
Background concentration of contaminant in receiving watercourse	Cu		mg/l		

Calculated Parameters

Dilution Factor	**DF**	**2.79E+01**		
Tier 2 Remedial Target	**LTC2**	**2.79E-01**	**mg/l**	For comparison with measured pore water concentration. This assumes Tier 1 Remedial Target is based on Target Concentration.
Groundwater flow below site		**or**		
		4.70E+02	**mg/kg**	For comparison with measured soil concentration. This assumes Tier 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	Groundwater flow below site

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 3 - Soil

ENVIRONMENT AGENCY

Input Parameters	Variable	Value	Unit	Source
Contaminant		Arsenic		from Tier 1
Target Concentration	C_T	0.01	mg/l	from Tier 1
Dilution Factor	DF	2.79E+01		from Tier 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in R&D Pub. 20

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Enter '1' if biodegradation rate is for the substance in water, '0' if rate is for decay in field conditions (i.e. field data from aquifer): 1

	Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	*No 1st order decay*
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source	Sz	3.39E+01	m	*Same as contaminant source (Tier 2)*
Plume thickness in aquifer at source	Sy		m	
Bulk density of aquifer materials	ρ	1.70E+00	g/cm^3	*Literature*
Effective porosity of aquifer	n	1.20E-01	fraction	*Literature*
Hydraulic gradient	i		fraction	
Hydraulic conductivity of saturated aquifer	K		m/d	
Distance to compliance point	x	1.50E+02	m	*Measured*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	9.90E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.69E+03	l/kg	*see options*
Longitudinal dispersivity	ax	5.42E+00	m	*see options*
Transverse dispersivity	az	5.42E-01	m	*see options*
Vertical dispersivity	ay	5.42E-02	m	*see options*

Parameter values should be checked against Tier 1 and 2

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Note: For Non-polar, Calculates Kd as: Kd = Koc . foc

Calculates Kd as: Kd = Koc,n(1 + 10pH-pKa)-1 + Koc,i[1-(1 + 10pH-pKa)-1]

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — 1.69E+03 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer — foc — fraction

Organic carbon partition coefficient — Koc — l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species — $K_{oc,n}$ — l/kg

Sorption coefficient for ionised species — $K_{oc,i}$ — l/kg

pH value — pH

Acid dissociation constant — pKa

Soil water partition coefficient — Kd — 1.69E+03 l/kg

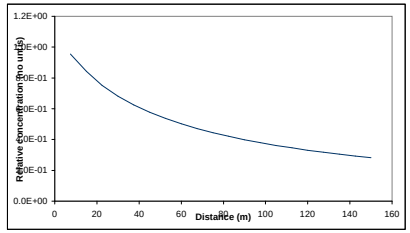
Define dispersivity (click brown cell and use pull down list)

Calculate dependant on distance to compliance point (0), specify dispersivity (1), or calc after Xu & Eckstein (2) ? 2

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00	15.00	5.42	m
Transverse dispersivity	**az**	0.00	1.50	0.54	m
Vertical dispersivity	**ay**	0.00	0.15	0.05	m

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
7.5	9.5E-01
15.0	8.4E-01
22.5	7.5E-01
30.0	6.8E-01
37.5	6.2E-01
45.0	5.8E-01
52.5	5.4E-01
60.0	5.0E-01
67.5	4.7E-01
75.0	4.5E-01
82.5	4.2E-01
90.0	4.0E-01
97.5	3.8E-01
105.0	3.6E-01
112.5	3.5E-01
120.0	3.3E-01
127.5	3.2E-01
135.0	3.0E-01
142.5	2.9E-01
150.0	2.8E-01

Calculated Parameters	Variable		
Groundwater flow velocity	v	2.30E-01	m/d
Retardation factor	Rf	2.39E+04	fraction
Decay rate used	λ	3.22E-105	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	4.15E-03	fraction
Rate of contaminant flow due to retardation	u	9.63E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	5.14E-01	fraction
Attenuation factor (C_O/C_{ED})	AF	1.95E+00	fraction

Remedial Targets

Remedial Target	**LTC3**	**5.42E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Tier 1 Remedial Target is based on Target Concentration.
		9.15E+02	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**150**	**m**	assumes Tier 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**5.14E-01**	**fraction**	Ogata Banks
after		**9.9E+99**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

This sheet calculates the Tier3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.E+99.

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	########
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Date of Workbook Issue: April 2002

This worksheet has been produced in combination with the document 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources' - Environment Agency R&D Publication 20, (1999).

Users of this worksheet should always refer to the User Manual, to R&D Publication 20 and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

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IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error f

Details to be completed for each assessment				
Site Name:	Radcliffe Road			
Site Address:				
Completed by:	Dipalee Patel			
Date:	01-Nov-06		Version:	1
Contaminant	Total PAH			
Target Concentration (C_T)	0.0001	mg/l	Origin of C_T:	UK Drinking Water Standards

This worksheet can be used to determine remedial targets for soils (Worksheets Tier 1 Soil, Tier 2 Soil and Tier 3 Soil) or to determine remedial targets for groundwater (Tier 3 Groundwater). For Tier 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparision with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).
Site details entered on this page are automatically copied to Tier 1, 2 and 3 Worksheets.
Worksheet options are identified by brown background and employ a pull-down menu or require a "0", "1" or "2" to be entered. Data entry are identified as blue backgı
Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.
It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The worksheet also calculates a number of frequently used hydrogeological equations.

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 1 - Soil

Select the Method of calculating the soil water Partition Co-efficient by using the Pull down menu below

User specified value for partition coefficient

Contaminant		**Total PAH**		
Target concentration	**C_T**	**0.0001**	**mg/l**	

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Water filled soil porosity	θ_w	1.20E-01	fraction	Literature
Air filled soil porosity	θa	2.90E-01	fraction	Literature
Bulk density of soil zone material	ρ	1.70E+00	g/cm^3	Literature
Henry's Law constant	H	1.86E-05	dimensionless	*Literature*
Entry if specify partition coefficient (option)				
Soil water partition coefficient	Kd	1.22E+04	l/kg	*Measured*
Entry for non-polar organic chemicals (option)				
Fraction of organic carbon (in soil)	foc		fraction	
Organic carbon partition coefficient	Koc		l/kg	
Entry for ionic organic chemicals (option)				
Sorption coefficient for neutral species	$K_{oc,n}$		l/kg	
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg	
pH value	pH		pH units	
Acid dissociation constant	pKa			
Soil water partition coefficient used in Tier Assessment	**Kd**	**1.22E+04**	**l/kg**	*Specified value*

This sheet calculates the Tier 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.

The measured soil concentration as mg/kg should be compared with the Tier 1 remedial target to determine the need for further action.

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

Calculated Parameters

Tier 1 Remedial Target		**1.22E+00**	**mg/kg**	(for comparison with soil analyses)
	LTC1	**0.0001**	**mg/l**	(for comparison with leachate test results)

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 2 - Soil

ENVIRONMENT AGENCY

Contaminant		**Total PAH**		from Tier 1
Target concentration	C_T	**0.0001**	**mg/l**	from Tier 1

This sheet calculates the Tier 2 remedial target for soils (mg/kg) or for pore water (mg/l). Three options are included dependent on the identified in receptor (groundwater, surface water, or groundwater abstraction). In general the assessment should be for groundwater below the site.

Select Target for Tier 2 Soil Assessment (click on brown cell below, then on pull-down menu)

Groundwater flow below site

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 2 remedial target to determine the need for further action. Equations presented in R&D Pub. 20

Input Parameters	**Variable**	**Value**	**Unit**	**Source of parameter value**
Standard entry				
Infiltration	Inf	2.12E-05	m/d	**lculated based on average rainfall and 99.9% hard cov**
Area of contaminant source	A		m^2	
Entry for groundwater flow below site				
Length of contaminant source in direction of groundwater flow	L	3.39E+01	m	**Hotspot area measured from scaled plan**
Saturated aquifer thickness	da	8.54E+00	m	**Phreatic Surface to impermeable strata**
Hydraulic Conductivity of aquifer in which dilution occurs	K	6.66E+00	m/d	**Calculated using average soakage rate over site**
Hydraulic gradient of water table	i	0	fraction	
Width of contaminant source perpendicular to groundwater flow	w	33 9/10	m	**Hotspot area measured from scaled plan**
Background concentration of contaminant in groundwater beneath site	Cu	9.00E-05	mg/l	**Assumed (<0.01mg/l)**
Define mixing zone depth by specifying or calculating depth (using pull down list)		**Calculate**		
Enter mixing zone depth	Mz		m	*used in tier assessment*
Calculated mixing zone depth	Mz	3.61E+00	m	*used in tier assessment* (Equation presented in Table 4.5, R&D Pub. 20)
Entry for groundwater abstraction				
Abstraction rate	Q		m^3/d	
Background concentration of contaminant in groundwater entering borehole	Cu		mg/l	
Entry for receiving stream				
Surface water flow upstream of discharge points under low flow conditions	Qu		m^3/d	
Background concentration of contaminant in receiving watercourse	Cu		mg/l	

Calculated Parameters

Dilution Factor	**DF**	**1.44E+01**		
Tier 2 Remedial Target	**LTC2**	**1.44E-03**	**mg/l**	For comparison with measured pore water concentration. This assumes Tier 1 Remedial Target is based on Target Concentration.
Groundwater flow below site		**or**		
		1.76E+01	**mg/kg**	For comparison with measured soil concentration. This assumes Tier 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)	Cc	0.00E+00	mg/l	
Calculated concentration within receptor (dilution only)		0.00E+00	mg/l	Groundwater flow below site

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	01-Nov-06
Version:	1

R&D Publication 20 Remedial Targets Worksheet, Release 2.2a

Tier 3 - Soil

ENVIRONMENT AGENCY

Input Parameters

	Variable	Value	Unit	Source
Contaminant		Total PAH		from Tier 1
Target Concentration	C_T	0.0001	mg/l	from Tier 1
Dilution Factor	DF	1.44E+01		from Tier 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks — Equations in R&D Pub. 20

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Enter '1' if biodegradation rate is for the substance in water, '0' if rate is for decay in field conditions (i.e. field data from aquifer): **1**

	Variable	Value	Unit	Source of parameter value
Half life for degradation of contaminant in water	$t_{1/2}$	9.00E+99	days	*No 1st order decay*
Calculated decay rate	λ	7.70E-101	$days^{-1}$	
Width of plume in aquifer at source	Sz	3.39E+01	m	*Same as contaminant source (Tier 2)*
Plume thickness in aquifer at source	Sy		m	
Bulk density of aquifer materials	ρ	1.70E+00	g/cm^3	*Literature*
Effective porosity of aquifer	n	1.20E-01	fraction	*Literature*
Hydraulic gradient	i		fraction	
Hydraulic conductivity of saturated aquifer	K		m/d	
Distance to compliance point	x	1.50E+02	m	*Measured*
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	
Time since pollutant entered groundwater	t	9.90E+99	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.22E+04	l/kg	*see options*
Longitudinal dispersivity	ax	5.42E+00	m	*see options*
Transverse dispersivity	az	5.42E-01	m	*see options*
Vertical dispersivity	ay	5.42E-02	m	*see options*

Parameter values should be checked against Tier 1 and 2

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Note: For Non-polar, Calculates Kd as: Kd = Koc . foc

Calculates Kd as: Kd = Koc,n(1 + 10pH-pKa)-1 + Koc,i[1-(1 + 10pH-pKa)-1]

Entry if specify partition coefficient (option)

Soil water partition coefficient — Kd — 1.22E+04 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer — foc — fraction

Organic carbon partition coefficient — Koc — l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species — $K_{oc,n}$ — l/kg

Sorption coefficient for ionised species — $K_{oc,i}$ — l/kg

pH value — pH

Acid dissociation constant — pKa

Soil water partition coefficient — Kd — 1.22E+04 l/kg

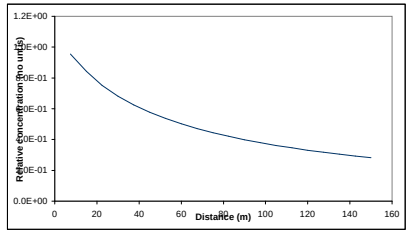
Define dispersivity (click brown cell and use pull down list)

Calculate dependant on distance to compliance point (0), specify dispersivity (1), or calc after Xu & Eckstein (2) ? **2**

		Enter value	Calc value	Xu & Eckstein	
Longitudinal dispersivity	**ax**	0.00	15.00	5.42	m
Transverse dispersivity	**az**	0.00	1.50	0.54	m
Vertical dispersivity	**ay**	0.00	0.15	0.05	m

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = $0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)
7.5	9.5E-01
15.0	8.4E-01
22.5	7.5E-01
30.0	6.8E-01
37.5	6.2E-01
45.0	5.8E-01
52.5	5.4E-01
60.0	5.0E-01
67.5	4.7E-01
75.0	4.5E-01
82.5	4.2E-01
90.0	4.0E-01
97.5	3.8E-01
105.0	3.6E-01
112.5	3.5E-01
120.0	3.3E-01
127.5	3.2E-01
135.0	3.0E-01
142.5	2.9E-01
150.0	2.8E-01

Calculated Parameters

	Variable		
Groundwater flow velocity	v	2.39E-01	m/d
Retardation factor	Rf	1.73E+05	fraction
Decay rate used	λ	4.45E-106	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	4.30E-03	fraction
Rate of contaminant flow due to retardation	u	1.38E-06	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	5.14E-01	fraction
Attenuation factor (C_O/C_{ED})	AF	1.95E+00	fraction

Remedial Targets

Remedial Target	**LTC3**	**2.81E-03**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Tier 1 Remedial Target is based on Target Concentration.
		3.43E+01	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**150**	**m**	assumes Tier 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	**C_{ED}/C_0**	**5.14E-01**	**fraction**	Ogata Banks
after		**9.9E+99**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

This sheet calculates the Tier3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks.By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Tier 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.E+99.

Site being assessed:	Radcliffe Road
Completed by:	Dipalee Patel
Date:	########
Version:	1

Environment Agency R+D20 Model Parameters, Assumptions and Limitations:

Model Parameters and Assumptions:

The parameter values used to derive the Attenuation Factor are given in the table below.

Parameters Used in Environment Agency R+D20 Model			
Parameter	**Unit**	**Value**	**Source**
Soil:water partition coefficients	l/kg	8.75E+04 (lead) 1.69E+03 (arsenic) 1.22E+04 (Total PAH)	Measured from chemical results (soil and eluate)
Target Concentration	mg/l	0.01 (lead) 0.01 (arsenic) 0.0001 (Total PAH)	UK Drinking Water Standards
Source Width (perpendicular to groundwater flow)	metres	33.9	Hotspot area (hardstanding) measured from scaled plan
Source Length (direction of groundwater flow)	metres	33.9	Hotspot area (hardstanding) measured from scaled plan
Infiltration Rate	m/day	2.12E-05	Based on average yearly rainfall in Isle of Wight (Met Office) and 99.9% hard cover. See below.
Saturated Aquifer Thickness	m	8.54	Based on average depth to impermeable strata in boreholes from phreatic surface (calculated from boreholes BH1, BH2 and BH3 drilled on-site)
Hydraulic Conductivity	m/day	6.66	Average soakage rate based on soakage tests carried out on-site
Water Filled Soil Porosity	fraction	1.20E-01	Literature – RBCA Tool Kit for Chemical Releases USCS Soil Type Properties (Based on silty sand).
Air Filled Soil Porosity	fraction	2.90E-01	Literature – RBCA Tool Kit for Chemical Releases USCS Soil Type Properties (Based on silty sand)
Bulk Density of Soil Zone Material	g/cm^3	1.70E+00	Literature – RBCA Tool Kit for Chemical Releases USCS Soil Type Properties (Based on silty sand)
Distance to Compliance Point	m	1.50E+02	Measured. See below.
Width of plume in aquifer at source	metres	33.9	Measured (assumed same as contaminant source)

The Environment Agency R+D20 model requires an input for the 'distance to compliance point' and 'width of plume at aquifer source'. As the width of the plume in the aquifer at source could not be measured, it has been conservatively assumed that the width is the same as that measured for the soil contamination thickness. A compliance point of 150m has been adopted for the analysis. This has been based on the measured distance to the nearest watercourse down groundwater gradient from the site, the River Itchen.

The soil water partition coefficient was calculated using the Tier 1 risk assessment from the leachate analysis carried out.

The infiltration rate has been based on the average yearly rainfall for the Isle of Wight, which is more realistic than a UK wide infiltration rate. The percentage of hardcover inputted into the worksheet was 99.9% as all Made Ground in areas of soft-landscaping and in proposed soakaway locations on the site will be excavated and removed from site. Therefore this risk assessment only relates to Made Ground being left under areas of permanent hardstanding, where soil infiltration rates will be negligible.

The data related to the minor aquifer underlying the site is based on a mixture of measured and literature based data. Literature was used to determine porosity and density measurements for the clay and sand deposits.

The values used for porosity and density are deemed realistic, the conductivity of the clay and sand is conservative.

The approach of the analysis is deemed very conservative and therefore any sensitivity changes are likely to increase the attenuation factors.

The literature based data used to provide values for the porosity, density and organic content of the soils underlying the site were based on silty sand deposits. The materials underlying the site consist of varying lithologies which include clays, sandy clays, sands and clayey sandy gravels. Therefore an assumed overall deposit of silty sand is realistic.