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DETAILED QUANTITATIVE RISK ASSESSMENT AND REMEDIATION UPDATE REPORT

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Client: Willowwalk (Thaxted) Developments Ltd	Subadra Consulting Ltd. Registered in England No. 4586038 Registered Office 13 Triangle Business Park, Stoke Mandeville, HP22 5BL	Report	FI03088 CL 016 Rev1
		Date	February 2019
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1 Introduction

1.1 The Purpose of This Assessment

We have been commissioned by Willowwalk (Thaxted) Developments Ltd to complete an updated Detailed Quantitative Risk Assessment for the former Southgate Service Station, Long Melford. Our assessment has generated site-specific target levels (target levels) following current best practice and adhering to current statutory guidance. The target levels correspond to the concentration of each contaminant below which poses no significant risk to controlled water receptors such as aquifers and/or nearby rivers and streams.

All the activities comprising this assessment were carried out in accordance with the procedures set out in our Quality Manual. Your attention is drawn to the Notice to Interested Parties included as Attachment One.

1.2 The Scope of This Assessment

Our assessment included:

- A review of all the available site data and any previous conceptual site models;
- A summary of remedial works carried out by the site's owner to date;
- Derivation of site-specific target levels for relevant contaminants in groundwater. These target levels are intended to be used to assess groundwater quality as part of long-term remediation works to be carried out during and following the redevelopment of the site.

Our assessment only addresses contaminants of concern associated with the site's use as stated in this report.

1.3 Previous Reports Relating to the Site

As part of our environmental assessment we have reviewed the reports listed in the following table.

Our Ref.	Report Title	Prepared By	Prepared on Behalf of	Date of Issue	Report Reference
Ref.1	Site Decommissioning Report	Subadra Consulting Ltd	Total UK Ltd	April 2005	FI03088 CL 003
Ref.2	Letter Report - Groundwater Monitoring			27th April 2005	FI03088 CL 004
Ref.3	Letter Report - Interceptor Excavation Works			30th June 2005	FI03088 CL 006
Ref.4	Letter Report - Groundwater Monitoring			27th August 2005	FI03088 CL 008
Ref.5	Detailed Quantitative Risk Assessment Report			April 2006	FI03088 CL 009

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Our Ref.	Report Title	Prepared By	Prepared on Behalf of	Date of Issue	Report Reference
Ref.6	Site Investigation Report, Detailed Quantitative Risk Assessment and Remedial Method Statement	Provectus Remediation Ltd	EA Property Developments Ltd	September 2011	100767/SI/ R001
Ref.7	Remediation Strategy and Verification Plan	Subadra Consulting Ltd	Willowwwalk (Thaxted) Developments Ltd	December 2018	Fi03088 CL 015

We have used information from these documents, where relevant, in other sections of this report.

Table One: Previous Environmental Reports Relating to the Site

1.4 Current Planning Status

Planning consent has been granted by Babergh District Council (Planning Reference 13/00875/FUL). The consent includes conditions relating to soil/groundwater contamination issues. These are reproduced below:

Condition Nine.

No development shall take place until:

(i) A strategy for investigating any contamination present on site has been submitted for approval by the Local Planning Authority;

(ii) Following approval of the strategy, an investigation shall be carried out in accordance with the strategy.

(iii) A written report shall be submitted detailing the findings of the investigation referred to in (ii) above, and an assessment of the risk posed to receptors by the contamination, for approval by the Local Planning Authority. Subject to the risk assessment, the report shall include a Remediation Scheme as required.

(iv) Any remediation work shall be carried out in accordance with the approved Remediation Scheme.

Following remediation, evidence shall be provided to the Local Planning authority verifying that remediation has been carried out in accordance with the approved remediation scheme.

Condition Ten.

1) No development approved by this planning permission shall take place until a scheme that includes the following components to deal with the risks associated with contamination of the site shall each be submitted to and approved, in writing, by the local planning authority:

1) A preliminary risk assessment which has identified:

- *all previous uses*
- *potential contaminants associated with those uses*
- *a conceptual model of the site indicating sources, pathways and receptors*
- *potentially unacceptable risks arising from contamination at the site.*

2) A site investigation scheme, based on (1) to provide information for a detailed assessment of the risk to all receptors that may be affected, including those off site.

3) The results of the site investigation and detailed risk assessment referred to in (2) and, based on these, an options appraisal and remediation strategy giving full details of the remediation measures required and how they are to be undertaken.

4) A verification plan providing details of the data that will be collected in order to demonstrate that the works set out in the remediation strategy in (3) are complete and identifying any requirements for longer-term monitoring of pollutant linkages, maintenance and arrangements for contingency action. Any changes to these components require the express written consent of the local planning authority. The scheme shall be implemented as approved.

Condition Eleven.

No occupation of any part of the permitted development shall take place until a verification report demonstrating completion of works set out in the approved remediation strategy and the effectiveness of the remediation shall be submitted to and approved, in writing, by the local planning authority. The report shall include results of sampling and monitoring carried out in accordance with the approved verification plan to demonstrate that the site remediation criteria have been met. It shall also include any plan (a "long-term monitoring and maintenance plan") for longer-term monitoring of pollutant linkages, maintenance and arrangements for contingency action, as identified in the verification plan. The long-term monitoring and maintenance plan shall be implemented as approved.

Condition Twelve.

No development should take place until a long-term monitoring and maintenance plan in respect of contamination including a timetable of monitoring and submission of reports to the Local Planning Authority, shall be submitted to and approved in writing by the Local Planning Authority.

Reports as specified in the approved plan, including details of any necessary contingency action arising from the monitoring, shall be submitted to and approved in writing by the Local Planning Authority. Any necessary contingency measures shall be carried out in accordance with the details in the approved reports.

On completion of the monitoring specified in the plan a final report demonstrating that all long-term remediation works have been carried out and confirming that remedial targets have been achieved shall be submitted to and approved in writing by the Local Planning Authority.

Condition Thirteen.

If, during development, contamination not previously identified is found to be present at the site then no further development (unless otherwise agreed in writing with the local planning authority) shall be carried out until the developer has submitted a remediation strategy to the local planning authority detailing how this unsuspected contamination shall be dealt with and obtained written approval from the local planning authority. The remediation strategy shall be implemented as approved.

Our Remediation Strategy and Verification Plan Report (Ref.7) was compiled to satisfy the parts of the planning conditions relating to the compilation of a Remediation Scheme in order to allow the development (and the remediation works which form a part of the development) to commence without further delay. We understand that this has been submitted to Bambergh District Council, together with the Site Investigation and Detailed Quantitative Risk Assessment Report (Ref.6) previously compiled by Provectus Remediation Ltd. Bambergh District Council have consulted the Environment Agency, who have commented as follows:

The DQRA undertaken by Provectus in 2011 is now out of date. The risk assessment will need to be updated taking into account current guidance including (but not exclusively):

- *CLAIRE - Petroleum Hydrocarbons in Groundwater: Guidance on the assessing of petroleum hydrocarbons using existing hydrogeological risk assessment methodologies.*
- *Land Contamination Groundwater Compliance Points: Quantitative risk assessments.*

Once the DQRA has been updated it may also be necessary to update the Subadra Remediation Strategy.

1.5 Objectives of This Report

This report provides an updated detailed quantitative risk assessment limited to an assessment of the risk to controlled waters, as requested by the Environment Agency.

2 Review of Site Data

2.1 Site Location

The site forms a roughly triangular area on the eastern side of Southgate Street, at the southern edge of Long Melford, Suffolk. The site's grid reference is 586178 244687 and it is approximately 31m above Ordnance Datum.

2.2 Site Description

The site has previously been used as a retail filling station. We decommissioned the site, removing the forecourt canopy, the known underground tanks and the site's interceptor in 2005/6. The site shop was left in place. Since then we understand that the site has remained derelict.

Figure One: The Site Viewed from the Road - September 2016

2.3 Site History (Ref.6 Section 2)

Historical maps show that the site was not developed until 1973, at which point a retail filling station was constructed. The filling station comprised four below-ground and two above-ground fuel storage tanks, a shop building and canopy. The site continued to operate as a filling station until 2004 and was decommissioned by us the following year with the known petroleum infrastructure being removed.

2.4 Ground Conditions (Refs. 1, 3, 5 and 6)

The site has been very extensively investigated over a number of years. In summary, the following have been completed:

- 2001/2 - Arcadis[1] constructed nine boreholes and five trial pits;
- 2004/6 - Subadra excavated and removed 575tonnes of contaminated soil and constructed a further fourteen trial pits;
- 2008/10 - Arcadis constructed ten boreholes and eighteen trial pits;
- 2011 - Provectus constructed nine boreholes and five trial pits.

Given the extent of the previous investigation works, in relation to the size of the site, we consider it unlikely that there would be significant benefit in carrying our further site investigation. The previous ground investigations confirmed the following geological strata beneath the site:

- Made Ground - LOOSE to MEDIUM DENSE grey brown slightly clayey sandy GRAVEL. This layer was generally less than 0.5m in thickness other than where tanks etc had been removed.
- River Terrace Deposits/Head Deposits - Interbedded SOFT to FIRM dark grey slightly sandy CLAY and MEDIUM DENSE grey fine to medium SAND with frequent gravel. This layer was present to between 2.2m and 2.8m depth below ground level. The River Terrace Deposits are classified as a Secondary Aquifer.
- Upper Chalk Formation - SOFT white putty CHALK. This layer was present from around 7m depth. The Upper Chalk Formation is classified as Principal Aquifer.

2.5 Groundwater

Our previous ground investigation confirmed groundwater to be present in the River Terrace Deposits at approximately 1.8m to 2.4m below ground level (Ref. 6). The nearest surface water is the River Stour, approximately 180m to the west and the nearest public water abstraction is ~2km to the south-east. The site lies within Zone II of a currently defined Source Protection Zone.

2.6 Contamination Observations from Previous Work by Others - Soil (Ref. 6)

Provectus summarised the contamination in soil as follows:

'Provectus 2011

Made Ground was encountered in some of the exploratory hole positions and Made Ground is commonly associated with the presence of contamination especially as ash and hydrocarbon odours were noted in some of the units.

[1] We have not had sight of any reports produced by Aracdis. Data from them reported here is based on summaries of the Arcadis reports provided by Provectus.

Some strong hydrocarbon odours were noted throughout the clay unit encountered in window sample WS5 (0.5m to 2.2m) and the lower section of the Made Ground unit (between 2.5m and 3.8mbgl) in borehole BHPR01. In addition strong hydrocarbon odours and dark black/blue and grey staining were noted within the top section of the sand and gravel unit in TP5 (1.6m to 2.7m), WS5 (2.2m to 3.2m), WS6 (1.9m to 3.7m and BHPR01 (3.8m to 4.7m).

Subadra\Arcadis

The underground tanks have been removed as part of the remedial works along with the two above ground tanks which housed leaded, unleaded, diesel and kerosene respectively (sic). During the works approximately 575tonnes on non-hazardous classified contaminated material (hydrocarbons) were removed from site to landfill. Residual hydrocarbon contaminated material may still remain in locations where source material has previously been removed. During the works undertaken by Subadra soil samples were collected from the sides and base of the excavation.

Arcadis reported measured concentrations of benzene, toluene, ethylbenzene and xylenes, MTBE, TPH fractions, PAHs and Chromium across the site, from a range of depths, in exceedance of the site specific assessment criteria defined for protection of on-site residents. Black staining was noted on the soil sample from BH301 between 0.6m and 15.0mbgl.

Following additional site investigation and risk assessment in 2009 Arcadis summarised that the following compounds exceeded their respective SSAC.

BH301 (0.6-1.2m) *Benzene, ethylbezene, xylenes, aliphatic C_5-C_6, aliphatic C_8-C_{16} and aromatic C_8-C_{16}*

TP303 (0.8-1.0m) *Benzene, aliphatic C_5-C_6 and aromatic C_8-C_{16}*

TP304 (1.0-1.5m) *Benzene and xylenes*

TP307 (1.0-1.05m) *Aliphatic C_{12}-C_{16}*

TP309 (1.5-1.8m) *Benzene, toluene, ethylbenzene and xylenes'*

2.7 Contamination Observations from Previous Work by Others - Groundwater (Ref. 6)

Provectus summarised the contamination in soil as follows:

'Provectus 2011

Groundwater was encountered in all the borehole locations during the site investigation works. The cable percussion driller recorded water strikes at 2.8m, 3.0m and 3.1mbgl respectively within the Made Ground and sand and gravel units. Groundwater seepage (fast) was noted during trial pitting at all five locations and levels ranged between 2.5mbgl and 2.9mbgl.

Standing water during the subsequent Provectus monitoring visits was encountered in all borehole locations (Provectus and historic). The water levels ranged between 1.76m to 2.40m within the Made Ground and sand and gravel unit.

As with the previous monitoring undertaken by Arcadis (February and March 2009) Provectus noted free-phase product in BH206 and BH301 and although the exact thickness could not be quantified an approximate thickness of 20mm was noted in both locations.

Arcadis

Arcadis reported the measured concentration of benzene sampled from BH9 (April and July 2008) and BH205 (July 2008) exceeds the Arcadis SSAC defined for the protection of neighbouring residents. Groundwater monitoring undertaken by Arcadis in 2009 measured concentrations of benzene and aromatic C_8-C_{10} that were in excess of SSAC human health receptors based on residential end-use.

Free-phase product was identified in BH206 and BH301. During February 2009 approximately 110mm of LNAPL was encountered in BH206, laboratory whole oil fingerprint analysis described the samples as a burnt amber liquid identified as gasoline, kerosene residues. During March 2009 a viscous dark brown product was encountered in BH301.

The distribution of the contamination within groundwater was considered to be to the east and south of the former underground storage tanks in the vicinity of the free-phase located in wells BH206 and BH301.'

The Provectus investigation work added little, if anything to our understanding of the site conditions, which we consider are better represented by the later of the work completed by Arcadis. Provectus provided site specific target levels for the site but these have also now been rejected by the Environment Agency.

2.8 Contamination Observations - 2018

In order to confirm the lateral extent of the hydrocarbons in the soil we constructed a series of fifteen trial pits across the site with samples taken from the visually most contaminated layer, in all cases between 2m and 4m depth. Samples were also taken for waste classification analysis to assist with subsequent excavation and off-site disposal of soil.

The location of these trial pits is shown in Figure Two below, together with the maximum concentration of Total Petroleum Hydrocarbons and Benzene detected in each trial pit.

The data from the trial pits confirmed the following:

- The hydrocarbons do not extend to the northern boundary of the site (EX112 and EX113);
- The hydrocarbons do not extend to the south western boundary of the site (EX107 and EX109)
- Significant hydrocarbon concentrations were detected in the centre of the site (EX108, EX110, EX114 and EX115).

Based on these data we concluded:

- Any soil excavation should extend to 4m depth;
- The sand and gravel layers in the upper 1m-2m should be stockpiled separately and assessed to determine whether it is suitable for re-use at the site;
- Contaminated soil should be disposed to an appropriately licensed site, with waste management documentation included in a verification report;
- Excavations should be backfilled with clean, inert material and compacted in accordance with relevant current standards.

The extent of soil contamination existing at the site prior to remediation is summarised in Figure Three.

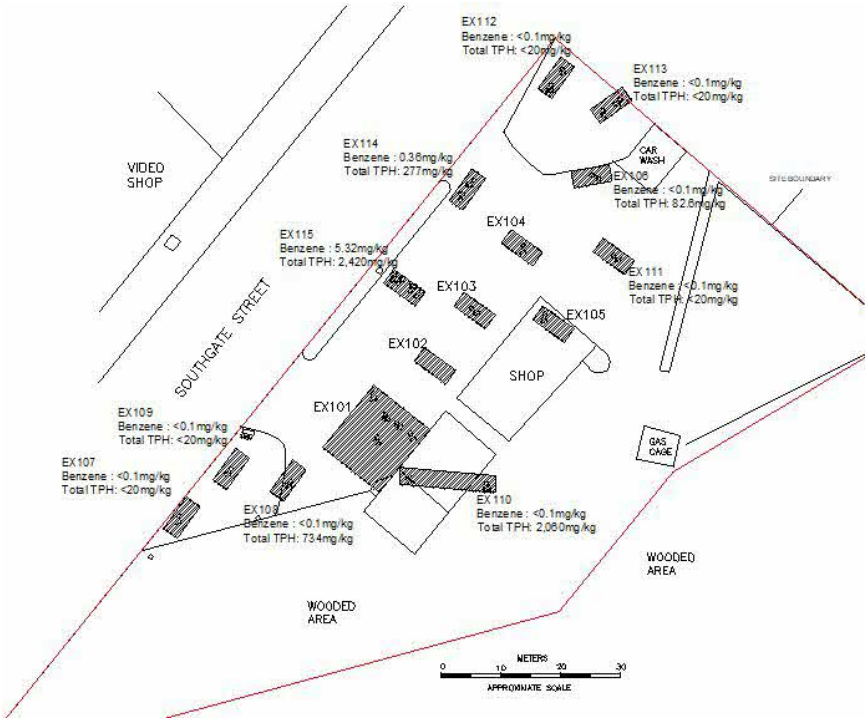

Figure Two: Trial Pits to Determine Lateral Extent of Hydrocarbons in the Soil

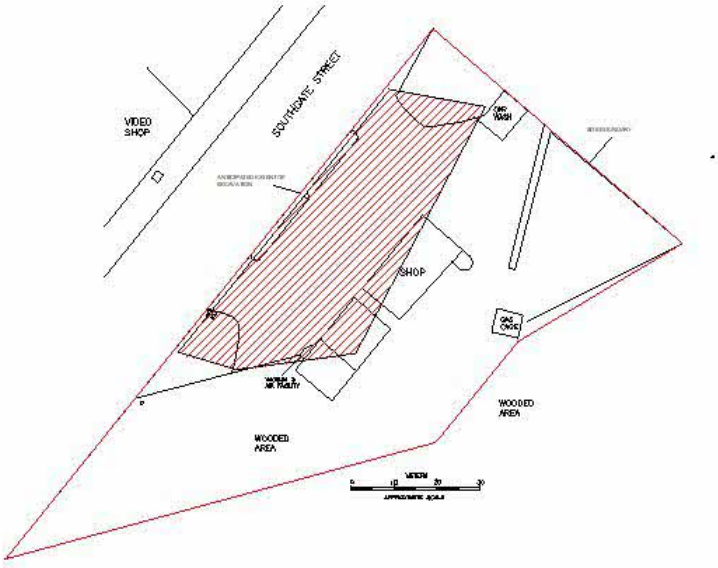

Figure Three: Anticipated Extent of Contaminated Soil Requiring Excavation

3 Summary of Remedial Works Carried Out by the Site Owner

Our client carried out targeted excavation and removal of hydrocarbon-impacted soil from within the area highlighted in Figure Three on the previous page. We have been provided with copies of the waste management documentation and these are summarised in the Table below:

Date	Haulier	Transfer Ticket Numbers	Destination	Tonnes	Classification
8th November 2018	TJ&WM Cardy Ltd WAFF No. 11603	33001-33003 33051-33053	MGL Transfer Station, Cowley Road, Cambridge	114.68	Contaminated Non-hazardous
9th November 2018		32580-32582 33054-33056 32665-32667		167.16	
12th November 2018		32583-32585 32709-32711 33057-33059		165.02	
13th November 2018		32712,32713, 32581,32586, 32588,32678, 33062		131.10	
		32587,33061		Not known	Mixed Inerts
14th November 2018		32589,32590, 32681,32683, 32685,32714, 32715,32719, 33063-33065		202.02	Contaminated Non-hazardous
20th November 2018		33067/32858, 33066/32857, 33068/32856, 32600/33519, 33156/33155, 33158/33157		115.78	
21st November 2018		33603-33608, 32720/33209, 32721/33210, 32722/33211, 33069/32859, 33070/32860, 33071/32861, 33160/33161		220.38	

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Date	Haulier	Transfer Ticket Numbers	Destination	Tonnes	Classification
21st November 2018	TJ&WM Cardy Ltd WAFF No. 11603	33166, 33168, 33170, 32862	MGL Transfer Station, Cowley Road, Cambridge	73.12	Contaminated Non-hazardous

Table Two: Summary of Material Removed to Landfill

A total of 1,189.26 tonnes of soil was removed during the excavation works. We carried out limited soil sampling and chemical analysis of the excavated soil stockpiled prior to disposal. The results of these analyses are summarised below:

Analyte	Unit	Sample Details								
		SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003
		0.1m	0.1m	0.1m	0.3m	0.3m	0.3m	0.5m	0.5m	0.5m
MTBE	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<1	<0.5	<0.5	<0.5
Benzene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
Toluene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
Ethylbenzene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
p+m Xylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1
o Xylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1

Analyte	Unit	Sample Details					
		SH003	SH003	SH003	SH003	SH003	SH003
		0.8m	0.8m	0.8m	1.0m	1.0m	1.0m
MTBE	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Toluene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Ethylbenzene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
p+m Xylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
o Xylene	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table Three: BTEX Results - Excavated Spoil Heap

Analyte	Unit	Sample Details				
		SH003	SH003	SH003	SH003	SH003
		0.1m	0.3m	0.5m	1.0m	1.0m
C_{6-8} Aliphatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5
$>C_{8-10}$ Aliphatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5
$>C_{10-12}$ Aliphatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5
$>C_{12-16}$ Aliphatic TPH	mg/kg	<5	<5	<5	<5	<5
$>C_{16-21}$ Aliphatic TPH	mg/kg	<5	<5	<5	<5	<5
$>C_{21-35}$ Aliphatic TPH	mg/kg	<10	<10	<10	<10	<10
C_{6-8} Aromatic TPH	mg/kg	<1	<1	<1	<1	<1
$>C_{8-10}$ Aromatic TPH	mg/kg	<1	<1	<1	<1	<1
$>C_{10-12}$ Aromatic TPH	mg/kg	<1	<1	<1	<1	<1
$>C_{12-16}$ Aromatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5
$>C_{16-21}$ Aromatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5
$>C_{21-35}$ Aromatic TPH	mg/kg	<2.5	<2.5	<2.5	<2.5	<2.5

Table Four: Speciated TPH Results - Excavated Spoil Heap

Analyte	Unit	Sample Details									
		SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003
		0.1m	0.1m	0.3m	0.3m	0.5m	0.5m	0.8m	0.8m	1.0m	1.0m
C_{6-8} TPH Band	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
$>C_{8-10}$ TPH Band	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
$>C_{10-12}$ TPH Band	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	0.878	<0.5	1.66	<0.5	<0.5
$>C_{12-16}$ TPH Band	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	1.71	<0.5	1.26	<0.5	<0.5
$>C_{16-21}$ TPH Band	mg/kg	2.21	0.957	1.08	1.85	0.801	0.818	1.26	1.1	0.805	0.69
$>C_{21-35}$ TPH Band	mg/kg	6.4	2.22	2.12	3.7	0.547	<0.5	1.98	<0.5	2.53	<0.5

Table Five: Banded TPH Results - Excavated Spoil Heap

Analyte	Unit	Sample Details							
		SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003
		0.1m	0.1m	0.3m	0.5m	0.5m	0.8m	0.8m	1.0m
Naphthalene	mg/kg	< 0.1	< 0.1	<0.1	< 0.1	< 0.1	<0.1	< 0.1	< 0.1
Acenaphthylene	mg/kg	< 0.1	0.17	0.24	0.18	0.14	0.14	0.17	0.13
Acenaphthene	mg/kg	< 0.1	< 0.1	<0.1	< 0.1	< 0.1	<0.1	< 0.1	< 0.1
Fluorene	mg/kg	< 0.1	0.12	0.29	0.16	0.13	<0.1	0.17	< 0.1
Phenanthrene	mg/kg	0.87	0.49	1.84	1.42	0.21	<0.1	0.88	0.14
Anthracene	mg/kg	0.25	0.25	0.66	0.52	0.18	0.16	0.37	0.15
Fluoranthene	mg/kg	1.57	1.02	4.76	3.78	0.6	0.8	1.53	0.4
Pyrene	mg/kg	1.37	0.92	4.11	3.32	0.55	0.74	1.26	0.35
Benzo(a)anthracene	mg/kg	0.73	0.84	2.39	1.87	0.68	0.81	1	0.54
Chrysene	mg/kg	0.69	0.44	1.78	1.46	0.25	0.28	0.58	0.14
Benzo(b)fluoranthene	mg/kg	1.04	1.35	2.74	2.33	0.88	1.09	1.2	0.68
Benzo(k)fluoranthene	mg/kg	0.44	0.33	1.08	0.71	0.16	0.48	0.3	< 0.1
Benzo(a)pyrene	mg/kg	0.81	1	2.18	1.78	0.51	0.89	0.76	0.37
Indeno(1,2,3-cd)pyrene	mg/kg	0.74	1.03	1.65	1.55	0.71	0.94	0.89	0.61
Dibenzo(ah)anthracene	mg/kg	0.24	0.49	0.62	0.54	0.44	0.56	0.46	0.42
Benzo(ghi)perylene	mg/kg	0.63	0.77	1.02	1.17	0.5	0.52	0.62	0.39
Total PAHs (EPA16)	mg/kg	9.4	9.2	25.4	20.8	5.9	7.4	10.2	4.3

Table Six: PAH Results - Excavated Spoil Heap

Analyte	Unit	Sample Details							
		SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003
		0.1m	0.5m	1.0m	0.2m	0.3m	0.4m	0.5m	0.8m
Arsenic	mg/kg	13	11	12	11	12	12	12	12
Barium	mg/kg	61	57	58	52	66	56	57	54
Beryllium	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1
Boron (Water Soluble)	mg/kg	< 1	< 1	< 1	1.1	< 1	< 1	< 1	< 1
Cadmium	mg/kg	0.2	0.2	0.2	< 0.2	0.2	0.2	0.2	0.2

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Analyte	Unit	Sample Details							
		SH003	SH003	SH003	SH003	SH003	SH003	SH003	SH003
		0.1m	0.5m	1.0m	0.2m	0.3m	0.4m	0.5m	0.8m
Chromium	mg/kg	16	20	16	18	19	18	19	17
Chromium (Hexavalent)	mg/kg	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Copper	mg/kg	20	18	20	16	23	20	18	18
Lead	mg/kg	52	43	41	31	47	40	43	41
Nickel	mg/kg	14	16	16	15	17	17	17	15
Selenium	mg/kg	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Vanadium	mg/kg	37	30	32	32	35	34	34	33
Zinc	mg/kg	96	78	91	83	91	88	90	87

Table Seven: CLEA Metals Results - Excavated Spoil Heap

At the time of reporting the excavation remains open and has yet to be backfilled.

4 Conceptual Site Model

4.1 Source - Contaminants of Concern

Contaminants	Areas Affected	Pathways	Receptors	Comment
PAHs Benzene TPH Aliphatic C_{12}-C_{16} Phytotoxic metals	Made Ground Clay components of River Terrace Deposits	Direct contact, ingestion, inhalation, surface run-off, horizontal and vertical migration of contaminants in permeable soils, uptake by vegetation.	Construction workers, future site occupants Buried services Flora and vegetation	Provision of a cover layer in areas of contamination and excavation of gross contamination (i.e. identified hotspots). Dust suppression measures during construction work. Appropriate PPE during works. **Note: This work has already been completed - see previous Section of this report.**

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Contaminants	Areas Affected	Pathways	Receptors	Comment
Benzene TPH Aliphatic C_{12}-C_{35}	Groundwater within sand and gravel components of River Terrace Deposits	Lateral and vertical migration of contaminants in groundwater	Controlled waters (River Stour) Construction workers, future site occupants Buried services	Localised hydrocarbon/benzene impacted groundwater within the sands and gravels require remedial mitigation measures (eg ex-situ pump and treat and oxygenation). Appropriate PPE during works.
Sulphates	Made Ground Clay components of River Terrace Deposits	Direct contact	Concrete foundations, building fabric and services	Appropriate sulphate-resistant materials for building foundations and services.
Soil gases and vapours	Made Ground River Terrace Deposits	Inhalation	Construction workers and future site occupants	High risk from methane gas. Elevated hydrocarbons/BTEX for inhalation in Made Ground locally on site and vapours have been identified. Appropriate precautions should be taken to protect groundworkers and the proposed development (appropriate gas protection measures in all buildings).
Free-phase hydrocarbons on groundwater	River Terrace Deposits	Direct contact Percolation through fills/surface run-off	Construction workers, future site occupants Surface water - River Stour	Removal of free-phase and treatment through an approved treatment system during redevelopment. Offsite disposal of recovered product Appropriate PPE during works.

Table Eight: Contaminants of Concern

The contaminants contained in the unsaturated soil under the site have already been excavated and removed as detailed in our Remedial Strategy and Verification Plan (Ref.7). We have therefore not assessed the risk posed by these contaminants further.

This updated detailed quantitative risk assessment assesses the risk posed to environmental receptors by hydrocarbons in the saturated soil and groundwater.

We assessed the risk to human receptors in our Remedial Strategy and Verification Plan. The target levels we calculated to mitigate these risks and which we reported in that document remain valid.

4.2 Source Delineation - Saturated Soil and Groundwater

The site data shows hydrocarbon-impacted soil largely coincident with the groundwater table. When analysing saturated soil samples, it is impossible to determine the proportion of hydrocarbons adsorbed onto the soil and the proportion dissolved in the soil's pore fluid. However, it is reasonable to assume that any hydrocarbons adsorbed onto the soil particles will first partition into the pore fluid before migrating to a receptor via groundwater. We have therefore only considered a dissolved hydrocarbon source in this risk assessment. For the purposes of this assessment we have assumed that the area of saturated soil and groundwater impacted by hydrocarbons is the same as the area of unsaturated soil requiring excavation presented in Figure Three.

4.3 Source Concentrations

The locations of groundwater monitoring wells remaining at the site in November 2018 are shown in Figure Four below.

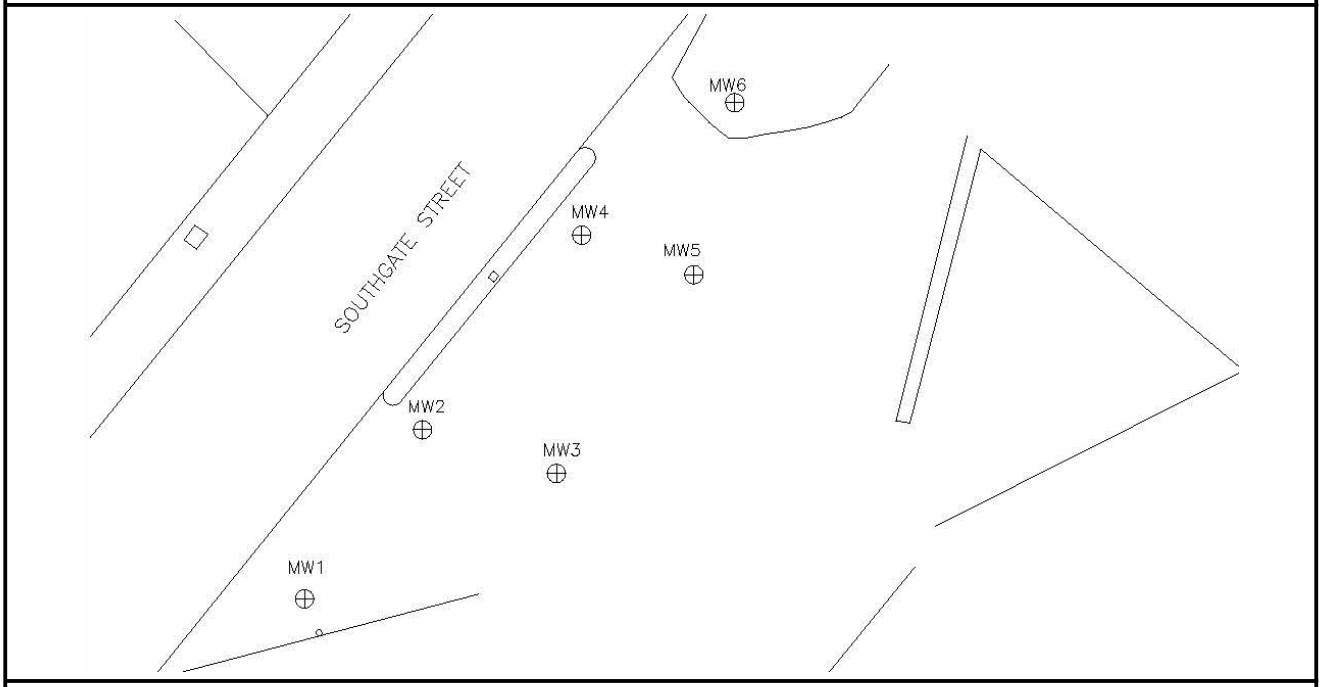

Figure Four: Monitoring Wells - November 2018

We sampled these wells on 15th November 2018, with each sample analysed for BTEX compounds and for speciated TPH groups. The maximum concentrations of hydrocarbons that we detected are summarised in Table Three below.

Contaminant of Concern	Maximum Concentration in Groundwater - November 2018 (μg/litre)
Benzene	1,960 (MW4)
Ethylbenzene	7,300 (MW4)
MTBE	2,840 (MW4)
Toluene	15,600 (MW4)
Xylenes	42,000 (MW4)
TPH Aromatic C_{8-10}	40,300 (MW3)
TPH Aromatic C_{10-12}	18,400 (MW3)
TPH Aromatic C_{12-16}	12,500 (MW3)
TPH Aromatic C_{16-21}	567 (MW2)
TPH Aromatic C_{21-35}	Not Detected

Table Nine: Concentrations of Contaminants of Concern

Note that the target levels we have derived are independent of their initial source concentrations. These have been included here for information only.

5 Detailed Quantitative Risk Assessment

5.1 Methodology – Risk to Controlled Waters

We have evaluated the risk to controlled water receptors using the Environment Agency's 'Remedial Targets Methodology Hydrogeological Risk Assessment for Land Contamination' (RTM). We have used RTM to determine targets for the site that will be protective of groundwater.

To do this we use a fate-transport model to calculate the likely impact on groundwater quality in hypothetical compliance wells located 50m and 100m from the contaminant source. We have then determined the maximum concentration of each contaminant that will not give rise to a concentration in the compliance well that exceeds pre-determined criteria.

In this assessment the compliance criteria comprise Environmental Quality Standards and/ or UK Drinking Water Standards.

Full details of the model's input parameters are included as Attachment Three.

5.2 Results

Compound	Solubility Limit (µg/l)	Site-Specific Target (µg/litre)	
		Compliance Point at 50m	Compliance Point at 100m
Benzene	1,780,000	29.5	139
Ethylbenzene	180,000	165	1,680
MTBE	51,000,000	145	1,020
Toluene	590,000	302,000	Solubility
Xylenes	191,000	145	1,020
TPH Aromatic C_{8-10}	65,000	242	1,690
TPH Aromatic C_{10-12}	25,000	350	3,180
TPH Aromatic C_{12-16}	5,800	484	5,480
TPH Aromatic C_{16-21}	510	110	406
TPH Aromatic C_{21-35}	6.6	Solubility	Solubility

Note: Sol – target is greater than solubility limit.: target is removal of free-phase, if present.

Table Ten: Groundwater Targets - Protective of Controlled Water Receptors

6 Discussion

6.1 Conclusions

This assessment has generated site-specific target levels following current best practice and adhering to current statutory guidance. These have been calculated to ensure that contaminant concentrations in the soil and groundwater below the target levels do not pose a significant risk to controlled water receptors such as aquifers and/or nearby rivers and streams. These are summarised in the Table Four above.

6.2 Recommendations

We recommend that our Remedial Strategy and Verification Plan be reviewed and, if necessary, revised once the soil excavation works have been completed and following post-excavation groundwater modelling, including monitoring for natural attenuation processes.

Specifically, we recommend that the need for additional groundwater treatment measures, such as active groundwater pump and treatment, be considered, depending on whether free-phase hydrocarbons remain under the site and on the concentrations of dissolved-phase hydrocarbons recorded in each of the various monitoring wells.

6.3 Limitations and Uncertainties

These target levels are appropriate for the assessment of groundwater quality in connection with the site's current use and any proposed redevelopment detailed in this report. They may not be appropriate for other uses or redevelopment schemes. Should any work on site encounter conditions varying to those used in our assessment, then the target levels should be reviewed and, if necessary, revised.

The basis of our risk assessment, together with our assumptions and input values, has not been agreed with the relevant regulatory authorities. The target levels presented in this report should be discussed and agreed with the relevant regulatory authorities prior to their use. Our models are reliant on data from limited investigations of the site and from literature-sourced values. Other conditions may exist in areas of the site that have not been fully investigated and which may invalidate the target values we have calculated. In this case, the target levels should be reviewed and, if necessary, revised.

Permeation of hydrocarbons into drinking water supply pipes poses a potential risk to on-site workers. This pathway has not been directly assessed by the numerical model. We have recommended/we recommend testing of drinking water supplies is carried out to determine whether any impact has occurred.

7 References

1. Subadra Consulting Ltd (April 2005) "Site Decommissioning Report", FI03088 CL 003.
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4. Subadra Consulting Ltd (August 2005) "Letter Report - Groundwater Monitoring", FI03088 CL 008
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6. Provectus Remediation Ltd (Septembber 2011) "Site Investigation Report, Detailed Quantitative Risk Assessment and Remedial Method Statement", 100767/SI/R001.
7. Subadra Consulting Ltd (December 2018) "Remediation Startegy and Verification Plan", FI03088 CL 015
8. Gustafson et al. (July 1997). 'Selection of Representative TPH Fractions Based on Fate and Transport Considerations' Total Petroleum Hydrocarbon Criteria Working Group Series Volume 3.
9. Environment Agency (November 2008). 'Compilation of Data for Priority Organic Pollutants for Derivation of Soil Guideline Values' Science Report SC050021/SR7
10. BP Oil International (2001). 'Risk-Integrated Software for Clean-ups, Users Manual Version 4.0', BP, Middlesex.
11. Environment Agency (2006). 'Remedial Targets Methodology. Hydrogeological Risk Assessment for Land Contamination' Environment Agency, Bristol
12. Environment Agency (January 2009). 'Updated Technical Background to the CLEA Model' Science Report SC050021/SR3
13. Environment Agency (April 2003). 'Fact Sheet for RISC', Fact Sheet FS-04.
14. Environment Agency (November 2012). 'Groundwater protection: Principles and practice (GP3)' Version 1. Environment Agency, Bristol.

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ATTACHMENT ONE:
NOTICE TO INTERESTED PARTIES

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NOTICE TO INTERESTED PARTIES

The purpose of our work is to provide general information on the environmental and/or geotechnical conditions existing at the site and related to soil and/or groundwater. The Client or others specified the scope of the investigation and the validity of our conclusions is limited by the scope of work specified. We are not responsible for any such limitations or omissions.

Where stated in this report, we have used information supplied by third parties. While we have evaluated as far as possible the validity of this information, we cannot guarantee its accuracy in any way whatsoever.

No investigation technique is capable of completely identifying all of the contaminants that might be present in the soil or groundwater under a site. Where specified in our report, we have examined the ground by constructing a number of boreholes and/or trial pits. We recovered samples of soil and/or groundwater from available exposures.

The depth and spacing of our Sampling locations were selected to ensure with a reasonable probability that they would be representative of the actual conditions across the whole site. However, safety considerations relating to existing site infrastructure may have restricted our ability to investigate all potential contaminant sources. Specifically, we were unable to investigate the soil and groundwater condition immediately adjacent to the underground structures and/or buried services. These limitations must be borne in mind when considering the conclusions reached in this report.

Soil is intrinsically variable and the spread of contaminants within the soil is therefore subject to a degree of non-uniformity. For these reasons no sampling technique can completely eliminate the possibility of obtaining samples that are not representative of the actual conditions. Our sampling techniques are intended to reduce the possibility to an acceptable level, within the limits imposed by the scope of the investigation.

Groundwater levels and soil vapour levels that we report were accurate at the time of the investigation. Groundwater and soil vapour levels are variable. Long term monitoring may be required to ensure that the levels recorded during our investigation are representative of long term and possible 'worst case' conditions. In accepting our recommendations and/or conclusions the Client acknowledges that further, more detailed investigation would allow a more accurate assessment of site conditions to be made and that this would reduce any consequential risk to the Client.

Our investigation was carried out to assess the significance of contamination resulting from use of the site as identified in this report. Unless we have indicated otherwise, no assessment of the potential impact of any other previous uses has been made. No investigation was carried out to determine whether or not any deleterious or hazardous materials (such as asbestos) have been used in the construction of the buildings present on the site. Unless otherwise stated no investigation or assessment has been made of the presence or otherwise of invasive plant species including but not limited to Japanese Knotweed.

Unless specifically stated otherwise, we have not assessed the effect of any proposed future construction activities on existing structures on or near to the site. Nor, unless stated otherwise, have we assessed the likely effect of trees on existing or proposed structures on or near the site.

We do not accept any responsibility for the cost of remedial works or other costs incurred in whatever way whatsoever as a result of any omissions, errors or other shortcomings in this report unless we have been given reasonable opportunity to verify ourselves that such faults exist and we have been given a reasonable opportunity to carry out works to remedy such faults ourselves using the most practicable means available to us. We do not accept liability for any consequential losses incurred by you while either we or others carry out any remedial works we deem necessary.

This report has been prepared for the Client, as specified on the cover page of this report. In accepting our recommendations and/or conclusions the Client accepts that the terms of our appointment were as detailed in the Proposal, or Proposals, that we provided to the Client before being appointed and that these terms supersede any other terms and/or conditions set out in any contracts agreed between ourselves and the Client, regardless of when such terms and/or conditions were agreed to by us and/or signed by us.

Use of, and reliance on, this report by other third parties will be at such third parties own risk, and we do not accept any liability or responsibility to them.

Neither the whole nor any part of this report, or any reference to it, may be included in any published document circular or statement or published in any way without our prior written approval.

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ATTACHMENT TWO:
PROPERTIES OF CONTAMINANTS OF CONCERN

Compound	Henry's Law Constant	K_{oc} (cm^3/g)	Information Source
Benzene	0.116	67.6	As given in Environment Agency Report SC050021/SR7.
Benzo(a)pyrene	$1.76x10^{-6}$	129,000	
Ethylbenzene	0.139	447	
MTBE	0.0169	12	RISC chemical database (Henry's Law constant value converted to 10˚C)
Naphthalene	$6.62x10^{-3}$	646	As given in Environment Agency Report SC050021/SR7. Average value for m, p and o xylenes.
Toluene	0.115	204	
Xylenes	0.104	453	
TPH: Aliphatic C_8-C_{10}	48.6	30,200	Environment Agency Report SC050021/SR7 recommends using values provided by Total Petroleum Hydrocarbons Working Group. Values taken from RISC Chemical Database, based on TPHWG. (Henry's Law constant value converted to 10˚C)
TPH: Aliphatic C_{10}-C_{12}	71.8	240,000	
TPH: Aliphatic C_{12}-C_{16}	254	5,370,000	
TPH: Aliphatic C_{16}-C_{35}	2410	575,000,000	
TPH: Aromatic C_8-C_{10}	0.290	1,580	
TPH: Aromatic C_{10}-C_{12}	0.0774	2,510	
TPH: Aromatic C_{12}-C_{16}	0.0254	5,010	
TPH: Aromatic C_{16}-C_{21}	0.00489	14,100	
TPH: Aromatic C_{21}-C_{35}	0.000144	126,000	

Table 2.1: Chemical Properties of Contaminants of Concern

Compound	Half-Life in Groundwater (days)	Information Source
Benzene	720	High-end value from Howard, Handbook of Environmental Degradation Rates, Lewis Publishers, 1989.
Benzo(a)pyrene	1,060	
Ethylbenzene	228	
MTBE	360	
Naphthalene	258	
Toluene	28	
Xylenes	360	

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Compound	Half-Life in Groundwater (days)	Information Source
TPH: Aliphatic C_8-C_{10}	360	Values for TPH fractions calculated from individual compounds (see below)
TPH: Aliphatic C_{10}-C_{12}	258	
TPH: Aliphatic C_{12}-C_{16}	204	
TPH: Aliphatic C_{16}-C_{35}	1660	
TPH: Aromatic C_8-C_{10}	360	
TPH: Aromatic C_{10}-C_{12}	258	
TPH: Aromatic C_{12}-C_{16}	204	
TPH: Aromatic C_{16}-C_{21}	1560	
TPH: Aromatic C_{21}-C_{35}	1750	

Table 2.2: Half-Life data for Contaminants of Concern

We have assigned half-lives to TPH groups based upon the criteria listed below.

- For the lower-range TPH values (C_6 to C_{16}) where we have data for only a few compounds, we have used the highest individual half-life in the TPH range to ensure a conservative assessment of risk.
- For the higher-range TPH values (C_{16} to C_{35}), where we have data for a greater number of compounds, we have used the average half-life in the TPH range as more appropriate for the overall behaviour of all the compounds within the range.

TPH Range	Individual Compounds Used in Calculations	Equivalent Carbon Number	Half-life in Groundwater (days)	Average Value of Half-life (days)
TPH >C_8-C_{10}	Ethylbenzene	8.5	228	360
	Xylenes	8.6	360	
	Styrene	8.83	210	
	1,2,4 Trimethylbenzene	9.8	56	
	1,3,5 Trimethylbenzene	9.6	–	
	n-Propylbenzene	9.5	–	
TPH >C_{10}-C_{12}	n-Butylbenzene	10.5	–	258
	Naphthalene	11.7	258	

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TPH Range	Individual Compounds Used in Calculations	Equivalent Carbon Number	Half-life in Groundwater (days)	Average Value of Half-life (days)
TPH >C_{12}-C_{16}	Acenaphthalene	15.5	204	204
	Biphenyl	14.26	14	
TPH >C_{16}-C_{21}	Fluorene	16.5	120	1,560
	Benzo(ghi)perylene	18	1,300	
	Phenanthrene	19.36	400	
	Anthracene	19.43	920	
	Pyrene	20.8	3,800	
	3-Methylchloanthrene	21	2,800	
TPH >C_{21}-C_{35}	Fluoranthene	21.85	880	1,750
	Benz(a)anthracene	26.37	1,360	
	Chrysene	27	2,000	
	Benzo(b)fluoranthene	30.14	1,220	
	Benz(k)fluoranthene	30.14	4,280	
	Benzo(a)pyrene	31	1,060	
	Indeno(1,2,3-cd)pyrene	35.01	1,460	

Table 2.3: Properties of Individual Compounds Used to Determine Half-lives values For TPH

Compound	Toxicity Parameter Type	Oral ($\mu g\ kg^{-1}\ bw\ day^{-1}$)	Inhalation ($\mu g\ kg^{-1}\ bw\ day^{-1}$)	Source
Benzene	Index Dose [1]	0.29	1.4	SC050021
Benzo(a)pyrene	Index Dose [1]	0.02	$0.07x10^{-3}$	R&D Tox Pub 2
Ethylbenzene	TDSI [2]	100	220	SC050021
MTBE	Reference Dose [3]	-	860	RISC database
Naphthalene	TDSI [2]	20	0.82 – adult 0.79 - child	R&D Tox Pub 20
Toluene	TDSI [2]	223	1,400	SC050021
Xylenes	TDSI[2]	180	58 – adult 55 - child	SC050021

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Compound	Toxicity Parameter Type	Oral ($\mu g\ kg^{-1}\ bw\ day^{-1}$)	Inhalation ($\mu g\ kg^{-1}\ bw\ day^{-1}$)	Source
TPH: Aliphatic C_8-C_{10}	Toxicity Dose [4]	100	900	P5-080/TR3
TPH: Aliphatic C_{10}-C_{12}	Toxicity Dose [4]	100	900	P5-080/TR3
TPH: Aliphatic C_{12}-C_{16}	Toxicity Dose [4]	100	900	P5-080/TR3
TPH: Aliphatic C_{16}-C_{35}	Toxicity Dose [4]	2,000	-	P5-080/TR3
TPH: Aromatic C_8-C_{10}	Toxicity Dose [4]	40	180	P5-080/TR3
TPH: Aromatic C_{10}-C_{12}	Toxicity Dose [4]	40	180	P5-080/TR3
TPH: Aromatic C_{12}-C_{16}	Toxicity Dose [4]	40	180	P5-080/TR3
TPH: Aromatic C_{16}-C_{21}	Toxicity Dose [4]	30	-	P5-080/TR3
TPH: Aromatic C_{21}-C_{35}	Toxicity Dose [4]	30	-	P5-080/TR3

Notes:

1 Index Dose – A level set for each non-threshold contaminant that represents a minimal risk level from possible soil exposures. Non-threshold substances are toxicants that do not have a threshold at which they pose no risk, i.e. there is always some risk at any level of exposure.

2 TDSI – Tolerable Daily Soil Intake. A finite dose set for each threshold toxicant below which adverse effects are not discernible.

3 Reference Dose – the toxicity parameter used by the EPA to evaluate compounds that do not pose a carcinogenic risk, e.g. a threshold compound. From the USEPA, based upon the Region 9 Preliminary Remediation Goals (1999).

4 Toxicity Dose – A finite dose set for each TPH range, approximately equivalent to TDSI. Where no TDSI has been published, the Toxicity Dose published in P5-080/TR3 has been used. The inhalation values are reported in P5-080/TR3 as concentrations (mg/m3). These have been adjusted for the female child body weight and indoor air inhalation rate to produce the toxicity dose.

Table 2.4: Toxicity Parameters of Contaminants of Concern Used for Human Health

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ATTACHMENT THREE:
RTM INPUT PARAMETERS

Compound	Compliance Criteria	
	(µg/litre)	Source
Benzene	1.0	The Water Supply (Water Quality) Regulations 2000
Benzo(a)pyrene	0.01	The Water Supply (Water Quality) Regulations 2000
Ethylbenzene	10	Former UK Drinking Water Standard for 'Dissolved Mineral Oil'
Naphthalene	10	Former UK Drinking Water Standard for 'Dissolved Mineral Oil'
Toluene	10	Former UK Drinking Water Standard for 'Dissolved Mineral Oil'
Xylenes	10	Former UK Drinking Water Standard for 'Dissolved Mineral Oil'
TPH	10	Former UK Drinking Water Standard for 'Dissolved Mineral Oil'

Table 3.1: Compliance Criteria

Parameter	Value	Data Source
Solution method	Ogata Banks	
Approach for vertical dispersion	Simulate vertical dispersion in one direction	
Nature of decay rate	Apply degradation rate to dissolved pollutants only	
Derivation of partition co-efficient	Calculate for non-polar organic chemicals	
Dispersivity	Dispersivities 10%, 1%, 0.1% of pathway length	
Width of plume (m)	20	Provectus
Plume thickness (m)	2.3	Provectus
Saturated aquifer thickness (m)	5.18	Provectus
Soil bulk density (g/cm^3)	1.81	Provectus
Effective porosity	0.3	Provectus
Hydraulic gradient	0.001	Provectus
Hydraulic conductivity (m/day)	25	Provectus
Fraction of organic carbon (g oc/g soil)	0.015	Provectus
Time since pollution entered groundwater (days)	$9e^{99}$	Steady State
Distance to compliance point (m)	50, 100	Environment Agency

Table 3.5: Input Parameters for Tier Three Groundwater