08-3031-01

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park
Wendover Road, Stoke Mandeville
Bucks HP22 5BL
Tel. 01296 739400
Fax. 01296 739401
e-mail: consultants@subadra.com
www.subadra.com

FURTHER SOIL INVESTIGATION AND UPDATED DETAILED QUANTITATIVE RISK ASSESSMENT REPORT

Manor Garage Filling Station, London Road, Purbrook, Portsmouth, PO7 5LQ

HAVANT BOROUGH COUNCIL
18 JUN 2010
RECEIVED

Report No: 01514 CL 015

June 2006

Client: BP Oil UK Ltd

Report Prepared By:

S L Pillsbury

Leigh Pillsbury

Report Reviewed By:

N Bowden

Nicky Bowden

Summary

The site is a closed and decommissioned petrol filling station located in a mixed residential and commercial area of Purbrook, Waterlooville, Portsmouth.

Subadra Ltd carried out an intrusive investigation at the site in February 2001. The results of the investigation indicated that hydrocarbon concentrations recorded in soil and groundwater posed a potential risk to human and environmental receptors.

Subadra Ltd carried out a site-specific Quantitative Risk Assessment in April 2002, for which they assumed a commercial end use for the site. The results of the risk assessment indicated that hydrocarbon concentrations recorded in soil and groundwater did not pose a risk to on-site workers, but that concentrations recorded in groundwater posed a potential risk to environmental receptors.

The site was closed in early July 2002. The petroleum installation at the site was decommissioned and removed from site in July and August 2002.

In January 2003 we commenced In-situ remediation, which continues to date.

We revised the risk assessment in July 2004 as Raglan Housing Association Ltd wished to purchase and redevelop the site for residential end use. The results of our revised assessment indicated the hydrocarbon concentrations recorded in groundwater posed a potential risk to the future on-site residents via the pathway of indoor air inhalation. We recommended that a gas-impermeable liner be installed beneath any buildings constructed on site and that all service ducts be sealed.

We have recently been given the details of the proposed redevelopment which comprises terraced housing with private gardens. At such sites, small extensions or conservatories may be built in the garden areas or additional services may be installed underneath the flooring, thus compromising the remedial effectiveness of gas-protection measures. We have therefore updated our risk assessment to take into account the risk posed by the pathway of indoor air inhalation on site.

Prior to completing our updated risk assessment we returned to site to undertake a surface soil investigation to determine the risk posed by surface soil concentrations to future site residents.

As part of our updated risk assessment, we have developed a conceptual model for the site, summarised as follows:

- Desk study information indicates that the site overlies a few metres of Head Deposits, which overlie London Clay. The Environment Agency classifies the Head Deposits as a minor aquifer and London Clay as a non-aquifer.
- The intrusive investigation found that the local site geology consists of 0.9m of sandy clay or gravely clay Made Ground, over at least 5m of clays or sands of the Head Deposits.
- Recent groundwater elevation data suggest that the depth to groundwater in the vicinity of the groundwater plume is at an average of 2.0m below ground level.
- We consider there to be both two soil sources and two localised areas of impacted groundwater source on-site.
- The proposed end use of the site is terraced housing with private gardens. The nearest off-site residential property is located 10m west of the site.
- The nearest surface water is an unnamed tributary of Wellington River located 150m south-west of the site.

Our updated detailed quantitative risk assessment was conducted using the RISC software package to assess the risk to human receptors and the Environment Agency's P20 methodology to assess the risk posed to environmental receptors by organic compounds.

Many of the input parameters have been updated from 2004 to account for recent UK guidance on chemical properties, soil properties, building parameters and exposure parameters.

The results of our recent soil sampling indicate that lead concentrations in three samples from Boreholes A, M and O, on the northern and southern site boundaries, exceed the SGV for residential end-use with plant uptake, indicating that the surface soils in these areas pose an unacceptable risk to on-site residents. The remaining seven samples would pass the CLEA Mean Value and Maximum Value tests, indicating that the soils in the central portion of the site are suitable for residential end use. Therefore, we recommend that it is necessary to remove or replace surface soils from the impacted edges of the site only.

Redevelopment works often strip and replace surface soils and may be sufficient to eliminate the potential risk. Subject to a review of proposed redevelopment plans we therefore recommend that these works could be undertaken in conjunction with the site redevelopment.

The results of our updated risk assessment for human and environmental receptors indicate that current on-site concentrations of hydrocarbons recorded in soil and groundwater do not pose an unacceptable risk to the identified receptors. We therefore consider that active remediation can now be halted.

We have calculated site-specific target levels for groundwater to facilitate post-remediation monitoring.

Your attention is drawn to the Notice to Interested Parties included as Attachment One.

Contents

SUMMARY 2

1 INTRODUCTION 6
- 1.1 Purpose 6
- 1.2 Previous Reports Used in This Assessment 6
- 1.3 Site Description and Setting 7
- 1.4 Risk Assessment Process 7

2 REVIEW OF WORK COMPLETED TO DATE 8
- 2.1 Site Assessment Report, February 2002 (Ref.1) 8
- 2.2 Quantitative Risk Assessment Report, April 2002 (Ref.2) 8
- 2.3 Remedial Action Plan, May 2002 (Ref.3) 9
- 2.4 Environmental Report on Site Decommissioning, October 2002 (Ref.4) 9
- 2.5 Remedial Implementation, January 2003 10
- 2.6 Revised Risk Assessment Letter, July 2004 (Ref.5) 10
- 2.7 Remediation Progress 10

ADDITIONAL SOIL INVESTIGATION 13
- 3.1 Soil Sampling 13
- 3.2 Inorganic Analysis Results 13
- 3.3 Organic Analysis Results 14

4 CONCEPTUAL SITE MODEL 15
- 4.1 Geological Model 15
- 4.2 Identified Sources 15
- 4.3 Contaminants of Concern 16
- 4.4 Estimated Source Concentrations 17
- 4.5 Identification of Receptors and Pollutant Linkages 17

5 RISK QUANTIFICATION 18
- 5.1 Human Receptors – Inorganic Constituents 18
- 5.2 Human Receptors – Organic Compounds 19
- 5.3 Environmental Receptors – Organic Compounds 20

6 SITE-SPECIFIC TARGET LEVELS 21

7 CONCLUSIONS AND RECOMMENDATIONS 22

8 OTHER REFERENCES 23

List of Figures

Figure One:	Estimated Sources 2002
Figure Two:	Decommissioning Excavations 2002
Figure Three:	Estimated Sources 2004
Figure Four:	Location of Soil Samples 2006
Figure Five:	Conceptual Site Model for Manor Garage Filling Station, Portsmouth
Figure Six:	Interpreted Sources 2006
Figure Seven:	Location of Nearby Receptors
Figure Eight:	Proposed Redevelopment

List of Attachments

Attachment One:	Notice to Interested Parties
Attachment Two:	Borehole Logs, Wells A to Q
Attachment Three:	Chemical Analysis Certificates
Attachment Four:	Toxicological and Chemical Properties of Contaminants of Concern
Attachment Five:	Evaluation of Pollutant Linkages
Attachment Six:	Acceptable Risk Levels
Attachment Seven:	Human Health Model (RISC) – Input Parameters and Pathway Results
Attachment Eight:	Environmental Receptor Model (P20 Spreadsheet) – Input Parameters

1 Introduction

The site consists of a closed petrol filling station. The petroleum installation was decommissioned and removed from site in 2002, although the shop and canopy remain on-site.

Subadra Ltd carried out an intrusive investigation at the site in February 2001. The results of the investigation indicated that hydrocarbon concentrations recorded in soil and groundwater posed a potential risk to human and environmental receptors.

Subadra Ltd carried out a site-specific Quantitative Risk Assessment in April 2002, for which they assumed a commercial end use for the site. The results of the risk assessment indicated that hydrocarbon concentrations recorded in soil and groundwater did not pose a risk to human receptors, but that concentrations recorded in groundwater posed a potential risk to environmental receptors.

The site was closed in early July 2002. The petroleum installation at the site was decommissioned and removed from site in July and August 2002. Soils around the former petroleum tanks were also removed from site during the decommissioning. Tier One Risk Based Screening Levels for residential end use were used to classify the soil at the site for removal.

In January 2003, we commenced in-situ remediation, which continues to date.

We were instructed to revise the risk assessment in July 2004 as Raglan Housing Association Ltd wished to purchase and redevelop the site for residential end use. The results of our assessment indicated the hydrocarbon concentrations recorded in groundwater posed a potential risk to the future on-site residents via the pathway of indoor air inhalation. We recommended that a gas-impermeable liner be installed beneath any buildings constructed on site and that all service ducts be sealed.

We have recently been given the details of the proposed redevelopment (see Figure Eight), which comprises terraced housing with private gardens. At such sites, small extensions or conservatories may be built in the garden areas or additional services may be installed underneath the flooring without planning permission, which would compromise the remedial effectiveness of gas-protection measures.

We therefore recommended that the risk assessment be updated and revised to account for both the indoor air pathway without a liner and the recent changes to risk guidance on chemical properties, soil properties, building parameters and exposure parameters.

We also recommended that the soils in the garden areas be tested to determine if concentrations of inorganic and hydrocarbon constituents posed a risk via surface soil pathways.

1.1 Purpose

The purpose of our further soil investigation was to determine if concentrations of inorganic and hydrocarbon constituents in the surface soils posed a risk to the future on-site residents.

The purpose of our updated detailed quantitative risk assessment is to evaluate the site-specific level of risk that the current soil and groundwater concentrations pose to the future on-site residents, off-site residents and environmental receptors. As part of this process, we have used the most recent UK guidance.

To facilitate post-remediation monitoring, we have calculated new site-specific target levels.

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 Previous Reports Used in This Assessment

We have referenced the following reports in compiling this assessment:

Ref.1 "Site Assessment Report", Report Ref. 01514 CL 001, February 2002. Completed by Subadra Ltd on behalf of BP Oil UK Ltd.

Ref.2 "Quantitative Risk Assessment Report", Report Ref. 01514 CL 002, April 2002. Completed by Subadra Ltd on behalf of BP Oil UK Ltd.

Ref.3 "Remedial Action Plan Report", Report Ref. 01514 CL 003, May 2002. Completed by Subadra Ltd on behalf of BP Oil UK Ltd.

Ref.4 "Environmental Report on Site Decommissioning", Report Ref. 01514 CL 004, October 2002. Completed by Subadra Ltd on behalf of BP Oil UK Ltd.

Ref.5 "Revised Risk Assessment", Letter Report Ref. 01514 CL 005, July 2004. Completed by Subadra Consulting Ltd on behalf of BP Oil UK Ltd.

This report should be read in conjunction with the above documents.

1.3 Site Description and Setting

The following data is summarised from the previous reports.

The site is a former BP petrol filling station, located at National Grid Reference 467278 107928 on London Road in a mixed residential and commercial area of Purbrook, Waterlooville, Portsmouth. The land surrounding the site slopes gently downwards to the south.

When operational, the site consisted of a retail filling station, with combined petrol and diesel forecourt, carwash, small shop and office and a gravel car park, used for car sales.

In July and August 2002 the petroleum installation at the site was decommissioned and removed from site, including the removal of the tanks, fuel and vent lines and most of the concrete cradles. The site shop and canopy remain on site.

The site is currently disused whilst undergoing active remediation, but is proposed for residential redevelopment consisting of terraced housing with individual gardens (see Figure Eight).

The area immediately surrounding the site comprises residential properties bordering the site to the west and a small park to the south (see Figure Seven). There are further residential and commercial properties over London Road to the east. A car dealership and workshop borders the site to the north.

Desk study information indicated that the site geology consists of Head Deposits overlying London Clay. The Environment Agency classifies the Head Deposits as a minor aquifer and London Clay as a non-aquifer.

Groundwater was interpreted to be in continuity with nearby surface water features. The direction of groundwater flow was interpreted to be towards the south-west, based on topography and the location of a nearby stream. The referenced reports identified no groundwater abstractions licensed by the Environment Agency within 2km of the site.

The referenced reports identified the nearest surface water to the site as an unnamed tributary of the Wallington River, located approximately 100m to the south-west. However, review of the ordnance survey map indicates that the nearest surface water feature is an 'issue' located 85m north-west of the site. The issue appears to enter a culvert to the west of the site and join with the unnamed tributary, which originates 150m south-west of the site.

The referenced reports identified no surface water abstractions licensed by the Environment Agency within 2km of the site.

1.4 Risk Assessment Process

Our risk assessment comprised the following stages:

- Construction of a Conceptual Site Model, including site-specific sources, pathways, and receptors;
- Evaluation of concentrations of relevant contaminants at the site;
- Fate-transport modelling to determine the concentration of these contaminants at each receptor;
- Quantification of the risk levels that the contaminant concentrations pose to each receptor;
- Where appropriate, determination of site-specific clean-up targets to reduce the toxicological risk to the receptors to acceptable levels.

2 Review of Work Completed to Date

We have carried out a review of previous works completed at the site to date that are relevant to our risk assessment.

2.1 Site Assessment Report, February 2002 (Ref.1)

Subadra Ltd. carried out an intrusive investigation of the site in November 2001. They constructed eight boreholes (Boreholes One to Eight) to a depth of up to 6.0m at the site. Permanent groundwater monitoring wells were installed in seven of the boreholes.

The investigation confirmed that the shallow geology underlying the site comprises Made Ground to approximately 0.9m depth underlain by Head Deposits. The Head Deposits were found to consist of a layer of sandy clay to a depth between 2.5m and 4.7m below ground level, underlain in most locations by clayey sand. London Clay was not encountered in the investigation.

Groundwater strike was encountered at approximately 3.5m below ground level in six of the boreholes, with an average groundwater resting level at 1.7m below ground level. No groundwater strike was encountered in Boreholes Four and Eight and both were dry when groundwater sampling was carried out a week after borehole installation.

As part of the site investigation, a total of forty samples were analysed by HS40/GC-FID for total petroleum hydrocarbons and BTEX compounds. BTEX compounds were detected in excess of the method detection limit of 0.1mg/kg in nine samples. Total petroleum hydrocarbons were detected in excess of the method detection limit of 0.5mg/kg in sixteen samples.

Eight representative soil samples were analysed by GC-MS for BTEX compounds and by GC-FID for total petroleum hydrocarbons by carbon group, naphthalene and benzo(a)pyrene. Total petroleum hydrocarbons in excess of the method detection limit were identified in all samples analysed. BTEX concentrations in excess of the method detection limit were identified in four samples. Concentrations of MTBE, benzo(a)pyrene and naphthalene were below detection limits in all samples analysed.

Five groundwater samples were analysed by GC-FID for total petroleum hydrocarbons by carbon group, naphthalene and benzo(a)pyrene. Six groundwater samples were analysed for BTEX and MTBE. TPH concentrations in excess of the method detection limit were identified in three of the five groundwater samples analysed. Naphthalene concentrations in excess of the method detection limit were identified in two of the five samples analysed. BTEX concentrations were identified in excess of the method detection limit in three samples. MTBE concentrations were identified in excess of the method detection limit in one sample. Concentrations of benzo(a)pyrene were below the method detection limit in all samples analysed.

Subadra Ltd undertook a preliminary risk assessment and concluded that the site may present a material risk of exposure to identified receptors with respect to the potential contaminants identified in the report. They therefore recommended that a Tier Two Quantitative Risk Assessment be undertaken.

2.2 Quantitative Risk Assessment Report, April 2002 (Ref.2)

In April 2002, Subadra Ltd undertook a Tier Two Quantitative Risk Assessment using the BP Risk-Integrated Software for Clean-Ups assuming a commercial end-use of the site.

Both soil and groundwater sources were identified at the site (see Figure One). Significantly elevated concentrations of hydrocarbons in soil were identified in only a few locations. However as low concentrations were identified in soil from most locations on site, Subadra Ltd assumed that the total area of soil at the site has been impacted by hydrocarbons. The identified groundwater source stretched from the centre of the pump island to the southern boundary of the site.

The risk was evaluated to on-site commercial workers, off-site residents located 10m from the site and groundwater at 100m from site.

The results of the risk assessment indicated that hydrocarbon concentrations recorded in soil and groundwater did not pose a risk to human receptors but did pose a potential risk to environmental receptors.

Site-specific target levels (SSTLs) were proposed, based upon commercial end-use.

2.3 Remedial Action Plan, May 2002 (Ref.3)

Subadra Ltd completed a remedial action plan that recommended the use dual phase vacuum extraction at the site. The low permeability and therefore low yield of the saturated soils meant that conventional groundwater pump and treat would take a long-term to achieve the remedial targets. The dual phase vacuum extraction system could be installed using the existing boreholes and same infrastructure as the pump and treat system. However the ability of the system to extract vapour would increase the volume of water abstracted and thus decrease the overall treatment time.

The regulatory authorities were approached in May 2002 for their opinion and approval as to the appropriateness of the SSTLs and proposed remedial technique.

The Environment Agency responded in May 2002, agreeing in principle to the target levels and remedial technique.

Havant District Council responded in September 2003, agreeing in principle to the target levels and remedial technique. They considered additional investigation for lead should be included in the close out report.

2.4 Environmental Report on Site Decommissioning, October 2002 (Ref.4)

The petroleum installation at the site was decommissioned during July and August 2002.

All five known underground tanks were excavated and removed from the site (see Figure Two). All the associated concrete cradles were broken out and removed except along the south western face of Tank Four. This cradle portion was left in place to prevent the adjacent property collapsing into the excavation. All the known fuel and vent lines were excavated and removed.

Soils surrounding the underground petroleum installation (the tanks and fuel lines) were also removed from site, including the area of Borehole One, where the highest TPH concentrations in soil were measured during the site investigation. Tier One Risk Based Screening Levels for residential end were used to classify the soil at the site.

The excavations were backfilled with Type II MoT material and compacted as specified.

Subadra Ltd visited the site on four occasions. Boreholes Six and Seven, which were damaged during the decommissioning works, were reinstalled. Two additional groundwater monitoring wells (Monitoring Wells One and Two) were installed in the backfill of the tank farm excavations.

A total of fifty-six soil samples were recovered from the faces and base of the excavations, four trial pits, the waste soil heap and from replacement Borehole Seven. All soil samples were analysed by HS40/GC-FID for Total Petroleum Hydrocarbons (TPH) and benzene, toluene, ethylbenzene and xylenes (BTEX). None of the samples recovered contained TPH, toluene, ethylbenzene or xylenes concentrations that exceeded the relevant target levels. However Sample Forty-four from Trial Pit Three and Sample Three from Borehole Seven contained concentrations of benzene exceeding the relevant risk based screening level.

Groundwater samples were recovered from the available boreholes and monitoring wells. All groundwater samples were analysed for TPH and BTEX. Samples recovered from Boreholes Six and Eight contained concentrations of TPH exceeding the relevant site-specific target levels.

As the post-decommissioning soils and groundwater concentrations remained above Tier One screening criteria, Subadra Ltd recommended that the remedial scheme outlined in the Remedial Action Plan be implemented to reduce these concentrations to acceptable levels.

2.5 Remedial Implementation, January 2003

We installed an extraction unit with air stripper at the site and commenced active remediation on January 13, 2003. The remedial unit was initially connected to Boreholes Two, Three, Six, Seven and Eight where hydrocarbon concentrations above the target levels were recorded.

Operations and groundwater quality at the site have been monitored on a monthly basis.

We initially anticipated that the active remediation process would take 9 to 12 months to lower hydrocarbon concentrations at the site to acceptable levels. However, the volume of groundwater we have been able to abstract from the site has been more limited that our initial investigations indicated. Because of the limited volumes of groundwater, large amounts of site have been entrained in the abstracted water, which has a negative impact on the operation of the remediation unit. In order to address this issue and reduce maintenance issues, we have reconfigured the remediation unit to pump on a cyclical basis rather than to abstract continuously.

2.6 Revised Risk Assessment Letter, July 2004 (Ref.5)

In October 2004 we were asked to revise the risk assessment to account for residential end-use as Raglan Housing Association Ltd entered into contract negotiations with BP to redevelop the site for residential end use.

We revised the source sizes to take into account additional information obtained during the decommissioning and ongoing remediation works (see Figure Three).

The soils around Borehole One were excavated and removed from site during decommissioning. Therefore, the revised soil source size and concentrations were based upon hydrocarbon concentrations measured in Boreholes Seven and Eight and Trial Pit Three that exceeded the target levels used in the decommissioning work.

Based upon analysis results obtained from groundwater monitoring carried out over the previous year, the location of the groundwater plume was considered to be to the south end of the site, hydraulically down-gradient of the former petroleum installation.

The results of our revised risk assessment indicated the hydrocarbon concentrations recorded in soils and groundwater posed a potential risk to on site residents via the pathway of indoor air inhalation.

We recommended that a gas-impermeable liner be installed beneath any buildings constructed on site and that all service ducts be sealed to prevent the migration of hydrocarbon vapours into the building.

The Environment Agency commented on our revised risk assessment in November 2004 confirming that the newly identified risk was to human health and so they did not need to comment on the proposed gas control measures. They understood the risk to groundwater was being mitigated by the active remediation system. .

Havant Borough Council commented on our revised risk assessment in November 2004. They stressed concerns about the sustainability of the proposed action. They considered that the proposed liner would only be a suitable remedial option if the redevelopment did not contain private gardens.

2.7 Remediation Progress

We continue to operate the remediation unit, which is currently abstracting from Boreholes Two, Three, Six, Seven and Eight.

Boreholes Three, Six and Eight were re-drilled in May 2005 to a depth of 5.0m as the initial wells had been blocked with sediment preventing the remediation system from abstracting groundwater effectively.

Hydrocarbon concentrations groundwater have steadily decreased during the operation of the remediation unit, but remain above 2002 target levels.

A summary of measured concentrations for the last seven months is noted in the tables below.

Borehole	Benzene Concentrations (µg/litre) 2002 SSTL = 1,000					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	<10	<10	<10	<10	<10	<10
MW2	<10	<10	<10	<10	<10	<10
BH2	<10	<10	<10	<10	<10	<10
BH3	<10	189	61.7	231	163	193
BH5	<10	<10	<10	<10	25.1	22.4
BH6	296	524	413	900	392	489
BH7	<10	<10	<10	44.6	39.3	28.6
BH8	<10	211	118	273	156	198

Note: Concentrations in **BOLD** exceed the specified SSTL

Table One: Benzene Analysis Results

Borehole	Toluene Concentrations (µg/litre) 2002 SSTL = 560,000					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	<10	<10	19.4	<10	<10	<10
MW2	<10	<10	<10	<10	<10	<10
BH2	<10	<10	<10	<10	<10	<10
BH3	<10	<10	<10	<10	<10	<10
BH5	<10	<10	<10	<10	<10	<10
BH6	919	1,240	210	710	717	546
BH7	<10	<10	<10	<10	<10	<10
BH8	<10	137	20.5	103	74.1	83.5

Note: Concentrations in **BOLD** exceed the specified SSTL

Table Two: Toluene Analysis Results

Borehole	Ethylbenzene Concentrations (µg/litre) 2002 SSTL = 36,000					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	<10	<10	<10	<10	<10	<10
MW2	<10	<10	<10	<10	<10	<10
BH2	<10	<10	<10	<10	<10	<10
BH3	91.3	<10	<10	<10	52.4	10.4
BH5	<10	<10	<10	<10	<10	<10
BH6	358	422	10	595	938	851
BH7	<10	<10	<10	<10	38.7	<10
BH8	<10	840	92.2	513	452	428

Note: Concentrations in **BOLD** exceed the specified SSTL

Table Three: Ethylbenzene Analysis Results

Borehole	Total Xylenes Concentrations (µg/litre) Current 2002 = 27,000					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	<20	<20	<20	<20	25.6	32.4
MW2	<20	<20	<20	<20	<20	<20
BH2	<20	<20	<20	<20	<20	<20
BH3	20	118	21.7	35.5	21.7	22.7
BH5	<20	<20	<20	<20	<20	<20
BH6	1,810	2,860	1,540	2,050	1,703	1,432
BH7	<20	<20	<20	26.8	64	33.9
BH8	93.1	1,100	552	742	549	591

Note: Concentrations in BOLD exceed the specified SSTL

Table Four: Total Xylenes Analysis Results

Borehole	Total TPH (C_6 to $<C_{15}$) Concentrations (µg/litre) 2002 SSTL = 1,330					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	<200	241	<200	<200	<200	242.3
MW2	<200	<200	<200	<200	<200	<200
BH2	<200	<200	237	200	<200	<200
BH3	<200	1,220	612	970	876	917
BH5	<200	<200	<200	<200	<200	<200
BH6	**6,510**	**11,000**	**4,990**	**8,400**	**6,535**	**5,833**
BH7	<200	<200	200	309	492	240
BH8	646	**6,390**	**2,700**	**4,020**	**3,529**	**3,535**

Note: Concentrations in BOLD exceed the specified SSTL

Table Five: Total Petroleum Hydrocarbons Analysis Results

Borehole	Depth to Groundwater (m)					
	04-Nov-05	15-Dec-05	17-Jan-06	10-Feb-06	19-Apr-06	09-May-06
MW1	0.682	0.889	0.835	1.081	1.081	0.924
MW2	0.998	1.203	1.143	1.392	1.392	1.231
BH2	1.715	1.945	1.809	2.118	2.118	2.045
BH3	1.854	2.033	1.994	2.205	2.205	2.114
BH5	1.335	1.651	1.518	1.694	1.694	1.523
BH6	1.512	1.845	1.698	2.078	2.078	1.946
BH7	2.312	2.11	2.241	2.294	2.294	2.521
BH8	1.593	2.085	1.924	2.346	2.346	2.217

Table Six: Measured Groundwater Depths

Over the last seven months the only recorded concentrations to exceed the target levels were TPH in groundwater samples from Boreholes Six and Eight. We consider this is likely to be a result of the prior blockage of the wells, which prevented abstraction from these locations. Groundwater samples from the remaining boreholes contained concentrations below the target levels. As Boreholes Six and Eight have been reinstalled and are currently being used for abstraction, we consider that we are now treating any residual contamination within their zones of influence.

Detectable concentrations of TPH below the SSTLs were noted in Boreholes Three and Seven, suggesting these wells can be used to delineate the edge of the plume.

In February we reduced the frequency of groundwater monitoring at the site from monthly to quarterly, as the decreasing groundwater concentrations indicate that such monitoring is sufficient to observe the progress at the site.

3 Additional Soil Investigation

3.1 Soil Sampling

Shallow soil at the site comprises Made Ground, which can contain inorganic contaminants such as heavy metals, that may pose a risk to human receptors. We understand that the redevelopment of the site includes gardens and therefore there will be a pathway between on site residents and any contaminants in shallow soil.

To determine whether shallow soil at the site poses a risk to future residents, samples of shallow Made Ground from the site must be analysed for inorganic contaminants and the results assessed against the CLEA Soil Guideline Values for residential end use.

As previous investigations did not include analysis of shallow soil samples for inorganic constituents, we returned to site on 19 April 2006 to collect surface samples for inorganic and organic analysis.

We drilled seventeen boreholes (Boreholes A to Q) to 1.2m below ground level, as shown in Figure Four.

We detected a slight hydrocarbon odour from 0.7m to 1.2m below ground level in Boreholes D, F G and H. We note that these locations are soils within or adjacent to the 2002 decommissioning excavation.

Based upon the geology encountered, we consider Boreholes E, F, G, P and Q to be located within the 2002 decommissioning excavation. The geology was noted to consist of a layer of gravel overlying intact sandy clay.

In all other boreholes, the ground was noted to consist of reworked sandy clay with brick, flint, sandstone or gravel inclusions to between 0.5m to 1.0m below ground level, underlain by intact sandy clay to the base of the boreholes.

3.2 Inorganic Analysis Results

We collected six soil samples from 0.4m below ground level and four samples from 0.8m below ground level to be analysed by ICP for a suite of inorganic constituents. The results are reported in the table below. The chemical analysis certificate is provided in Attachment Three.

We note that the concentrations of lead in Borehole A at 0.8m, Borehole M at 0.4m and Borehole O at 0.4m are above the Soil Guideline Value for residential end use with plant uptake.

Borehole	Depth (m)	Primary Soil Type	Concentration (mg/kg)						
			Arsenic	Cadmium	Chromium	Lead	Mercury	Nickel	Selenium
BH A	0.4	Gravely Clay	4	< 1	16	150	< 1	4	< 2
BH A	0.8	Gravely Clay	5	< 1	17	1,300	< 1	5	< 2
BH B	0.4	Gravely Clay	6	< 1	17	190	< 1	7	< 2
BH K	0.4	Gravely Clay	5	< 1	14	120	< 1	6	< 2
BH K	0.8	Sandy Clay	6	< 1	8	28	< 1	7	< 2
BH M	0.4	Sandy Clay	10	2	18	500	< 1	13	< 2
BH O	0.4	Sandy Clay	10	< 1	22	1,400	< 1	14	< 2
BH O	0.8	Clay	6	< 1	15	51	< 1	8	< 2
BH P	0.4	Gravely Clay	6	< 1	17	120	< 1	8	< 2
BH Q	0.8	Gravely Clay	11	< 1	18	120	< 1	12	< 2

Table Seven: UKAS Accredited Inorganic Compounds Analysis Results - – Soil Samples

3.3 Organic Analysis Results

Our July 2004 revised risk assessment (Ref.5) indicated that benzene concentrations in soils posed an unacceptable risk to on-site residents via the pathway of indoor air inhalation. The site is to be redeveloped as individual residential units with gardens and any future construction at these properties could limit the effectiveness of the gas control measures we recommended to break this pathway.

We therefore collected shallow soil samples from across the non-excavated portion of the site to be analysed for volatile organic compounds.

The locations of Boreholes A to O were selected to be outside the excavation area based upon the estimated excavation area shown in Figure Two. The locations of Boreholes P and Q were selected to be inside the excavation area, for testing of the inorganic concentrations in the backfill.

A representative sample from each borehole was analysed by our in-house UKAS accredited laboratory using GC-FID for BTEX and volatile (C_6 to C_{15}) total petroleum hydrocarbons reported by carbon range. The chemical analysis certificate is provided in Attachment Three.

The concentrations recorded in the majority of samples were below the detection limits. The results of the analyses where we encountered concentrations exceeding the relevant method detection limits are summarised in the table below.

Borehole	Depth (m)	Concentration (mg/kg)							
		Total Petroleum Hydrocarbons				Benzene	Toluene	Ethyl-benzene	Total Xylenes
		C_6-C_8	>C_8-C_{10}	>C_{10}-C_{12}	>C_{12}-C_{15}				
E	0.6	1.04	2.56	<0.5	<0.5	0.93	0.13	0.39	1.47
I	0.5	<0.5	<0.5	2.77	8.95	<0.1	<0.1	<0.1	<0.2

Table Eight: BTEX and Volatile TPH Bands Analysis Results for Soil Samples – 19 April 2006

The soil concentration data indicates that the surface soils to 1.2m depth in the previously identified soil source area to the southern portion of the site (centred on Boreholes 7A and Eight and Trial Pit Three) has been effectively remediated.

The laboratory detections of hydrocarbons in Boreholes E and I and the odours in Boreholes D, F, G and H suggest that there is a second, low concentration surface soil source just south of the area excavated in 2002 but north of the 2004 identified soil source.

4 Conceptual Site Model

A section view of our Conceptual Site Models (CSM) for this site is shown in Figure Five.

Where possible we have used site data for all physical parameters. Where site data was not available, we have used literature values from alternative UK sources, as detailed in Attachments Seven and Eight.

4.1 Geological Model

We have reviewed the descriptions of shallow geology under the site provided by the previous intrusive investigation and the recent soil investigation (Ref.1 and Section 3.1 above).

The local geology comprises on average 0.9m of sandy or gravely clay Made Ground, overlying at least 5m of clays or sands of the Head Deposits.

The initial groundwater strike was at 3.5m below ground level on average. However, recent groundwater monitoring indicates that the groundwater depth in the area of the plume is currently resting at 2.0m. We have therefore modelled groundwater as being present at 2.0m

We have modelled the unsaturated zone as comprising two layers: 0.9m of silty clay to represent the Made Ground, underlain by a 1.1m thick lens of silty loam to represent the unsaturated Head Deposits. We have not used the lens for those modelling runs that assess volatilisation from the shallow soil source on site, as the top of the soil source lies within the overlying Made Ground. For the modelling runs that assess volatilisation from the deeper soil source we have used a thinner lens of 0.2m to represent the Head Deposits between the top of the source at 1.2m and the base of the Made Ground at 0.9m. We modelled the aquifer as silty loam to represent the Head Deposits.

4.2 Identified Sources

Based upon the previous assessments and current site data, we consider there to be two potential soil sources and a groundwater source on site.

Deeper Soil Source

Our previous assessment work in 2004 identified a soil source to the south of the site, extending from the surface to 3.0m depth (Figure Three). Data from our most recent investigation indicates that surface soils to a depth of 1.2m in this area are no longer impacted with hydrocarbons.

The soil in the saturated zone, below 2m, has been treated along with groundwater. The decreasing hydrocarbon concentrations recorded in groundwater indicate that concentrations in the soil source are also likely to have decreased. The only pathways between the saturated soil source and identified receptors are via groundwater and we therefore have not assessed the saturated soil source separately. We consider that when groundwater concentrations recorded under the site are at acceptable levels, the saturated soil source also no longer poses a risk.

We do not have any current data regarding the soil between 1.2m and 2m in this 2004 source area. As hydrocarbon concentrations in the overlying soil have decreased during our remedial work, we consider it likely that concentrations in this area have also decreased. However as the critical pathway identified by the previous risk assessment was the volatilisation to indoor air, we have refined the delineation of this source using the new data and assessed the risk to on-site residents as a precaution.

Shallow Soil Source

We consider there to be a newly identified shallow soil source, located between the deep tank excavation area and the 2004 soil source. We have based this shallow soil source on the laboratory detections of hydrocarbons in Boreholes E and I and the odours in Boreholes D, F, G and H. We have used the tank farm excavation area (excavation to 4m depth) and the non-detects in our 2006 boreholes to delineate the soil source. Based upon the depths of detections and odours, we have modelled the soil source as extending from 0.5m to 1.5m below ground level. We note that defining the source area in this manner results in part of the area from which fuel lines were excavated, during the decommissioning of the site, being incorporated into the defined source area. The excavation in the fuel line area extended to approximately 0.5m, so the modelled source lies below the depth of the excavation.

Groundwater Source

We have based the groundwater source on Boreholes Six and Eight, which continue to contain concentrations that exceed the target levels. The concentrations below detection limits in Borehole Two indicate that the groundwater plume is not continuous across the southern portion of each site, but is instead localised about each well. We have used Boreholes Three and Seven, which have concentrations just above detection limits but well below the 2002 target levels, to delineate each groundwater plume.

To model the risk posed by impacted groundwater we have combined the two identified source areas (10m x 10m and 15m x 5m) to produce a single groundwater source (interpreted area 15m x 15m as a conservative estimate).

Source Sizes

The source size data for the three assessed source areas are summarised in the table below. The affected areas are shown schematically in Figure Six.

Parameter	Deep Soil Source	Shallow Soil Source	Groundwater Source
Depth to Top of Source from Ground Level (m)	1.2	0.5	2.0
Thickness of Source (m)	0.8	1.0	1.0
Length Parallel to Groundwater Flow (m)	25	30	15
Width Perpendicular to Groundwater Flow (m)	25	15	15

Table Nine: Determination of Source Area

4.3 Contaminants of Concern

The site has historically been used as a petrol filling station.

Our previous work has shown that petrol-range compounds pose a risk at the site. We have therefore carried out our risk assessment using the following contaminants of concern:

- Benzene, ethybenzene, toluene and xylenes to represent the compounds present in petrol;
- Total Petroleum Hydrocarbons (TPH) grouped following the recommendations made by the TPH Criteria Working Group.

The chemical properties of our identified source compounds are listed in Attachment Two.

4.4 Estimated Source Concentrations

The 2004 soil source was based upon elevated soil concentrations in Trial Pit Three (at 1.0m depth), Borehole 7A (1.9m depth) and Borehole Eight (1.0m depth). Our recent surface sampling within the source area (Boreholes J, K, L and N) indicates that concentrations to 1.2m depth within this area are below detection limits. We have therefore used the maximum concentrations or detection limits measured in Borehole 7A to represent the source concentrations in this deeper soil source area as a whole.

We have used the maximum concentrations measured in our recent soil sampling (Table Eight) as representative of concentrations in the shallow soil source as a whole.

We have used the maximum groundwater concentrations recorded on site during the last seven months (Tables One to Six) as representative of the groundwater source as a whole.

The concentrations used in this updated risk assessment are detailed in the table below.

Compound	Deeper Soil Source (mg/kg)			Shallow Soil Source (mg/kg)			Groundwater Source (µg/litre)		
	Maximum Value	Sample Location	Sample Depth (m)	Maximum Value	Sample Location	Sample Depth (m)	Maximum Value	Sample Location	Date
Benzene	0.3	7A	1.9m	0.93	E	0.6	900	BH6	10/02/06
Ethylbenzene	0.2	7A	1.9m	0.39	E	0.6	938	BH6	19/04/06
Toluene	0.1	7A	1.9m	0.13	E	0.6	1,240	BH6	15/12/05
Xylenes	0.6	7A	1.9m	1.47	E	0.6	2,860	BH6	15/12/05
TPH: Aliphatic C_6-C_8	2.8	7A	1.5m	1.04	E	0.6	4,510	BH6	15/12/05
TPH: Aliphatic C_8-C_{10}	2.8	7A	1.5m	2.56	E	0.6	5,930	BH6	15/12/05
TPH: Aliphatic C_{10}-C_{12}	1.3	7A	1.5m	2.77	I	0.5	1,020	BH6	15/12/05
TPH: Aliphatic C_{12}-C_{16}	1.3	7A	1.5m	8.95	I	0.5	78.1	BH6	15/12/05
TPH: Aromatic C_7-C_8	<0.5	7A	-	1.04	E	0.6	4,510	BH6	15/12/05
TPH: Aromatic C_8-C_{10}	<0.5	7A	-	2.56	E	0.6	5,930	BH6	15/12/05
TPH: Aromatic C_{10}-C_{12}	<0.5	7A	-	2.77	I	0.5	1,020	BH6	15/12/05
TPH: Aromatic C_{12}-C_{16}	<0.5	7A	-	8.95	I	0.5	78.1	BH6	15/12/05

Table Ten: Source Concentrations for Updated Risk Assessment

4.5 Identification of Receptors and Pollutant Linkages

The site is proposed to be redeveloped for future residential end use with gardens (see Figure Eight).

We interpret that groundwater flow is to the south-west (Refs.1 and 4). We have therefore assumed that all receptors to the south or west of the site are located hydraulically down-gradient from the site. The identified nearest off-site receptors are shown in Figure Five.

The nearest off-site human receptors are residents located 10m west of the site. The nearest environmental receptor is an unnamed tributary of the Wallington River, which emerges from a culvert 150m to the south-west of the site.

A detailed discussion of the potential pollutant linkages is provided in Attachment Five. The pathways modelled in our risk assessment are summarised in the table below.

Sources	Pathway Components	Receptors
Hydrocarbon Impacted Soils	Dermal contact with surface soil	On-site residents
	Ingestion of surface soil	Pathways applies only to soil sources at 1m depth or shallower, in garden or landscaped areas
	Vegetable Ingestion	
	Volatilisation to indoor air Inhalation of indoor air	On-site residents
	Volatilisation to outdoor air Inhalation of outdoor air	
	Leaching to groundwater Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off-site residents 10m from the site
	Leaching to groundwater Migration of groundwater off-site Impact on surface water	Unnamed tributary of Wellington River 150m from the site
Hydrocarbon Impacted Groundwater	Volatilisation to indoor air Inhalation of indoor air	On-site residents
	Volatilisation to outdoor air Inhalation of outdoor air	
	Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off-site residents 10m from the site
	Migration of groundwater off-site Impact on surface water	Unnamed tributary of Wellington River 150m from the site

Table Eleven: Identified Pollutant Linkages

5 Risk Quantification

5.1 Human Receptors – Inorganic Constituents

We have evaluated the risk posed by inorganic contaminants to human receptors by comparing the measured values to the published CLEA Soil Guideline Values (SGV).

In accordance with the CLEA methodology we have calculated the 95% confidence limits of the measured mean of contaminant concentrations and compared the upper 95th percentile with the SGV. Concentrations of contaminants will vary across a site and so the use of the 95th percentile addresses the uncertainty of comparing the measured mean concentration directly with the SGV and therefore ensures that the risk assessment is conservative. This is called the Mean Value Test.

We have also applied Maximum Value Test to assess whether the maximum value (i.e. the highest contaminant concentration in the data set) can be considered as representative of the site's shallow fill material as a whole. A 'maximum value statistic' is calculated as a measure of the extent to which the maximum value recorded deviates from the other values in the data set. A 'critical value' is determined, based on the number of samples in the data set, which relates to the chance of wrongly classifying a maximum value as an outlier (i.e. not representative of the shallow fill material) when it is actually from the same underlying population as the other values. We have used the more stringent 10% critical values in this assessment.

If the maximum value statistic exceeds the critical value, the maximum value is classed as an outlier and the sample is not deemed representative of the shallow fill material. This could mean that the sample is from a localised area of contamination where further investigation would be required. If the maximum value statistic is less than the critical value then the value is representative of the shallow fill material and the results of the Mean Value Test are applicable.

The results of these analyses are summarised in the following table:

	Concentration (mg/kg)						
	Arsenic	Cadmium	Chromium	Lead	Mercury	Nickel	Selenium
Upper 95th percentile of mean sample concentration	8	<1	18	492	<1	10	<2
Soil Guideline Value – Residential End Use with plant uptake	20	8	130	450	8	50	35
Max Value Test: Accepted (✓)/ Requires further investigation (X)	✓	✓	✓	✓	✓	✓	✓

Table Twelve: Inorganic Risk Assessment Results

The upper 95th percentile of the mean lead concentration exceeds the SGV for residential end-use with plant uptake, indicating that lead in surface soils poses an unacceptable risk to on-site residents.

A review of the sample data shows that lead concentrations above the SGV were measured only in three samples from Boreholes A, M and O. The remaining seven samples, would pass the Mean Value and Maximum Value tests, indicating that the soils in the central portion of the site are suitable for residential end use. Therefore, we recommend that it is necessary to remove or replace surface soils from the impacted edges of the site only.

Redevelopment works often strip and replace surface soils and may be sufficient to eliminate the potential risk. Subject to a review of proposed redevelopment plans we therefore recommend that these works could be undertaken in conjunction with the site redevelopment.

5.2 Human Receptors – Organic Compounds

Our quantitative risk assessment to determine the impact of organic contaminants on human receptors has been carried out using the Risk-Integrated Software for Clean-ups (RISC).

The Environment Agency has developed the Contaminated Land Exposure Assessment Model (CLEA) to generate Soil Guideline Values (SGVs) for contaminated soils. However, CLEA does not address the risk to off-site human receptors. SGVs are not yet available for all compounds.

The technical basis for CLEA has been published (R & D Publication CLR 10), so that the CLEA framework and parameters may be applied to appropriate models to assess the full human health risk posed by a site. The Environment Agency acknowledges that one of the appropriate models is RISC ("Fact Sheet for RISC", Environment Agency Fact Sheet FS-04, April 2003).

RISC is based upon the American Society for Testing and Materials (ASTM) Risk Based Corrective Action (RBCA) methodology, but has the flexibility to alter transport and exposure parameters. We have adopted the CLEA principles and parameters into RISC, most notably by amending the software to include an index dose assessment for non-threshold compounds and by inputting CLEA parameters wherever available. Therefore, our assessment is consistent with CLEA, but allows for a broader assessment of sources, compounds and pathways.

Acceptable risk levels are set out in Attachment Six.

As detailed in Attachment Seven, we have used the source concentrations (in Table Nine above) and the appropriate conceptual site model input parameters to calculate the concentrations from each source at each receptor. We have then used the appropriate exposure parameters taken from CLEA to calculate the risk levels for each compound-pathway linkage.

The pathway-specific results of our detailed quantitative risk assessment for human receptors are presented in Attachment Seven and summarised in the tables below. We have calculated a cumulative Index Dose Ratio for all pathways for all non-threshold compounds and a Cumulative Hazard Index for all pathways summed for all compounds for threshold compounds. Values above 1.0 indicate that the site poses a risk to human receptors.

Compound / Site User	Index Dose Ratio for Non-Threshold Substances			
	Soil Sources		Groundwater Source	
	On-site Resident	Off-site Resident	On-site Resident	Off-site Resident
Benzene	0.92	1.2×10^{-3}	0.29	0.13

Note: Values in **BOLD** indicate that this pathway poses an unacceptable risk to the identified receptor

Table Thirteen: Summary of Human Risk Levels – All Non-Threshold Compounds

Compound / Site User	Cumulative Hazard Indexes - All Pathways			
	Soil Sources		Groundwater Source	
	On-site Resident	Off-site Resident	On-site Resident	Off-site Resident
All Threshold Compounds	5.6×10^{-3}	$<10^{-13}$	0.024	8.4×10^{-3}
All TPH Fractions	0.031	$<10^{-13}$	0.068	2.9×10^{-3}

Note: Values in **BOLD** indicate that this pathway poses an unacceptable risk to the identified receptor

Table Fourteen: Summary of Human Risk Levels – All Threshold Compounds

The results of our risk modelling for human receptors indicate that the current soil and groundwater concentrations do not pose a risk to identified human receptors via the identified pathways.

5.3 Environmental Receptors – Organic Compounds

We have evaluated the risk to environmental receptors (e.g. groundwater resources and surface water bodies) using the methodology outlined in Environment Agency "Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources" (R&D Technical Report P20).

We have used the source concentrations from Table Nine and the appropriate input values (listed in Attachment Eight) to calculate concentrations in groundwater at the environmental compliance point.

The nearest surface water to the site is an unnamed tributary of the Wallington River, located approximately 150m to the south-west. We have set the compliance point to this location.

Our P20 modelling results are presented in the table below. Any value above the associated compliance criteria indicates that the site concentrations pose a potential risk to the receptor.

Concentration / Compound	Modelled Groundwater Concentration 150m from Site		Groundwater Compliance Criteria
	Soil Source (µg/litre)	Groundwater Source (µg/litre)	(µg/litre)
Benzene	0.35	0.92	30 [1]
Ethylbenzene	$6.4x10^{-4}$	$9.1x10^{-3}$	20 [1]
Toluene	$1.4x10^{-12}$	$3.8x10^{-12}$	50 [1]
Xylenes	0.020	0.026	30 [1]
TPH: Aliphatic C_6-C_8	0.014	0.46	50 [3] (Total TPH may not exceed this value)
TPH: Aliphatic C_8-C_{10}	$5.3x10^{-4}$	0.55	
TPH: Aliphatic C_{10}-C_{12}	$1.7x10^{-5}$	0.019	
TPH: Aliphatic C_{12}-C_{16}	$1.5x10^{-6}$	$4.0x10^{-4}$	
TPH: Aromatic C_7-C_8	0.22	4.6	50 [3] (Total TPH may not exceed this value
TPH: Aromatic C_8-C_{10}	0.011	0.55	
TPH: Aromatic C_{10}-C_{12}	$1.7x10^{-3}$	0.019	
TPH: Aromatic C_{12}-C_{16}	$8.7x10^{-4}$	$4.0x10^{-4}$	

Notes: Concentrations shown in **BOLD** denote an unacceptable risk
1 Environment Agency EQS, existing or proposed
2 US EPA Guideline Value
3 Surface Water Regulations 1996

Table Fifteen: Modelled Concentrations in Groundwater for Environmental Compliance

The results of our P20 modelling indicate that all modelled groundwater concentrations are below environmental compliance criteria for surface water. Therefore, we conclude that there is no current risk to the unnamed tributary of the Wallington River 150m south-west of the site.

6 Site-Specific Target Levels

The results of our updated risk assessment modelling indicates that current on-site concentrations have been sufficiently lowered so as to not pose a risk to the identified human and environmental receptors. We therefore consider that active remediation can now be halted.

To facilitate post-remediation groundwater monitoring we have calculated site-specific target levels for groundwater using the identified pollutant linkages and the compounds that initially posed a risk.

We have used the same models as used to assess the potential risk to back-calculate hydrocarbon concentrations in the sources that will not pose an unacceptable risk to the identified receptors.

The site-specific target level (SSTL) for each compound is taken as the lowest of the remedial targets calculated for each pathway . The pathway-specific remedial target levels and consequent SSTLs are given in the tables below.

Target Levels / Compound	Pathway-Specific Remedial Targets for Groundwater Source				Groundwater SSTLs
	On-site Resident Indoor Air Inhalation (µg/litre)	On-site Resident Outdoor Air Inhalation (µg/litre)	Off-site Resident Indoor Air Inhalation (µg/litre)	Unnamed tributary of Wallington River 150m (µg/litre)	(µg/litre)
Benzene	3,100	SOL	6,900	29,000	**3,100**
Ethylbenzene	SOL	SOL	SOL	207,000	**207,000**
MTBE	12,000,000	SOL	41,000,000	218,000	**218,000**
Toluene	240,000	SOL	SOL	$1.6x10^{10}$	**240,000**
Xylenes	SOL	SOL	SOL	33,000	**33,000**
TPH: C_6-C_8 [1]	290,000	SOL	SOL	8,100	**8,100**
TPH: C_8-C_{10} [1]	SOL	SOL	SOL	91,000	**91,000**
TPH: C_{10}-C_{12} [1]	SOL	SOL	SOL	440,000	**440,000**
TPH: C_{12}-C_{16} [1]	SOL	SOL	SOL	160,000	**160,000**
TPH: C_{16}-C_{21} [1]	NR	NR	NR	580	**580**
TPH: C_{21}-C_{35} [1]	NR	NR	NR	530	**530**

Notes: RES – the target risk cannot be exceeded at any concentration because the SSTL exceeds the residual concentration
NR – no risk at any concentration, the pathway target concentration for MTBE exceeds 1x106 mg/kg. TPH fractions >C16 do not volatilise and thus pose no risk via inhalation.
1 – pathway targets for TPH have been set to the lower of the pathway target for the aliphatic or aromatic fraction
2 – the target risk cannot be exceeded at any concentration; the pathway target has been set to the residual concentration to ensure that all free-phase is removed from soils.

Table Sixteen: Site-Specific Target Levels for Groundwater

Our calculated target levels are proposed only and must be agreed with the Environment Agency and local authority prior to use. Removal work should not proceed until the Environment Agency and local authority have been consulted on the proposed target levels and have had a chance to comment. We do not accept responsibility for associated shortcomings arising from the use of these target levels without the prior consent of the regulators.

7 Conclusions and Recommendations

The results of our recent soil sampling indicate that lead concentrations near Boreholes A, M and O exceed the SGV for residences with plant uptake, indicating that the surface soils in these areas pose an unacceptable risk to on-site residents. The 95th percentile lead value without these three boreholes would pass the Mean Value and Maximum Value tests, indicating that the soils in the central portion of the site are suitable for residential end use. Therefore, we recommend that it is necessary to replace or remove surface soils on the impacted edges of the site only.

Redevelopment works often strip and replace surface soils and may be sufficient to eliminate the potential risk. Subject to a review of proposed redevelopment plans we therefore recommend that these works could be undertaken in conjunction with the site redevelopment.

The results of our updated risk assessment for human and environmental receptors indicate that current on-site concentrations of hydrocarbon concentrations in both soil and groundwater do not pose an unacceptable risk to the identified receptors. We therefore consider that active remediation can now be halted.

We have calculated site-specific target levels for groundwater to facilitate post-remediation monitoring.

8 Other References

BP Oil International (2001). "Risk-Integrated Software for Clean-ups, Users Manual Version 4.0", BP, Middlesex.

DEFRA and Environment Agency (2002) "The Contaminated Land Exposure Assessment Model (CLEA): Technical Basis and Algorithms" R&D Publication CLR 10 Environment Agency, Bristol.

DEFRA and Environment Agency (2003) "Contaminants in Soil: Collation of Toxicological Data and Intake Value for Humans. Benzene" R&D Publication TOX11, Environment Agency, Bristol.

DEFRA and Environment Agency (2004a) "Soil Guideline Values for Ethylbenzene Contamination" Science Report SGV 16, Environment Agency, Bristol.

DEFRA and Environment Agency (2004b) "Soil Guideline Values for Toluene Contamination" Science Report SGV 15, Environment Agency, Bristol.

DEFRA and Environment Agency (2004c) "Contaminants in Soil: Collation of Toxicological Data and Intake Value for Humans. Ethylbenzene" R&D Publication TOX17, Environment Agency, Bristol.

DEFRA and Environment Agency (2004d) "Contaminants in Soil: Collation of Toxicological Data and Intake Value for Humans. Toluene" R&D Publication TOX14, Environment Agency, Bristol.

DEFRA and Environment Agency (2004e) "Contaminants in Soil: Collation of Toxicological Data and Intake Value for Humans. Xylenes" R&D Publication TOX19, Environment Agency, Bristol.

Environment Agency (1999a). "Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources" R&D Publication 20, Environment Agency, Bristol.

Environment Agency (1999b). "The Fuel Additive MTBE – a Groundwater Protection Issue", Environment Agency, Bristol.

Environment Agency (2003a). "Fact Sheet for RISC", Fact Sheet FS-04, Environment Agency, Bristol.

Environment Agency (2003b). "Review of the Fate and Transport of Selected Contaminants in the Soil Environment", Technical Report P5-079/TR1, Environment Agency, Bristol.

Environment Agency (2004a). "Update on Estimating Vapour Intrusion into Buildings", CLEA Briefing Note 2, Environment Agency, Bristol.

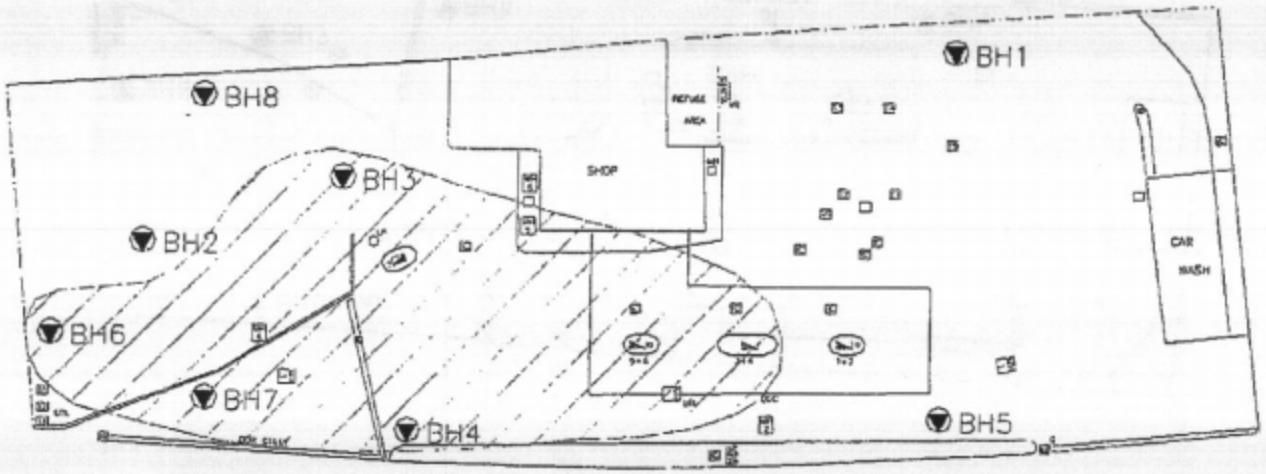
Environment Agency (2004b). "Update of Supporting Values and Assumptions Describing UK Building Stock", CLEA Briefing Note 3, Environment Agency, Bristol.

Environment Agency (2005). "Update on the Dermal Exposure Pathway", CLEA Briefing Note 1, Environment Agency, Bristol.

Environment Agency and Golder Associates (2002). "ConSim Version 1.06", Golder Associates, Nottingham.

Howard, P.H. (1991). "Handbook of Environmental Degradation Rates" Lewis Publishers, Chelsea, MI.

FIGURES



SCALE
0m 5m 10m 15m

SUBADRA

Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE.
LONDON ROAD,
PORTSMOUTH,
HANTS.

DATE : APRIL 2002
SUBADRA ARCHIVE NO : 01514 DR 017
DRAWING BY : NB CHECKED BY : DC

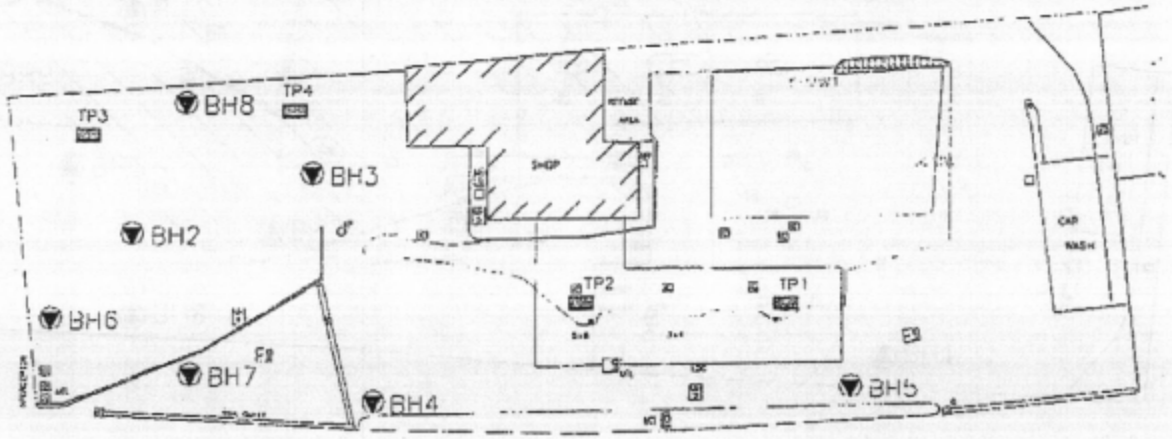
PUMP ISLAND
MANHOLE
PILLAR
BUILDING
CANOPY OUTLINE
BH1 BOREHOLE LOCATION

NOTE: SOIL SOURCE ASSUMED TO COVER THE SITE

ESTIMATED GROUNDWATER PLUME LOCATION

ESTIMATED SOURCES 2002

FIGURE ONE



SCALE
0m 5m 10m 15m

NOTE: THIS DRAWING IS NOT TO SCALE. EXTENTS OF EXCAVATION ARE BASED ON VISUAL ESTIMATES AND ACCURACY CANNOT BE GUARANTEED

SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE,
LONDON ROAD,
PORTSMOUTH,
HANTS.

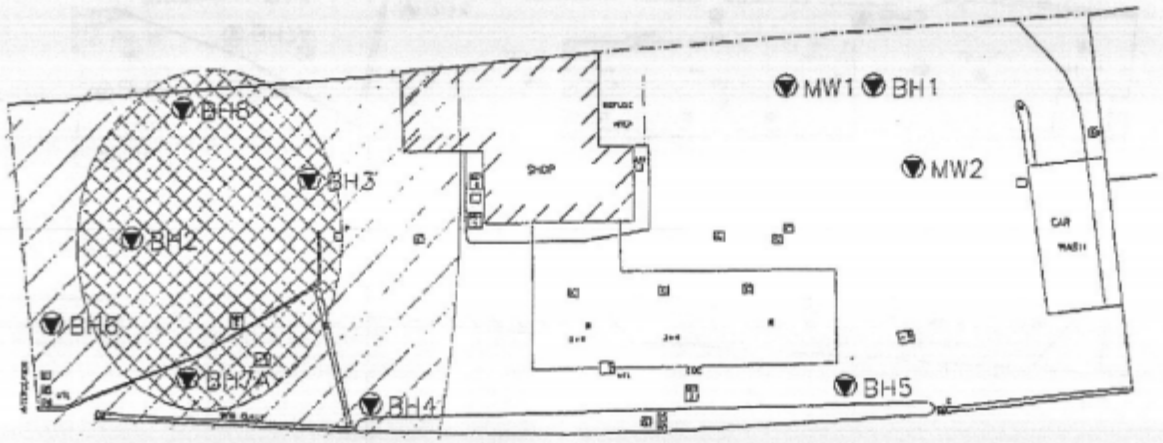
DATE : JULY 2002
SUBADRA ARCHIVE NO : 01514 DR 016
DRAWING BY : W.P CHECKED BY : J.D.R

MONITORING WELL LOCATION
TRIAL PIT LOCATION
AREA OF EXCAVATION
REMAINING CONCRETE CRADLE
BH1 BOREHOLE LOCATION

0m–0.5m
0.5m–1.0m
1.0m–1.5m
1.5m–2.0m
2.0m–2.5m
2.5m–3.0m
3.0m–3.5m
3.5m–4.0m
4.0m–4.5m

DECOMMISSIONING EXCAVATIONS 2002

FIGURE TWO



SCALE
0m 5m 10m 15m

NOTE: THIS DRAWING IS NOT TO SCALE. EXTENTS OF EXCAVATION ARE BASED ON VISUAL ESTIMATES AND ACCURACY CANNOT BE GUARANTEED

SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE,
LONDON ROAD,
PORTSMOUTH,
HANTS.

DATE : JULY 2004
SUBADRA ARCHIVE NO : 01514 DR 019
DRAWING BY: NJB CHECKED BY: DE

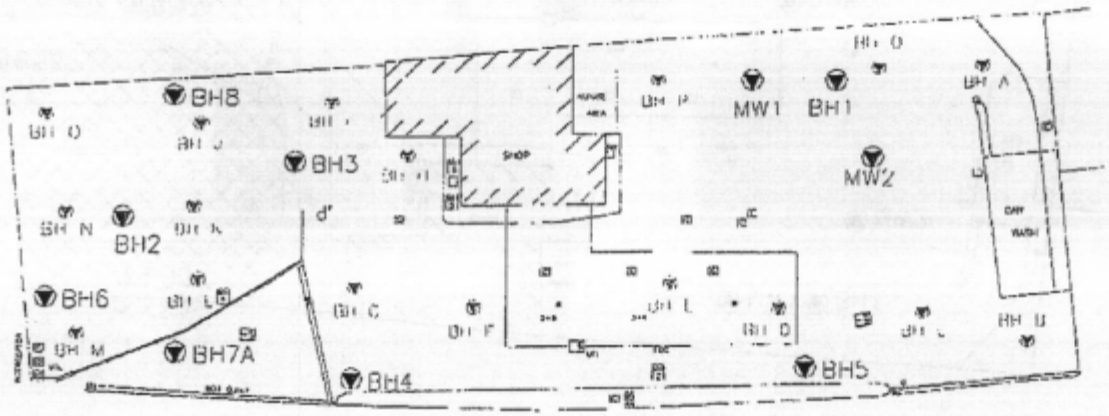
BH1 BOREHOLE LOCATION

INTERPRETED SOIL PLUME

INTERPRETED GROUNDWATER PLUME

ESTIMATED SOURCES 2004

FIGURE THREE



SCALE
0m 5m 10m 15m

SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE,
LONDON ROAD,
PORTSMOUTH,
HANTS.

DATE : MAY 2006

SUBADRA ARCHIVE NO : 01514 DR 022

DRAWING BY: JSR CHECKED BY: IP

BH K 2006 SOIL SAMPLING LOCATION

BH1 MONITORING WELL LOCATION

SOIL SAMPLE LOCATIONS
19 APRIL 2006

FIGURE FOUR

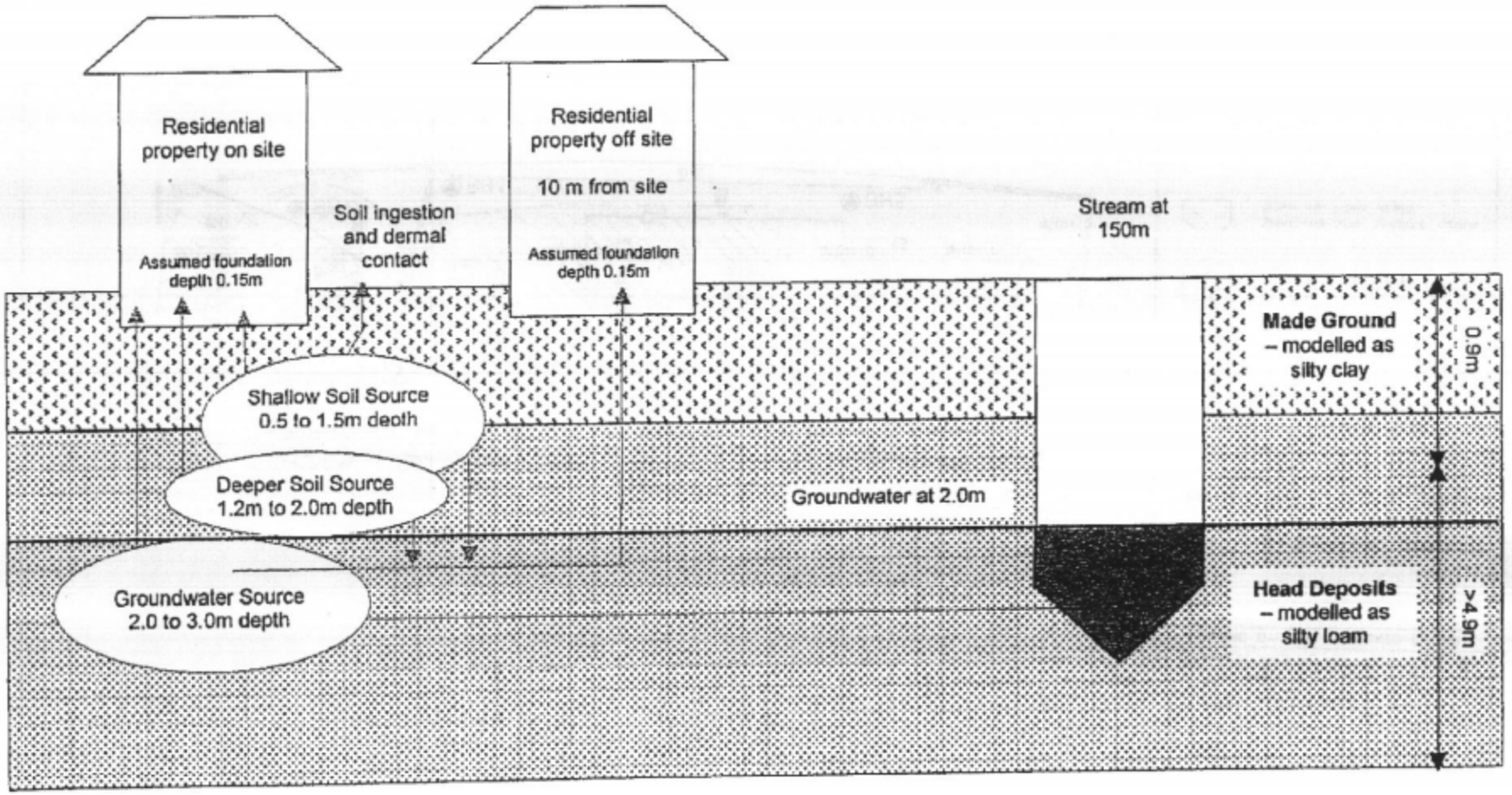
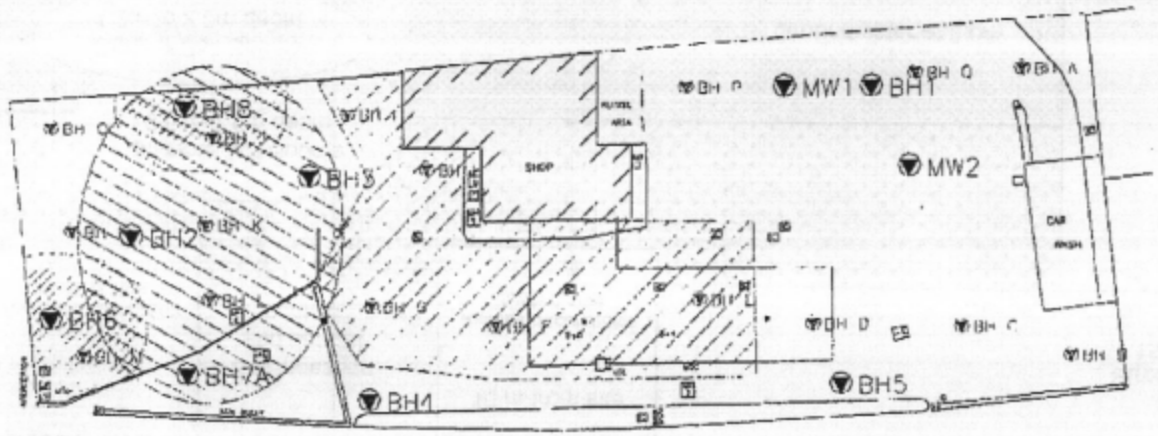


Figure Five: Conceptual Model for Manor Garage Filling Station, Portsmouth



SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5HL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE.
LONDON ROAD,
PORTSMOUTH,
HANTS.

DATE : MAY 2006

SUBADRA ARCHIVE NO : 01514 DR 022

DRAWING BY: JSR CHECKED BY: LP

N

BH1 MONITORING WELL LOCATION

BH K 2006 SOIL SAMPLING LOCATION

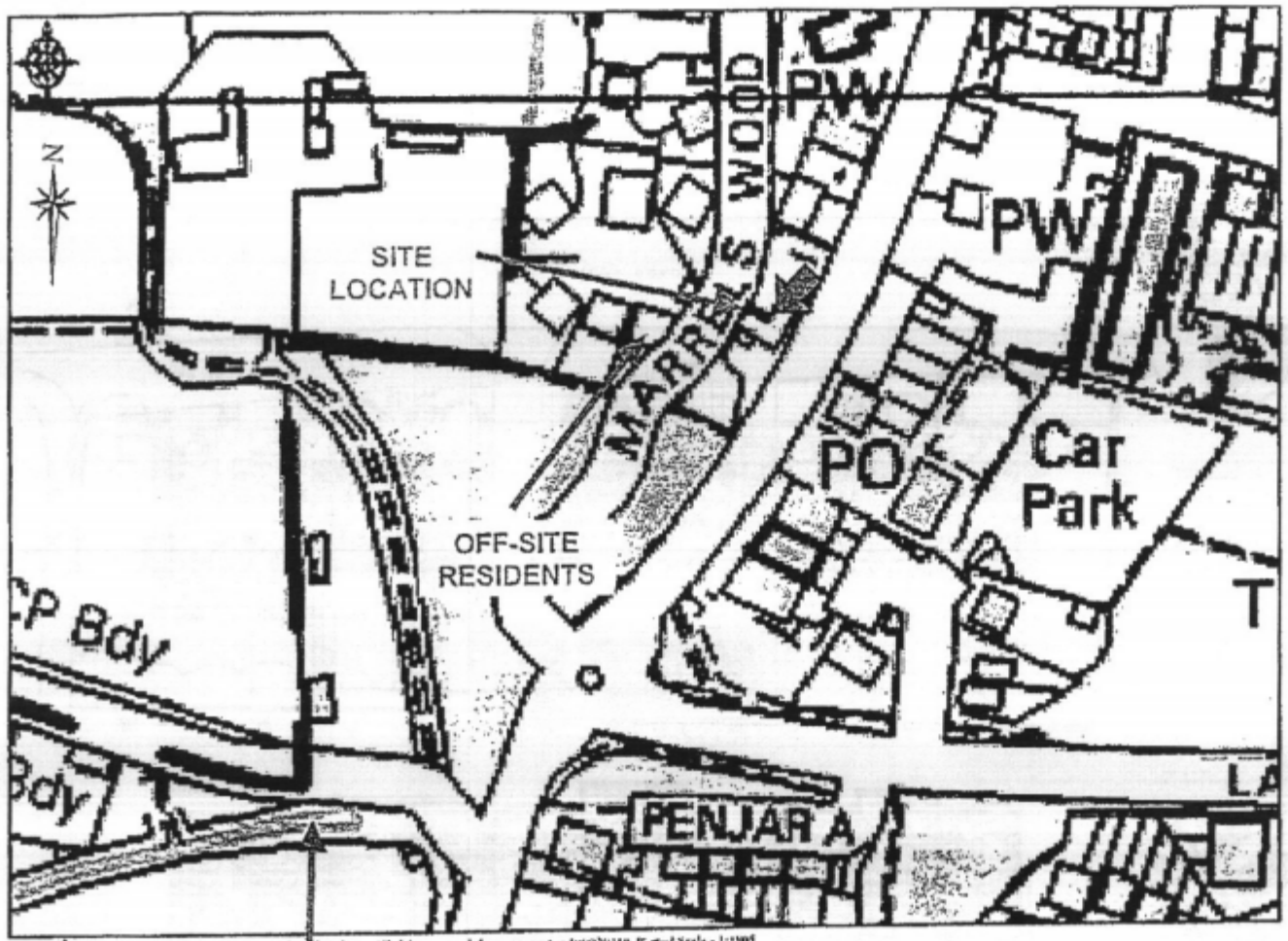
GROUNDWATER SOURCE (2006)
2.0m to 3.0m depth

DEEPER SOIL SOURCE (2004)
1.2m to 2.0m depth

SHALLOW SOIL SOURCE (2006)
0.5m to 1.5m depth

INTERPRETED SOURCES
2006

FIGURE SIX



Unnamed Tributary of
Wallington River

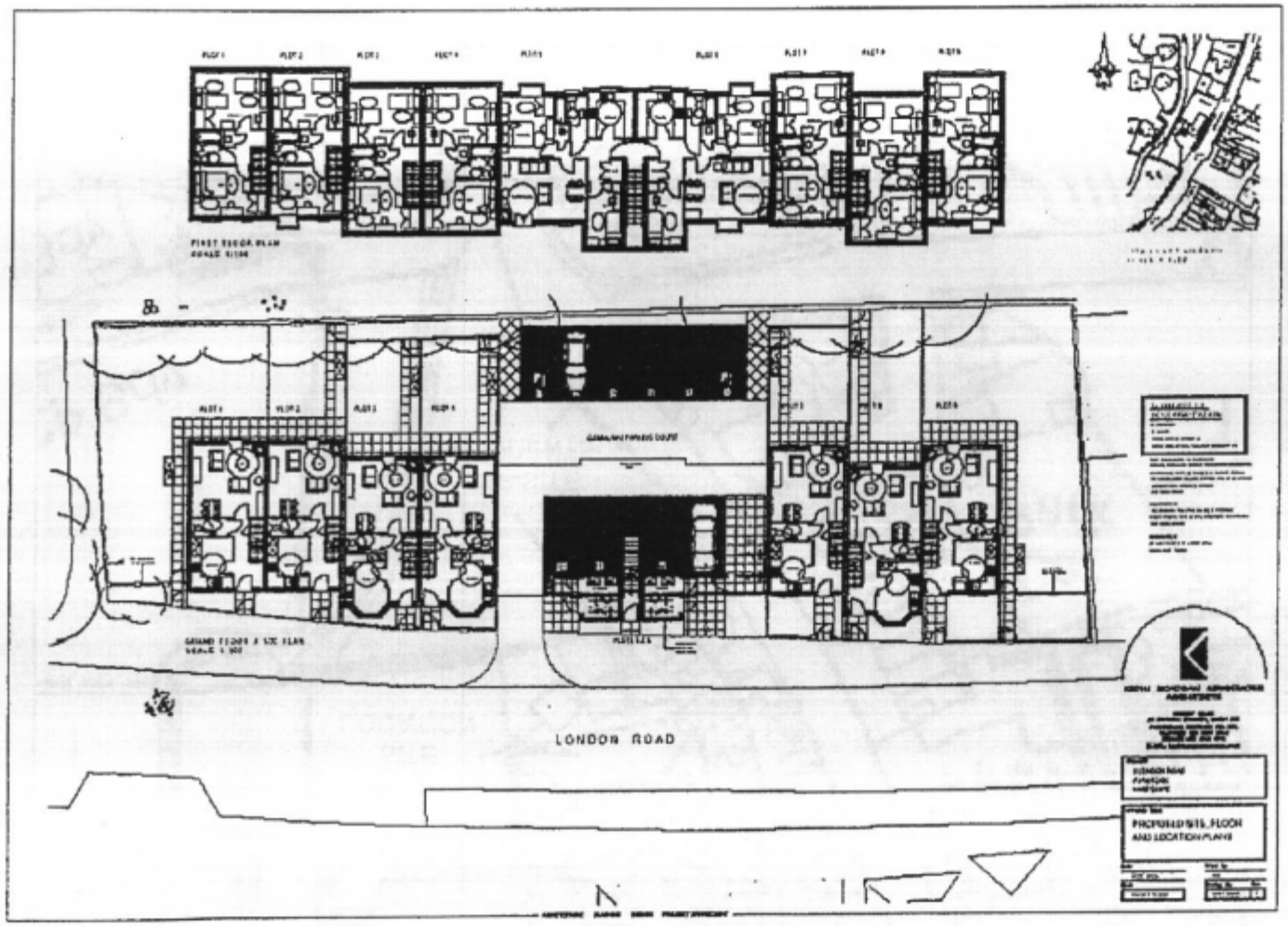
SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5DL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE,
LONDON ROAD,
PORTSMOUTH, HANTS.
PO7 5LQ

DATE : MAY 2005
SUBADRA ARCHIVE NO : 01514 OR 020
DRAWING BY : LP | CHECKED BY : NJB

LOCATION OF
NEARBY RECEPTORS

FIGURE SEVEN



SUBADRA
Unit 13, Triangle Business Park
Stoke Mandeville, Bucks HP22 5UL
Tel. 01296 739400 Fax. 01296 739401

MANOR GARAGE,
LONDON ROAD,
PORTSMOUTH, HANTS.
PO7 5LQ

DATE : APRIL 2006

SUBADRA ARCHIVE NO :01514 DR 021

DRAWING BY : LP CHECKED BY : NJB

PROPOSED
REDEVELOPMENT

FIGURE EIGHT

ATTACHMENT ONE:
NOTICE TO INTERESTED PARTIES

NOTICE TO INTERESTED PARTIES

The purpose of our quantitative risk assessment is to assess the toxicological risk to on-site and off-site receptors posed by soil and groundwater conditions encountered at the site.

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.

When examining the voracity of the base data used in this assessment, we would make the following comments. 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.

Soil is, however, 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 have simply reduced the possibility to an acceptable level.

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.

This 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 have been used in the construction of the buildings present on 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 we carry out any remedial works we deem necessary.

This report has been prepared for BP Oil UK Ltd. Use of, and reliance on, this report by other third parties will be at such third parties own risk, and we are unable to accept any liability or responsibility to third parties.

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.

This report and its contents, together with any supporting correspondence or other documentation, remain the property of Subadra Consulting Limited until paid for in full.

ATTACHMENT TWO:
BOREHOLE LOGS

Borehole No. A

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m TARMAC
								0.2 To 1.0 m LOOSE, RED, Gravelly CLAY
				M1		METALS		
				S1		BTEX		
				M2		METALS		
1								

Borehole terminated at: 1 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. J

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m VERY SOFT, BROWN, Very Sandy CLAY
								0.2 To 0.5 m YELLOW SANDSTONE
								0.5 To 1.2 m FIRM, LIGHT BROWN/RED, Sandy CLAY
				S10		BTEX		
1								

Borehole terminated at: 1 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. K

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT (N) or Su (kPa)	Description
0								0.0 To 0.2 m VERY SOFT, BROWN, Very Sandy CLAY
								0.2 To 0.5 m YELLOW SANDSTONE
				M5		METALS		
				S11		BTEX		0.5 To 1.2 m FIRM, LIGHT BROWN/RED, Sandy CLAY
				M6		METALS		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. H

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.2 To 0.7 m MADE GROUND
1				S8		BTEX		0.7 To 1.2 m BLUE/GREY CLAY with occasional flint

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: Slight Odour 0.7 to 1.2 m
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. I

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m CONCRETE
								0.2 To 0.5 m GRAVEL
				S9		BTEX		0.5 To 1.2 m CLAY
				M4		METALS		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. B

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m TARMAC
								0.2 To 1.0 m LOOSE, RED, Gravelly CLAY
				M3		METALS		
				S2		BTEX		
1								1.0 To 1.2 m SOFT, BROWN, Sandy CLAY

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwaler Encountered

Dwn: TA
Ckd: JR

Borehole No. C

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m TARMAC
								0.2 To 0.8 m LOOSE, RED, Sandy CLAY
				S3		BTEX		
1								0.8 To 1.2 m SOFT, BLUE/BROWN, Sandy CLAY

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered
Dwn: TA
Ckd: JR

Borehole No. D

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m CONCRETE
								0.2 To 0.8 m LOOSE, RED, Sandy CLAY With small angular flint gravel
				S4		BTEX		
1								0.8 To 1.2 m SOFT, BLUE/GREY, Sandy CLAY

Borehole terminated at: 1.2 m

Hydrocarbon odour/staining: Yes 0.8 to 1.2 m

Groundwater monitoring well installed to: No Well Installed

Groundwater encountered at: No Groundwater Encountered

Dwn: TA

Ckd: JR

Borehole No. E

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.4 m MADE GROUND
				S5		BTEX		0.4 To 1.2 m SOFT, GREY/GREEN, Slightly Sandy CLAY with occasional small Gravels
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: Yes 0.4 to 1.2 m
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. F

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	Date	19-04-2006
Project Code	BP01514	Ground Level	
Coordinates		Equipment	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m TARMAC
								0.2 To 0.8 m LOOSE, WHITE/YELLOW Sandy GRAVEL
				S6		BTEX		
1								0.8 To 1.2 m CLAY

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: Slight Odour 0.8 to 1.2 m
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. G

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0.0 To 0.2 m CONCRETE
								0.2 To 0.7 m LOOSE GRAVEL
				S7		BTEX		
								0.7 To 1.2 m CLAY
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: Slight odour 0.8 1.2 m
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. L

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT (N') or Su (kPa)	Description
0								0.0 To 0.2 m SOFT, BLACK/BROWN, Sandy CLAY with frequent Flint
				S12		BTEX		0.2 To 0.5 m BROWN CLAY
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. M

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT (N) or Su (kPa)	Description
0								0.0 To 0.5 m SOFT, BLACK/BROWN, Sandy CLAY with frequent Flint
				M7		METALS		
				S13		BTEX		0.5 To 1.2 m BROWN CLAY
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. N

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	Date	19-04-2006
Project Code	BP01514	Ground Level	
Coordinates		Equipment	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT (N) or So (kPa)	Description
0								0.0 To 0.5 m SOFT, BLACK/BROWN, Sandy CLAY with frequent Flint
								0.5 To 0.5 m BROWN CLAY
				S14		BTEX		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. O

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT (N) or Su (kPa)	Description
0								0.0 To 0.5 m SOFT, BLACK/BROWN, Sandy CLAY with frequent Flint
				M8		METALS		
				S15		BTEX		0.5 To 1.2 m BROWN CLAY
				M9		METALS		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. P

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0. To 1.2 m Gravelly CLAY with BLACK Flint
				M10		METALS		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

Borehole No. Q

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville
Tel. 01296 739400 Fax. 01296 739401.

Project Name	Manor Garage	**Date**	19-04-2006
Project Code	BP01514	**Ground Level**	
Coordinates		**Equipment**	Excavator

Depth (m)	Monitoring Well	Water Level	Log	Sample	Geotechnical Test	Environmental Test	SPT ('N') or Su (kPa)	Description
0								0. To 1.2 m Gravelly CLAY with BLACK Flint
				M11		METALS		
1								

Borehole terminated at: 1.2 m
Hydrocarbon odour/staining: No
Groundwater monitoring well installed to: No Well Installed
Groundwater encountered at: No Groundwater Encountered

Dwn: TA
Ckd: JR

ATTACHMENT THREE:
CHEMICAL ANALYSIS CERTIFICATES

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park
Wendover Road
Stoke Mandeville HP22 5BL
Tel. 01296 739400
Fax. 01296 739401
e-mail: consultants@subadra.com
website: www.subadra.com

19th April 2006, Ninth Edition

Analysis Report

Site name: Manor Garage Filling Station
Site number: 01514
Subadra test report number: 01514 DA 083
Client Name: BP Oil UK Ltd
Address: London Road
Purbrook
Portsmouth

No. of samples	Soil/ Water	CoC No.	Analysis	Date samples recovered	Date samples received	Date samples analysed	Requested Turnaround
15	Soil	1711	BTEX	19th April 2006	20th April 2006	26th April 2006	7 days

Analysis method: Modified US EPA Method 5021 – Extraction using static equilibrium headspace with gas injection. Analysis covering C_6 – C_{15} hydrocarbon boiling range, including individual BTEX components.

Additional comments:

Analysis report authorised by:

Dr Katherine Powell
Laboratory Quality Assurance
Subadra Consulting Limited

Date of issue: 11th May 2006

UKAS TESTING 2628

U – Test Accredited to UKAS

N – Test not accredited to UKAS

S – Test Performed at Sub-Contractor's Laboratory

Please note – Results relate only to the items tested

Test Report – Manor Garage Filling Station, London Road, Purbrook, Portsmouth

Total Petroleum Hydrocarbons by Carbon Group $C_5 - C_{35}$ – Soil Samples

Date of sampling: 19th April 2006

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park, Stoke Mandeville, HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

Method – In-House developed from US EPA Method 5021:
Liquid – gas extraction using headspace
Gas injection GC-FID
Analysis with comparison to SUP 713 custom standard

Sample Location	Laboratory Number	Sample Number	Sample Depth (m)	Soil Description	LOD	UKAS	Detected Concentration (mg/kg)			
							$C_5 - C_6$	$>C_6 - C_{10}$	$>C_{10} - C_{12}$	$>C_{12} - C_{35}$
BHA	SBP01514.003001	S1	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5
BHB	SBP01514.003002	S2	0.7		0.5	U	<0.5	<0.5	<0.5	<0.5
BHC	SBP01514.003003	S3	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5
BHD	SBP01514.003004	S4	0.8		0.5	U	<0.5	<0.5	<0.5	<0.5
BHE	SBP01514.003005	S5	0.6		0.5	U	1.04	2.56	<0.5	<0.5
BHF	SBP01514.003006	S6	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5
BHG	SBP01514.003007	S7	0.6		0.5	U	<0.5	<0.5	<0.5	<0.5
BHH	SBP01514.003008	S8	1		0.5	U	<0.5	<0.5	<0.5	<0.5
BHI	SBP01514.003009	S9	0.5		0.5	U	<0.5	<0.5	2.77	8.95
BHJ	SBP01514.003010	S10	0.7		0.5	U	<0.5	<0.5	<0.5	<0.5

Test Report – Manor Garage Filling Station, London Road, Purbrook, Portsmouth

Total Petroleum Hydrocarbons by Carbon Group $C_6 - C_{15}$ – Soil Samples

Date of sampling: 19th April 2006

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park, Stoke Mandeville, HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

Method – In-House developed from US EPA Method 5021:
Liquid – gas extraction using headspace
Gas injection GC-FID
Analysis with comparison to SUP 713 custom standard

Sample Location	Laboratory Number	Sample Number	Sample Depth (m)	Soil Description	LOD	UKAS	Detected Concentration (mg/kg)			
							$C_6 - C_8$	$>C_8 - C_{10}$	$>C_{10} - C_{12}$	$>C_{12} - C_{16}$
BHK	SBP01514.003011	S11	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5
BHL	SBP01514.003012	S12	0.6		0.5	U	<0.5	<0.5	<0.5	<0.5
BHM	SBP01514.003013	S13	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5
BHN	SBP01514.003014	S14	0.6		0.5	U	<0.5	<0.5	<0.5	<0.5
BHO	SBP01514.003015	S15	0.5		0.5	U	<0.5	<0.5	<0.5	<0.5

Total Petroleum Hydrocarbons by Carbon Group BTEX – Soil Samples

Date of sampling: 19th April 2006

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park, Stoke Mandeville, HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

Method – In-House developed from US EPA Method 5021:

- Liquid – gas extraction using headspace
- Gas injection GC-FID
- Analysis with comparison to SUP 713 custom standard

Sample Location	Laboratory Number	Sample Number	Sample Depth (m)	Soil Description	LOD	UKAS	Detected Concentration (mg/kg)				
							Benzene	Toluene	Ethyl-benzene	P+M Xylene	O-Xylene
BHA	SBP01514.003001	S1	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHB	SBP01514.003002	S2	0.7		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHC	SBP01514.003003	S3	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHD	SBP01514.003004	S4	0.8		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHE	SBP01514.003005	S5	0.6		0.1	U	0.93	0.13	0.39	1.27	0.20
BHF	SBP01514.003006	S6	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHG	SBP01514.003007	S7	0.6		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHH	SBP01514.003008	S8	1		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHI	SBP01514.003009	S9	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHJ	SBP01514.003010	S10	0.7		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1

Test Report – Manor Garage Filling Station, London Road, Purbrook, Portsmouth

Total Petroleum Hydrocarbons by Carbon Group BTEX – Soil Samples

Date of sampling: 19th April 2006

SUBADRA
Consultants in the Earth Sciences
Unit 13, Triangle Business Park, Stoke Mandeville, HP22 5BL
Tel. 01296 739400 Fax. 01296 739401

Method – In-House developed from US EPA Method 5021:
- Liquid – gas extraction using headspace
- Gas injection GC-FID
- Analysis with comparison to SUP 713 custom standard

Sample Location	Laboratory Number	Sample Number	Sample Depth (m)	Soil Description	LOD	UKAS	Detected Concentration (mg/kg)				
							Benzene	Toluene	Ethyl-benzene	P+M Xylene	O-Xylene
BHK	SBP01514.003011	S11	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHL	SBP01514.003012	S12	0.6		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHM	SBP01514.003013	S13	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHN	SBP01514.003014	S14	0.6		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1
BHO	SBP01514.003015	S15	0.5		0.1	U	<0.1	<0.1	<0.1	<0.1	<0.1

End of Report

Scientific Analysis Laboratories

Report Number:	76235-1
Date of Report:	04-May-2006
Client:	Subadra Consulting Ltd, Unit 13, Triangle Business Park, Wendover Rd, Stoke Mandeville, Bucks. HP22 5BL
Client Contact:	Ms Jemma Reinsch
Client Job Reference:	01514
Client Site Reference:	Manor Garage
Client Purchase Order:	03915
Date Job Received at SAL:	24-Apr-2006
Date Analysis Started:	25-Apr-2006
Date Analysis Completed:	04-May-2006

The results reported relate to samples received at the laboratory
Opinions and interpretations expressed herein are outside the scope of UKAS accreditation
This report should not be reproduced except in full without the written approval of the laboratory
Tests covered by this certificate were conducted in accordance with SAL SOPs

Key to symbols used in this report:
W: Analysis was performed at another SAL Laboratory
S: Analysis was sub-contracted
N: Analysis is not UKAS accredited
U: Analysis is UKAS accredited

Report checked and authorised by: Daniel Vaughan, Project Manager

1549
Group

Report Number: 76235-1

Results

Soil

				SAL Ref:	76235 001	76235 002	76235 003	76235 005	76235 006
				Client Ref:	BHA 0.4m	BHA 0.8m	BHB 0.4m	BHK 0.4m	BHK 0.8m
				Type:	Soil	Soil	Soil	Soil	Soil
Determinand	Method	Units	LOD	Symbol					
Cyanide (Total)	Colorimetry	mg/kg	1	U	<1	<1	<1	<1	<1
Phenols (Total-Mono)	Colorimetry	mg/kg	1	U	<1	<1	<1	<1	<1
Sulphide	Colorimetry	mg/kg	10	N	<10	<10	<10	<10	<10
Sulphur (Free)	Grav	mg/kg	500	N	<500	<500	<500	<500	<500
Arsenic	ICP/OES	mg/kg	1	U	4	5	6	5	6
Boron (water-soluble)	ICP/OES	mg/kg	1	N	<1	<1	<1	<1	<1
Cadmium	ICP/OES	mg/kg	1	U	<1	<1	<1	<1	<1
Chromium	ICP/OES	mg/kg	1	U	16	17	17	14	18
Copper	ICP/OES	mg/kg	1	U	4	13	11	14	8
Lead	ICP/OES	mg/kg	1	U	150	1380	190	120	28
Mercury	ICP/OES	mg/kg	1	U	<1	<1	<1	<1	<1
Nickel	ICP/OES	mg/kg	1	U	4	6	7	6	7
Selenium	ICP/OES	mg/kg	2	U	<2	<2	<2	<2	<2
Sulphate(2:1)	ICP/OES	g/l	0.1	N	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	ICP/OES	mg/kg	1	U	28	150	36	130	31
pH	Probe			U	8.3	8.6	7.8	9.8	11.3

Soil

				SAL Ref:	76235 007	76235 008	76235 009	76235 010	76235 011
				Client Ref:	BHM 0.4m	BHO 0.4m	BHO 0.8m	P 0.4m	Q 0.4m
				Type:	Soil	Soil	Soil	Soil	Soil
Determinand	Method	Units	LOD	Symbol					
Cyanide (Total)	Colorimetry	mg/kg	1	U	<1	<1	<1	<1	<1
Phenols (Total-Mono)	Colorimetry	mg/kg	1	U	<1	<1	<1	<1	<1
Sulphide	Colorimetry	mg/kg	10	N	<10	<10	<10	<10	<10
Sulphur (Free)	Grav	mg/kg	500	N	<500	<500	<500	<500	<500
Arsenic	ICP/OES	mg/kg	1	U	10	10	6	6	11
Boron (water-soluble)	ICP/OES	mg/kg	1	N	<1	<1	<1	<1	<1
Cadmium	ICP/OES	mg/kg	1	U	2	<1	<1	<1	<1
Chromium	ICP/OES	mg/kg	1	U	18	22	15	17	18
Copper	ICP/OES	mg/kg	1	U	68	440	11	12	42
Lead	ICP/OES	mg/kg	1	U	500	1400	51	120	120
Mercury	ICP/OES	mg/kg	1	U	<1	1	<1	<1	<1
Nickel	ICP/OES	mg/kg	1	U	23	14	8	8	12
Selenium	ICP/OES	mg/kg	2	U	<2	<2	<2	<2	<2
Sulphate(2:1)	ICP/OES	g/l	0.1	N	<0.1	<0.1	<0.1	<0.1	<0.1
Zinc	ICP/OES	mg/kg	1	U	110	650	35	39	130
pH	Probe			U	7.6	7.7	7.8	8.3	10.6

Produced by: Scientific Analysis Laboratories Ltd, Medlock House, New Elm Road, Manchester. M3 4JH Page 2 of 2

ATTACHMENT FOUR:

TOXICOLOGICAL AND CHEMICAL PROPERTIES OF CONTAMINANTS OF CONCERN

Toxicity Parameters

Benzene	Index Dose	0.29	0.91	R&D Tox Pub 11
Ethylbenzene	TDSI[1]	100	170	R&D Tox Pub 17
MTBE	Reference Dose [3]	-	860	RISC
Toluene	TDSI[1]	200	71 – child	R&D Tox Pub 14
TPH: Aliphatic C_6-C_8	Reference Dose[2]	5,000	5,000	EA P5-080/TR1
TPH: Aliphatic C_8-C_{10}	Reference Dose[2]	100	270	EA P5-080/TR1
TPH: Aliphatic C_{10}-C_{12}	Reference Dose[2]	100	270	EA P5-080/TR1
TPH: Aliphatic C_{12}-C_{16}	Reference Dose[2]	100	270	EA P5-080/TR1
TPH: Aliphatic C_{16}-C_{35}	Reference Dose[2]	2000	-	EA P5-080/TR1
TPH: Aromatic C_7-C_8	Reference Dose[2]	200	110	EA P5-080/TR1
TPH: Aromatic C_8-C_{10}	Reference Dose[2]	40	55	EA P5-080/TR1
TPH: Aromatic C_{10}-C_{12}	Reference Dose[2]	40	55	EA P5-080/TR1
TPH: Aromatic C_{12}-C_{16}	Reference Dose[2]	40	55	EA P5-080/TR1
TPH: Aromatic C_{16}-C_{21}	Reference Dose[2]	30	-	EA P5-080/TR1
TPH: Aromatic C_{21}-C_{35}	Reference Dose[2]	1000	-	EA P5-080/TR1
Xylenes	TDSI[1]	178 – child	60 – child	R&D Tox Pub 19

Notes: 1 TDSI – Tolerable Daily Soil Intake. This has also been applied to contaminants in groundwater
2 Toxicity Dose is approximately equivalent to TDSI. Where no TDSI has been published, the Toxicity Dose published in the Environment Agency Science Paper P5-080/TR1 has been used, with adjustments for the female child body weight and indoor air inhalation rate, to assess toxicity.
3 Reference Dose is approximately equivalent to TDSI. Where no TDSI or toxicity dose has been published, the Reference Dose published in RISC has been used.

Chemical Properties

Benzene	0.118	134.1	16	720
Ethylbenzene	0.163	432	10	228
MTBE	0.0169	12	180	360
Toluene	0.137	178	22	28
TPH: Aliphatic C_6-C_8	34.2	4,000	180	720
TPH: Aliphatic C_8-C_{10}	48.6	31,600	28	360
TPH: Aliphatic C_{10}-C_{12}	71.8	251,000	48	258
TPH: Aliphatic C_{12}-C_{16}	254	5,010,000	102	204
TPH: Aliphatic C_{16}-C_{35}	2410	1,000,000,000	2140	4280
TPH: Aromatic C_7-C_8	0.177	250	180	720
TPH: Aromatic C_8-C_{10}	0.290	1,580	28	360
TPH: Aromatic C_{10}-C_{12}	0.0774	2,510	48	258
TPH: Aromatic C_{12}-C_{16}	0.0254	5,010	102	204
TPH: Aromatic C_{16}-C_{21}	0.00489	15,800	1900	3800
TPH: Aromatic C_{21}-C_{35}	0.000144	126,000	2140	4280
Xylenes	0.141	455	28	360

Notes: 1 – Henry's Law constant at 10C, revised using CLEA Briefing Note 2; original Henry's Law values taken from P5-079 (EA, 2003b) for BTEX, RISC chemical database for TPH
2 – Koc taken from P5-079 (EA, 2003b) for BTEX, RISC chemical database for TPH.
3 – First Order Decay Half Life from Howard, Handbook of Environmental Degradation Rates, Lewis Publishers, 1989.

For the TPH ranges, we have calculated the corrected Henry's Law value for individual compounds within the indicated TPH ranges. We have then used the average ratio of change for the Henry's Law, between 20°C and 10°C, to calculate the change in Henry's Law for the given TPH range.

A limitation to this method is that hexane is the only aliphatic compound about which sufficient information is available to calculate the corrected Henry's Law constant. All other compounds for which we have sufficient information are aromatic.

We have also calculated an average half-life for each TPH ranges, based upon individual compounds within the indicated TPH ranges.

We grouped the compounds according to their equivalent carbon number as given in Total Petroleum Hydrocarbons Criteria Working Group - Volume 3, as follows:

Properties of Individual TPH Compounds

TPH Range	Individual Compounds Used in Calculations	Equivalent Carbon Number	Calculation Type	Half-life	
				Soil	Groundwater
TPH >C_6-C_8	Cyclohexane	6.59	Half-life	180	360
	Benzene	6.5	Henry's Law Half-life	16	720
	Toluene	7.58	Henry's Law Half-life	22	28
	Hexane	6	Henry's Law	–	–
TPH >C_8-C_{10}	Ethylbenzene	8.5	Henry's Law Half-life	10	228
	Xylenes	8.6	Henry's Law Half-life	28	360
	Styrene	8.83	Half-life	28	210
	1,2,4 Trimethylbenzene	9.8	Henry's Law Half-life	28	56
	1,3,5 Trimethylbenzene	9.6	Henry's Law	–	–
	n-Propylbenzene	9.5	Henry's Law	–	–
TPH >C_{10}-C_{12}	n-Butylbenzene	10.5	Henry's Law	–	–
	Naphthalene	11.7	Henry's Law Half-life	48	258
TPH >C_{12}-C_{16}	Acenaphthalene	15.5	Henry's Law Half-life	102	204
	Biphenyl	14.26	Half-life	7	14
TPH >C_{16}-C_{21}	Fluorene	16.5	Henry's Law Half-life	60	120
	Benzo(ghi)perylene	18	Half-life	650	1300
	Phenanthrene	19.36	Half-life	200	400
	Anthracene	19.43	Half-life	460	920
	Pyrene	20.8	Henry's Law Half-life	1900	3800
	3-Methylchloanthrene	21	Half-life	1400	2800
TPH >C_{21}-C_{35}	Fluoranthene	21.85	Half-life	440	880
	Benz(a)anthracene	26.37	Half-life	680	1360
	Chrysene	27	Henry's Law Half-life	1000	2000
	Benzo(b)fluoranthene	30.14	Half-life	610	1220
	Benz(k)fluoranthene	30.14	Half-life	2140	4280
	Benzo(a)pyrene	31	Henry's Law Half-life	530	1060
	Indeno(1,2,3-cd)pyrene	35.01	Half-life	730	1460

ATTACHMENT FIVE:
EVALUATION OF POLLUTANT LINKAGES

Sources	Pathway Components	Receptors
Hydrocarbon Impacted Soils	Vegetable ingestion	On site residents Pathways apply to surface soil source (at depths of less than 1m) in garden or landscaped areas only
	Dermal contact with surface soil	
	Ingestion of surface soil	
	Volatilisation to indoor air Inhalation of indoor air	On site residents
	Volatilisation to outdoor air Inhalation of outdoor air	
	Leaching to groundwater Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off site residents, 10m from site
	Leaching to groundwater Migration of groundwater off-site Volatilisation to outdoor air Inhalation of outdoor air	Not modelled as indoor air inhalation pathway always produces a higher risk than outdoor air inhalation pathway.
	Leaching to groundwater Migration of groundwater off-site Groundwater migration to abstraction Ingestion of, inhalation of and dermal contact with groundwater	No active pathway. There are no surface or groundwater abstractions within 2km of the site. Future abstractions are unlikely due to nature of aquifer.
	Leaching to groundwater Migration of groundwater off-site Environmental Receptors	Unnamed tributary of Wellington River lies 150m south-west of site
Hydrocarbon Impacted Groundwater	Volatilisation to indoor air Inhalation of indoor air	On site residents
	Volatilisation to outdoor air Inhalation of outdoor air	On site residents
	Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off site residents, 10m from site
	Migration of groundwater to off site Volatilisation to outdoor air Inhalation of outdoor air	Not modelled as indoor air inhalation pathway always produces a higher risk than outdoor air inhalation pathway.
	Migration of groundwater to off site Groundwater migration to abstraction Ingestion of, inhalation of and dermal contact with groundwater	No active pathway. There are no surface or groundwater abstractions within 2km of the site. Future abstractions are unlikely due to nature of aquifer.
	Migration of groundwater off-site Environmental receptors	Unnamed tributary of Wellington River lies 150m south-west of site

ATTACHMENT FIVE:
EVALUATION OF POLLUTANT LINKAGES

Sources	Pathway Components	Receptors
Hydrocarbon Impacted Soils	Vegetable ingestion	On site residents Pathways apply to surface soil source (at depths of less than 1m) in garden or landscaped areas only
	Dermal contact with surface soil	
	Ingestion of surface soil	
	Volatilisation to indoor air Inhalation of indoor air	On site residents
	Volatilisation to outdoor air Inhalation of outdoor air	
	Leaching to groundwater Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off site residents, 10m from site
	Leaching to groundwater Migration of groundwater off-site Volatilisation to outdoor air Inhalation of outdoor air	Not modelled as indoor air inhalation pathway always produces a higher risk than outdoor air inhalation pathway.
	Leaching to groundwater Migration of groundwater off-site Groundwater migration to abstraction Ingestion of, inhalation of and dermal contact with groundwater	No active pathway. There are no surface or groundwater abstractions within 2km of the site. Future abstractions are unlikely due to nature of aquifer.
	Leaching to groundwater Migration of groundwater off-site Environmental Receptors	Unnamed tributary of Wellington River lies 150m south-west of site
Hydrocarbon Impacted Groundwater	Volatilisation to indoor air Inhalation of indoor air	On site residents
	Volatilisation to outdoor air Inhalation of outdoor air	On site residents
	Migration of groundwater off-site Volatilisation to indoor air Inhalation of indoor air	Off site residents, 10m from site
	Migration of groundwater to off site Volatilisation to outdoor air Inhalation of outdoor air	Not modelled as indoor air inhalation pathway always produces a higher risk than outdoor air inhalation pathway.
	Migration of groundwater to off site Groundwater migration to abstraction Ingestion of, inhalation of and dermal contact with groundwater	No active pathway. There are no surface or groundwater abstractions within 2km of the site. Future abstractions are unlikely due to nature of aquifer.
	Migration of groundwater off-site Environmental receptors	Unnamed tributary of Wellington River lies 150m south-west of site

ATTACHMENT SIX:
ACCEPTABLE RISK LEVELS

A. Previously Used Risk-Based Screening Levels for Human Receptors (2002)

Benzene	0.29	2.0	17	99	1,000
Benzo(a)pyrene	0.58	2.4	-	-	NS
Ethylbenzene	150	150	780	10,000	36,000
MTBE	470	7,500	2,400,000	39,000,000	1,800
Naphthalene	49	49	160	2,000	1,800
TPH – C_6-C_{10}	37	970	240	4,100	1,330
TPH – C_{10}-C_{12}	330	330	310	4,100	1,330
TPH – C_{12}-C_{16}	sat	sat	310	4,100	1,330
TPH – C_{16}-C_{21}	sat	sat	230	sol	1,330
TPH – C_{21}-C_{35}	sat	sat	sol	sol	1,330
Toluene	31	490	1,600	20,000	560,000
Total Xylenes	82	sat	16,000	sol	27,000

Note: Sat = Acceptable risk not exceeded at maximum theoretical saturation concentration.
Sol = Acceptable risk not exceeded at maximum theoretical solubility of compound in water.

B Non-Threshold Substances for Human Receptors – Index Dose Ratio

Non-threshold substances are toxicants that have no threshold dose, there is always some risk at any level of exposure. Under the CLEA approach these compounds are assessed in terms of a soil Index Dose, a level set for each toxicant that represents a minimal risk level from possible soil exposures.

For non-threshold substances, we assess risk by evaluating the index dose ratio to see if the chronic average daily intake for all pathways exceeds the index dose for the given compound:

$$IDR_{xy} = CADD_{xy} / ID_x$$

where

IDR_{xy}	Index Dose Ratio for chemical x for exposure pathway y;
$CADD_{xy}$	Chronic average daily intake for chemical x and exposure pathway y;
ID_x	Acceptable Index Dose for chemical x and exposure pathway y from CLEA publications.

We then sum the index dose ratio for each chemical for each receptor to determine the overall risk posed by the site.

C. Threshold Substances for Human Receptors – Hazard Index

Threshold substances are toxicants that have a finite dose below which adverse effects are not discernible. For each threshold substance, we have modelled the exposure risk using the standard hazard index. This is defined as the ratio of exposure to toxicity for each compound and exposure pathway:

$$HI_{xy} = CADD_{xy} / TDSI_{xy}$$

where

HI_{xy}	Hazard Index for chemical x and exposure pathway y;
$CADD_{xy}$	Chronic daily intake for chemical x and exposure pathway y;
$TDSI_{xy}$	Tolerable Daily Soil Intake for chemical x and exposure pathway y from CLEA publications. If a CLEA-defined *TDSI* is unavailable, the toxicity dose from P5-080/TR3 or another appropriate source will be utilised.

We then sum the hazard indexes for each pathway, then all pathways for each receptor to determine the overall risk posed by the site.

D. Acceptable Risk Levels for Human Receptors

Where we are assessing a residence, we will assess the exposure to a child resident as children are more sensitive to contaminants than adults. We have defined the acceptable risks as follows:

Residents	1.0	1.0	<1.0	<1.0

E. Environmental Receptors

For environmental receptors, the site is considered to pose an unacceptable risk if modelled groundwater concentrations from releases at the site exceed the noted criteria below.

In order of preference, the following sources have been used to derive the compliance standards: UK Drinking Water Standards (for groundwater receptors), Environmental Quality Standards (for surface water receptors), Surface Water Regulations, other UK guidance, Word Health Organisation Drinking Water Guideline Values, and US EPA Drinking Water Guidelines Values.

Benzene	30[1]	1[2]
Ethylbenzene	20[1]	20[1]
MTBE	20[3]	15[4]
Toluene	50[1]	50[1]
TPH: Aliphatic C_8-C_8	50[5] (Total TPH cannot exceed this value)	50[5] (Total TPH cannot exceed this value)
TPH: Aliphatic C_8-C_{10}		
TPH: Aliphatic C_{10}-C_{12}		
TPH: Aliphatic C_{12}-C_{16}		
TPH: Aliphatic C_{16}-C_{35}		
TPH: Aromatic C_6-C_8	50[5] (Total TPH cannot exceed this value)	50[5] (Total TPH cannot exceed this value)
TPH: Aromatic C_8-C_{10}		
TPH: Aromatic C_{10}-C_{12}		
TPH: Aromatic C_{12}-C_{16}		
TPH: Aromatic C_{16}-C_{21}		
TPH: Aromatic C_{21}-C_{35}		
Xylenes	30[1]	30[1]

Notes: 1 – Environment Agency EQS, existing or proposed
2 – The Water Quality Regulations, 2000
3 – US EPA Guideline Value
4 – Odour threshold, "The Fuel Additive MTBE – a Groundwater Protection Issue", Environment Agency, 1999
5 – Surface Water Regulations 1996

ATTACHMENT SEVEN:

HUMAN HEALTH MODEL (RISC) – INPUT PARAMETERS AND PATHWAY RESULTS

Risk Assessment Runs

1	Deeper Soil	On-site resident	Indoor air inhalation	No
2	Deeper Soil	On-site resident	Outdoor air inhalation	No
3	Shallow Soil	On-site resident	Surface Soils - dermal contact, soil ingestion and vegetable ingestion	No
4	Shallow Soil	On-site resident	Indoor air inhalation	No
5	Shallow Soil	On-site resident	Outdoor air inhalation	No
6	Shallow Soil	Off-site resident	Indoor air inhalation	No
7	Groundwater	On-site resident	Indoor air inhalation	No
8	Groundwater	On-site resident	Outdoor air inhalation	No
9	Groundwater	Off-site resident	Indoor air inhalation	No
SSTL1	Groundwater	On-site resident	Back-calculation of Run 8 to generate SSTL	–
SSTL2	Groundwater	On-site resident	Back-calculation of Run 9 to generate SSTL	–
SSTL3	Groundwater	Off-site resident	Back-calculation of Run 10 to generate SSTL	–

RISK ASSESSMENT INPUT PARAMETERS

Deeper Soil Source Geometry

Depth to top of contamination (m)	1.2	Site data – Soil source is assumed to be from 1.2m to 2.0m
Thickness of soil source area (m)	0.8	
Length of soil source in direction of groundwater flow (m)	25	Site data – Values from 2004 risk assessment
Width of soil source perpendicular to direction of groundwater flow (m)	25	

Shallow Soil Source Geometry

Depth to top of contamination (m)	0.5	Site data – Soil source is assumed to be from 0.5m to 1.5m. Due to modelling constraints, in Run 2 the source is modelled as just below building foundation (0.6m source depth, 0.1m below foundation)
Thickness of soil source area (m)	1.0	
Length of soil source in direction of groundwater flow (m)	30	Site data – Estimate based on data from recent sampling (see Sections 3.3 and 4.2 and Figure Six)
Width of soil source perpendicular to direction of groundwater flow (m)	15	

Groundwater Source Geometry

Depth to top of contamination (m)	2.0	Site data – average depth to groundwater level in plume area (see Table 6)
Thickness of source plume (m)	1	Assumed
Length of source plume in direction of groundwater flow (m)	15	Site data – Estimated area of groundwater impact from recent sampling (see Sections 2.7 and 4.2 and Figure Six)
Width of source plume perpendicular to direction of groundwater flow (m)	15	

Unsaturated Soil Properties

The represents the unsaturated Made Ground present from the surface to 0.9m below ground level.

Lithology	Silty clay	Site data – to represent Made Ground
Total porosity (cm^3/cm^3)	0.51	CLEA recommended values for clay soil (CLEA Briefing Note 2, Table 3)
Water content (cm^3/cm^3)	0.45	
Soil bulk density (g/cm^3)	1.6	
Saturated Conductivity (m/day)	0.81	
Fraction of organic carbon (g oc/g soil)	0.018	ConSim average value for Boulder Clay
Infiltration (cm/year)	7	Based on NERC effective rainfall data (115mm/year), assuming 50% hardstanding cover, and drainage system efficiency of 80%

Lens Properties – Runs 1, 2, 6, 7, 8 and 9

The lens represents the unsaturated Head Deposits present from 0.9m to 2.0m. The lens was not used in Runs 3, 4 or 5 which model surface soil pathways and indoor and outdoor air concentrations from the shallow soil source, as the top of the shallow soil source is within the Made Ground that overlies the Head Deposits

Lithology	Silty Loam	Site data – to represent Head Deposits
Thickness of Lens (m)	1.1 (0.3)	Site data – to represent thickness of unsaturated Head Deposits. Value of 0.3m used for Runs 1 and 2 to represent the 0.3m of Head Deposits between the base of the Made Ground at 0.9m and the top of the source at 1.2m
Total porosity (cm^3/cm^3)	0.51	CLEA recommended values for loam (CLEA Briefing Note 2, Table 3)
Water content (cm^3/cm^3)	0.36	
Soil bulk density (g/cm^3)	1.4	
Fraction of organic carbon (g oc/g soil)	0.046	Site data – average for Head Deposits (Ref.1, Attachment 3)

Aquifer Properties

Lithology	Silty Loam	Site data – to represent Head Deposits
Effective porosity (cm^3/cm^3)	0.25	RISC recommended value for silty loam
Fraction of organic carbon (g oc/g soil)	0.046	Site data – average for Head Deposits (Ref.1, Attachment 3)
Hydraulic conductivity (m/day)	0.43	Site data – Average of all rising head tests
Soil bulk density (g/cm^3)	1.4	CLEA recommended value for loam (CLEA Briefing Note 2, Table 3)
Hydraulic gradient (m/m)	0.018	Site data – 27 August 2002 (Ref.4)

On-Site Building Dimensions - Residential

Distance to foundation from soil source (m)	1.05 0.35	Deeper Soil Source at 1.2m. Shallow soil source at 0.5m. Building foundation extends to 0.15m.
Distance to foundation from groundwater source (m)	1.85	Site data – Groundwater at 2.0m, assumed foundation of 0.15m.
Cross-sectional area of foundation (m^2)	45	Proposed redevelopment plans indicate that the footprint of the units will be 5m x 9m. Assumed storey height of 2.4m and other parameters from CLEA Briefing Note 3, Appendix 1 for a residential property
Volume of building (m^3)	108	
Length of foundation perimeter (m)	28	
Number of air exchanges per day	12	
Thickness of foundation walls (m)	0.15	
Crack fraction	0.001	
Pressure Differential ($g/cm\text{-}s^2$)	30	
Depth of foundation (m)	0.15	
Vapour Permeability of vadose zone (cm^2)	$5.3x10^{-9}$	Calculated from CLEA Briefing Note 2, Appendix 3 for clay soil

Off-Site Building Dimensions - Residential

Lateral distance from source (m)	10	Site data – nearest residential property (see Figure Seven)
Distance to foundation from groundwater source (m)	1.85	Site data – Groundwater at 2m depth, foundation assumed 0.15m below surface
Cross-sectional area of foundation (m^2)	108	OS map indicates that the footprint of the nearest off-site residence is 12m x 9m. Assumed storey height of 2.4m and other parameters from CLEA Briefing Note 3, Appendix 1
Volume of building (m^3)	259	
Number of air exchanges per day	12	

Off-Site Building Dimensions – Residential (Continued)

Thickness of foundation walls (m)	0.15	
Crack fraction	0.001	
Depth of foundation (m)	0.15	CLEA Briefing Note 3, Appendix 1 recommendations for residential property

Outdoor Box Model

Box height (m)	0.47	CLR10, Table 5.7 The average of heights for a child of 0 to 6 years is 0.93m. CLEA recommends that half the height is used to allow for time spent sitting or crawling etc
Box length (m)	25 30 15	Site data – Longest dimension of deeper soil source / shallow soil source / groundwater source as a conservative measure, since predominant wind direction is unknown
Wind speed (m/second)	4	CLR 10, Section 6.93. SGVs have been calculated assuming a wind speed of 8 knots ≈ 4 m/second

RECEPTOR POINT CONCENTRATIONS – HUMAN RECEPTORS

Benzene		$2.4x10^{-4}$	$9.6x10^{-7}$	$1.5x10^{-3}$	$6.6x10^{-6}$	$4.0x10^{-6}$	$9.7x10^{-4}$	$3.4x10^{-6}$	$4.3x10^{-4}$
Ethylbenzene		$5.5x10^{-5}$	$2.2x10^{-7}$	$2.2x10^{-4}$	$9.4x10^{-7}$	$<10^{-13}$	$9.6x10^{-4}$	$3.1x10^{-6}$	$4.7x10^{-5}$
Toluene		$6.3x10^{-5}$	$2.6x10^{-7}$	$1.7x10^{-4}$	$7.4x10^{-7}$	$<10^{-13}$	$1.3x10^{-3}$	$4.4x10^{-6}$	$7.9x10^{-7}$
Aliphatic TPH	C_6-C_8	$1.6x10^{-2}$	$6.2x10^{-5}$	$1.2x10^{-2}$	$5.0x10^{-5}$	$<10^{-13}$	$1.1x10^{-2}$	$3.0x10^{-5}$	$5.5x10^{-11}$
	C_8-C_{10}	$2.9x10^{-3}$	$1.1x10^{-5}$	$5.3x10^{-3}$	$2.3x10^{-5}$	$<10^{-13}$	$1.5x10^{-2}$	$4.1x10^{-5}$	$<10^{-13}$
	C_{10}-C_{12}	$2.5x10^{-4}$	$9.8x10^{-7}$	$1.1x10^{-3}$	$4.6x10^{-6}$	$<10^{-13}$	$2.8x10^{-3}$	$7.4x10^{-6}$	$<10^{-13}$
	C_{12}-C_{16}	$4.4x10^{-5}$	$1.7x10^{-7}$	$6.2x10^{-4}$	$2.6x10^{-6}$	$<10^{-13}$	$2.8x10^{-4}$	$7.5x10^{-7}$	$<10^{-13}$
Aromatic TPH	C_7-C_8	$1.8x10^{-3}$	$7.1x10^{-6}$	$1.3x10^{-3}$	$5.9x10^{-6}$	$<10^{-13}$	$6.2x10^{-3}$	$2.0x10^{-5}$	$1.1x10^{-3}$
	C_8-C_{10}	$4.3x10^{-4}$	$1.7x10^{-6}$	$7.8x10^{-4}$	$3.4x10^{-6}$	$<10^{-13}$	$9.6x10^{-3}$	$2.9x10^{-5}$	$1.3x10^{-6}$
	C_{10}-C_{12}	$5.1x10^{-5}$	$2.1x10^{-7}$	$2.1x10^{-4}$	$1.0x10^{-6}$	$<10^{-13}$	$9.6x10^{-4}$	$3.6x10^{-6}$	$2.2x10^{-9}$
	C_{12}-C_{16}	$1.5x10^{-5}$	$7.0x10^{-8}$	$1.9x10^{-4}$	$1.1x10^{-6}$	$<10^{-13}$	$3.7x10^{-5}$	$2.1x10^{-7}$	$<10^{-13}$
Xylenes		$1.5x10^{-4}$	$6.0x10^{-7}$	$7.5x10^{-4}$	$3.3x10^{-6}$	$<10^{-13}$	$3.0x10^{-3}$	$1.0x10^{-5}$	$1.7x10^{-4}$

Note: Receptor point concentrations for surface soil pathways are the concentrations in the soil (mg/kg).

Exposure Parameters for Child Resident Receptor

Body weight (kg)	14.5	Mean of weights for age classes 0-6 years old. (CLR10 Table 5.6)
Exposure duration (years)	6	Exposure duration for child resident (CLR10 Table 3.2)
Exposure frequency (events/year)	365	Exposure duration for child resident (CLR10 Table 3.2)
Ingestion rate for soil (mg/day)	100	Rate for child aged 0-6 years old (CLR10 Table 6.1)
Total skin surface area (cm^2)	6,167	Mean for age groups 0-6 years (CLEA Briefing Note 1, App 1)
Total skin exposed as fraction	0.265	Mean fraction for age groups 0-6years (CLEA Briefing Note 1, Table 2)
Soil/Skin Adherence Factor (mg/cm^2)	1.00	Soil to skin adherence factor for children 0-16 (CLEA Briefing Note 1, Table 3)
Root vegetable ingestion rate (g/day)	61.6	Average of age classes 0-16 for root vegetable, calculated using body weight (CLR10 Table 6.3)
Above ground vegetable ingestion rate (g/day)	16.1	Average of age classes 0-16 for above ground vegetable, calculated using body weight (CLR10 Table 6.3)
Fraction grown in home garden	0.280	Average of home-grown fraction of all vegetable types (CLR10 Table 6.4)
Fraction organic carbon in garden soil	0.10	Conservative value for garden soil – from "Best Practice Guidance for Land Regeneration Note 5", Forest Research, 2006 and ConSim minimum value for organic silt and peat.
Inhalation rate for indoor air (m^3/hour)	0.193	Calculated proportionally from active and passive respiration. (CLR10 Tables 4.4 and 5.9)
Time indoors (hours/day)	20.7	Sum of passive and active indoor hours (CLR10 Table 4.4)
Lung retention factor	1.0	Conservative value
Active respiration rate (for outdoor air inhalation) (m^3/hour)	0.399	Calculated proportionally from active and passive respiration. (CLR10 Tables 4.4 and 5.9)
Time outdoors (hours/day)	2.7	Sum of passive and active outdoor hours (CLR10, Table 4.4)

RISK LEVELS FOR IDENTIFIED HUMAN RECEPTORS

DEEPER SOIL SOURCE

Benzene	0.071	7.8×10^{-5}

Ethylbenzene	8.8×10^{-5}	9.5×10^{-8}
Toluene	2.5×10^{-5}	2.7×10^{-7}
Xylenes	6.9×10^{-4}	7.5×10^{-7}
Cumulative Risk - Individual Compounds	8.0×10^{-4}	1.1×10^{-6}
TPH: Aliphatic C_6-C_8	8.6×10^{-4}	9.2×10^{-7}
TPH: Aliphatic C_8-C_{10}	2.9×10^{-3}	3.1×10^{-6}
TPH: Aliphatic C_{10}-C_{12}	2.5×10^{-4}	2.7×10^{-7}
TPH: Aliphatic C_{12}-C_{16}	4.5×10^{-5}	4.8×10^{-8}
TPH: Aromatic C_7-C_8	4.4×10^{-3}	4.8×10^{-6}
TPH: Aromatic C_8-C_{10}	2.1×10^{-3}	2.3×10^{-6}
TPH: Aromatic C_{10}-C_{12}	2.5×10^{-4}	2.9×10^{-7}
TPH: Aromatic C_{12}-C_{16}	7.5×10^{-5}	9.5×10^{-8}
Cumulative Risk – All TPH Fractions	7.6×10^{-3}	7.5×10^{-6}

To calculate the cumulative hazard index, the hazard index either the aliphatic or the aromatic TPH fraction for each TPH range (e.g. C_6-C_8), which ever was higher, was added to the cumulative sum since the full measured TPH concentration was assigned to both fractions to carry out the risk assessment.

SHALLOW SOIL SOURCE

Benzene	0.022	0.036	0.35	0.44	$5.4x10^{-4}$	$1.2x10^{-3}$

Ethylbenzene	$2.7x10^{-5}$	$4.4x10^{-5}$	$1.2x10^{-4}$	$3.5x10^{-4}$	$4.1x10^{-7}$	$<10^{-13}$
Toluene	$4.5x10^{-6}$	$7.3x10^{-6}$	$3.6x10^{-5}$	$6.4x10^{-4}$	$7.7x10^{-7}$	$<10^{-13}$
Xylenes	$5.7x10^{-5}$	$8.3x10^{-5}$	$2.4x10^{-4}$	$3.4x10^{-3}$	$4.1x10^{-6}$	$<10^{-13}$
Cumulative Risk - Individual Compounds	$8.9x10^{-5}$	$1.3x10^{-4}$	$4.0x10^{-4}$	$4.4x10^{-3}$	$5.3x10^{-6}$	$<10^{-13}$
TPH: Aliphatic C_6-C_8	$1.4x10^{-6}$	$2.3x10^{-6}$	$2.1x10^{-6}$	$6.5x10^{-4}$	$7.5x10^{-7}$	$<10^{-13}$
TPH: Aliphatic C_8-C_{10}	$1.8x10^{-4}$	$2.9x10^{-4}$	$9.4x10^{-5}$	$5.4x10^{-3}$	$6.2x10^{-6}$	$<10^{-13}$
TPH: Aliphatic C_{10}-C_{12}	$1.9x10^{-4}$	$3.1x10^{-4}$	$3.8x10^{-5}$	$1.1x10^{-3}$	$1.3x10^{-6}$	$<10^{-13}$
TPH: Aliphatic C_{12}-C_{16}	$6.2x10^{-4}$	$1.0x10^{-3}$	$3.1x10^{-5}$	$6.3x10^{-4}$	$7.2x10^{-7}$	$<10^{-13}$
TPH: Aromatic C_7-C_8	$3.6x10^{-5}$	$5.9x10^{-5}$	$3.5x10^{-4}$	$3.3x10^{-3}$	$4.0x10^{-6}$	$<10^{-13}$
TPH: Aromatic C_8-C_{10}	$4.4x10^{-4}$	$7.2x10^{-4}$	$1.9x10^{-3}$	$3.9x10^{-3}$	$4.7x10^{-6}$	$<10^{-13}$
TPH: Aromatic C_{10}-C_{12}	$1.5x10^{-3}$	$2.5x10^{-3}$	$2.4x10^{-3}$	$1.1x10^{-3}$	$1.4x10^{-6}$	$<10^{-13}$
TPH: Aromatic C_{12}-C_{16}	$5.7x10^{-5}$	$8.3x10^{-5}$	$2.4x10^{-4}$	$9.3x10^{-4}$	$1.5x10^{-8}$	$<10^{-13}$
Cumulative Risk – All TPH Fractions	$2.6x10^{-3}$	$4.3x10^{-3}$	$4.9x10^{-3}$	0.011	$1.3x10^{-5}$	$<10^{-13}$

To calculate the cumulative hazard index, the hazard index either the aliphatic or the aromatic TPH fraction for each TPH range (e.g. C_6-C_8), which ever was higher, was added to the cumulative sum since the full measured TPH concentration was assigned to both fractions to carry out the risk assessment.

GROUNDWATER SOURCE

Benzene	0.29	$2.8x10^{-4}$	0.13

Ethylbenzene	$1.5x10^{-3}$	$1.4x10^{-6}$	$7.6x10^{-5}$
Toluene	$5.1x10^{-3}$	$4.6x10^{-6}$	$3.1x10^{-6}$
Xylenes	0.014	$1.2x10^{-6}$	$7.6x10^{-4}$
Cumulative Risk - Individual Compounds	0.021	$1.8x10^{-5}$	$8.4x10^{-4}$
TPH: Aliphatic C_6-C_8	$6.3x10^{-4}$	$4.5x10^{-7}$	$3.0x10^{-12}$
TPH: Aliphatic C_8-C_{10}	$1.6x10^{-2}$	$1.1x10^{-5}$	$<10^{-13}$
TPH: Aliphatic C_{10}-C_{12}	$2.8x10^{-3}$	$2.0x10^{-6}$	$<10^{-13}$
TPH: Aliphatic C_{12}-C_{16}	$2.9x10^{-4}$	$2.1x10^{-7}$	$<10^{-13}$
TPH: Aromatic C_7-C_8	$1.5x10^{-2}$	$1.3x10^{-5}$	$2.9x10^{-3}$
TPH: Aromatic C_8-C_{10}	$4.8x10^{-2}$	$3.9x10^{-5}$	$6.6x10^{-6}$
TPH: Aromatic C_{10}-C_{12}	$4.8x10^{-3}$	$4.9x10^{-6}$	$1.1x10^{-8}$
TPH: Aromatic C_{12}-C_{16}	$1.9x10^{-4}$	$2.8x10^{-7}$	$<10^{-13}$
Cumulative Risk – All TPH Fractions	0.068	$5.7x10^{-5}$	$2.9x10^{-3}$

Notes: NR – TPH compounds >C16 do not pose a risk via inhalation as they do not volatilise.

To calculate the cumulative hazard index, the hazard index either the aliphatic or the aromatic TPH fraction for each TPH range (e.g. C_6-C_8), which ever was higher, was added to the cumulative sum since the full measured TPH concentration was assigned to both fractions to carry out the risk assessment.

ATTACHMENT EIGHT:

ENVIRONMENTAL RECEPTOR MODEL (P20 SPREADSHEET) MODEL – INPUT PARAMETERS

Location of Environmental Receptor – Surface Water Feature

Distance hydraulically down-gradient (m)	150	Site data – distance to where unnamed tributary of Wellington River emerges from protected culvert
Distance hydraulically cross-gradient (m)	0	Conservative case

Solution Methods

Tier One - Soil	Calculate for non-polar organic chemicals
Tier Two – Soil	Groundwater flow below site
Tier Three – Soil	Ogata Banks
Tier Three – Groundwater	Ogata Banks

Tier One – Soil Source

Lithology	Silty Clay	Site data – to represent Made Ground
Water filled soil porosity (cm^3/cm^3)	0.45	CLEA recommended values for clay soil (CLEA Briefing Note 2, Table 3)
Air filled soil porosity (cm^3/cm^3)	0.06	
Bulk density (g/cm^3)	1.6	
Fraction organic carbon of soil (g oc/g soil)	0.018	ConSim recommended value for clay (based upon Boulder Clay soil type)

Tier Two – Soil Source

Infiltration (m/day)	2×10^{-4}	Based on MORECS effective rainfall data (115mm/year), assuming 50% hardstanding cover, and drainage system efficiency of 80%
Length of soil source in direction of groundwater flow (m)	30	Site data – see Figure Six
Width of soil source perpendicular to direction of groundwater flow (m)	15	
Saturated aquifer thickness (m)	4	Site data – assumed thickness of the saturated Head Deposits at the site

Tier Two – Soil Source (Continued)

Hydraulic conductivity (m/day)	0.43	Site data – average of rising head tests
Hydraulic gradient (m/m)	0.018	Site data – 27 August 2002 (Ref.4)
Mixing zone thickness (m)	3.85	Maximum allowed by model for aquifer thickness of 4m

Tier Three – Soil Source

Width of soil source perpendicular to direction of groundwater flow (m)	15	Site data – see Figure Six
Bulk density of aquifer(g/cm^3)	1.4	CLEA recommended value for loam
Effective porosity of aquifer (cm^3/cm^3)	0.25	RISC recommended value for silty loam
Fraction organic carbon of aquifer (g oc/g soil)	0.046	Site data – average for Head Deposits (Ref.1, Attachment 3)

Tier Three – Groundwater Source

Width of plume perpendicular to direction of groundwater flow (m)	20	Site data – see Figure Four
Plume Thickness at source (m)	1	Assumed
Saturated Aquifer Thickness (m)	4	Site data – assumed thickness of the saturated Head Deposits at the site
Bulk density of aquifer (g/cm^3)	1.4	CLEA recommended value for loam
Effective porosity of aquifer	0.25	RISC recommended value for silty loam
Hydraulic gradient	0.018	Site data – 27 August 2002 (Ref.4)
Hydraulic conductivity of aquifer (m/day)	0.15	Site data – average of rising head tests
Fraction of organic carbon of aquifer (g oc/g soil)	0.046	Site data – average for Head Deposits (Ref.1, Attachment 3)
Time since pollution entered groundwater (days)	9.9×10^{99}	Spreadsheet default

SUBADRA

Consultants in the Earth Sciences

Unit 13, Triangle Business Park
Wendover Road, Stoke Mandeville
Bucks HP22 5BL
Tel. 01296 739400
Fax. 01296 739401
e-mail: consultants@subadra.com
www.subadra.com

Jonathan Driver
Havant Borough Council
Civic Offices
Havant
Hampshire
PO9 2AX

Our Ref : 01514 RE 024
Your Ref : DCS/EH/JPD/070227001
30 April 2007

Dear Jonathan

Manor Garage Filling Station

Thank you for your letter of 27 February 2007 regarding the above site.

I have addressed your comments below.

P20 Input Parameters

We do not have empirical site data to demonstrate that biodegradation is taking place. We have therefore carried out sensitivity analysis for the half-lives used. The P20 methodology recommends sensitivity analysis is carried out using +/- 20% of the input values. We have therefore calculated SSTLs using the half-life + 20%. We have also calculated SSTLs using the half life +50% to ensure a conservative assessment. The results are summarised in the table below.

Compound	Half-life	SSTL (µg/litre)	Half life + 20%	SSTL (µg/litre)	Half life + 50%	SSTL (µg/litre)
Benzene	720	29,300	864	18,300	1,080	11,000
Ethylbenzene	228	1,070,000	275	762,000	342	272,000
Toluene	28	$1.6x10^{13}$	33.6	$8.2x10^{14}$	42	$3.1x10^{13}$
Xylenes	360	327,000	432	156,000	540	70,100
TPH $C_{6/7}$-C_8	720	8,130	864	5,070	1,080	**3,070**
TPH C_8-C_{10}	360	90,700	432	43,300	540	19,500
TPH C_{10}-C_{12}	258	44,100	310	177,000	387	67,000
TPH C_{12}-C_{16}	204	164,000	245	580,000	306	189,000
TPH C_{16}-C_{21}	3,800	576	4,560	507	5,710	445
TPH C_{21}-C_{35}	4,280	529	5,136	471	6,420	419

Table One: Sensitivity Analysis for half Lives

As noted in our letter of December 2006, a single concentration 1,170µg/litre of TPH C_{16}-C_{21} recorded in the sample recovered from Borehole Eight taken in August 2006 exceeded the 2006 SSTLs. The remaining results were all lower than the 2006 SSTLs.

The results of the sensitivity analysis indicate that one additional concentration, 2.710µg/litre of TPH C_7-C_8 recorded in the sample recovered from Borehole Six in July 2006, exceeds the SSTLs calculated using the literature half life + 50%. Concentrations in all five samples recovered from Borehole Six since July 2006 have been below all of the SSTLs presented in the table above and therefore we do not consider this single results to indicate a risk to the stream located 150m from site.

P20 SSTLs

You have noted that no updated SSTL is proposed for TPH following the update to P20 sheets undertaken in December 2006.

The SSTL proposed for TPH in the 2002 was determined by calculating an SSTL for each individual TPH fraction, using 50ug/litre as the compliance criteria for each fraction. The lowest SSTL recorded for an individual fraction and used this as the SSTL for TPH as a whole. This is an extremely conservative approach as it does not reflect the information available for each TPH fraction.

In our revised risk assessment undertaken in 2006, rather than producing a single SSTL for TPH as a whole, we have produced SSTLs for each TPH fraction, which provides a better assessment of the risk posed and reflects the more detailed analytical data available. We calculated the SSTL for each fraction using compliance criteria of 0.0877ug/litre (splitting the statutory compliance criteria of 50ug/litre equally between each of the six TPH fractions).

Tables Seven and Eight in our letter of December 2006 (Ref. 01514 RE 023) gave the recorded concentrations for TPH in the ranges C_6-C_{15} and the C_8-C_{35} ranges respectively. These values were calculated from analytical results for the individual TPH fractions. The values highlighted were those where the concentration measured for an individual TPH range exceeded the SSTL for that specific range. As this presentation may have been rather misleading, we have provided the complete analytical data for each TPH range along with the proposed SSTLs in the attached tables.

We are unable to calculate an SSTL for C_{12}-C_{15} as published chemical data is available only for the C_{12}-C_{16} fraction.

I trust that the above discussion addresses your queries. If you require any future information, please do not hesitate to contact me.

Yours sincerely

Nicky Bowden

Subadra Consulting Limited

Enc: Tables Two to Seven

Borehole	TPH (C_6 to C_8) Concentrations (µg/litre) 2006 SSTL = 8,100				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	<50	<50	<50	<50	<50
MW2	<50	<50	<50	<50	<50
BH2	<50	78.7	<50	<50	<50
BH3	345	278	60.5	312	320
BH5	<50	<50	<50	<50	<50
BH6	3,710	2,310	1,660	1,940	2,190
BH7	<50	<50	<50	<50	<50
BH8	1,880	1,410	614	1,560	2,250

Table Two: Total Petroleum Hydrocarbons C_6-C_8 Analysis Results

Borehole	TPH (C_8 to C_{10}) Concentrations (µg/litre) 2006 SSTL = 91,000				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	170	138	113	<50	<50
MW2	380 [1]	<50	<50	<50	<50
BH2	<50	<50	<50	<50	<50
BH3	285	154	58.0 [1]	155	178
BH5	<50	<50	<50	<50	<50
BH6	5,568	5,710 [1]	2,470	2,290	2,730
BH7	960 [1]	<50	<50	<50	<50
BH8	1,301	1,180	731 [1]	2,250	3,300

Table Three: Total Petroleum Hydrocarbons C_8-C_{10} Analysis Results

Borehole	TPH (C_{10} to C_{12}) Concentrations (µg/litre) 2006 SSTL = 440,000				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	179	167	165	59.6	55.6
MW2	140 [1]	56.6	<50	<50	<50
BH2	<50	<50	<50	130	<50
BH3	200	155	136	118	177
BH5	<50	<50	<50	<50	<50
BH6	1,070	1,440	700	921	635
BH7	410 [1]	<50	<50	<50	<50
BH8	522	464	269	573	771

Table Four: Total Petroleum Hydrocarbons C_{10}-C_{12} Analysis Results

Borehole	TPH (C_{12} to C_{15}/C_{16}) Concentrations (µg/litre) 2006 SSTL = 160,000				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	<50	79.3 [1]	<50	<50	<50
MW2	<50	95.7 [1]	<50	<50	<50
BH2	<50	<50	<50	<50	<50
BH3	<50	<50	<50	<50	<50
BH5	<50	<50	<50	<50	<50
BH6	50 [1]	195 [1]	98.3 [1]	135 [1]	<50
BH7	50 [1]	<50	<50	<50	<50
BH8	90 [1]	<50	<50	<50	<50

Table Five: Total Petroleum Hydrocarbons C_{12}-C_{15}/C_{16} Analysis Results

Borehole	TPH (C_{16} to C_{21}) Concentrations (µg/litre) 2006 SSTL = 580				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	<50	<50	<50	<50	159
MW2	80	79.3	<50	<50	120
BH2	<50	<50	<50	<50	<50
BH3	<50	<50	<50	<50	<50
BH5	<50	<50	<50	<50	<50
BH6	<50	79.7	113	101	<50
BH7	120	<50	<50	<50	<50
BH8	60	1,170	<50	<50	<50

Table Six: Total Petroleum Hydrocarbons C_{16}-C_{21} Analysis Results

Borehole	TPH (C_{21} to C_{35}) Concentrations (µg/litre) 2006 SSTL = 530				
	26-Jul-06	10-Aug-06	19-Sep-06	9-Oct-06	14-Nov-06
MW1	160	206	<50	<50	<50
MW2	<50	307	<50	<50	<50
BH2	50	53.9	<50	<50	<50
BH3	<50	64.4	<50	<50	<50
BH5	<50	56.5	<50	<50	<50
BH6	<50	68.0	<50	<50	<50
BH7	150	53.0	<50	<50	<50
BH8	<50	<50	<50	<50	<50

Table Seven: Total Petroleum Hydrocarbons C_{21}-C_{35} Analysis Results

Havant
BOROUGH COUNCIL

Civic Offices
Havant
Hampshire
PO9 2AX

T. 023 9247 4174
F. 023 9248 0263
DX 50005 Havant
www.havant.gov.uk

Ms. Jemma Reinsch
Subadra Consulting ltd.
Unit 13 triangle Business Park
Wendover Road
Stoke Manderville
Buckinghamshire

HP22 5BL

Our Ref: DCS/EH/JPD/070227001
Your Ref: GP/CL/158
Direct Line: 02392 446672
Ask For: Mr Jonathan Driver

Date: 27/02/2007

Dear Ms. Reinsch,

Re: Manor Garage Filling Station; Updated P20 Spreadsheets, and Validation Monitoring

I have been reviewing the updated Quantitative Risk Assessment Spreadsheets copies to Havant Borough Council along with your letter to Catherine Cockburn of the Environment Agency (ref: GP/CL/H/158); dated December 1st, 2006.

I would like to address some of the points made, and give an overview of Environmental Health's position in respect of the remedial works undertaken to date, alongside the target concentrations used for the assessment of success for those works.

P20 Assessment Sheets, input Parameters & Site Specific target levels (SSTL's): Groundwater.

Input Parameters

It is understood that the P20 assessment sheets were produced *de novo*, where possible using parameter values determined from site data, or using current UK sources in preference to US EPA data from (for example) the RBCA toolkit or RISC database.

The use of EA P5-079 ensures that the assessments are directly applicable to the UK legislative framework, and the updated parameters from this source are agreed as appropriate.

It is also noted that the assessments include the biological degradation option, with literature-based half-life parameters. The agency advice is that these parameters should only be used where bio-degradation has been demonstrated under normal conditions. I am also aware that the P20 model is sensitive to the use of this parameter, along with the rate selected and the distance to the relevant receptor.

Therefore, I would appreciate it if you could please confirm whether empirical data collected from the site is considered to either demonstrate, or support the assumption that biodegradation is likely, given local soil conditions.

I can confirm that the stated contaminant source parameters are considered appropriate (length, width, depth), as are the aquifer & groundwater properties, and the use of a conservative estimate of background concentration.

SSTL's

I note from the P20 sheets supplied on the enclosed CD, that both the "Tier 3 Soils" and "Tier 3 Groundwater" worksheets display target values with a "#NAME?" error function for values for comparison with both pore-water & soils.

From the sheets supplied, only the Tier 2 SSTL's can be accepted / verified. Tier 2 does not account for biodegradation rates or contaminant retardation (sorption / attenuation) in soils.

It is assumed from the differences in magnitude between P20 Tier 2 SSTL's & 2006 SSTL's reported in GP/CL/H/158, that the report refers to Tier 3 Groundwater SSTL's, and that the P20 sheets supplied are suffering from a technical error arising from the transfer to CD, or from, being opening using a different version release of Microsoft Excel.

Please check the integrity of the files, and if possible, resubmit electronic copies to Environmental Health for our records.

Groundwater Concentrations

It is understood that BH3, 6 & 8 were re-drilled in 2005 following a loss of groundwater yield due to silting of the slotted pipe in the well response zone. It is noted that this action caused a marked increase in dissolved phase concentrations from Boreholes 6 & 8, although an overall reduction in concentrations was reported subsequent monitoring rounds, from summer of 2005.

Strongest statistical trends indicate:

- an overall (marginal) **increase** in the concentration of Benzene (ND-383 µg/l) in BH8 (R^2 0.5492)
- an overall **increase** in the concentration of Ethylbenzene (358-868 µg/l) in BH6 (R^2 0.4017)
- an overall **decrease** in the concentration of Toluene (919-368 µg/l) in BH6 (R^2 0.5458)
- an overall **decrease** in the concentration of TPH C6-C15 (6510-3365 µg/l) in BH6 (R^2 0.4947)

All other values fall below 0.4 (40% similarity), and it is therefore inappropriate to draw any conclusion in relation to concentration trends.

An R^2 value of 1.0 indicates a perfect fit of the linear regression to the empirical (measured) data. All the above values quoted are for simple linear regression, using

equivalent data (i.e. TPH calculated from total of applicable carbon bands for sampling undertaken from 02/10/2007, Total Xylenes as summed value of M & P and O-Xylenes etc.).

Stronger statistical fits can be achieved using polynomial regression lines, improving fit to an R^2 of approximately 0.7 in some cases. Using this method is less conclusive however, as it accounts for an increasing in concentration from monitoring undertaken in the autumn of 2006; evident in all measured parameters.

I therefore cannot agree that there has been a conclusive overall reduction in concentrations over the period 01/11/2005 – 01/11/2006 across all parameters, however; it is noted that particularly for BTEX compounds, the concentrations identified are well within the SSTL's reported in the GP/CL/H/158 document.

As acknowledged in the report, all stated SSTL's have been met with the exception of TPH within BH6 & BH8, which although demonstrated as likely to represent a trend of decreasing concentration over time, still exceed the SSTL by 168-244% (BH6, and BH8 respectively). It should be noted however that the Tier 2 SSTL's supplied are exceeded for determinands in all boreholes (with the exception of BH2), as reported the latest round of monitoring (14/11/2006). It is essential therefore that uncorrupted Tier 3 sheets are submitted in order to confirm that the SSTL's stated in the report are appropriate.

It is also noted that no updated SSTL is proposed for Total hydrocarbon contamination following the update to P20 sheets undertaken in December 2006. Sheets are provided for C6-C8, C7-C8, C8-C10, C10-C12 (Aliphatic & Aromatic), and C12-C16. Summed SSTL's for these compounds could be used to generate a new TPH C6-C15 SSTL (in line with amendments for BTEX P20 assessment revisions) as a conservative estimate, or alternatively an accurate assessment of risk could be made by producing a C12-C15 sheet, and summing P20 Tier 3 SSTL's for specific carbon bands to produce a suitable TPH target level for comparison with the latest monitoring results.

In line with comments above, please re-submit P20 spreadsheets that display "Tier 3 Groundwater" SSTL's for hydrocarbon bands, if a Tier 3 assessment has been completed. Please also provide P20 assessment sheets for BTEX determinands including Tier 3 Groundwater results.

Following confirmation of the parameterisation of the Tier 3 (groundwater) sheets for all determinands (BTEX and individual bands within the C6-C35 range), I am prepared to accept that the determined SSTL's have been met for the protection of controlled surface waters.

Yours Sincerely



Jonathan Driver
Environmental Control Officer