Land Science

[redacted]

PHASE I AND II GEO-ENVIRONMENTAL GROUND INVESTIGATION

[redacted]

21ST MAY 2019

Site:	[redacted]
Title:	**PHASE I AND PHASE II GEO-ENVIRONMENTAL GROUND INVESTIGATION**
Client:	[redacted]
Date:	**21st MAY 2019**
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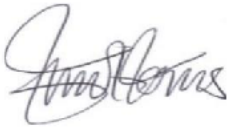
Authorised by:		**ELLIOT TOMS CEnv M.Sc., B.Sc. (Hons.), FGS, MIEnvSci** **Managing Director**

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GROUND INVESTIGATION

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1 INTRODUCTION

1.1 General

Land Science was instructed by [redacted] on behalf of [redacted] (the Client) to undertake a Phase I and II Geo-Environmental Ground Investigation in relation to a hydrocarbon fuel spill at [redacted]. The location of the site is shown on Figure 1, which is centred at grid reference [redacted]

1.2 The Site

The area under investigation comprised [redacted] offices situated at the centre of the site, with a large asphalt car park located to the west and soft landscaping surrounding the perimeter of the site. An electrical sub-station and boiler house was situated in the centre of the site.

The layout of the existing site is indicated on Figure 2, and a walkover survey is presented in section 4.0. The area was approximately 1.38 hectares. It was understood that the client was in ownership of the site.

1.3 Environmental Incident

Land Science was informed by [redacted] that their client, [redacted], had experienced a petroleum hydrocarbon fuel leak at their premises. This was reported to be due to an initial mechanical failure in the boiler house and subsequent failure of the containment measures. It is estimated that 1200ltrs of petroleum hydrocarbon fuel had escaped below the boiler house.

It was also made aware to Land Science that a hydrocarbon sheen had been seen in a stream downslope to the east of the site, and that it was possible that the petroleum had reached the River [redacted] nearby.

1.4 Previous Investigations

Land Science was not aware of any previous desk studies or ground investigation(s) undertaken on this site and for this scheme.

1.5 Scope of Works

In accordance with the scope specified by Land Science, the investigation comprised the following:

- A desk study
- 7no. 3.00m Dynamic (windowless) sampler boreholes
- 3no 15.00m open hole rotary boreholes
- 3no 15.00m standpipe installation, to be monitored on six return visits

The fieldwork was conducted on the 16/03 and between the 21/03 and 23/05 under the supervision of Land Science. The six return monitoring visits were conducted between 27/03 and 07/05.

A total of five dynamic (windowless) sampler boreholes and three open hole rotary boreholes were drilled around the perimeter of the existing office buildings on site.

1.6 Geo-Environmental Objectives

A phase I (desk study) and phase II (intrusive investigation) was required, to provide a generic quantitative risk assessment (GQRA) in respect of the site, adjacent land uses, and the wider environment.

A preliminary phase I assessment ("desk study") was required, to consider possible risks posed to the site, adjacent land uses, and the wider environment.

1.7 Standards

Where practicable, the investigation was undertaken in accordance with the following standards and guidance:

- Model Procedures for the Management of Contaminated Land, DEFRA and Environment Agency, September 2004 ("CLR11").
- Guiding Principles for Land Contamination, Environment Agency, March 2010, ("GPLC").

Other technical sources have been cited in respect of specific aspects of the investigation, as referenced throughout the text.

1.8 Confidentiality and Limitations

This report may be relied upon by the Client and their agents and consultants, and should be read and used only in full.

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2 PHASE I DESK STUDY (ENVIROCHECK)

2.1 General

A geo-environmental desk study was prepared, and included a review of:

- Maps and historical borehole records from the British Geological Survey;
- Historical Ordnance Survey maps;
- An environmental data report.

Copies of relevant data are presented in Appendix E.

2.2 Geology

Based on British Geological Survey (BGS) 1:50,000 sheet number [redacted] the geology of the site was anticipated to comprise the following succession:

Strata		Generic description
Bedrock Geology	Barren Red Member	Red and grey mottled mudstones (seatearth) and siltstones and 'Pennant' type lithic sandstone lacking workable coals. It is between 230m thick in the Radstock Syncline and 275m thick in the Coalpit Heath Syncline
	Farrington Member	Grey mudstone with sporadic subordinate sandstone (lithic arenite) beds and numerous thin coal seams associated with comparatively thick seatearth clays. Varying in thickness from 425m in the Radstock Syncline to less than 60m in the Bristol coalfield.

As displayed on sheet [redacted] a large amount of alluvium is mapped beyond the site boundary towards the River [redacted] in the east. A small amount of head deposits comprising clay, silt, sand and gravel is also mapped approximately 100m north of the site.

The Mercia Mudstone Group is mapped towards the south-east and south-west of the site. In the south-east the Mercia Mudstone is faulted against the Barren Red Member and Farrington Member.

2.3 Historical Boreholes

Records of old boreholes are held by the BGS. The following relevant borehole records were identified:

Location	BGS Reference	Drilled Length (m)	Borehole Name
75m N	[redacted]	10.36	[redacted]
95m NE		6.09	
144m E		6.09	

These records have been summarised below:

Keynsham By-Pass B1		
Strata	**Base Depth (m bgl)**	**Summary Description**
Topsoil	0.15	Description not provided
Not provided	0.60	Soft slightly organic, red brown silty CLAY.
	1.80	Soft to firm, light brown, weathered, friable gritty, silty CLAY.
	2.10	Grey friable silty CLAY
	2.70	Moderately compact red brown clayey SAND. And poorly graded mixed gravel.
	3.00	Angular sandstone fragments
	3.90	Soft red brown silty CLAY with few sandstone fragments.
	5.70	Moderately compact brown sandy SILT. With coarse sand and mixed gravel.
	6.00	Compact yellowish gritty silty SAND and poorly graded gravel.

Keynsham By-Pass R3		
Strata	**Base Depth (m bgl)**	**Summary Description**
Topsoil	0.50	Description not provided
Not provided	3.00	Soft to firm light brown slightly silty CLAY with few small sandstone fragments.
	3.90	Moderately compact light brown gritty clayey silty SAND. With angular mixed gravel.
	6.00	Compact yellowish brown silty sandy GRAVEL

2.4 Background Geochemistry

The BGS publish a series of different estimated background levels of selected contaminants, which are useful for land quality assessments, to establish whether results may be attributed to pollution or soil parent material composition.

The BGS estimate the natural background concentrations of certain potentially harmful elements based on rural topsoil and stream sediment analysis. Data relevant to the site is summarised below:

Location	Arsenic	Cadmium	Chromium	Lead	Nickel
On Site	15 - 25 mg/kg	<1.8 mg/kg	60 - 90 mg/kg	<100 mg/kg	15 - 30 mg/kg
	15 - 25 mg/kg	<1.8 mg/kg	60 - 90 mg/kg	100 - 200 mg/kg	15 - 30 mg/kg

2.5 Geological Hazards

The BGS produce hazard assessment maps for a selection of common geotechnical datasets, and the classifications referring to the site (and immediate vicinity – if relevant) are summarised below:

Dataset	Location	Hazard:
Collapsible Ground Stability Hazards	On Site	Very Low
Compressible Ground Stability Hazards		No Hazard
Ground Dissolution Stability Hazards		No Hazard
Landslide Ground Stability Hazards		Very Low
Running Sand Ground Stability Hazards		No Hazard
Shrinking or Swelling Clay Ground Stability Hazards		Very low-No Hazard

2.6 Mining and Natural Cavities

A search of various databases for coal mining, mining, brine compensation, and natural cavities was carried-out, and the findings are summarised below:

Database	Results
CBSCB Compensation District	No features found
Coal Mining Affected Areas	Features found - see below
Non-Coal Mining Areas of Great Britain	No features found
Mining Instability	Features found – see below
Man-Made Mining Cavities	No features found
Natural Cavities	

In an area which may be affected by coal mining activity. It is recommended that a coal mining report is obtained from the Coal Authority.

Location	Mining Evidence:	Source:
On site	Inconclusive Coal Mining	Ove Arup & Partners

2.7 Radon Potential

The requirement for Radon Protection Measures (RPM) has been assessed in accordance with BRE 211:2015[1]. Public Health England and the BGS estimate the potential for radon and the requirement for Radon Protection Measures on site as follows:

Affected Area	Protection Measure
The property is in an Intermediate probability radon area (5 to 10% of homes are estimated to be at or above the Action Level).	Basic radon protective measures are necessary in the construction of new dwellings or extensions

2.8 Hydrogeology

The BGS borehole records identified groundwater standing at depths in the range of 0.75 to 0.80m bgl. Based on the geology and topography of the local area, shallow groundwater was anticipated.

2.9 Groundwater Flooding

The BGS have produced a series of hazard assessments for the potential of flooding from groundwater, and data relating to the site and a 50m radius is summarised below.

Location	Flooding type
On site	Limited Potential for Groundwater Flooding to Occur
33m SE	Potential for Groundwater Flooding to Occur at Surface

2.10 Aquifer Designations

The Environment Agency classifies geological units across England into different designations as Aquifers. The designations for strata beneath the site are given below, which corresponds to an overall designation as a Secondary A Aquifer.

Strata	Classification	Details
Bedrock Aquifer Designations	Secondary A	Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
Superficial Aquifer Designations	Secondary A 13m E	

2.11 Groundwater Abstractions

Groundwater abstractions identified as part of the desk study within a radius of 1000m of the site are summarised below.

Location	Operator	Location	Abstraction
851m E	[redacted]	[redacted]	General Agriculture: Spray Irrigation - Direct
851m E			
854m E			Food and Drink: Non-Evaporative Cooling
854m E			Food and Drink: Process Water and boiler feed
889m E			Food and Drink: General Use (Medium Loss)
889m E			Food & Drink: General Cooling (Existing Licences Only) (High Loss)
894m E			Food and Drink: General Cooling (Existing Licences Only) (Low Loss)
894m E			Food and Drink: Process Water
896m E			
896m E			
896m E			Food & Drink: General Cooling (Existing Licences Only) (High Loss)
896m E			Food and Drink: General Use (Medium Loss)
896m E			Food and Drink: General Cooling (Existing Licences Only) (Low Loss)

896m E			Food & Drink: General Cooling (Existing Licences Only) (High Loss)
897m E	Cadbury Limited	Borehole	Food and Drink: General Use (Medium Loss)
902m E			Food and Drink: General Cooling (Existing Licences Only) (Low Loss)

2.12 Source Protection Zones

A groundwater Source Protection Zone (SPZ) is an area of protection placed around a well or borehole that supplies groundwater of potable quality. No SPZ have been identified on and within 250m of the site according to Environment Agency mapping.

2.13 Surface Water Features

The nearest surface water feature identified on Ordnance Survey mapping was located 20m to the east. The River Avon was also noted approximately 250m to the north-east.

The Ordnance Survey also map water network lines, and the following data on site and in the vicinity is summarised below:

Location	Watercourse Length (m)	Watercourse Level	Details
20m E	216.4	On ground surface	Watercourse Form: Inland river Watercourse Name: Not Supplied Permanent: TRUE Catchment Name: [redacted] Primacy: 1
44m E	44.9		
45m E	54.8		
49m NE	236.1		
53m E	52.8		
80m E	7.6		
87m E	188		
87m E	7.2		
94m E	83.6		

2.14 Surface Water Abstractions

Surface water abstractions identified as part of the desk study on site and in the vicinity of the site are summarised below.

Location	Operator	Abstraction	Details
533m S	[redacted]	[redacted]	Type: Water may be abstracted from a single point Source: Surface Authorised Start: 01-Mar Authorised End: 31-Oct Permit Start Date: 24th March 1966
538m S			Source: River Daily Rate (m3): 91 Yearly Rate (m3): 1136 [redacted]
750m SW			Source: River Daily Rate (m3): 18 Yearly Rate (m3): 726 [redacted]
827m SW			Type: Water may be abstracted from a single point Source: Surface Authorised Start: 01-Apr Authorised End: 31-Oct Permit Start Date: 1st August 1966
836m SW			Source: River Daily Rate (m3): 27 Yearly Rate (m3): 1140 Expired: 07-Oct-1992; [redacted]
851m E			Type: Water may be abstracted from a single point Source: Surface Authorised Start: 01-Mar Authorised End: 31-Oct Permit Start Date: 24th March 1966

2.15 Surface Water Flooding

Dataset	Location	Type	Flood plain type
Extreme flooding from rivers or sea without defences	On site	Extent of extreme flooding from rivers or sea without defences	Fluvial Models
Flooding from rivers or sea without defences	On site	Extent of flooding from rivers or sea without defences	
Extreme flooding from rivers or sea without defences	29m NE	Extent of extreme flooding from rivers or sea without defences	
Flooding from rivers or sea without defences	30m NE	Extent of flooding from rivers or sea without defences	
Extreme flooding from rivers or sea without defences	40m SE	Extent of extreme flooding from rivers or sea without defences	Fluvial Events
	41m SE		Fluvial Models and Fluvial Events
	41m SE		Fluvial Models
	53m SE		Fluvial Models and Fluvial Events
	74m NE		Fluvial Events
	92m E		

Land potentially susceptible to flooding from seas, rivers, reservoirs and surface water is identified by the Environment Agency. Current mapping indicated the site to be located in 'Flood Zone 1' an area identified as having a low probability of flooding.

2.16 Licences Database Search

A search of various industrial land use databases was carried-out, however no relevant land uses were identified.

2.17 Contemporary Trade Directories

A search of contemporary trade directory databases was made, however no relevant features were identified on site and in the vicinity.

2.18 Points of Interest

A search of "points of interest" was made, however no relevant features were identified on site and in the vicinity.

2.19 Fuel Station Entries

A search of "fuel station entries" was made, however no relevant features were identified on site and in the vicinity.

2.20 Underground Pipelines and Cables

A search of records of major underground pipelines and cable infrastructure (not to be confused with utilities) revealed no relevant features on site or within the vicinity

2.21 Discharge Consents

Discharge consents identified on site and in the vicinity are summarised on the following table:

Location	Purpose	Details
On site	[redacted]	Type: Sewage Discharges - Final/Treated Effluent - Not Water Company Receiving Water: [redacted] Status: Not Supplied
		Type: Trade Effluent Discharge-Site Drainage Receiving Water: [redacted] Status: Not Supplied
		Type: Miscellaneous Discharges - Mine / Groundwater as Raised Receiving Water: [redacted]

	[redacted]	Status: Not Supplied
		Type: Discharge of Other Matter-Surface Water Receiving Water: [redacted] Status: Not Supplied
		Type: Miscellaneous Discharges - Mine / Groundwater as Raised Receiving Water: [redacted] Status: Not Supplied
54m E		Type: Sewage Discharges - Unspecified - Water Company Receiving Water: [redacted] Status: Not Supplied

2.22 Waste Management Facilities

Searches of various databases of current and historical waste management facilities (including mapped areas of possible infilled land) are summarised on the following table:

Database	Results
Historical Landfill Sites	Features found – see below
Licensed Waste Management Facilities	No features found
Registered Landfill Sites	
BGS Recorded Landfill Sites	
Integrated Pollution Control Registered Waste Sites	
Local Authority Recorded Landfill Sites	Features found – see below
Registered Waste Transfer Sites	No features found
Registered Waste Treatment or Disposal Sites	
Potentially Infilled Land	Features found – see below

Historical Landfill Sites:

Location	Licence Holder	Specified Waste Type	Details
[redacted]		Deposited Waste included Inert Waste	EA Waste Ref: 0 Regis Ref: Not Supplied WRC Ref: Not Supplied BGS Ref: Not Supplied Other Ref: [redacted]

Local Authority Recorded Landfill Sites:

Location	Location of material	Last Reported Status	Types of Waste	Date of Closure
251m W	[redacted]	Unknown	Soils	Not Supplied

Potentially Infilled Land:

Dataset	Location	Use	Date of Mapping
Potentially Infilled Land (Non-Water)	On site	Unknown Filled Ground (Pit, quarry etc)	1982
Potentially Infilled Land (Non-Water)	112m S		

3 SITE HISTORY

3.1 Historical Maps

Large scale (e.g. 1:2,500) historical maps dating between 1888 and 1994 were reviewed to identify the history of the site and local area. The outline of the site shown is geo-referenced to the current grid system; due to inaccuracies in mapping techniques the actual boundary on older maps may vary. Smaller scale (e.g. 1:10,000) maps were reviewed, but did not provide further relevant historical information. Given the size of these file sizes, smaller scale maps are not appended to the report but are available separately.

In summary, the site comprised part of a *quarry* from the year 1891 to 1904, before it appeared that the *quarry* and surrounding *quarries* within the immediate vicinity of the site were no longer operative. A small *building* was also noted on site from the year 1891 to 1964. From the year 1964 office buildings had been constructed on site, commensurate with the present day.

The local area largely comprised open fields with a few residential dwellings and small businesses. A *quarry* was noted 100m to the south from the year 1897 to 1904. *The Great Western Railway Line* and *Lodge Farm* were all noted to the north from the year 1888, commensurate with the present day. From 1974, the A4 was constructed adjacent to the site, an *engineering works, tank* and *car body workshop* were constructed 170m to the north, these have remained to the present day.

The key apparent features noted on site and the surrounding area are summarised below.

Land use	Location	Dates	Description
Lodge Farm	175m N	1888-Present	• *Lodge Farm* was noted to the north.
[redacted]	100m N	1888-Present	• The [redacted] *line* was noted to the north
Building	On site	1891-1964	• A small *building* was present in the south of the site. • The surrounding area comprised open fields and a few residential dwellings
Quarries	On site	1891-1904	• Part of the site and the surrounding area comprised a small number of *quarries;* particularly within the north-east corner of the site. • By the year 1904 the *quarry* on site and the *quarry* 100m south appeared no longer to be in use. Mapped as *'old quarry'* • A small number of coniferous and non-coniferous trees were noted on site.
Offices	On site	1964-Present	• By 1964 the small building on site had been removed and *offices* had been built in place, commensurate with the present day. • The surrounding area comprised primarily open fields with few residential dwellings.
[redacted]	12m N	1974-Present	• The [redacted] had been constructed within the immediate vicinity of the site.
Engineering Works	168m N	1974-1994	• An *engineering works* was noted to the north. • The surrounding area comprised open fields and few residential dwellings and a small number of local businesses
Tank (unknown use)	170m N	1974-1994	• Historical maps display a *tank* present until 1994. It is possible that the tank was present in 1999, but does not appear to exist in the present day
Car Body Workshop	170m N	1974-Present	• A car body shop was noted in close proximity to the *engineering works* and *tank*

3.2 Aerial Photographs

Aerial photographs dating from 1999 available within the Envirocheck report were also reviewed. In summary, the site remained largely unchanged from the historical map dated 1994 and to the present-day aerial photographs available online.

The surrounding was also largely unchanged. Present day aerial photographs available online displayed buildings associated with [redacted]165m to the West of the site.

4 SITE WALKOVER

4.1 General

A site walkover was undertaken prior to the fieldwork on 13/03/2019. Photographs of the site are provided in Appendix A.

4.2 Site Layout

In summary, the site comprised a broadly rectangular shaped plot of land. A large three-storey complex of brick and concrete office buildings with a central courtyard area was situated in the middle of the site. A large, open, asphalt car parking area occupied the west of the site, with a few grass lawns positioned around the perimeter, tall mature trees were noted to the east.

Many underground services were identified on site, which included water mains, high voltage electricity (linking to an electrical sub-station in the centre of the site), and fuel pipes feeding the boiler house (also in the centre of the site). Several manholes comprising drainage, sewerage and telecommunication services were also noted in and around the buildings.

4.3 Surrounding Area

The site was located in a predominately suburban area, on the outskirts of [redacted] Situated between [redacted] 150m to the south and the [redacted] 12m to the north. The River [redacted] and associated tributaries were noted 180m northeast of site. It appeared that the surrounding land comprised open fields used for arable farming and for recreational use, with several residential houses and local businesses.

4.4 Elevation and Topography

The topography of the local area sloped moderately to the west, and more steeply to the east. The site was located on the east facing slope of [redacted]

An escarpment was noted within the eastern boundary of the site, possibly related to the excavation of sandstone during quarrying noted on site from the year 1981-1904. Retaining structures were noted at the top of the escarpment. The site sloped steeply in the north-east corner down to the floodplains of the River [redacted]

4.5 Ground Conditions

No immediate evidence of significant structural movement was observed or was reported to Land Science. However, our inspection was cursory, and a full survey was outside the scope of this report.

4.6 Surface Water and Groundwater

No surface water features were identified on site, though a spring and stream were noted to the eastern boundary of the site. No evidence of shallow groundwater, such as boggy waterlogged soils or water loving plants etc., were noted on site.

4.7 Trees and Vegetation

A small number of semi-mature and mature tall trees were noted around the perimeter of the site, particularly along the east of the site boundary. Several shrubs and flower beds were also noted towards the east of the site.

A detailed arboricultural survey was outside the scope of this report. A survey may be required for tree root protection purposes or for assessing the depth of foundations in the vicinity of trees.

4.8 Evidence of TPH Product

Throughout the walkover of the site, several manholes and service trenches were highlighted (by the client) exhibiting visual contamination and significant malodour. It was evident that product had migrated through the sites drainage system. Remedial measures had been put in place where the product had been identified. Product was also identified off-site within neighbouring streams and tributaries to the River [redacted]

5 CONCEPTUAL SITE MODEL (CSM)

5.1 General

A preliminary geo-environmental Conceptual Site Model (CSM) was formulated for the site based on the desk study & site walkover. The model should be revised when, any ground investigation data is available, or where unexpected conditions are encountered.

The model has been designed primarily in accordance with established procedures in BS5930, BS10175 and CLR11, and also draft ISO guidance. In accordance with best practice, the model has been used to identify possible contamination risks following a source-pathway-receptor ('SPR') approach.

5.2 Site Setting

Based on the anticipated ground conditions revealed in the desk study, the following generalised soil and groundwater model is anticipated:

Strata	Depths	Soil types	Groundwater
Made Ground	1.00	Mixed composition with manmade fragments	Shallow perched water
Barren Red Member	10.00+	Mudstone and Sandstone	Water strikes
Farrington Member			

5.3 Potential Sources

The principle of primary and secondary sources has been adopted in accordance with ISO/CD 21365. Further information is given in the accompanying notes, and are summarised as follows:

A **primary source** is for instance a leaking tank or drainage, industrial activity, buried fill materials, etc, identified as part of the desk study and site walkover.

A **secondary source** is either soils, ground gases, volatile vapours and groundwater, in which any resulting contamination may occur.

For instance, a leaking tank may contaminate soils and generate vapours, or buried fill materials may represent a source of ground gases or groundwater pollution.

It should be noted that sources may also be receptors; for instance, groundwater may both be a receptor (as in the background chemical quality of an aquifer or resource) and in turn become a source (contaminated waters impacting on buried concrete structures).

Further guidance is given in the accompanying notes.

Identified primary and secondary sources of possible contamination arising in soils identified as part of the desk study and site walkover on site are summarised on the following table.

Primary Source	Description	Contaminants	Secondary Source(s)
Made Ground	Made Ground may exist across the site, given the historical land-uses including the quarry. Fill may also occur under buildings and hardstandings etc. The provenance of such materials is unknown and may be contaminated.	Wide range of possible metals, non-metals, organic contaminants, asbestos, etc.	Soils Groundwater
Petroleum Hydrocarbon spillage on site	The anaerobic and aerobic degradation of hydrocarbon compounds by biological processes may result in the generation of Carbon Dioxide and to a lesser extent Methane. Furthermore, such biological action may deplete concentrations of Oxygen. Short chain light	Short chain light hydrocarbons may also give rise to the direct generation of Volatile Organic Compound (VOC) vapours.	Soils Ground gas Groundwater

	hydrocarbons may also give rise to the direct generation of Volatile Organic Compound (VOC) vapours.		

5.4 Identified Receptors

The following potential receptors associated with the site have been considered in this report:

- End users
- Soft landscaping
- Plastic potable water pipes
- Surface water - Surface water in lakes and rivers etc.
- Groundwater - Water below ground in permeable strata

The potential source-pathway-receptor linkages have been grouped by receptor and are discussed separately in the following sections.

- Concrete excluded (no risk from TPH's)

5.5 Excluded Receptors

The following potential receptors were excluded from the assessment as they are covered by other legislative controls and are outside the remit of this report.

Receptor	Description	Notes
Ecological receptors	Statutory protected species or wildlife areas	An assessment of such risks was outside the scope of this report.
Site workers	Persons involved in construction works	Any risks posed to site workers would be controlled through other regimes including Health & Safety legislation, the CDM regulations and COSHH regulations etc.

5.6 End Users

The following tables identify the potential source-pathway-receptor linkages considered in this report. Off-site sources impacting on off-site receptors have not been considered.

The current land-use comprises corporate office buildings of [redacted] Hard landscaping covers the majority of the site with a few areas of soft landscaping comprising grass lawns and flower beds.

Source(s)	Pathway(s)	Active
Soils	Dermal contact with soil and soil-borne dust	Y
	Ingestion of soil and soil-borne dust	Y
	Inhalation of soil-borne dust	Y
	Consumption of homegrown produce	N
Volatile vapours	Inhalation, ignition	Y
Ground gases	Inhalation, ignition	Y
Ground-water	Direct contact	N

5.7 Soft Landscaping

No significant soft landscaping was identified, with the site essentially covered with hardstanding. No evidence of existing plant phytotoxicity was observed, and was unlikely to be a significant issue

Source(s)	Pathway(s)	Active
Soils	Plant uptake, phytotoxic effects	N
Volatile vapours	Root asphyxiation, ignition, phytotoxic effects	N
Ground gases	Root asphyxiation, ignition, phytotoxic effects	N
Ground-water	Plant uptake, phytotoxic effects	N

5.8 Potable Water Supplies

Plastic potable water supply pipes are susceptible to chemical attack. Two water supply pipes were identified in the west of the site:

Source(s)	Pathway(s)	Active
Soils	Chemical attack	Y
Volatile vapours	Not applicable	N/A
Ground gases	Not applicable	N/A
Ground-water	Chemical attack	Y

5.9 Groundwater

The site overlies the Barren Red Member and Farrington Member of interbedded mudstone and sandstone, that has been identified as a secondary A aquifer; geological strata with permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. Alluvial clay, silt and sand was also noted 13m to the east of the site and has also been identified as a secondary A aquifer.

Source(s)	Pathway(s)	Active
Soils	Leaching-out, migration through the water table	Y
Volatile vapours	Not applicable	N/A
Ground gases	Not applicable	N/A
Ground-water		

5.10 Surface water

The River [redacted] and associated tributaries were identified in close proximity to the site.

Source(s)	Pathway(s)	Active
Soils	Leaching-out, migration through the water table	Y
Volatile vapours	Not applicable	N/A
Ground gases	Not applicable	N/A
Ground-water		

6 INTRUSIVE INVESTIGATION

A factual record of the conditions encountered during the physical investigation of the site is presented in the following sections.

6.1 Investigation Strategy

Based on the findings of the conceptual site model, the intrusive investigation was based on the following strategy:

Aspect	Position	Target depth (m bgl)	Achieved depth (m bgl)	Existing Location	Testing, installations etc
Dynamic Sampler boreholes	DS01	3.00	2.50	Surrounding the location of the hydrocarbon fuel spill.	PID
	DS02		1.60		
	DS03		2.00		
	DS04		2.00		
	DS05		0.95		
Rotary Boreholes	BH01	15.00	15.00	Close to underground holding tank, up hydraulic gradient of the spill.	SP
	BH02			North of the fuel spill, located near to the surface water drainage	
	BH03			Down hydraulic gradient of the spill location, located near to the surface water drainage	

PID = Photo Ionisation Detection (VOC)
SP = Standpipe

Position	Coordinates	
	Easting	Northing
DS01	[redacted]	
DS02		
DS03		
DS04		
DS05		
BH01		
BH02		
BH03		

An explanation of the excavation and testing types are given in the following sections.

6.2 Dynamic (Windowless) Sampling (DS)

Dynamic Sampling entails 1m long hollow tubes with liners driven into the ground and retracted in order to obtain samples. The process is repeated sequentially to the target depth, unless impenetrable strata or borehole instability prevent further progress. The liners are split, logged, tested, and subsampled. Sample compression can occur within the liners, and the sampler can sometimes become blocked. Sample recovery is typically class 2 as defined in Eurocode 7.

In total 5no dynamic sampler boreholes were drilled, positioned around and as close to the boiler house where the proposed fuel leak was noted. The purpose of the dynamic sampler boreholes was to quantify any contamination through the superficial geology and perched groundwater. DS06 and DS07 were not progressed due to underground services.

None of the dynamic sampler boreholes achieved the target depth of 3.00m bgl, with all boreholes refusing on competent strata at depths in range of 1.60 to 2.50m bgl. No immediate signs of potential contaminated soils were noted during the excavations.

6.3 Rotary Boreholes (Open hole)

Open hole rotary drilling uses a high-powered truck mounted motor to rotate drilling rods connected to a drill bit into the ground. The drilling rods are hollow, allowing a water-based cooling fluid or compressed air to be pumped to the bottom of the hole acting as a coolant and a means of removing the cuttings of soil and rock. (Smith, 2014)

In total 3no open hole, rotary boreholes were drilled using a compressed air flush to a depth of 15.00m bgl, with full 15.00m installs. The purpose of the deep rotary borehole installations was to analyse groundwater movement and composition within the bedrock. No immediate signs of potential contaminated soils were noted during the drilling.

6.4 Monitoring Wells (MW)

Monitoring wells were installed in all rotary boreholes. The installations were sealed through the Made Ground, with the response zone in the underlying Superficial deposits, the Red Barren Member and Farrington Member. The pipework comprised 50mm diameter HDPE, sealed using hydrated bentonite pellets and the slotted response zone packed with 10mm pea shingle.

7 GROUND CONDITIONS

7.1 General

The expected ground conditions were anticipated to comprise Made Ground over the Red Barren Member over the Farrington Member to depth. However, the investigation did not encounter the anticipated ground conditions.

A thin layer of superficial clay was noted across the site within all excavation locations; situated below the Made Ground and above the Red Barren Member.

A summary of the encountered conditions is presented below.

Base Depth (m bgl)					Strata
DS01	DS02	DS03	DS04	DS05	
0.15	0.15	0.20	-	-	Hardstanding
0.65	0.50	0.30	0.60	0.60	Made Ground
2.50+	1.60+	2.00+	2.00+	0.95 +	Superficial Deposits

Base Depth (m bgl)			Strata
BH01	BH02	BH03	
0.15	0.15	0.20	Hardstanding
0.60	1.00	0.60	Made Ground
2.70	1.50	1.00	Superficial Deposits
9.00	9.80	14.00	Barren Red Member
15.00+	15.00+	15.00+	Farrington Member

The identification of materials encountered as specific geological strata is tentative and should be used as a guide, and interpolation between or below investigation points should be treated with caution.

7.2 Hardstandings

Positions DS01, DS02 and DS03 were located within the car park, courtyard area and outside of the reception respectively. A thin layer of asphalt was encountered to depths of 0.15 and 0.20m bgl within these positions.

BH01 and BH02 were located within the car park, BH03 was located within the courtyard area. These positions also encountered a thin layer of asphalt was identified 0.15 to 0.20m bgl, the hardstanding at BH03 was cored using a concrete corer.

7.3 Made Ground

Made Ground was encountered within all dynamic sampler and rotary borehole positions to depths of 0.30 and 1.00m bgl and generally comprised a greyish brown sandy GRAVEL, coarse sand and fine to coarse, angular to subangular concrete, flint and Type 1 material.

Positions DS04 and DS05 located to the rear of the existing buildings did not encounter the above strata. A dark brown gravelly, CLAY/SILT. With gravels comprising fine to coarse, subangular to subrounded, brick, concrete and bituminous material were recorded to depths of 0.60 and 0.20m bgl respectively. A greyish brown slightly clayey, very gravelly SAND, with brick, concrete, china and flint gravels, with metal fragments was noted below to a depth of 0.60m bgl within DS05.

Cobble sized concrete fill was recorded within excavation positions DS02, BH02 and BH03 at depths of 0.40m bgl, 0.65-1.00m bgl and 0.50m bgl respectively.

7.4 Superficial Deposits

Superficial deposits were encountered to depths of 0.95 and 2.70m bgl and generally comprised reddish brown gravelly, silty CLAY. Becoming a pinkish, reddish brown with depth. Gravels comprise fine to medium subangular mudstone and sandstone. With occasional sand lenses, black speckles and decayed rootlets.

7.5 Barren Red Member

Below the superficial deposits, the Barren Red Member was encountered within all rotary boreholes to depths of 9.00 and 14.00m bgl and generally comprised reddish brown interbedded MUDSTONE and SANDSTONE.

7.6 Farrington Member

Below the Barren Red Member, the Farrington Member was encountered to a depth of 15.00m bgl within all rotary boreholes and comprised grey SANDSTONE.

7.7 Roots and Rootlets

Roots and rootlets were identified within certain locations during the site visits. A summary of the roots and rootlets recorded within the excavation positions is presented below.

Position	Roots	Rootlets
DS01	None encountered	0.65-1.70m bgl; rare decayed rootlets
DS03		0.30-0.80m bgl; abundant decayed rootlets
DS04	0.00-0.60m bgl; abundant roots	0.00-0.60m bgl; abundant rootlets 0.60-2.00m bgl; rare rootlets
DS05	0.00-0.20m bgl; occasional roots 0.20-0.95m bgl; rare roots	0.00-0.20m bgl; occasional rootlets 0.20-0.95m bgl; rare rootlets

7.8 Field Evidence of Contamination

No evidence of possible soil contamination (such as staining, malodours, or brightly coloured soils) was identified in the field.

Made Ground was identified 0.30 to 1.00m bgl, and such materials may be imported from an unknown source or mixed with hazardous materials, and as such may contain a wide range of potential contaminants. All such materials should be treated as suspect unless proven otherwise.

7.9 Groundwater

Perched groundwater was struck during the excavation of DS01 and DS03. Groundwater within the bedrock was encountered in BH01 and BH02. Depths of groundwater recorded during drilling are recorded together with water monitoring data overleaf in section 8.1.

7.10 Stability

No instability was recorded during drilling.

8 MONITORING DATA

8.1 Groundwater Monitoring

Furthermore, groundwater was recorded in the six return monitoring visits, standing at depths in the range of 5.86 to 14.20m bgl. The following depths to groundwater are to the groundwater level and does not include the LNAPL thickness perched on the water table.

Position	During drilling (m bgl)	Return monitoring – Depth of groundwater (m bgl)					
		27/03	03/04	11/04	18/04	24/04	07/05
DS01	2.50	No standpipe installed					
DS03	2.00						
BH01	5.50	5.86	7.68	7.30	9.54	10.52	10.15
BH02	14.50	6.21	6.48	6.49	7.10	7.61	7.23
BH03	DRY	13.79	14.00	13.77	13.92	13.97	14.20

During the return monitoring visits, a layer of Light Non-Aqueous Phase Liquid (LNAPL) was noted on top of the groundwater within BH01. All boreholes were dipped using an interface probe to reveal the thickness of any LNAPL present. Positions that contained potential hydrocarbons were sampled using a hydrocarbon bailer for analysis. A summary of the recorded LNAPL thickness is presented below.

Position	During drilling	Return monitoring - Thickness of LNAPL above groundwater (m)					
		27/03	03/04	11/04	18/04	24/04	07/05
BH01	No LNAPL present.	LNAPL present. Thickness not recorded	0.84	0.35	0.49	0.62	0.50
BH02		No LNAPL present					
BH03							

Purging of all the TPH product present within BH01 has been in effect from the second return monitoring visit. Product has been identified within BH01 on a weekly basis with varying thicknesses as presented above.

Purging of the groundwater in BH02 and BH03 has also been in effect since the second monitoring visit in order to retain a fresh groundwater sample on a weekly basis.

Groundwater levels may vary seasonally and with variations in rainfall. Water may also become perched upon cohesive strata or around features such as foundations, and may also occur from leaking drains and water mains etc.

8.2 Ground Gas Monitoring

The results of the ground gas monitoring are summarised on the following table. Depending on the parameter with the maximum (peak) or minimum readings are reported, as stated.

Measurement		BH01	BH02	BH03
Carbon Dioxide %	Maximum	0.0-4.5	0.0-0.3	0.0-0.6
Methane %	Maximum	0.0-0.1	0.0	0.0
Oxygen %	Minimum	1.8-15.9	19.1-20.5	19.1-20.5
VOCs ppm	Maximum	0.2-296.7	0.0-0.1	0.1-3.6
Flow rate l/hr	Full range	-0.3-0.1	-0.1-0.1	0.0-0.2

Below is a summary of the atmospheric pressure conditions during the monitoring visits:

Visit	Pressure (recorded on site)	Published pressure trend
27/03/2019	1030-1033mB	Rising high
03/04/2019	998mB	Falling low
11/04/2019	1024-1027mB	Rising high
18/04/2019	1018-1019mB	
24/04/2019	987mB	Falling low
07/05/2019	1011-1013mB	Falling high

Copies of relevant data are presented in Appendix C.

9 GEO-ENVIRONMENTAL TESTING

9.1 PID Screening

VOC analysis in headspace was carried-out in samples of Made Ground and Superficial Deposits from all dynamic sampler boreholes broadly in accordance with the methodology set-out in CIRIA C682. None of the samples exhibited VOC's above the detection limit (<0.1ppm).

The purpose of the screening was to identify samples which may be impacted by organic contaminants (such as VOC's, SVOC's, petroleum hydrocarbons, diesel, etc) and to assist in prioritising samples for laboratory analysis.

9.2 Geochemical Laboratory Analysis

Samples were selected for geochemical analysis, based on the following rationale:

- Representative samples of natural soils were analysed for speciated TPH and VOC/SVOC, in order to distinguish if any contamination was present within the superficial geology. The samples were taken from DS01, DS02 and DS03, three positions in close proximity and downslope of the spill location;
- Samples of groundwater were obtained from BH01, BH02 and DS03 during the intrusive investigation and BH01, BH02 and BH03 during the return monitoring visits and were tested for Speciated TPH and VOC/SVOC. Samples of LNAPL from BH01 were tested for Product ID.

A summary of the testing scheduled from the intrusive investigation conducted on the 15/03 and between the 21/03 and 23/03 March 2019 and further testing from following monitoring visits are given below:

Intrusive Investigation			
Sample	**Strata**	**Suite**	
		TPH7	**VOC/SVOC**
DS01 2.00m	Superficial Deposits	✓	✓
DS02 1.00m		✓	✓
DS02 1.60m		✓	✓
DS03 2.00m		✓	✓
BH01 Water	Groundwater	✓	✓
BH02 Water		✓	✓
DS03 Water		✓	✓

Return Monitoring				
Sample	**Date sampled**	**Suite**		
		Product ID	**TPH 7**	**VOC/SVOC**
BH01 (Mixed Product)	27/03/2019	✓	-	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓
BH01 LNAPL	03/04/2019	✓	✓	✓
BH01Water		-	✓	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓
BH01 Water	11/04/2019	-	✓	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓
BH01 Water	18/04/2019	-	✓	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓
BH01 Water	24/04/2019	-	✓	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓
BH01 Water	07/05/2019	-	✓	✓
BH02 Water		-	✓	✓
BH03 Water		-	✓	✓

The relevant screening suites are defined below. Where duplicate analysis exists between suites, each test is performed only once:

Suite	Definition
TPH7	Speciated TPH: Total petroleum hydrocarbons CWG banding incl. Aliphatic and aromatic split plus BTEX and MTBE.
VOC/SVOC	Determination of volatile organic compounds by headspace GC-MS

9.3 Results

Testing results with positive ID for TPH have been summarised in the following table, results below detection limit have not been provided:

Sample	Date sampled	Results
DS03 Water	15/03/2019	Low amounts of Aliphatic TPH detected, no Aromatic TPH detected.
BH01 Water	15/03/2019	Trace of Aromatic TPH detected, just above the testing detection limit.
BH01 (Mixed Product)	27/03/2019	LNAPL detected in borehole during monitoring. TPH Product ID testing detected a total ion count (TIC trace) with a carbon range from C10 to C35. The sample TIC trace is complex, showing aromatic and aliphatic product sources. The trace does not match the standard product profiles but is suggestive of diesel fuel.
BH01 LNAPL	03/04/2019	High quantities of Aliphatic & Aromatic TPH detected.
BH01 LNAPL	11/04/2019	High quantities of Aliphatic & Aromatic TPH detected.
BH01 LNAPL	18/04/2019	High quantities of Aliphatic & Aromatic TPH detected.
BH01 LNAPL	24/04/2019	High quantities of Aliphatic & Aromatic TPH detected.
BH01 LNAPL	07/05/2019	High quantities of Aliphatic & Aromatic TPH detected.

Copies of relevant data are presented in Appendix D.

10 CONCLUSIONS

10.1 General

TPH Product was identified within DS03 in perched groundwater, near the main building, as well as traces within BH01 during the initial investigation. Over the following 6no weeks of return monitoring visits TPH product has been identified in the monitoring well at BH01.

The monitoring visits have identified a sustained quantity of TPH product (testing has indicated this to be diesel) in the groundwater at BH01, which is approx. 21.80mOD and ranging between 0.35 - 0.84m thick. Nothing untoward has been identified within BH02 or BH03.

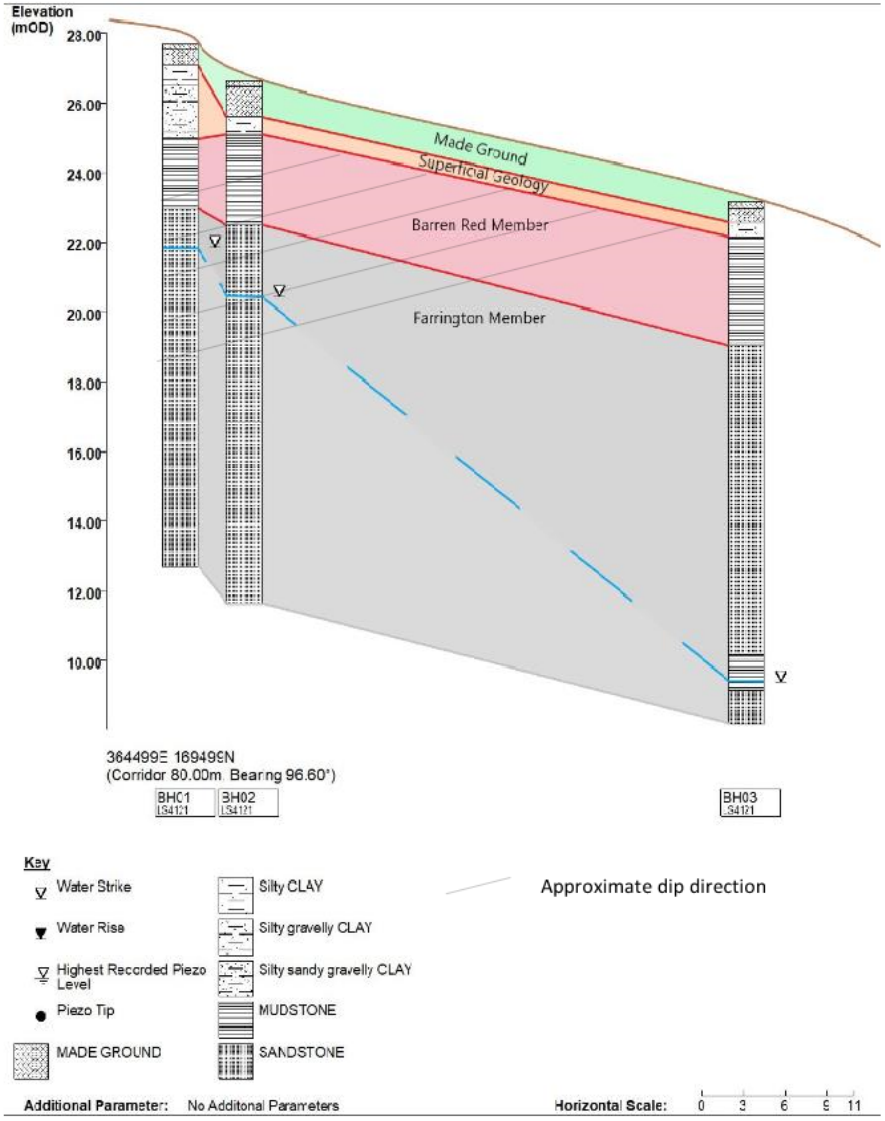
These findings give rise to several potential pathways that need to be investigated urgently.

10.2 Groundwater

The site contained both shallow (perched) groundwater within superficial deposits and deeper groundwater within the bedrock. TPH product was identified within the groundwater in BH01 and shallow perched groundwater in DS03.

This deep groundwater on site is modelled, from the monitoring wells, to be flowing in an easterly direction. Indicating that any product entering the groundwater at the source of the spill may be directed away from BH01, under the existing buildings, and towards surface water features to the east.

The presence of TPH product within BH01 indicates that the product has either travelled through the ground (against groundwater flow) or has found another pathway. Local bedding orientations with the Barren Red and Farrington Members support the theory that the product may have travelled through the strata to the groundwater at BH01. The geological cross-section below models the potential for groundwater flow along dipping bedding planes.



10.3 Superficial deposits

TPH was identified within the perched water of DS03. The potential for migration of product through made ground and superficial deposits must therefore be considered.

However, DS03 was the only position and sample to contain traces of TPH product.

10.4 Foundation trenches

As the TPH product was identified in DS03 next to the main building, it raises the possibility that the product is sat within the trenches/made ground surrounding the foundations of the building. This manmade cavity could provide a settling point for the product.

10.5 Service trenches

During the walkover, several manholes and service trenches were highlighted (by the client) to show evidence of malodour and visual contamination. It was evident that product had found its way into the sites drainage system.

In addition to this, the product could also be pooling around the outside of the pipes/trenches or within ducting etc, particularly in the immediate vicinity of the boiler house. With the extent of services on site unknown and no current service drawings, it's hard to conclude on the viability of this pathway.

10.6 Historical tank leakages

BH01 is located adjacent to the storage tank which provides the boiler house with oil. There is the potential for historical/existing tank leakage, which is aiding the consistent return of product on return monitoring visits despite the removal of product each time.

11 RECOMMENDATIONS

The following recommendations have been made:

1. Hold preliminary discussions with remediation contractor(s);
2. Undertake a PAS128 utilities survey including GPR (for services avoidance and to located possible service trenches);
3. Drill 2no new groundwater monitoring wells, one in the vicinity of DS03, one in the car park beyond BH01;
4. Drill further boreholes on a grid basis to map the extent of contamination (if any) in shallow soils and do VOC "spike tests";
5. Excavate trial holes around the existing foundations and service trenches in the area, perhaps using vacuum excavation;
6. Pressure test (or other checks) on the tank and pipework filling system.

In terms of remediation, we would advise:

- Continuing to bail out the TPH product from BH01 manually for the time being, but otherwise considering groundwater purging system with oil-water separators to remove product, and analysis of the groundwater to evaluate the dissolved phase; dissolved phase treatment (e.g. air sparging, activated carbon filtration, etc) to clean up the water itself (prior to disposal under licence to sewer);
- Chasing-out contaminated soils saturated with product; this will be in and around the storage tank, foundations and service ducts/trenches. Depending on 5) this could potentially be significant;
- A long term plan for dealing with residual groundwater risks including a Detailed Quantitative Risk Assessment (DQRA); the outcome of this may involve a long-term water monitoring program and possibly some form of treatment.

REPORT CONDITIONS

Interpretation of ground conditions inherently depends on the conditions revealed by a limited data set. Land Science takes all reasonable professional care in preparation of this report, using current standards and industry best practice. However, we accept no liability whatsoever expressed or implied in respect of:

- The scope, extent or design of an investigation.
- Any conditions not directly revealed by the investigation.
- Published standards or methodologies used or adopted in this report.
- The opinion of any other party including any regulator, authority or stakeholder.
- Any dispute, claim or consequential loss arising from this report.
- Any matter other than ground conditions in the area under investigation.

Information contained in this report is intended for the use of the Client and his agents for the purposes set out, and we accept no liability for its use by other party or for any other purpose.

This report makes no representation on other matters such as ecology, agronomy, arboriculture, structural condition, building materials, boundaries and planning etc.

No aspect of this report should be taken as a guarantee whatsoever that a site is free of pollution, contamination or hazardous materials.

The levels of mobile liquid or gaseous contaminants may vary over time. Further or additional investigation may be necessary.

GLOSSARY OF TERMS

ACM	Asbestos Containing Material
BGS	British Geological Survey
BRE	Building Research Establishment
BS	British Standard
CBR	California Bearing Ratio
CDM	Construction Design and Management regulations
CIRIA	Construction Industry Research and Information Association
CL:AIRE	Contaminated Land: Applications in Real Environments
CLEA	Contaminated Land Exposure Assessment model
CSM	Conceptual Site Model
EA	Environment Agency
EQS	Environmental Quality Standards
FOC	Fraction of Organic Carbon
GAC	Generic Assessment Criterion
m bgl	Meters Below Ground Level
NHBC	National House Building Council
mod	Metres above Ordnance Datum
PAH's	Polycyclic Aromatic Hydrocarbons
PBET	Physiological Based Extraction Testing
PHE	Public Health England
PID	Photo-Ionisation Detector
PQRA	Preliminary Quantitative Risk Assessment
PSD	Particle Size Distribution Test
RMS	Remediation Method Statement
SGV	Soil Guideline Value
SOM	Soil Organic Matter
SPZ	Source Protection Zone
SPT	Standard Penetration Test
SSSI	Sites of Special Scientific Interest
ST-WEL	Short Term Workplace Exposure Limit
SVOC's	Semi-Volatile Organic Compounds
TPH	Total Petroleum Hydrocarbons
TRRL	Transport Road Research Laboratory
TWA-WEL	Time Weighted Average Workplace Exposure Limit
UK HBF	United Kingdom House Building Federation
VOC's	Volatile Organic Compounds
WAC	Waste Acceptance Criteria

ACCOMPANYING NOTES

Screening Suites

The LS1 routine screening suite is based broadly upon determinands listed within the former ICRCL guidance note 59/83 2nd edition 1987, CLR publication CLR8, and Environment Agency R&D66 publication. Additional testing for stone and moisture content, fraction of organic carbon ('foc'), and pH value, were also undertaken. Given that Sulphate is not a priority in terms of human health, water soluble Sulphate is analysed instead in order to assess the risks posed to the built environment.

Site Workers

Site managers are responsible for the safety of persons in their employ under a variety of instruments including the CDM regulations and Health & Safety at Work Act. In terms of working on contaminated sites, guidance can be sought from the CIRIA publication entitled "A Guide for Safe Working on Contaminated Sites".

Any work in confined spaces confined spaces should only be carried out following appropriate risk assessment and following suitable safety protocols in accordance with the HSE guidance entitled "Work in Confined Spaces". A detailed risk assessment can be prepared in this respect, but is outside the scope of this appointment.

Discovery Strategy

Unexpected soil conditions may be encountered during the process of site demolition and construction. Examples may include oily pockets within the soil, pockets of cement boarding or fibrous materials within the soil, black ashy materials, soils exhibiting strong odours, brightly coloured materials, and former structures or brickwork.

Should previously undiscovered contamination be encountered during construction by the ground worker's, this should be reported to the Geo-Environmental Consultant immediately in order that any necessary inspection may be made. All site workers should be made aware of their responsibility to observe, report, and act on any potentially suspicious or contaminated materials they may encounter.

Primary and Secondary Sources

The secondary sources used in this report are: soil, groundwater and ground gases, as summarised below:

Secondary source	Summary
Soil	Contaminants bound into or entrained with the soil matrix, for instance ashes, clinkers, bituminous materials, asbestos containing materials, etc. Also, soils may become contaminated by other activities, such as leaking chemical storage, drainage and the like, becoming bound into the soil mineralogy or organic matter. Soils may also generate soil-borne dusts and volatile organic compounds may generate organic vapours.
Volatile vapours	Many organic compounds are either volatile or semi volatile (at different temperatures and pressures) which mean they will volatilise and generate vapours. In an enclosed system, the ratio of vapours to other compartments will come into equilibrium, but in open systems the process may continue until the source has been depleted.
Ground gases	Organic matter, including wastes, hydrocarbons and other compounds, will decay through microbial action. This will primarily release Carbon Dioxide but may also release Methane under anaerobic conditions. This may be an issue in natural soils (e.g. alluvium and dock silt) in man-made soils (e.g. landfill sites and filled ground) and other environments (e.g. mine workings).
Groundwater	Contaminants may dissolve into pore water which in turn can percolate downwards into the groundwater table. Rapid discharge of fluids may also enter groundwater directly. Organic compounds may form separate light or dense non-aqueous phase liquids upon or at the base of the water column. Organic contaminants may generate organic vapours.

REFERENCES

1 Radon: Guidance on protective measures for new buildings, BRE Report BR 211, 2015 2ND edition