

EARTH ENVIRONMENTAL
& GEOTECHNICAL

GeoEnvironmental Investigation

Knowsley Street

Cheetham Hill

June 2019

On behalf of

Azhar Property Ltd

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**GEOENVIRONMENTAL
INVESTIGATION**

**KNOWSLEY STREET
CHEETHAM HILL**

Report Ref: A2406/19/B.0

JUNE 2019

Prepared on Behalf of:

Azhar Property Ltd

By:

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Version B.0

Date: 26th June 2019

Prepared for: Azhar Property Ltd

Prepared by: Earth Environmental & Geotechnical Ltd
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Definition of Version Code:

- D. Applied during initial drafting of the report before it has been reviewed.
- C. Applied after the report has been reviewed but before it has been approved by the Project Manager.
- B. Applied after the Project Manager has approved the report ready for issue to the client.
- A. Applied to reports after external/internal review.

The version number starts at "0" and is raised by "1" at each re-type.



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1.0 INTRODUCTION

1.1 Background

A Geo-Environmental Site Investigation has been commissioned by Azhar Property (the Client) to examine ground conditions for a proposed two-storey commercial unit with storage areas.

1.2 Previous Investigations

Earth Environmental & Geotechnical Ltd Phase 1 Desk Study A2406/18, dated February 2018)

The desk study highlighted that the first buildings observed on the site, from the historical mapping, were seen in the 1891 mapping belonging to a railway ticket manufactory. The site becomes increasingly developed over time, being labelled as a ticket printing works in the 1950s and a clothing factory in the 1960s.

The risk to end users from potential soil contamination and ground gas generation was concluded to be **LOW to MEDIUM** based on a proposed commercial end use. The risk to groundwater was considered **LOW to MEDIUM**.

An intrusive investigation was recommended to establish geotechnical parameters for the proposed development and to provide a contamination assessment of the site to confirm whether there are any associated potential risks.

1.3 Terms of Reference

Earth Environmental and Geotechnical Ltd (EEG) was commissioned by the Client to undertake a Geo-Environmental Investigation of the site in accordance with a proposal A2406 dated 27th February 2019.

The objectives of this investigation are as follows:

- *Assess the presence and likely extent of any potential environmental hazards (soil contamination and ground gas) associated within the areas of the site investigated;*
- *Assess the ground conditions for design of foundations.*

1.4 Limitations of the Study

The report is written in the context of an agreed scope of work and budget and should not be used in a different context. New information, improved practices or changes in legislation may require a reinterpretation of the report in whole or in part. EEG reserve the right to amend either conclusions or recommendations in light of any further information that may become available. The report is provided for the sole use by the client and is confidential to them.

Recommendations within this report are also based on exploratory records and examination of samples and, where applicable, laboratory tests. No liability can be accepted for conditions not revealed by the boreholes, particularly at intervening locations. Whilst every effort is made to ensure accuracy of data supplied, all opinions expressed as to the spatial distribution of strata between sampling locations is for guidance only and no responsibility is accepted as to its accuracy.

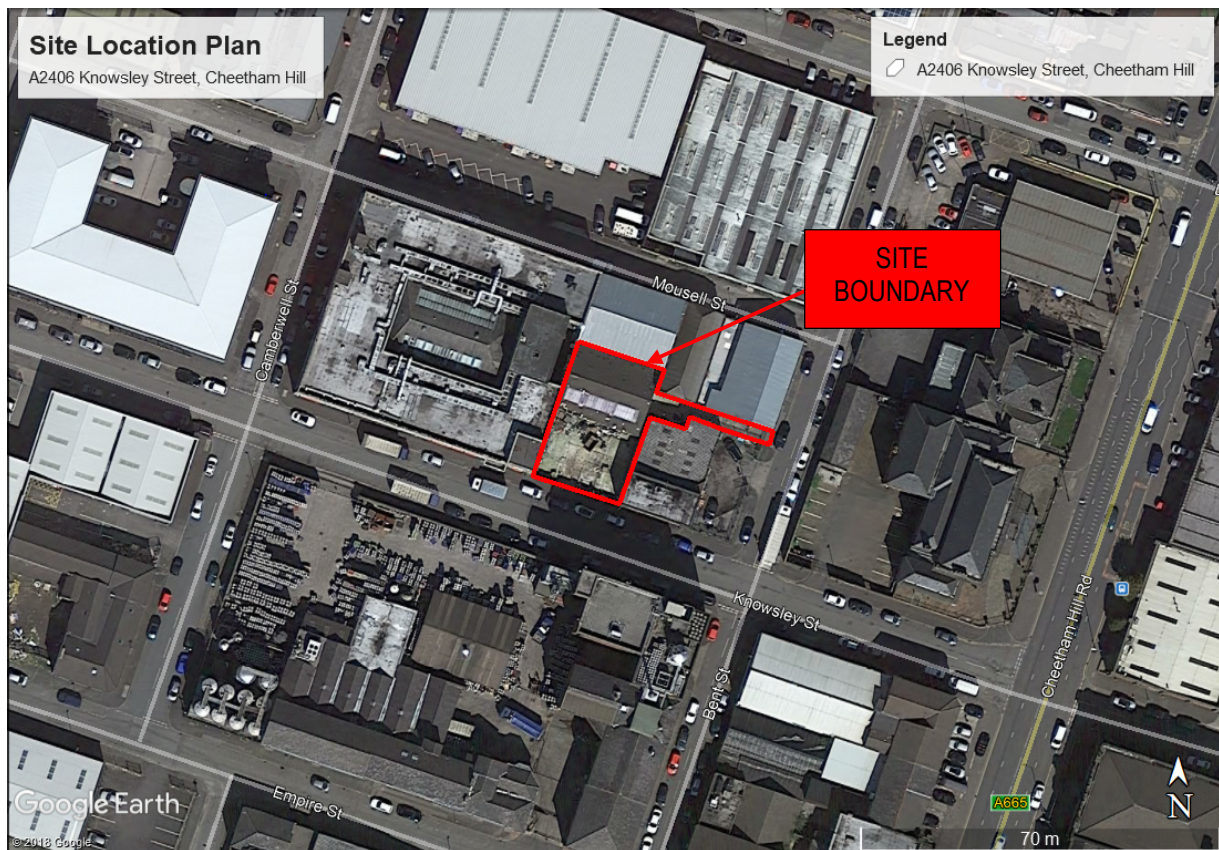
2.0 SITE LOCATION & DESCRIPTION

The site is a mostly rectangular shaped plot of land with maximum dimensions of 41m NW-SE by 27m NW-SE and at the time of the investigation the site was an empty plot that had been stripped of any previous structures. The site is bordered by commercial units to the north, east and west with Knowsley Street running adjacent to the south with a brewery beyond. The topography of the site is generally flat and level.

The approximate National Grid Reference for the centre of the site is SJ 84109 99720 (X: 384109, Y: 399720) with the closest postcode being M8 8HQ. The site was accessed via a gate from Knowsley Street adjacent to the southern site boundary.

A location plan is shown in Figure 1.

Figure 1 Site Location Plan



Site photographs are presented in Figures 2 to 5 overleaf.

Figure 2 View of the site, looking south west



Figure 3 View of the site, looking north



Figure 4 Access gate from Knowsley Street



Figure 5 Soils encountered during drilling

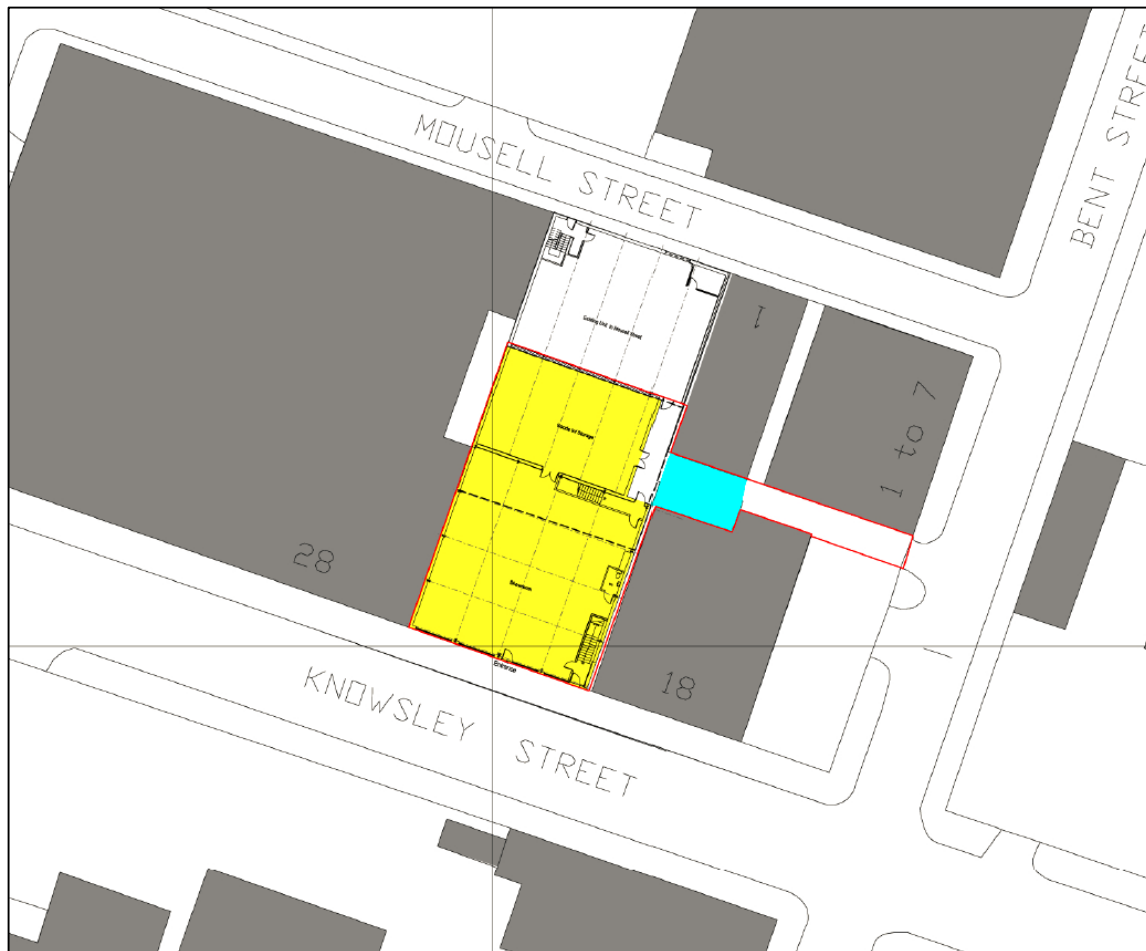


2.1 Proposed Development

It is understood that the Client that the client proposes the erection of a two-storey building to create one wholesale cash and carry unit (Sui Generis Use), with ancillary storage to the rear of the ground floor and first floor area (Planning reference 116914/FO/2017).

Figure 6, below, shows an extract from the proposed development plan.

Figure 6 Development Layout Plan



3.0 SITE INVESTIGATION

3.1 Exploratory Fieldwork

The fieldwork was carried out by EEG on 5th April 2019 and comprised:

- Five window sample boreholes (designated WS01 to WS04 inclusive) were each sunk to a depth of 5.0m below existing ground level. Window sampler boring is carried out with a small, track-mounted rig, which uses a chain-driven trip hammer to drive sampling tubes or penetrometers into the ground. These tools are coupled to the anvil of the hammer by solid drill rods. Sampling tubes comprise “windowless samplers”, which are plain sampler tubes in which a continuous disturbed sample is recovered within a semi-rigid plastic liner. In order to reduce friction within the borehole, sampling tubes of progressively smaller diameter are used as the borehole depth increases. Sampler diameters generally range from between approximately 90mm to 50mm. Standard Penetration Tests (SPTs) were undertaken in the boreholes in accordance with BS EN ISO 22476-3. Exploratory Hole logs are included in Appendix 1.
- On completion, all five of the window sample boreholes were installed with 50mm diameter monitoring standpipes to enable subsequent gas and groundwater monitoring.

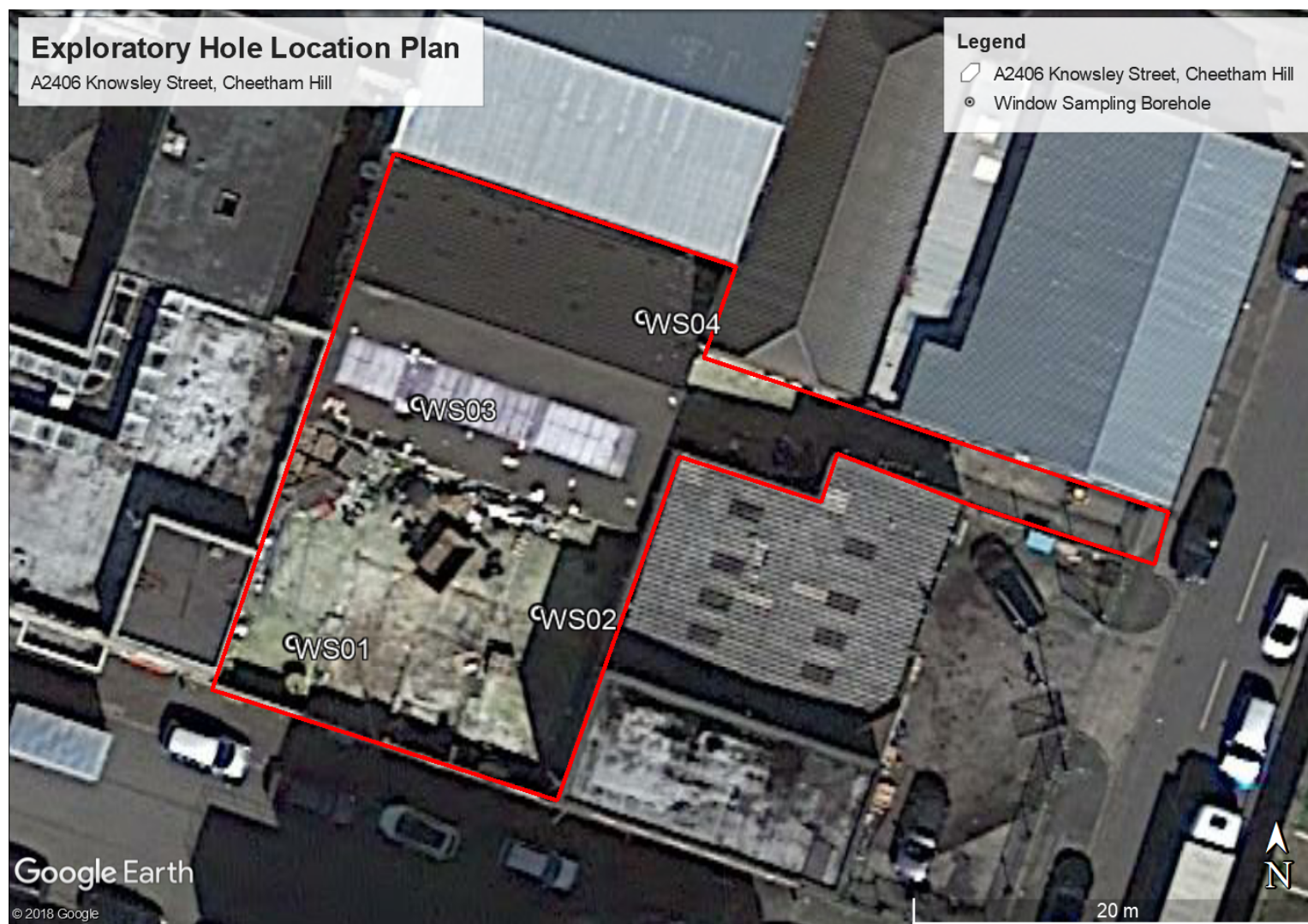
The exploratory hole locations were determined by EEG prior to the investigation taking place. Locations are shown on the Exploratory Hole Location Plan (Figure 7) overleaf.

Each exploratory location was scanned using a Cable Avoidance Tool (CAT) in order to locate unrecorded underground services, and the exploratory locations were repositioned if necessary.

On completion, all samples recovered from the site were taken to a specialist laboratory for testing.

All site investigation work was supervised full time by a representative of EEG. The logging of soils and rocks has been carried out in accordance with BS5930⁽²⁰¹⁵⁾ except where superseded by the soil and rock description methodology in BS EN14688-1⁽²⁰⁰²⁾, BS EN 14688-2⁽²⁰⁰⁴⁾ and BS EN 14689-1⁽²⁰⁰³⁾.

Figure 7 Exploratory Hole Location Plan



All locations and elevations were surveyed by use of a hand-held Trimble GPS with antennae, capable of achieving an accuracy of less than 10cm, depending on the prevailing satellite coverage and obscuring by trees and structures.

The exploratory hole logs are presented within Appendix 1.

A summary of exploratory holes undertaken during the investigation is presented in Table 1, below.

Table 1: Summary of Exploratory Holes Undertaken

Hole	Type	Depth (m)	Date Started	Date Finished	Backfill Details
WS01	WS	5.00	12/04/2019	12/04/2019	SP
WS02	WS	5.00	12/04/2019	12/04/2019	SP
WS03	WS	5.00	12/04/2019	12/04/2019	SP
WS04	WS	5.00	12/04/2019	12/04/2019	SP
WS=Window Sampling Borehole, SP=Standpipe					

3.2 Laboratory Testing Programme

3.2.1 Geotechnical Testing

A programme of laboratory testing was carried out on samples taken from the various strata to assist in classification and determine the engineering properties of the materials underlying the site. The test procedures used were generally in accordance with the methods described in BS1377:1990.

Details of the specific tests used in each case are given overleaf.

TEST	STANDARD (BS1377:1990)	No.
Liquid Limit, Plastic Limit, Plasticity Index	Part 2, Clause 4 / 5	2
Particle Size Distribution	Part 2, Clause 9	2
Undrained Triaxial	Part 7, Clause 9	2
Sulphate content of 2:1 soil: water extract	Part 3,	2
pH value	Part 3,	2

The results of the laboratory geotechnical tests are discussed in Section 5 and included in Appendix 2.

3.2.2 Environmental Testing

The environmental chemistry of the ground was investigated by specialist chemical analysis of selected samples, scheduled by EEG and carried out by DETS.

Chemical analyses were carried out on four soil samples and were submitted for the following suite of determinants:

Asbestos Screen, Arsenic, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Thiocyanate, Phenol, Sulphate (SO₄), Sulphide, pH, Sulphur, Soil Organic Matter and speciated Polyaromatic Hydrocarbons (PAH) and Total Petroleum Hydrocarbons (TPH).

The results of the laboratory contamination tests are discussed in Section 7 and included in Appendix 3.

4.0 GROUND CONDITIONS ENCOUNTERED

4.1 Soil Profile Encountered

The BGS mapping for the area indicates the site to be underlain by superficial deposits of Devensian Till (Diamicton) and solid geology of the Chester Pebble Beds Formation (Sandstone).

The sequence of strata encountered beneath the site was:

- **Made Ground –**
 - Clay of varying sand and gravel contents containing brick, glass, concrete, carbonaceous fragments, mudstone and sandstone.
 - Sand of varying clay and gravel content containing brick, clinker, concrete, glass, carbonaceous fragments and sandstone.
- **Devensian Till Deposits –**
 - Sandy gravelly clay containing carbonaceous fragments, sandstone and mudstone.
 - Slightly silty slightly sandy slightly gravelly clay containing carbonaceous fragments, sandstone and mudstone.

The depths of the various materials encountered in each of the exploratory holes are summarised in the following table.

Table 2 : Summary of Ground Conditions Encountered

Hole	Depth to Stratum (m)			GROUNDWATER (mbgl)
	MADE GROUND	Sandy Gravelly CLAY	Silty Sandy Gravelly CLAY	
WS01	GL-0.60	0.60-1.20	1.20-5.00	-
WS02	GL-0.40	0.40-1.20	1.20-5.00	-
WS03	GL-0.40	0.40-1.20	1.20-5.00	-
WS04	GL-1.30	-	1.30-5.00	-

4.2 Observable Indications of Contamination

During the ground investigation, made ground materials were encountered incorporated into the made ground clays and sands. This included brick, concrete, clinker and glass gravel.

4.3 Obstructions

No obstructions were encountered as a result of made ground. Sandstone cobbles were encountered in WS04 3.00-5.00m that slowed drilling work.

4.4 Groundwater

Groundwater was not encountered during the drilling of the boreholes.

During the subsequent gas and groundwater monitoring of the boreholes, groundwater was detected between 0.50m (WS03) and below the base of the monitoring wells (WS02).

5.0 ENGINEERING PROPERTIES OF SOILS ENCOUNTERED

The following sections discuss the engineering properties of the strata encountered, based on results of in situ testing and laboratory testing obtained during this investigation.

5.1 Made Ground

Variable Made Ground was encountered across the site to depths of between 0.40m and 1.30m. Made Ground is not typically considered to be a suitable founding material, and as such, no geotechnical testing was carried out on the material.

Given the shallow depth of the Made Ground, no Standard Penetration Tests (SPT) were carried out in the material.

Sulphate content and pH value determination tests were carried out on six samples of the Made Ground by the chemical laboratory. The **water-soluble sulphate** content of the samples ranged between 74 mg/l SO₄ to 941 mg/l SO₄ with **pH values** of 7.0 to 7.4.

5.2 Devensian Till Deposits – Clay

Clay was encountered in all of the excavations situated beneath a mantle of Made Ground at the surface.

SPT tests carried out in the Clay resulted in **SPT N values** of 7 to 33, as shown on the SPT vs Depth Plot overleaf (Figure 8). These results suggest the Clay is typically soft to very stiff.

Results of the SPTs in the Clay are summarised in the table below.

Table 3: Summary of Design Parameters (Clay)

Depth (m)	SPT N Value Range	Design N Value*	Average Measured Undrained Shear Strength kN/m ²	Equivalent Shear Strength** (kN/m ²)	Coefficient of Volume Compressibility**
1.0-2.0	7-11	9	130	40.5	0.24
2.0-3.0	14-20	14	126	63	0.15
3.0-4.0	18-21	19	-	85.5	0.13
4.0-5.0	21-33	21	-	94.5	0.13
*Based on lower quartile of SPT N value **Based on correlation by Stroud & Butler ⁽¹⁹⁷⁵⁾					

Two **particle size distribution (PSD)** tests were carried out on samples of the Clay. The laboratory described the material as stiff brown silty sandy clay.

Sulphate content and pH value determination tests were carried out on two samples of the Clay. The **water-soluble sulphate** content of the samples was between 290-340 mg/l SO₄ with **pH values** of 6.9-7.0.

Two Atterberg Limit tests was carried out on samples of the Clay. Results of the tests reported **liquid limit** values of 36-37% and **plastic limit** values of 13%, resulting in **plasticity index** values of 23-24%. These results suggest the Clay to be of **intermediate plasticity**.

Results are shown on the Plasticity Chart (Figure 9) overleaf. Full test results are included in Appendix 2.

For design purposes, a value of plasticity index = 23% is recommended, based on the average of the results.

In accordance with NHBC Chapter 4.2 Building Near Trees⁽²⁰⁰³⁾ soils can be classified in terms of volume change potential, using the relationship:

$$Ip' = Ip \times \frac{\% \text{ less than } 425\mu\text{m}}{100\%}$$

Ip' = modified plasticity index

Ip = plasticity index.

Based on the laboratory test results, the above relationship and Table 1 of NHBC Chapter 4.2, the samples of Silty Clay have a **medium volume change potential**.

Single stage triaxial testing was carried out on two samples of the Clay. These produced **undrained shear strength** values of 126 to 130 kN/m².

Figure 8 SPT vs Depth Plot

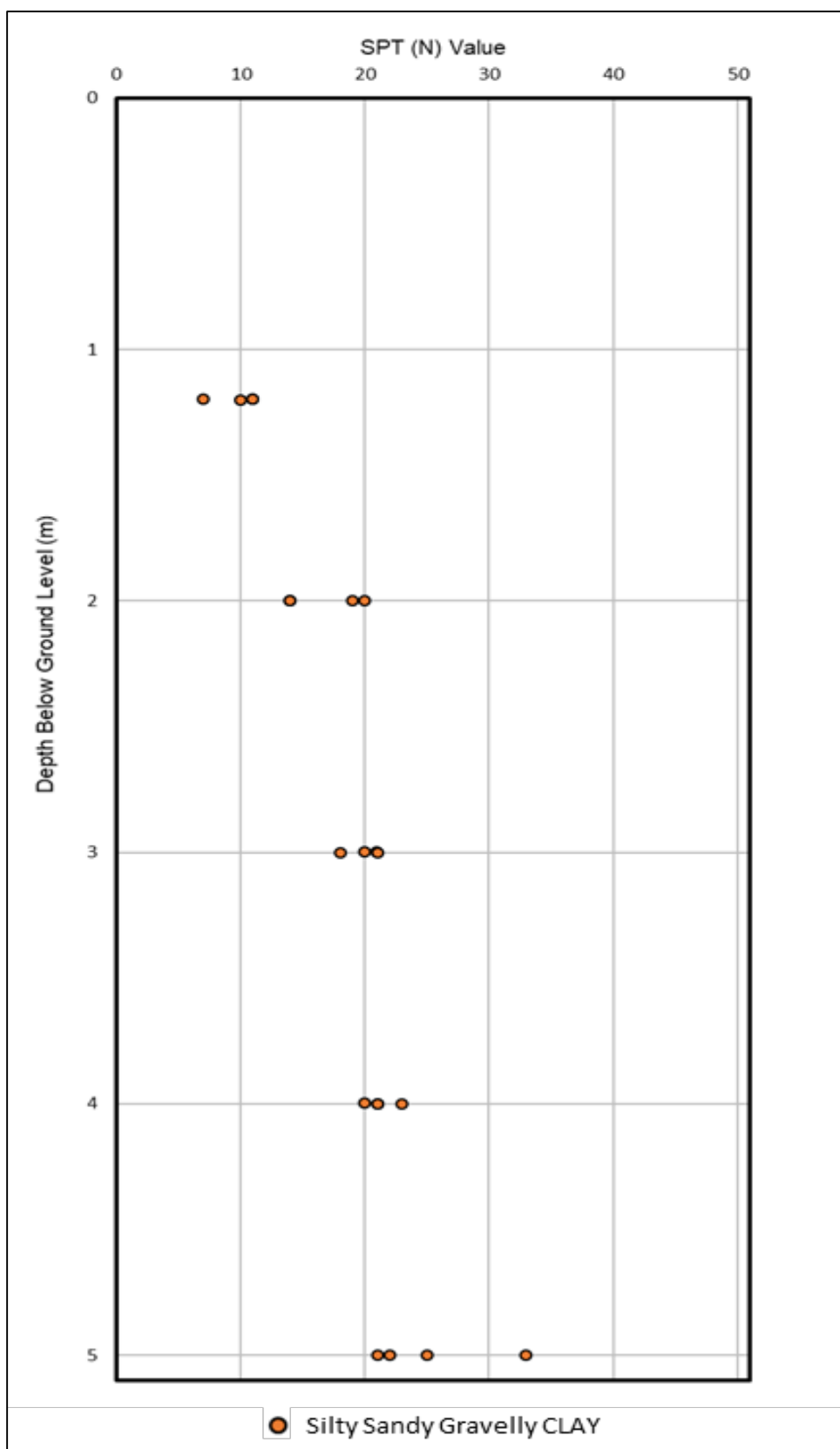
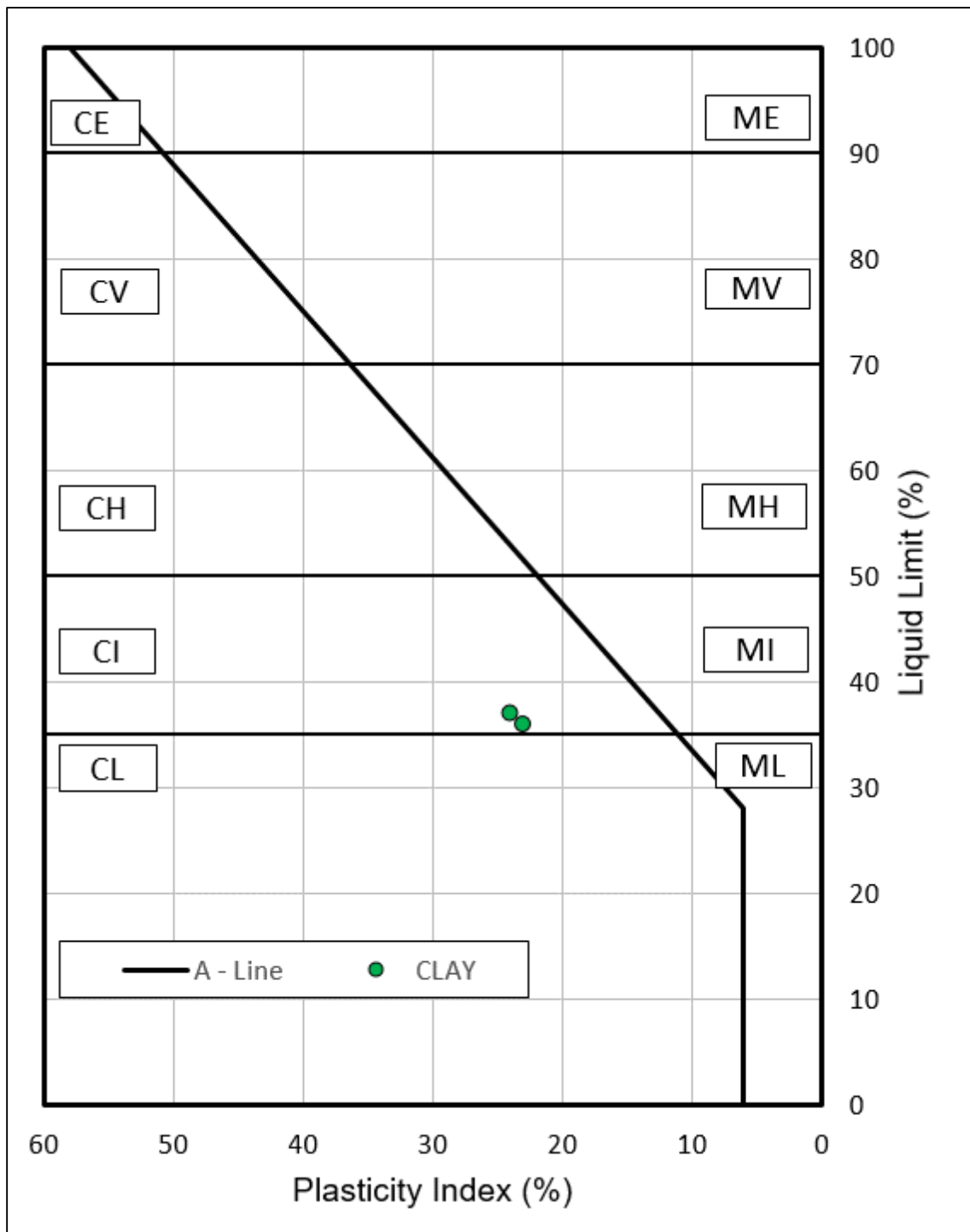


Figure 9 Plasticity Chart



6.0 GEOTECHNICAL ASSESSMENT

6.1 Proposed Development

It is understood that the Client that the client proposes the erection of a two-storey building to create one wholesale cash and carry unit (Sui Generis Use), with ancillary storage to the rear of the ground floor and first floor area.

6.2 Ground Conditions

The exploratory holes generally encountered Made Ground over Sandy Gravelly Clay which is in turn underlain by Silty Sand Gravelly Clay.

6.3 Foundation Considerations

Conventional shallow strip foundations are considered suitable for the site, bearing into the natural firm/stiff clays. For clays of medium volume change potential, the NHBC recommended a minimum foundation depth of 0.90m below the lowest of the existing or finished ground level. Shallow strip footings are considered in Section 6.3.1, below.

6.3.1 Shallow Strip Foundations

The following table summarises anticipated allowable bearing pressures for strip foundations placed at different depths in the natural clays encountered at founding level. The bearing capacities are calculated based on Hansen's⁽¹⁹⁷⁸⁾ method and assuming a factor of safety against bearing capacity failure of 3. For the purpose of the calculation, groundwater has been assumed to be at 1.0m bgl.

Table 4: Summary of Allowable Bearing Pressures for Strip Foundations

Foundation Depth	Strata	Design Value (Section 6)	Strip Foundation Width	Allowable Bearing Pressure
1.0m	CLAY	$c_u = 40.5\text{kN/m}^2$	0.60m	104kN/m ²
			0.75m	101kN/m ²
			0.90m	99kN/m ²
1.5m		$c_u = 40.5\text{kN/m}^2$	0.60m	110kN/m ²
			0.75m	108kN/m ²
			0.90m	106kN/m ²
2.0m		$c_u = 63\text{kN/m}^2$	0.60m	172kN/m ²
			0.75m	169kN/m ²
			0.90m	167kN/m ²
2.5m		$c_u = 63\text{kN/m}^2$	0.60m	176kN/m ²
			0.75m	174kN/m ²
			0.90m	171kN/m ²

If any Made Ground, particularly loose or soft material is encountered at foundation level this should be excavated and replaced with suitable granular fill or the foundation extended to suitable strata. Floor slabs may be designed as ground bearing where Made Ground is excavated and replaced with suitable granular fill.

All foundation excavations should be inspected by a suitable qualified engineer to prove that the founding strata is suitable and uniform along the length of the foundation, and capable of taking the anticipated structural loadings.

6.4 Ground Floor Slabs

Floor slabs should be designed as suspended with a subfloor void appropriate to medium volume change potential where located within the zone of influence of a tree or if Made Ground of 600mm thickness or greater is present.

6.5 Pavement Design

The ground investigation identified the soil type at subgrade level to typically be either Made Ground or natural Clay, with plasticity index of 23%. Based on the recommendations for design CBR values provided in Interim advice note 73/06, Revision 1⁽²⁰⁰⁹⁾, a CBR value for the natural Clay would be 3-4%.

Once formation level for the new road pavements has been achieved, formation excavations should be examined by a suitably experienced engineer or inspector to check for soft or unsuitable material, which should be removed and replaced with compacted granular fill. Also, to ensure good compaction and remove unevenness, the formation should be compacted with equipment suitable for use in the ground conditions encountered. Careful inspection of this work will also help identify any soft spots at or just below formation level.

Exposed subgrades are likely to deteriorate rapidly on exposure to wet weather and should be shaped to shed water. Subbase should be placed as soon as possible to minimise the exposure of subgrade to adverse weather conditions.

6.6 Chemical Attack on Buried Concrete

Chemical testing of samples taken from beneath the site show elevated levels of water-soluble sulphates in the Made Ground and near neutral pH conditions.

Based on these conditions, it is recommended that for foundations the Design Sulphate Class for the site, as defined in BRE Special Digest 1⁽²⁰⁰⁵⁾, be taken as DS-2, and the Aggressive Chemical Environment for Concrete (ACEC) site classification be taken as AC-2.

The recommendations of BRE Special Digest 1 should be followed for concrete foundations and ground bearing floor slabs.

6.7 Suitability of Excavated Materials

Acceptability criteria and testing, and methods of compaction/placement will depend on the type of contract and specification used for the construction of the proposed development and it is recommended that earthworks specifications are reviewed by a suitably qualified engineer, once these have been prepared by the relevant parties.

6.8 Temporary Works

Formations in the natural materials will be susceptible to damage both by weather and trafficking, and should be protected immediately on exposure, particularly in areas where construction plant will access the site.

Excavations are likely to be unstable and should be battered back to an angle of 1 in 2, or a system of close sheeting and shoring adopted to ensure stability, and in particular where personnel are required to enter excavations. All excavations should be adequately supported where personnel are required to enter.

Groundwater seepages could be encountered near surface within excavations, particularly during the wetter months of the year. Pumping of excavations from a suitable located sump is likely to be required to keep excavations dry.

All natural materials on site should be capable of being excavated using conventional excavating machinery.

7.0 SOIL CONTAMINATION RISK ASSESSMENT

7.1 Tier I Human Health Soil Risk Assessment – Groundworkers During Development

To assess the risk of soil contamination to construction and ground workers during development, guidelines from the HSE Document 'Protection of workers and the general public during development of contaminated land' (1991) are used. The document assesses soil contamination test results and classifies the site as being uncontaminated or contaminated with varying degrees of contamination from 'slight' to 'unusually heavy'.

The guideline values and laboratory test results are summarised in the following table:

Table 5: Summary of Guideline Values for Protection of Workers and the General Public During Development of Contaminated Land

Contaminant	Typical Values* for:					Test Results	Class
	Uncontaminated Soils	Slight Contamination	Contaminated	Heavy Contamination	Unusually Heavy Contamination		
	Class A	Class B	Class C	Class D	Class E		
pH (alkaline)	7 - 8	8 - 9	9 - 10	10 - 12	12	7.0-7.4	A
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	8-37	A-B
Cadmium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 0.2-1.1	A-B
Chromium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	15-28	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	17-111	A-B
Lead	0 - 500	500 - 1000	1000 - 2000	2000 - 1%	1.0%	27-405	A
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	<1	A
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	15-33	A-B
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	36-213	A
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	<1-1.7	A
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	0.8-2.4	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	21-41	A
Sulphate	0 - 2000	2000 - 5000	5000 - 1%	1% - 5%	5.05%	328-2447	A
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	<5-11	A-B
Cyanide (free)	0 - 1	1 - 5	5 - 50	50 - 100	100	<2	A
Phenol	0 - 2	2 - 5	5 - 50	50 - 250	250	<2	A

Based on the above contaminant concentrations, a **LOW** potential risk from soil contamination to construction workers, ground workers and members of the public during construction, and appropriate measures, such as PPE, site health plans, appropriate disposal of material arisings will mitigate this risk.

7.2 Tier I Human Health Soil Risk Assessment – Future Site Users

The following sections provide a Human Health Soil Assessment for groundworkers during development and future commercial end users.

At a Tier I stage the long term (chronic) human health toxicity of the soil has been assessed with reference to DEFRA/Environment Agency Contaminated Land Exposure Assessment (CLEA) Soil Guideline Values (SGV) for generic site land uses, soils and exposure. Where Environment Agency generic guidance is absent, reference has been made to the Chartered Institute of Environmental Health (CIEH) S4ULs for human health risk assessment.

In the case of arsenic, cadmium, hexavalent chromium, lead and benzo(a)pyrene DEFRA Category 4 Screening levels have been adopted. A conservative Soil Organic Matter (SOM) of 1% has been adopted for organic chemicals for the purposes of the initial assessment. A SOM of 6% has been adopted for inorganic chemicals as detailed in 'The LQM / CIEH S4ULS for human health assessment', (2015). The soil chemical testing results are presented in Appendix 3 and summarised in Table 6, below.

Table 6: Assessment of Soil Chemical Data

Parameter	WS01 0.50m MG	WS02 0.20m MG	WS03 0.30m MG	WS04 0.70m MG	Assessment Criteria (mg/kg)
Arsenic	8	37	23	8	640
Boron	1.7	< 1	< 1	< 1	240000
Beryllium	0.8	2.4	1.1	1	12
Cadmium	< 0.2	1.1	0.4	< 0.2	190
Chromium	17	28	15	18	8600
Free Cyanide	< 2	< 2	< 2	< 2	34
Hexavalent Chromium	< 2	< 2	< 2	< 2	33
Copper	17	111	31	25	68000
Lead	27	405	95	31	2300
Mercury	< 1	< 1	< 1	< 1	1100
Nickel	15	33	19	17	980
Selenium	< 3	< 3	< 3	< 3	12000
Vanadium	21	41	27	25	9000
Zinc	36	213	78	43	730000
pH	7.2	7	7.4	7.2	N/A
Naphthalene	< 0.1	< 0.1	0.21	< 0.1	190 (76.4) ^{sol}
Acenaphthylene	< 0.1	0.14	0.13	< 0.1	84000 (57.0) ^{sol}
Acenaphthene	< 0.1	< 0.1	0.19	< 0.1	83000 (86.1) ^{sol}
Fluorene	< 0.1	0.12	0.31	< 0.1	63000 (30.9) ^{sol}
Phenanthrene	< 0.1	1.21	2.72	< 0.1	22000
Anthracene	< 0.1	0.82	0.58	< 0.1	520000
Fluoranthene	< 0.1	3.74	3.31	< 0.1	23000
Pyrene	< 0.1	3.4	3.62	< 0.1	54000
Benzo(a)anthracene	< 0.1	1.83	1.63	< 0.1	170
Chrysene	< 0.1	1.09	1.67	< 0.1	350
Benzo(b)fluoranthene	< 0.1	1.58	1.6	< 0.1	44
Benzo(k)fluoranthene	< 0.1	0.43	0.69	< 0.1	1200
Benzo(a)pyrene	< 0.1	0.99	1.4	< 0.1	35
Indenol(1,2,3-cd)pyrene	< 0.1	0.84	0.71	< 0.1	3.5
Di-benz(a,h)anthracene	< 0.1	< 0.1	0.13	< 0.1	500
Benzo(ghi)perylene	< 0.1	0.59	0.67	< 0.1	3900
Phenol	< 2	< 2	< 2	< 2	760
Aliphatic >C5 - C6	< 0.01	< 0.01	< 0.01	< 0.01	3200 (304) ^{sol}
Aliphatic >C6 - C8	< 0.05	< 0.05	< 0.05	< 0.05	7800 (144) ^{sol}
Aliphatic >C8 - C10	< 2	< 2	< 2	< 2	2000 (78) ^{sol}

Parameter	WS01 0.50m MG	WS02 0.20m MG	WS03 0.30m MG	WS04 0.70m MG	Assessment Criteria (mg/kg)
Aliphatic >C10 - C12	< 2	< 2	< 2	< 2	9700 (48) ^{sol}
Aliphatic >C12 - C16	< 3	< 3	< 3	< 3	59000 (24) ^{sol}
Aliphatic >C16 - C21	< 3	< 3	< 3	< 3	1,600,000
Aliphatic >C21 - C34	< 10	29	< 10	< 10	1,600,000
Aromatic >C5 - C7	< 0.01	< 0.01	< 0.01	< 0.01	26000 (1220) ^{sol}
Aromatic >C7 - C8	< 0.05	< 0.05	< 0.05	< 0.05	56000 (869) ^{Vap}
Aromatic >C8 - C10	< 2	< 2	< 2	< 2	3500 (613) ^{Vap}
Aromatic >C10 - C12	< 2	< 2	< 2	< 2	16000 (364) ^{sol}
Aromatic >C12 - C16	< 2	< 2	< 2	< 2	36000 (169) ^{sol}
Aromatic >C16 - C21	< 3	4	14	< 3	28000
Aromatic >C21 - C35	< 10	10	18	< 10	28000
Asbestos	Not Detected	Detected	Not Detected	Not Detected	-
Asbestos Type	-	Chrysotile	-	-	-
Asbestos Matrix	-	Present as bundles	-	-	-

Notes for Table 6

Concentrations in **red** above assessment criteria.

No elevated chemical contaminants of concern have been identified in any of the samples tested during this investigation with respect to the long-term protection of human health, when compared to commercial end use assessment criteria.

Asbestos has been detected in WS02 at 0.20m. The type of asbestos has been determined to be chrysotile and is reported as being present as bundles. Asbestos quantification testing has determined there to be 0.002% asbestos present in this sample.

7.3 Soil Waste Assessment

An assessment of the disposal characteristics of the soil in accordance with Environment Agency guidance WM3.1, edition of May 2018, "Guidance on the classification and assessment of waste" has been carried out for the soils on site using HazWasteOnline.

All the soils tested have been classified as Non-Hazardous, the results of which are presented in Table 7 below.

Table 7: Waste Classification of Soils

Location	Depth (m bgl)	HazWasteOnline Classification
WS01	0.50	Non-Hazardous
WS02	0.20	Non-Hazardous
WS03	0.30	Non-Hazardous
WS04	0.70	Non-Hazardous

Full results of the Soil Waste Assessment are presented in Appendix 4.

8.0 GROUND GAS RISK ASSESSMENT

The potential risk associated with gases being generated in the ground (whether from natural or man-made sources) depends on the concentrations of gas and its flow rate to the surface. These factors are assessed by monitoring of the gas installations in the boreholes. The variable nature of gas generation and the effect of barometric pressure on gas flow, means that the volume of gas potentially reaching the ground surface is normally inconsistent over time.

Four gas monitoring visits have been completed by Earth Environmental & Geotechnical Ltd. The monitoring visits were conducted at the site between 1st May and 20th May 2019 and the results obtained recorded methane (CH₄) levels of between 0.0% and 0.2% by volume (v/v) and carbon dioxide (CO₂) levels ranging from 0.0% to 3.1% v/v. Oxygen concentrations of between 16.7% and 19.7% v/v were also recorded.

Gas flow rates were recorded using a dedicated flow meter. A maximum flow rate of 0.3l/hr was detected in borehole WS01 during the second visit. Atmospheric pressure was recorded to be between 983mb and 1020mb.

Full results of the monitoring to date are presented in Appendix 5.

Table 8.5 of CIRIA Report 665 (2007), presented below as Table 8, provides information on current UK practice with respect to appropriate gas protection measures based upon a Gas Screening Value (GSV). A GSV for the site has been obtained by multiplying the maximum concentration of gas by the maximum flow rate, which represents worst-case scenario conditions.

- Carbon dioxide: maximum flow rate = 0.3l/hr, max concentration = 3.1%
- Methane: maximum flow rate = 0.3l/hr, max concentration = 0.2%.

Based on the above figures, the GSV is calculated as:

- **Carbon dioxide:** $GSV = 0.3 \times 3.1 / 100 = 0.0093 \text{ litres/hr}$
- **Methane:** $GSV = 0.3 \times 0.2 / 100 = 0.0006 \text{ litres/hr}$

The above results suggest the site can be given a Characteristic Situation-1 (CS-1), i.e. 'Very Low Risk' classification, in accordance with Table 8 overleaf. This is due to the Gas Screening Values of both methane and carbon dioxide not exceeding the <0.07 l/hr threshold for CS-1 classification.

Table 8: Modified Wilson & Card Classification (CIRIA Report 665)

Characteristic Situation (CIRIA Report 149)	Risk Classification	GSV (CH₄ or CO₂) (l/hr)	Additional Factors	Typical Source of Generation
1	Very Low Risk	<0.07	Typically, methane $\leq 1\%$ v/v and/or carbon dioxide $\leq 5\%$ v/v. Otherwise consider increase to Situation 2.	Natural Soils with low organic content. "Typical" Made Ground.
2	Low Risk	<0.7	Borehole flow rate not to exceed 70l/hr. Otherwise increase to Situation 3.	Natural soil, high peat/organic content. "Typical" Made Ground.
3	Moderate Risk	<3.5		Old landfill, inert waste, mineworking flooded.
4	Moderate to High Risk	<15	Quantitative risk assessment required to evaluate scope of measures required.	Mineworking susceptible to flooding, completed landfill (WMP 26B criteria)
5	High Risk	<70		Mineworking unflooded inactive with shallow workings near surface.
6	Very High Risk	>70		Recent landfill site.

9.0 REVISED CONCEPTUAL MODEL

A Revised Conceptual Model has been prepared for the site and is presented as Table 11, overleaf. The Revised Conceptual Model reviews the Preliminary Conceptual Model (PCM) presented as Table 3 in Section 5.0 of EEG Phase 1 GeoEnvironmental Investigation report (Reference: A2406/18, dated February 2018) using the information obtained during this site investigation and considers the source-pathway-receptor linkages present alongside the likelihood, severity and risk level as defined within Table 9 and Table 10 below. The assessment of probability, a modified risk table, and certain consequence definitions are based on CIRIA C552 and CLR11.

Table 11 considers whether a pollution linkage is present and provides a preliminary qualitative assessment of risk based on the information currently available. Where a possible linkage is identified, it does not necessarily mean that a significant risk exists but indicates that further information is required through appropriate site investigation to substantiate the conceptual model.

The Revised Conceptual Model is based on a proposed commercial end use.

Table 9: Consequence, Probability and Risk

Probability	Consequence	Risk
High Likelihood- There is a pollution linkage and an event either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution	Very High – acute risk to the human health likely to result in significant harm. Risk of severe or irreversible effect on ground/surface water quality. Catastrophic damage to buildings / property.	Very High – there is a high potential that the source-pathway-receptor scenarios may give rise to harm to human health or the environment and remedial action is likely to be required.
Likely – there is a pollution linkage and all the elements are present, which means that it is probable an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.	High – Severe or irreversible effect on human health. Temporary severe or irreversible effect on ground/surface water quality. Reduction of water quality rendering groundwater or surface water unfit to drink and/or substantial adverse impact on groundwater dependant environmental receptors.	High – it is likely that the source-pathway-receptor scenarios may give rise to an impact on human health or the environment, which may require remediation and/or control measures to mitigate risks
Low likelihood– there is a pollutant linkage and circumstances are possible for an event could occur. However, it is by no means certain that even over a longer period such event would take place, and is less likely in the shorter term	Moderate – Long term or short-term moderate effect on human health. Moderate effect on ground/surface water quality, reversible with time. Reduced reliability of a supply at a groundwater or surface water abstraction source	Moderate – it is possible that the source-pathway-receptor scenarios may give rise to an impact on human health or the environment, however it is either relatively unlikely that such are would be severe, or if any harm were to occur it is more likely that harm would be mild.
Unlikely – there is a pollution linkage but circumstances are such that it is doubtful that an event would occur even in the very long term.	Low – Non-permanent health effects to human health (easily prevented by means such as personal protective clothing etc.) Slight effect on ground/surface water quality, reversible with time. Marginal reduced reliability of a supply at a groundwater or surface water abstraction source.	Low – it is possible that harm could arise at the source, however it is likely that the risk would at worst be mild.
		Very Low – it is unlikely that the source-pathway-receptor scenarios will give rise to an impact on human health or the environment.

Table 10: Estimation of Level of Risk

		Consequence			
		High	Moderate	Low	Very low
Probability	High Likelihood	Very High	High risk	Moderate risk	Moderate to low risk
	Likely	High risk	Moderate risk	Moderate to low risk	Low risk
	Low Likelihood	Moderate risk	Moderate to low risk	Low risk	Very low risk
	Unlikely	Moderate to low risk	Low risk	Very low risk	Very low risk

9.1 Sources of Contamination

The Phase I Desk Study report for the site outlined the potential for the presence of soil and groundwater contamination associated with:

- Historical land uses.

The site investigation identified the following:

- Made Ground to a maximum depth of 1.30m;
- No samples tested were in exceedance of chemical screening criteria relevant to commercial end use;
- Asbestos fibre bundles were identified in the sample taken from WS02 at 0.20m.

9.2 Receptors

The following receptors have been considered for the construction and operational stages of the proposed redevelopment.

- Current site users
- Adjacent land users
- Future land users
- Construction workers during site development works
- Underlying Groundwater

9.3 Pollutant Pathways

The following pathways have been considered for the construction and operational stages of the proposed redevelopment.

- Direct contact via dermal contact, ingestion, inhalation of potentially contaminated soils;
- Downward vertical migration of contaminants to groundwater and lateral migration to nearby water courses;
- Vertical or lateral migration of ground gas.

Table 11: Revised Conceptual Model

Source	Pathway	Receptor	Probability	Consequence	Risk	Comment
Made Ground (Exceedances of Heavy Metals)	Dermal contact, ingestion and inhalation of soils dust	Current Site Users	Unlikely	Moderate	Low	The site is currently a vacant plot. The risk to current site users from potential contamination is considered to be LOW .
		Adjacent land users	Unlikely	Moderate	Low	No elevated concentrations of contaminants were recorded in any of the samples tested compared to commercial end use criteria. The risk is considered LOW however usual dust control measures should be implemented as part of good site working practices during construction to reduce dust generation.
		Future land users	Unlikely	Moderate	Low	No elevated concentrations of contaminants were recorded in any of the samples tested compared to commercial end use criteria. The proposed development is for a commercial unit. The risk to future site users via direct exposure is considered to be LOW .
		Construction Workers	Unlikely	Moderate	Low	Assuming appropriate health and safety measures are adopted (in line with CDM and other relevant health and safety guidance) a LOW risk to construction workers is anticipated.
	Downward vertical/lateral leaching and migration of contaminants	Underlying shallow groundwater	Unlikely	Moderate	Low	The site is underlain by Principal and Secondary (Undifferentiated) aquifers. No elevated concentrations of contaminants were recorded in any of the samples tested compared to commercial end use criteria. The risk to controlled waters is therefore considered LOW .
	Vertical or lateral migration of ground gas	Current Site Users	Unlikely	Moderate	Low	The site is currently a vacant plot of land. The risk to current site users from ground gas is therefore considered LOW .

Source	Pathway	Receptor	Probability	Consequence	Risk	Comment
		Adjacent land users	Unlikely	Moderate	Low	Based on monitoring data obtained to date, no significantly elevated concentrations of CO ₂ and CH ₄ have been recorded at the site. The risk to adjacent site users from ground gas is considered LOW .
		Future land users	Unlikely	Moderate	Low	Based on monitoring data obtained to date, no significantly elevated concentrations of CO ₂ and CH ₄ have been recorded at the site. The risk to future site users from ground gas is therefore considered LOW .
		Construction Workers	Unlikely	Moderate	Low	Construction workers may be exposed to low oxygen conditions in confined spaces and excavations, however, the duration will be short term. The risk to construction is considered LOW .
Asbestos	Inhalation of fibres	Current/ Future/ Adjacent site users	Unlikely	High	Low	Low amounts of asbestos fibres were detected in one of the soil samples tested. The proposed development will be covered by hardstanding. Asbestos is only harmful when disturbed. The risk of direct contact with receptors is therefore considered LOW .
		Adjacent Land Users	Low Likelihood	High	Moderate	Low amounts of asbestos was detected in one sample of the Made Ground. Asbestos is only harmful when disturbed and becomes airborne i.e. during construction/excavation works. The risk to adjacent land users during construction is therefore considered MODERATE . Appropriate precautions such as ensuring the soils do not become dry and dusty would reduce the risk to LOW .

Source	Pathway	Receptor	Probability	Consequence	Risk	Comment
		Construction Workers	Likely	High	High	Low amounts of asbestos were detected in the Made Ground. Construction workers are likely to be exposed to soil during construction work. The risk to construction workers is therefore considered HIGH. Basic asbestos management will be required as a minimum and implementation of appropriate health and safety measures should be adopted in line with CDM and other relevant health and safety guidance.

10.0 CONCLUSIONS AND RECOMMENDATIONS

The following section provides a summary of the conclusions and recommendations based on the findings of the site investigation.

10.1 Soil Contamination

Ground conditions across the site generally comprised a covering of made ground to a maximum depth of 1.30m followed by gravelly clay which is in turn underlain by silty sandy gravelly clay.

None of the soil samples tested contained contaminants in exceedance of the chemical screening criteria relevant to a commercial end use.

There is therefore considered to be a **LOW** overall potential risk from soil contamination to construction workers, ground workers and members of the public, and appropriate measures, such as PPE, site health plans, appropriate disposal of material arisings will mitigate this risk.

10.2 Asbestos

Asbestos in the form of Chrysotile bundles was detected in one soil sample tested on the site (WS02 0.20m).

Quantification of the asbestos revealed that the sample contained 0.002% asbestos by mass.

Considering the proposed commercial development with full coverage of hard standing, the risk posed to end users from asbestos is concluded to be **LOW**.

However, the risk to groundworkers during the construction phase is considered **MODERATE**, with a **MODERATE** risk to adjacent land users (due to the potential generation of airborne fibres).

As a minimum the following precautions will be required to minimise the risk to construction workers and adjacent land users:

- Communicate the risk to site personnel at induction stage;
- Ensure soils do not dry out and become dusty.

10.3 Soil Waste Assessment

The soils have been classified as Non-Hazardous in accordance with Environment Agency guidance WM3.1.

10.4 Ground Gas

Monitoring results obtained recorded maximum methane (CH₄) levels of 0.2% v/v and maximum carbon dioxide (CO₂) levels of 3.1% v/v. Oxygen levels as low as 16.7% v/v were also recorded. A maximum flow rate of 0.3 l/hr was detected.

The site has been classified as Characteristic Situation-1 (CS-1) based on GSV values below 0.07 l/hr. Based on this classification, there is considered to be a **LOW** risk from ground gas and no ground gas protective measures are required in the proposed scheme.

10.5 Foundations

Conventional shallow strip foundations are considered suitable for the site, bearing into the natural firm/stiff clay at a minimum depth of 1.0m.

10.6 Site Personnel

As with all construction sites, personnel working on the site during the construction period should be encouraged to maintain a high standard of personal hygiene and on-site washing facilities should be available.

APPENDIX 1

EXPLORATORY HOLE LOGS

APPENDIX 2

GEOTECHNICAL TESTING RESULTS

APPENDIX 3

CHEMICAL TESTING RESULTS

APPENDIX 4

SOIL WASTE ASSESSMENT

APPENDIX 5

MONITORING DATA

APPENDIX 6

REPORT LIMITATIONS

REPORT LIMITATIONS

This contract was completed by Earth Environmental & Geotechnical Ltd on the basis of a defined programme and scope of works and terms and conditions agreed with the client. This report was compiled with all reasonable skill, and care, bearing in mind the project objectives, the agreed scope of works, the prevailing site conditions, the budget and staff resources allocated to the project.

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It is Earth Environmental & Geotechnical Ltd understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was an important factor in determining the scope and level of the services. Should the purpose for which the report is used, or the proposed use of the site change, this report will no longer be valid and any further use of, or reliance upon the report in those circumstances by the client without Earth Environmental & Geotechnical Ltd review and advice shall be at the client's sole and own risk.

The report was written in 2019 and should be read in light of any subsequent changes in legislation, statutory requirements and industry best practices. Ground conditions can also change over time and further investigations or assessment should be made if there is any significant delay in acting on the findings of this report. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of Earth Environmental & Geotechnical Ltd. In the absence of such written advice of Earth Environmental & Geotechnical Ltd, reliance on the report in the future shall be at the client's own and sole risk. Should Earth Environmental & Geotechnical Ltd be requested to review the report in the future, Earth Environmental & Geotechnical Ltd shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between Earth Environmental & Geotechnical Ltd and the client.

The observations and conclusions described in this report are based solely upon the services that were provided pursuant to the agreement between the client and Earth Environmental & Geotechnical Ltd. Earth Environmental & Geotechnical Ltd has not performed any observations, investigations, studies or testing not specifically set out or mentioned within this report.

Earth Environmental & Geotechnical Ltd is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, Earth Environmental & Geotechnical Ltd did not seek to evaluate the presence on or off the site of electromagnetic fields, lead paint, radon gas or other radioactive materials.

The services are based upon Earth Environmental & Geotechnical Ltd observations of existing physical conditions at the site gained from a walkover survey of the site together with Earth

Environmental & Geotechnical Ltd interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The findings and recommendations contained in this report are based in part upon information provided by third parties, and whilst Earth Environmental & Geotechnical Ltd have no reason to doubt the accuracy and that it has been provided in full from those it was requested from, the items relied on have not been verified.

No responsibility can be accepted for errors within third party items presented in this report. Further Earth Environmental & Geotechnical Ltd was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the services. Earth Environmental & Geotechnical Ltd is not liable for any inaccurate information, misrepresentation of data or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Earth Environmental & Geotechnical Ltd and including the doing of any independent investigation of the information provided to Earth Environmental & Geotechnical Ltd save as otherwise provided in the terms of the contract between the client and Earth Environmental & Geotechnical Ltd.

Where field investigations have been carried out these have been restricted to a level of detail required to achieve the stated objectives of the work. Ground conditions can also be variable and as investigation excavations only allow examination of the ground at discrete locations. The potential exists for ground conditions to be encountered which are different to those considered in this report. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and Earth Environmental & Geotechnical Ltd] based on an understanding of the available operational and historical information, and it should not be inferred that other chemical species are not present.

The groundwater conditions entered on the exploratory hole records are those observed at the time of investigation. The normal speed of investigation usually does not permit the recording of an equilibrium water level for any one water strike. Moreover, groundwater levels are subject to seasonal variation or changes in local drainage conditions and higher groundwater levels may occur at other times of the year than were recorded during this investigation.

Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan, but is (are) used to present the general relative locations of features on, and surrounding, the site.