



EARTH ENVIRONMENTAL
& GEOTECHNICAL

GeoEnvironmental Site Investigation Report

Dobfield Road

Rochdale

April 2023

On behalf of

Jared Bullock

Earth Environmental & Geotechnical Ltd
Houldsworth Mill Business & Arts Centre
Houldsworth Street
Stockport
SK5 6DA

Tel : 0161 975 6088

Email info@earthenvironmental.co.uk
www.earthenvironmental.co.uk

**GEOENVIRONMENTAL
INVESTIGATION REPORT**

DOBFIELD ROAD

ROCHDALE

Report Ref: A5182/22/SI/V3

APRIL 2023

Prepared on Behalf of:

JARED BULLOCK

By:

Earth Environmental & Geotechnical Ltd
Houldsworth Mill Business & Arts Centre
Houldsworth Street
Stockport
SK5 6DA

DISTRIBUTION:

1 electronic copy Jared Bullock

GEOENVIRONMENTAL INVESTIGATION REPORT

DOBFIELD ROAD, ROCHDALE

Report Reference: A5182/22/SI/V3

Version B.2

Date: 2nd April 2023

Prepared for: Jared Bullock

Prepared by: Earth Environmental & Geotechnical Ltd
Houldsworth Mill Business & Arts Centre
Houldsworth Street
Stockport
SK5 6DA

Definition of Version Code:

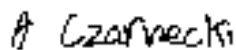
- D. Applied during initial drafting of the report before it has been reviewed.
- C. Applied after the report has been reviewed but before it has been approved by the Project Manager.
- B. Applied after the Project Manager has approved the report ready for issue to the client.
- A. Applied to reports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

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

Written by:



Daniel Shanks
Senior GeoEnvironmental Consultant



Approved by:

Adam Czarnecki
Company Owner

TABLE OF CONTENTS

1.0	EXECUTIVE SUMMARY	1
2.0	INTRODUCTION	2
2.1	BACKGROUND	2
2.2	EXISTING PLANNING APPLICATIONS	2
2.2	PREVIOUS INVESTIGATIONS.....	2
2.2.1	<i>LK Consult, Desk Based Coal Mining Risk Assessment, reference: LKC 20 1164, dated February 2020.</i>	<i>2</i>
2.3	TERMS OF REFERENCE.....	2
2.4	REPORT SCOPE	3
2.5	LIMITATIONS OF THE STUDY	3
3.0	SITE LOCATION & DESCRIPTION	4
3.1	PROPOSED DEVELOPMENT.....	7
4.0	SITE INVESTIGATION	8
4.1	EXPLORATORY FIELDWORK.....	8
4.2	LABORATORY TESTING	11
4.2.1	<i>Geotechnical Testing</i>	<i>11</i>
4.2.2	<i>Environmental Testing</i>	<i>11</i>
5.0	GROUND CONDITIONS ENCOUNTERED	12
5.1	SOIL PROFILE ENCOUNTERED.....	12
5.2	OBSERVABLE INDICATIONS OF CONTAMINATION.....	12
5.3	OBSTRUCTIONS.....	13
5.4	GROUNDWATER	13
5.5	ROCKHEAD.....	14
6.0	ENGINEERING PROPERTIES OF SOILS ENCOUNTERED	15
6.1	GENERAL.....	15
6.2	GRANULAR	15
6.3	CLAY.....	16
7.0	GEOTECHNICAL ASSESSMENT	21
7.1	PROPOSED DEVELOPMENT.....	21
7.2	GROUND CONDITIONS ENCOUNTERED	21
7.3	FOUNDATION CONSIDERATIONS.....	21
7.3.1	<i>Conventional Shallow Depth Strip/Pad Foundations</i>	<i>21</i>
7.4	PAVEMENT DESIGN.....	23
7.5	CHEMICAL ATTACK ON BURIED CONCRETE	23
7.6	SUITABILITY OF EXCAVATED MATERIALS	24
7.7	TEMPORARY WORKS	24
8.0	SOIL CONTAMINATION RISK ASSESSMENT	25
8.1	TIER I HUMAN HEALTH SOIL RISK ASSESSMENT – GROUNDWORKERS DURING DEVELOPMENT.....	25
8.2	TIER I HUMAN HEALTH SOIL RISK ASSESSMENT – FUTURE SITE USERS.....	25
8.3	SOIL WASTE ASSESSMENT.....	28
9.0	GROUNDWATER MONITORING RESULTS	30
10.0	GROUND GAS AND RADON GAS CONTAMINATION RISK ASSESSMENT.....	32
11.0	COAL MINING RISK ASSESSMENT	38
12.0	CONCLUSIONS & RECOMMENDATIONS	40
12.1	SOIL CONTAMINATION.....	40

12.2	ASBESTOS.....	40
12.3	GROUNDWATER CONTAMINATION	40
12.4	FOUNDATIONS.....	40
12.5	SOIL DISPOSAL	40
12.6	LAND GAS	41
12.7	COAL MINING	41
12.8	RISK TO BURIED (WATER) SERVICES.....	41
12.9	SITE PERSONNEL.....	41
12.10	OTHER MATTERS.....	41

LIST OF FIGURES

Figure 1	Site Location Plan
Figure 2	General Site Photographs
Figure 3	Proposed Development Plan
Figure 4	Exploratory Hole Location Plan
Figure 5	SPT N1(60) v Depth Plot
Figure 6	Strength v Depth Plot
Figure 7	Plasticity Chart
Figure 8	Gas Ratio Ternary Plot
Figure 9	Carbon Dioxide: Oxygen Ratio Plot
Figure 10	Nitrogen/Oxygen: Carbon Dioxide Ratio Plot
Figure 11	Extract from LK Consult Coal Mining Risk Assessment
Figure 12	Cross Section (A - A') of Encountered Coal Seams

TABLES

Table 1	Shear Strength Definitions
Table 2	Summary of Exploratory Holes Undertaken
Table 3	Summary of Laboratory Geotechnical Tests Undertaken
Table 4	Summary of Ground Conditions Encountered
Table 5	Summary of Laboratory Geotechnical Test Results
Table 6	Summary of Design Parameters (Granular)
Table 7	Summary of Design Parameters (Clay)
Table 8	Soil Desiccation Indicators in the Clay
Table 9	Summary of Allowable Bearing Pressures
Table 10	Summary of Anticipated Settlements (Granular)
Table 11	Comparison of Capping Thickness with and without Geotextile
Table 12	Summary of Guideline Values for Protection of Workers and the General Public During Development of Contaminated Land
Table 13	Soil Results Comparison with C4SL/S4UL Values
Table 14	Waste Classification of Soils
Table 15	Summary of WAC Test Results
Table 16	Groundwater Results Comparisons with EQS/Drinking Water Quality Values
Table 17	Characteristic Situation (Wilson et al 2006/2007 modified from Wilson and Card, 1999)
Table 18	Summary of Geology Encountered

APPENDICES

Appendix 1	Exploratory Hole Logs
Appendix 2	Dynamic Probe Results
Appendix 3	Geotechnical Testing Results
Appendix 4	Chemical Testing Results
Appendix 5	Soil Waste Assessment

Appendix 6	Ground Gas Monitoring Data
Appendix 7	Report Limitations

1.0 EXECUTIVE SUMMARY

Appointment	A Site Investigation has been commissioned by Jared Bullock to examine ground conditions for a proposed development at the land south of Dobfield Road, Rochdale.
The Investigation	The investigation comprised ten windowless samples, three rotary open holes and nine machine dug trial pits with associated sampling, in situ testing, monitoring, laboratory geotechnical, and environmental testing.
The Site	The site is located approximately 2.3km northeast of Rochdale Town Centre with the approximate National Grid Reference for the centre of the site being SD 91758 13865, (X: 391758 Y: 413865), with the nearest available postcode of OL16 3AW. At the time of this investigation, the site comprised a large, vacant plot of land that was once associated with the on-site stables to the south of Dobfield Road. A training paddock, covered with rubber chippings and a geotextile membrane, is currently located in the southwest of the site, adjacent to a small building in the southwest corner of the site, owned by Pennine Distribution & Training Ltd. The site is generally bound by wooden and Heras fences and is largely surrounded by vacant land, with Firgrove Business Park to the northeast.
Ground Conditions Encountered	The exploratory holes generally encountered topsoil, overlying variable, medium dense SAND, to a maximum depth of 4.50m bgl. Firm to stiff CLAY was encountered in all window sampling locations, below the sand to a maximum depth of 6.00m bgl. Made ground was recorded in all trial pit locations, overlying the sand, to a maximum depth of 1.30m bgl. Seepage of perched groundwater was encountered in TP1, TP2, TP5, TP6 and TP9, between 2.40m and 2.60m bgl. Perched groundwater was encountered in the exploratory boreholes at depths between 2.50m and 3.00m bgl.
Ground Gas Assessment	Detailed assessment of the data, with specific reference to gas ratios shows that the ground gas composition generally resembles air, not landfill or harmful ground gas. The risk from ground gas is therefore considered "very low" with a characteristic situation of CS1, with gas protection measures not required.
Geotechnical Assessment	Shallow strip/pad foundation placed in the natural sand at approximately 1.00m bgl or below should be appropriate for the current proposed development, dependent on allowable bearing pressures and tolerance of structures to settlement. Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement and piles.
Contamination Assessment	Risk from contamination to groundworkers during development – Moderate to Low Risk from contamination to future site users – Moderate to Low. Risk from contamination to controlled waters - Low. Asbestos was not encountered in the soil samples collected from the site. Soil Waste Assessment: 10 samples tested, 10 classified as Non-Hazardous. WAC Testing: 4 samples tested, 4 classified as Inert Waste due to high organic topsoil.
Coal Mining Assessment	3no. rotary open hole boreholes drilled in area of probable shallow coal mine workings, in the southwest of the site. Exploratory holes encountered a sequence of interbedded mudstone and sandstone with a thin coal seam encountered at each location. All lithologies were identified to be intact, with no loss of flush or drilling returns. No elevated ground gas identified during drilling.
<i>This sheet is intended to provide a summary only of the report. It does not provide a definitive engineering analysis for the purposes of costing or construction and is subject to the limitation of the agreed brief.</i>	

2.0 INTRODUCTION

2.1 Background

A Site Investigation has been commissioned by Jared Bullock to examine ground conditions for a proposed development at the land south of Dobfield Road, Rochdale.

2.2 Existing Planning Applications

2.2.1 Planning Application to Rochdale Borough Council, 20/01093/FUL, dated September 2020.

A planning application has been submitted for the site to Rochdale Borough Council (Reference: 20/01093/FUL) for the proposed development of 8no. dwellings with associated hard and soft landscaping and car parking. The application was approved in June 2021.

2.2 Previous Investigations

2.2.1 LK Consult, Desk Based Coal Mining Risk Assessment, reference: LKC 20 1164, dated February 2020.

The report highlighted that the site was recorded to be underlain by the Pennine Lower Coal Measures Formation, comprising interbedded mudstone, coal seams, siltstone, and sandstone, with superficial deposits of Glaciofluvial deposits of sand and gravel recorded on site.

The Arley (coal) seam was identified to cross the south of the site, bearing 120°. This seam is recorded to be of workable thickness, between 0.90m - 2.00m thick.

According to data from The Coal Authority, there are no records of past underground mine workings beneath the site, and no recorded shafts within the local area. There are also no records of subsidence and mine gas in the area.

However, the report highlights that the Coal Authority states there is the likelihood for probable unrecorded shallow workings beneath the southeast of the site.

The report recommended further investigation comprising rotary open hole drilling to 30.00m bgl, within the area of the proposed development, due to the presence of shallow coal seams of a workable thickness within the site area resulting in the potential for unrecorded shallow mine workings beneath the site.

2.3 Terms of Reference

Earth Environmental and Geotechnical Ltd (EEG) have been commissioned by the Client, to undertake a Site Investigation of the site in accordance with proposal A5182/22 dated 23rd December 2022. The objectives of this investigation are as follows:

- *Provide factual information on the work undertaken including sampling location plan, trial pit/borehole logs, monitoring, geotechnical and chemical testing.*
- *Tier 1 (semi-quantitative) risk assessment will be undertaken. This will compare the concentrations of soil, ground gas and groundwater contaminants identified*

against current and appropriate published guidelines, in relation to identified receptors, e.g. existing/ future end users and site neighbours.

- *Assessment of ground conditions for foundation design.*
- *Potential surplus soil waste characterisation.*
- *Assessment of shallow coal mining regime.*

2.4 Report Scope

This report presents full factual records of the site work carried out, the ground conditions encountered in the exploratory holes, the in situ and laboratory test results. All information collected has been used to provide an interpretation of the ground conditions, with recommendations on geotechnical design and potential ground contamination risks for the proposed development.

2.5 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 considering 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 and trial pits, 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.

3.0 SITE LOCATION & DESCRIPTION

The site is located approximately 2.3km northeast of Rochdale Town Centre with the approximate National Grid Reference for the centre of the site being SD 91758 13865, (X: 391758 Y: 413865), with the nearest available postcode of OL16 3AW.

The site is an irregular shaped parcel of land with current access via Dobfield Road to the north of the site. The maximum dimensions of the proposed site are approximately 120m west to east and 177m northeast to southwest. The site occupies an area of approximately 0.79 hectares. The site is generally flat and level.

At the time of this investigation, the site comprised a large, vacant plot of land that was once associated with the on-site stables to the south of Dobfield Road. A training paddock, covered with rubber chippings and a geotextile membrane, is currently located in the southwest of the site, adjacent to a small building in the southwest corner of the site, owned by Pennine Distribution & Training Ltd. The site is generally bound by wooden and Heras fences and is largely surrounded by vacant land, with Firgrove Business Park to the northeast.

The site location is shown in the aerial photograph presented as Figure 1, below.

Figure 1: Site Location Plan



General site photographs are presented in Figure 2, overleaf.

Figure 2: General Site Photographs

View across the site, looking southwest



View across the training paddock, looking east



View of the on-site building, owned by PDTL, looking southwest



Photograph of representative soils (TP7)



3.1 Proposed Development

It is understood that the client intends to demolish all existing structures on-site and construct eight new, detached residential properties. The development will include private gardens and parking for each property, along with slight alterations to the existing access.

A proposed development plan is shown in Figure 3, below.

Figure 3: Proposed Development Plan



4.0 SITE INVESTIGATION

4.1 Exploratory Fieldwork

The fieldwork was carried out by EEG on the 27th & 28th of January and on the 21st & 22nd of February 2023 and comprised:

- Ten window sample boreholes (designated WS1 to WS10) were each sunk to depths of between 3.00m and 6.00m below existing ground level. All boreholes were drilled with the intention of reaching 6.00m bgl, however many were terminated early due to refusals on cobbles and boulders. 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. Groundwater observations were noted where possible. These observations relate to the time of the investigation only, and do not necessarily reflect seasonal fluctuations. Exploratory hole logs are included in Appendix 1. Exploratory hole locations were selected on-site by an EEG engineer based on the proposed development layout and avoiding known services. 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.
- 50mm diameter standpipes were installed all the boreholes at depths between 3.00 and 6.00m below ground level. Installation and backfill details are shown with the appropriate borehole log sheet. EEG carried out groundwater/ground gas monitoring in standpipes after the fieldwork period, the results of which are presented in Appendix 6.
- Three dynamic probe tests were carried out to a maximum depth of 9.10m alongside the window sample boreholes. The tests were terminated due to refusals in suspected bedrock material. The results of the probe tests are included as Appendix 2.
- Nine trial pits (designated TP1 - TP9) were excavated to a maximum depth of 3.00m, using a wheeled, backhoe excavator. All the trial pits were terminated early due to side wall collapse. Chemical samples were recovered from the excavated material as pitting proceeded. Trial pits were backfilled immediately on completion of sampling. Exploratory hole logs for the trial pits are available in Appendix 1.
- Three boreholes (designated RH1 - RH3 inclusive) were drilled to 30.00m below existing ground level, using a track-mounted rotary open hole drilling rig. The boreholes were initially drilled through overburden using a rock roller down the hole hammer, producing a 112mm nominal diameter hole. Water was used as the flushing medium. The boreholes were backfilled on completion with bentonite grout. Exploratory hole logs are included in Appendix 1.

On completion, samples recovered from the site were taken to specialist laboratories for chemical and geotechnical testing.

Soil samples of approximately 1.25kg were recovered in amber jars for volatile analysis and plastic tubs for general analysis. All the samples were labelled and stored in cool boxes prior to being collected by courier at the end of the day for delivery to the DETS laboratory. If collection was not possible the same day, then samples were stored in the sample storage fridge at the EEG offices below 4°C.

Samples were tracked using appropriate Chain of Custody forms provided by DETS.

It should be noted that hexavalent chromium soil is analysed using the USEPA recommended method of alkaline leach. This method limits chromium (VI) reduction to chromium (III).

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⁾.

The descriptive terminologies such as firm, etc formerly used within older versions of BS5930 to describe strength now solely relate to consistency. Shear strength is now defined related to results obtained in the field (using a hand vane for example) or in the laboratory (from triaxial tests), as detailed in Table 1 below.

Table 1: Shear Strength Definitions

Term based on measurement	Undrained Strength (c_u) definition in kN/m ² (from BS EN ISO 14688-2: 2004, 5.3, Table 5)
Extremely Low Strength	<10
Very Low Strength	10 to 20
Low Strength	20 to 40
Medium Strength	40 to 75
High Strength	75 to 150
Very High Strength	130 to 300
Extremely High Strength	300 to 600

An Exploratory Hole Location Plan is presented as Figure 4, overleaf.

A summary of exploratory holes undertaken during the investigation are presented in Table 2 below.

Table 2: Summary of Exploratory Holes Undertaken

Hole	Type*	Depth (m)	Date Started	Date Finished	Easting (m)	Northing (m)	Backfill Details**
WS1	WS	5.00	27/01/2023	27/01/2023	391779	413899	SP
WS2	WS	5.00	27/01/2023	27/01/2023	391793	413889	SP
WS3	WS	4.00	27/01/2023	27/01/2023	391803	413871	SP
WS4	WS	3.00	27/01/2023	27/01/2023	391778	413858	SP
WS5	WS	5.00	26/01/2023	26/01/2023	391763	413837	SP
WS6	WS	5.00	26/01/2023	26/01/2023	391737	413829	SP

WS7	WS	6.00	26/01/2023	26/01/2023	391710	413839	SP
WS8	WS	6.00	26/01/2023	26/01/2023	391728	413853	SP
WS9	WS	5.00	27/01/2023	27/01/2023	391747	413871	SP
WS10	WS	5.00	27/01/2023	27/01/2023	391769	413886	SP
TP1	TP	2.50	27/01/2023	27/01/2023	391800	413893	A
TP2	TP	2.80	27/01/2023	27/01/2023	391810	413870	A
TP3	TP	3.00	27/01/2023	27/01/2023	391778	413840	A
TP4	TP	2.30	27/01/2023	27/01/2023	391762	413832	A
TP5	TP	2.50	27/01/2023	27/01/2023	391723	413811	A
TP6	TP	2.60	27/01/2023	27/01/2023	391727	413839	A
TP7	TP	2.00	27/01/2023	27/01/2023	391750	413855	A
TP8	TP	2.80	27/01/2023	27/01/2023	391767	413869	A
TP9	TP	2.60	27/01/2023	27/01/2023	391751	413878	A
RH1	RO	30.00	21/02/2023	21/02/2023	391744	413851	G
RH2	RO	30.00	21/02/2023	21/02/2023	391733	413838	G
RH3	RO	30.00	22/02/2023	22/02/2023	391719	413839	G

*WS=Windowless Sample, TP=Trials Pit
**SP=Standpipe, A=Arising, G=Grout

Figure 4: Exploratory Hole Location Plan



4.2 Laboratory Testing

4.2.1 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 tests were scheduled by EEG and carried out by Murray Rix. 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 in Table 3 below.

Table 3: Summary of Laboratory Geotechnical Tests Undertaken

TEST	STANDARD	No.
Particle size distribution (wet)	BS1377:1990 Part 2, Clause 9.2	5
Moisture Content	BS1377:1990 Part 2, Clause 3.2	10
Liquid Limit, Plastic Limit, Plasticity Index	BS1377:1990 Part 2, Clause 4/5	10
Sulphate content of 2:1 soil: water extract	BS1377:1990 Part 3, Clause 5	10
pH value	BS1377:1990 Part 3, Clause 9	10

The results of the laboratory geotechnical tests are discussed in Section 6 and included in Appendix 3.

4.2.2 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, a UKAS and MCERTS accredited laboratory.

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

Asbestos Screen, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol, Sulphate (SO₄), Sulphide, pH, Soil Organic Matter, Speciated Polycyclic Aromatic Hydrocarbons (PAH), Speciated Total Petroleum Hydrocarbons (TPH).

Four of the soil samples were also submitted for Waste Acceptance Criteria (WAC) testing.

The results of the laboratory soil contamination tests are discussed in Section 8 and included in Appendix 4.

Five perched groundwater samples were obtained from the boreholes on site and were submitted for the following suite of determinants:

Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Vanadium, Zinc, Cyanide, Phenol, Sulphate (SO₄), Sulphide, pH, Total Organic Carbon (TOC), Speciated Polycyclic Aromatic Hydrocarbons (PAH), Speciated Total Petroleum Hydrocarbons (TPH).

The results of the laboratory water contamination tests are discussed in Section 9 and included in Appendix 4.

5.0 GROUND CONDITIONS ENCOUNTERED

5.1 Soil Profile Encountered

The BGS mapping for the area indicates the site to be underlain by Glaciofluvial deposits comprising sand and gravel. The solid geology beneath the site is recorded to be the Pennine Lower Coal Measures comprising mudstone, coal seams, siltstone, and sandstone. The sequence of strata encountered beneath the site was as follows:

- **Topsoil** was encountered in all exploratory holes, excluding TP5, comprising:
 - Slightly clayey, slightly silty, loamy, slightly gravelly SAND, containing gravel of red brick and mudstone.
- **Made Ground** was encountered in all exploratory holes, comprising:
 - Slightly clayey, slightly silty, gravelly SAND, containing gravel of red brick, concrete, and mudstone.
 - Slightly silty, gravelly SAND, containing gravel of red brick and concrete.
 - Slightly clayey, slightly silty, gravelly SAND, containing gravel of mudstone, quartzite, and flint.
 - Sandy GRAVEL of concrete, red brick, and sandstone.
- **Sand** was encountered in all exploratory holes, comprising:
 - Medium dense, slightly clayey, slightly silty, gravelly SAND, containing gravel of mudstone, quartzite, and flint.
 - Medium dense, slightly clayey, silty, gravelly SAND, containing gravel of mudstone, quartzite, and flint. High cobble content.
 - Medium dense, clayey, silty, gravelly SAND, containing gravel of mudstone, quartzite, and flint. High cobble content.
 - Medium dense, slightly silty, slightly gravelly SAND, containing gravel of mudstone, quartzite, and flint. High cobble content.
 - Medium dense, silty, gravelly SAND, containing gravel of mudstone, quartzite, and flint.
 - Medium dense, slightly clayey, gravelly SAND, containing gravel of sandstone and mudstone.
 - Medium dense SAND.
 - Medium dense, slightly gravelly SAND, containing gravel of sandstone.
- **Clay** was encountered in all exploratory holes, comprising:
 - Firm to stiff CLAY.
 - Stiff to very stiff, slightly gravelly CLAY, containing gravel of sandstone.
 - Stiff, slightly sandy, slightly gravelly CLAY, containing gravel of sandstone.
- **Pennine Lower Coal Measures** was encountered in all rotary open hole boreholes comprising interbedded mudstone and hard sandstone. Coal was encountered in each rotary location between 8.20m - 8.40m in RH1, 8.80m - 9.00m in RH2 and 10.00m - 10.30m in RH3.

The depths of the various materials encountered in the exploratory holes are summarised in Table 4, overleaf.

5.2 Observable Indications of Contamination

Aside from small amounts of red brick and concrete in the made ground, no visual or olfactory signs of contamination were identified during the investigation.

5.3 Obstructions

Relic red brick foundations were encountered at 1.00m bgl in TP2. Multiple cobbles and boulders within the natural glaciofluvial deposits were encountered that caused minor delays during the drilling. No further man-made obstructions were encountered during the investigation.

5.4 Groundwater

Seepage of perched groundwater was encountered in TP1, TP2, TP5, TP6 and TP9, between 2.40m and 2.60m bgl.

Perched groundwater was encountered in the exploratory boreholes at depths between 2.50m and 3.00m bgl.

Subsequent groundwater monitoring visits identified perched groundwater at depths between 1.71m and 4.18m bgl.

Table 4: Summary of Ground Conditions Encountered

Hole	Depth to Stratum (m bgl)				GROUNDWATER (m bgl)
	TOPSOIL	MADE GROUND	SAND	CLAY	
WS1	GL - 0.55	-	0.55 - 3.00	3.00 - 5.00+	3.00
WS2	GL - 0.50	-	0.50 - 3.00	3.00 - 5.00+	3.00
WS3	GL - 0.60	-	0.60 - 3.00	3.00 - 4.00+	3.00
WS4	GL - 0.50	-	0.50 - 2.80	2.80 - 3.00+	3.00
WS5	GL - 0.40	-	0.40 - 4.50	4.50 - 5.00+	3.00
WS6	-	GL - 0.45	0.45 - 3.00	3.00 - 5.00+	3.00
WS7	-	GL - 0.65	0.65 - 3.00	3.00 - 6.00+	2.50
WS8	GL - 0.40	-	0.40 - 2.90	2.90 - 5.00+	2.70
WS9	GL - 0.50	-	0.50 - 2.30	2.30 - 5.00	3.00
WS10	GL - 0.70	-	0.70 - 3.00 4.00 - 4.60	3.00 - 4.00 4.60 - 5.00+	2.70
TP1	GL - 0.20	0.20 - 0.50	0.50 - 2.50	-	2.40
TP2	GL - 0.40	0.40 - 1.00	1.00 - 2.80	-	2.60
TP3	GL - 0.30	0.30 - 0.90	0.90 - 3.00	-	-
TP4	GL - 0.40	0.40 - 1.00	1.00 - 2.30	-	-
TP5	GL - 0.40	0.40 - 1.30	1.30 - 2.50	-	2.40
TP6	GL - 0.30	0.30 - 0.70	0.70 - 2.60	-	2.40
TP7	GL - 0.30	0.30 - 1.20	1.20 - 2.00	-	-
TP8	GL - 0.60	0.60 - 1.30	1.30 - 2.80	-	-
TP9	GL - 0.40	0.40 - 1.20	1.20 - 2.60	-	2.40

5.5 Rockhead

Rockhead was encountered in the rotary boreholes between 8.00m and 8.10m bgl.

Full rotary borehole logs are provided in Appendix 1.

Suspected bedrock was encountered between 8.00m and 8.50m bgl, based on refusals in the dynamic probe tests, conducted next to borehole locations.

Full dynamic probe results are provided in Appendix 2.

6.0 ENGINEERING PROPERTIES OF SOILS ENCOUNTERED

6.1 General

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

Table 5: Summary of Laboratory Geotechnical Test Results

Location	Depth (m)	Strata*	CLASSIFICATION												STRENGTH	CHEMICAL	
			Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Modified Plasticity Index (%)	PSD Cobbles %	PSD Gravel (%)	PSD Sand (%)	PSD Silt (%)	PSD Clay (%)	Bulk Density Mg/m ³	Dry Density (Mg/m ³)	Shear Strength (kN/m ²)	pH Value	Water Soluble Sulphate SO ₄ (mg/l)
WS1	3.25	CLAY	19.7	34	18	16	16	-	0	2	78	20	-	-	-	7.1	50
WS2	3.50	CLAY	19.8	34	20	14	13	-	-	-	-	-	-	-	-	7.0	140
WS3	3.25	CLAY	17.5	37	17	20	18	-	-	-	-	-	-	-	-	7.1	120
WS4	2.90	CLAY	21.1	38	17	21	20	-	1	9	69	21	-	-	-	7.1	110
WS5	4.90	CLAY	19.2	38	18	20	18	-	5	12	63	20	-	-	-	7.2	200
WS6	2.90	CLAY	16.4	37	15	22	20	-	-	-	-	-	-	-	-	7.1	170
WS7	3.20	CLAY	15.3	36	14	22	19	-	7	13	59	21	-	-	-	7.5	240
WS8	4.50	CLAY	25.7	42	20	22	21	-	-	-	-	-	-	-	-	7.1	100
WS9	4.00	CLAY	21.5	31	16	15	14	-	5	3	73	19	-	-	-	7.2	130
WS10	4.80	CLAY	15.4	32	14	18	18	-	-	-	-	-	-	-	-	7.0	110

6.2 Granular

SPT tests carried out in the granular material were corrected for SPT hammer energy efficiency and overburden pressure and resulted in N1(60) values between 11 and 65, as shown on the SPT v Depth Plot in Figure 5 (overleaf). This result suggests the granular material is medium dense.

For design purposes, N values of 14 - 29 have been adopted. Based on the correlation by Peck, Hanson and Thornburn⁽¹⁹⁷⁴⁾, this gives an **angle of shearing resistance** of between $\phi=31^\circ - 36^\circ$.

Table 6: Summary of Design Parameters (Granular)

Depth	SPT N Value Range	Average N Value	Design N Value*	Equivalent Soil Density	Angle of Internal Friction (degrees ^o)**
1.20	14 - 65	36	29	Medium Dense	36°
2.00	11 - 38	19	16	Medium Dense	32°
3.00	14	14	14	Medium Dense	31°
*Based on lower quartile N1(60) value					
**Based on the correlation by Peck, Hanson and Thornburn ⁽¹⁹⁷⁴⁾					

6.3 Clay

SPT tests carried out in the cohesive material were corrected for SPT hammer energy efficiency and overburden pressure and resulted in N1(60) values of between 12 and 60, as shown on the SPT v Depth Plot in Figure 5 (overleaf). This result suggests the cohesive material is firm to very stiff.

Atterberg Limit tests were carried out on ten samples of the clay. Results of the test reported **liquid limit** values in the range of 31% to 42% and **plastic limit** values in the range of 14% to 20%, resulting in values of **plasticity index** in the range of 14% to 22%. These results suggest the clay to be of **low to medium plasticity**. Results are shown on the Plasticity Chart in Figure 6, overleaf.

For design purposes, a value of plasticity index = 22% is recommended, based on the upper quartile value of the results.

The **coefficient of volume compressibility (mv)** has been estimated using the following correlation by Stroud and Butler ⁽¹⁹⁷⁵⁾: for a clay with a plasticity index of 22%, $mv = 1 / (0.516 \times N \text{ value})$. This correlation gives values of coefficient of volume compressibility in the range 0.14m²/MN to 0.06m²/MN, as shown in Table 7. The results suggest the clay has a **medium to low compressibility**.

Particle Size Distribution (PSD) tests were carried out on five clay samples. A breakdown of the test results is shown in Table 5 above and in Appendix 3.

The **water-soluble sulphate** content of the ten clay samples ranged from 50mg/l to 240mg/l SO₄, together with **pH values** of 7.0 to 7.5.

Table 7: Summary of Design Parameters (Clay)

Depth	SPT N Value Range	Average N Value	Design N Value*	Equivalent Shear Strength** (kN/m ²)	Coefficient of Volume Compressibility** (mv)
3.00	14 - 30	21	14	72 (Medium Strength)	0.14 (Medium Compressibility)
4.00	12 - 60	30	20	103 (High Strength)	0.10 (Medium to Low Compressibility)
5.00	23 - 49	29	24	121 (High Strength)	0.08 (Low Compressibility)
6.00	31	31	31	160 (Very High Strength)	0.06 (Low Compressibility)
*Based on lower quartile N value and correlations by Peck Hanson and Thornburn ⁽¹⁹⁷⁴⁾					
**Based on correlation by Stroud & Butler ⁽¹⁹⁷⁵⁾					

It is recommended that for assessing ultimate bearing capacities, where the lower values are critical, the lower quartile value of N values is used. Based on the N Values in the above table, the equivalent shear strength values were in the range of 72 - 160 kN/m², suggesting that the clay is of medium to very high strength.

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

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

I'_p = modified plasticity index,

I_p = plasticity index.

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

The **Natural Moisture Content** (NMC) and **Liquid Limit** (LL) of the soil can be used to give an indication of **soil desiccation**, i.e., where the NMC is less than 40% of the LL, the soil is inferred to be desiccated, as summarised in Table 8, below.

Table 8: Soil Desiccation Indicators in the Clay

Location	Depth (m)	Liquid Limit (%)	40% Liquid Limit (%)	Natural Moisture Content (%)	Desiccation
WS1	3.25	34	14	19.7	No
WS2	3.50	34	14	19.8	No
WS3	3.25	37	15	17.5	No
WS4	2.90	38	15	21.1	No
WS5	4.90	38	15	19.2	No
WS6	2.90	37	15	16.4	No
WS7	3.20	36	14	15.3	No
WS8	4.50	42	17	25.7	No
WS9	4.00	31	12	21.5	No
WS10	4.80	32	13	15.4	No

The results in the above table show that none of the samples show evidence of desiccation.

Figure 5 SPT N1(60) v Depth Plot

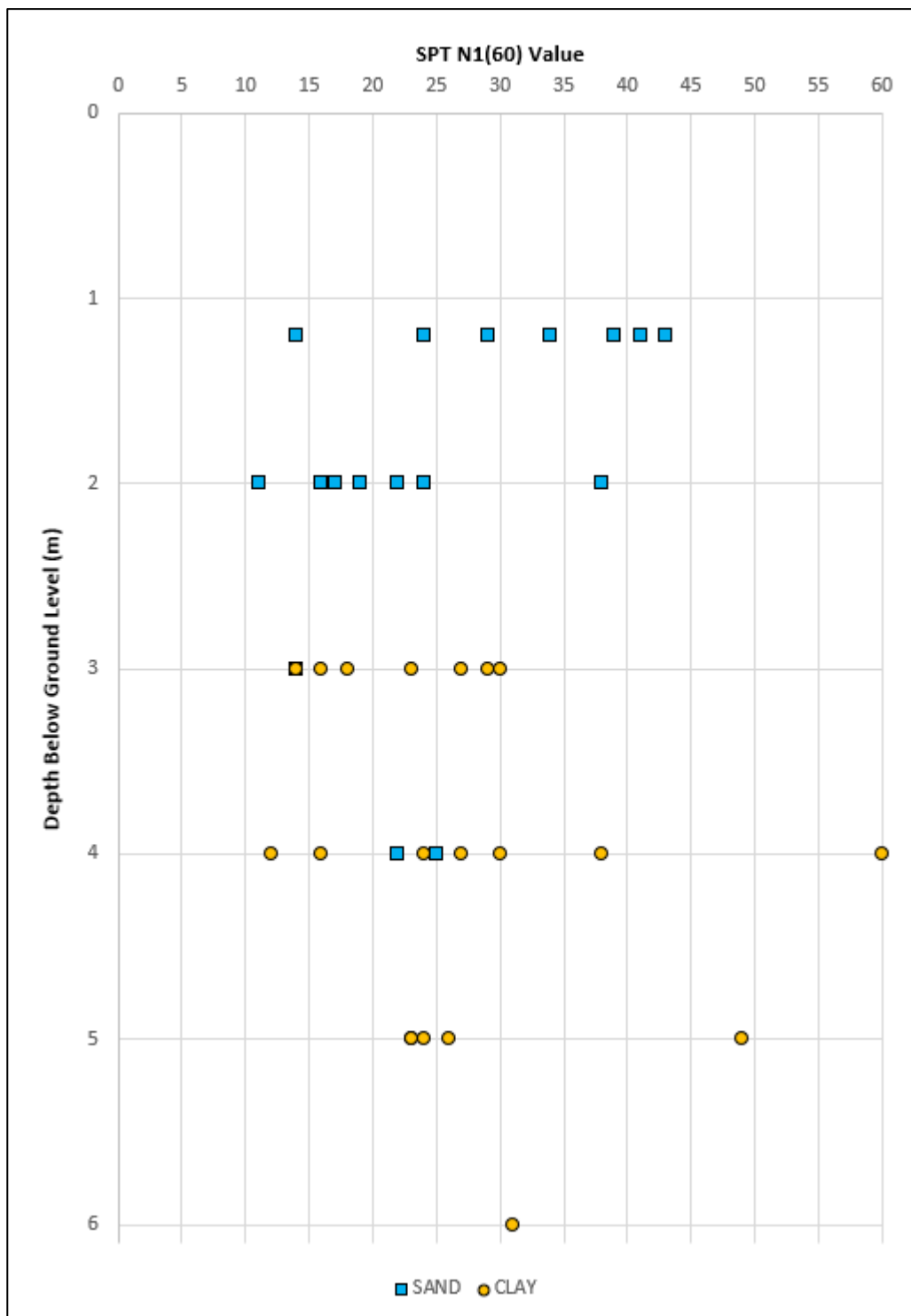


Figure 6 Strength v Depth Plot

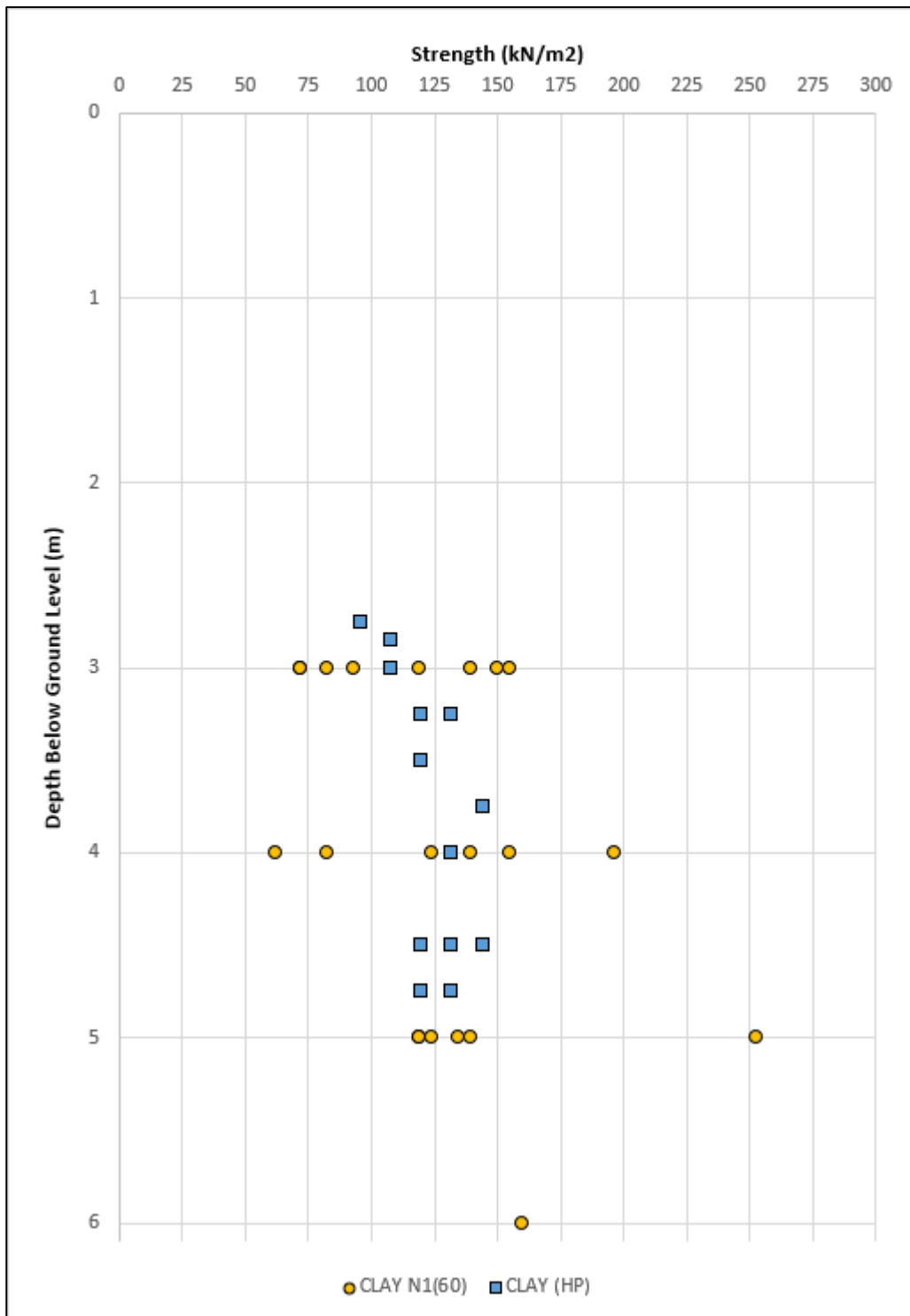
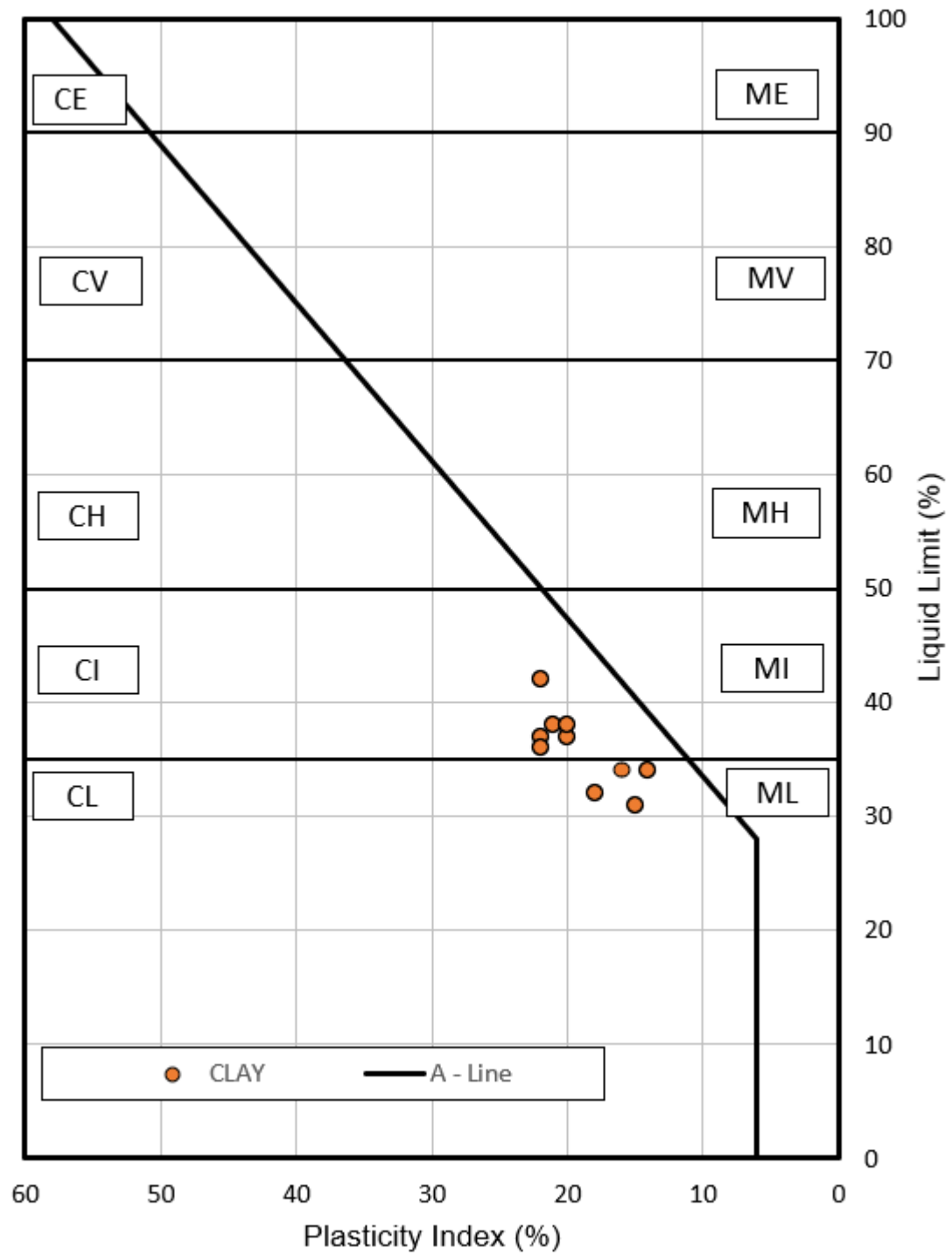


Figure 7 Plasticity Chart



7.0 GEOTECHNICAL ASSESSMENT

7.1 Proposed Development

It is understood that the client intends to demolish all existing structures on-site and construct 8 new, detached residential properties. The development will include private gardens and parking for each property, along with slight alterations to the existing access.

At the time of writing this report the anticipated structural loadings were not known.

7.2 Ground Conditions Encountered

The exploratory holes generally encountered topsoil, overlying variable, medium dense SAND, to a maximum depth of 4.50m bgl. Firm to stiff CLAY was encountered in all window sampling locations, below the sand to a maximum depth of 6.00m bgl.

Made ground was recorded in all trial pit locations, overlying the sand, to a maximum depth of 1.30m bgl.

Seepage of perched groundwater was encountered in TP1, TP2, TP5, TP6 and TP9, between 2.40m and 2.60m bgl.

Perched groundwater was encountered in the exploratory boreholes at depths between 2.50m and 3.00m bgl.

7.3 Foundation Considerations

Based on the ground conditions encountered conventional shallow depth foundations (strip/pad), placed in the natural sand, should be suitable at 1.00m below ground level, depending on allowable bearing pressures and tolerance of structures to settlement.

Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement and piles.

7.3.1 Conventional Shallow Depth Strip/Pad Foundations

Shallow foundations should be taken down below any Topsoil or Made Ground and placed in the natural sand. 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 at least 150mm into suitable natural strata.

Foundations should be placed in materials of similar bearing and consolidation characteristics to avoid potential differential settlement occurring.

Table 9 overleaf summarises anticipated allowable bearing pressures for shallow foundations placed in the natural clay and sand. 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 1.71m bgl, as this was the shallowest water was encountered during the subsequent monitoring visits.

Table 9: Summary of Allowable Bearing Pressures

Foundation Strata	Design Value (Section 6)	Foundation Depth (m bgl)	Foundation Type	Foundation Size (m)	Allowable Bearing Pressure (kN/m ²)
GRANULAR	$\phi = 36^\circ$	1.0	Strip	0.4	342
				0.9	381
			Pad	1.0 x 1.0	536
				2.0 x 2.0	548
	$\phi = 36^\circ$	1.5	Strip	0.4	493
				0.9	503
			Pad	1.0 x 1.0	777
				2.0 x 2.0	761
	$\phi = 32^\circ$	2.0	Strip	0.4	366
				0.9	365
			Pad	1.0 x 1.0	561
				2.0 x 2.0	541
	$\phi = 32^\circ$	2.5	Strip	0.4	412
				0.9	413
			Pad	1.0 x 1.0	638
				2.0 x 2.0	618

Table 10 below summarises anticipated settlements of the above foundations in sand based on design values discussed in Section 6. Settlement in granular soils typically comprises a large amount of immediate settlement as loads are applied and a smaller proportion of consolidation settlement, which will occur over a longer period of time. As the proposed foundation loading is not known, for the purposes of these calculations a foundation loading of 75kN/m² has been used.

Table 10: Summary of Anticipated Settlement (Granular)

Foundation Depth (m bgl)	Foundation Strata	Foundation Type	Foundation Size (m)	Pad Foundation Loading (kN/m ²)	Settlement* (mm)		
					Lower Limit	Upper Limit	Best Estimate
1.0 – 1.5	SAND	Strip	0.4	75	0	2	1
			0.9	75	1	4	2
		Pad	1.0 x 1.0	75	1	3	1
			2.0 x 2.0	75	1	4	2
2.0 - 2.5	SAND	Strip	0.4	75	1	6	2
			0.9	75	2	10	4
		Pad	1.0 x 1.0	75	1	7	2
			2.0 x 2.0	75	2	11	4

*Immediate settlement

Floor slabs should be designed as suspended if Made Ground of 600mm thickness or greater is present. Made ground is not considered an appropriate bearing stratum due to its variable nature. 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. If foundations cross from granular to cohesive soils, nominal reinforcement should be incorporated.

7.4 Pavement Design

The ground investigation identified the soil type at subgrade level to typically be granular. Based on the recommendations for design CBR values provided in Interim advice note 73/06, Revision 1 (2009), a CBR value for granular soils would be 20-60% and for clay would be 4-5%.

A conservative design CBR value of 1% should be adopted in areas where Made Ground is encountered at subgrade level.

Consideration should be given to the potential differing ground conditions near surface, which could cause pavements to be constructed on variable made ground. In this context a flexible pavement design may be required.

Consideration should also be given to the use of geotextiles to allow reduction of capping thickness. For examples biaxial geogrids such as Tensar SSLA20 and SSLA30 are often used to reduce capping thickness. The advice of a suitable contractor should be sought as to the most appropriate type of geotextile to use in the ground conditions encountered at this site. For guidance, the following table gives a comparison of granular layer thickness with and without the use of a geotextile, in accordance with the requirement of HA25/94 Part 2.

It should be noted the type of construction will depend on proposed finished pavement levels across the site and it is recommended the pavement design is reviewed once these levels are known. In this context, it is essential further in situ CBR testing is carried out once formation levels are known to confirm design CBR values.

Table 11: Comparison of Capping Thickness with and without Geotextile

CBR	Unreinforced			Reinforced with Tensar Geogrid				
	Sub-base	Capping	Total	Sub-base	Capping	No. of grids	Total	Thickness saving
0.5%	Design not suitable			200mm	400mm	2	600mm	-
1.0%	150mm	600mm	750mm	400mm	0	1	400mm	350mm
1.5%	150mm	600mm	750mm	310mm	0	1	310mm	440mm
2.0%	150mm	600mm	750mm	260mm	0	1	260mm	490mm
3.0%	150mm	350mm	500mm	210mm	0	1	210mm	290mm
4.0%	150mm	300mm	450mm	175mm	0	1	175mm	275mm
5.0%	150mm	250mm	400mm	160mm	0	1	160mm	240mm
These figures are suitable for light access roads and car parks, based on 1000 standard axles. For heavier loaded pavements the advice of specialist contractor should be sought.								

All 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.

7.5 Chemical Attack on Buried Concrete

Chemical tests (see Appendices) show low levels of water-soluble sulphates and near neutral conditions. Based on these conditions, it is recommended that for concrete placed in natural strata the Design Sulphate Class for the site, as defined in BRE Special Digest 1⁽²⁰⁰⁵⁾, be taken as DS-1, and the Aggressive Chemical Environment for Concrete (ACEC) site classification be taken as AC-1s. The recommendations of BRE Special Digest 1 should be followed for concrete foundations and ground bearing floor slabs.

7.6 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.

Near surface soft natural clays are unlikely to be suitable as structural fill and should be used for landscaping purposes only, providing they are not contaminated.

Granular Made Ground could be suitable for re-use as structural fill, providing it is not contaminated and does not contain excessive amounts of clay and providing moisture contents are controlled during placement. The control of moisture contents will be important as the cohesive content of this stratum is likely to be sensitive to moisture content changes.

7.7 Temporary Works

Formations 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 in Made Ground 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.

8.0 SOIL CONTAMINATION RISK ASSESSMENT

8.1 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 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 12: 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 (acid)	6 - 7	5 - 6	4 - 5	2 - 4	<2	5.1 - 6.9	A - B
pH (alkaline)	7 - 8	8 - 9	9 - 10	10 - 12	12	-	-
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	6 - 41	A - B
Cadmium	0 - 1	1 - 3	3 - 10	10 - 50	50	<0.2 - 0.7	A
Chromium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	14 - 23	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	14 - 155	A - B
Lead	0 - 500	500 - 1000	1000 - 2000	2000 - 1%	1.0%	17 - 939	A - B
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	<1	A
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	12 - 26	A - B
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	36 - 430	A - B
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	<1	A
Selenium	0 - 1	1 - 3	3 - 10	10 - 50	50	<2	A
Barium	0-500	500-1000	1000-2000	2000-1.0%	1.0%	42 - 992	A - B
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	<0.5 - 1.1	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	21 - 33	A
Sulphate	0 - 2000	2000 - 5000	5000 - 1%	1% - 5%	5.05%	347 - 1243	A
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	<5	A
Cyanide (free)	0 - 1	1 - 5	5 - 50	50 - 100	100	<1	A
Phenol	0 - 2	2 - 5	5 - 50	50 - 250	250	<2	A

Based on the above results it is considered there is a **MODERATE to LOW** potential risk from soil contamination to construction workers, ground workers and members of the public during construction. Appropriate measures, such as PPE, site health plans, and appropriate disposal of material arising will mitigate any risk.

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

The following section provides a Human Health Soil Assessment for future site users. The following section compares the results of contamination analyses to residential types of end development as specified by Defra/LQM/CIEH. As part of the contamination assessment, the chemical results obtained by EEG have been screened against accepted compliance criteria, namely:

- Defra C4SL Health Criteria Values (March 2014), where available; and
- Tier 1 assessment values - based on LQM/CIEH Suitable 4 Use Levels ⁽²⁰¹⁵⁾ (S4ULs).

The soil chemical testing results are summarised in Table 13, below.

Table 13: Soil Results Comparison with C4SL/S4UL Values

Determinand	C4SL/S4UL Levels Residential (mg/kg)	TP1 0.20m	TP2 0.60m	TP3 0.80m	TP4 0.50m	TP5 0.40m	TP6 0.70m	TP7 0.30m	TP8 0.50m	TP9 0.20m	WS1 0.70m	WS4 0.60m	WS7 0.50m	WS8 0.60m	WS9 0.25m	WS10 0.55m	No of Exceedances
Metals																	
Arsenic	37	41	14	13	26	15	16	11	11	16	8	6	7	8	14	8	1
Boron	290	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Cadmium	22	< 0.2	< 0.2	0.3	0.3	< 0.2	< 0.2	0.7	< 0.2	0.2	< 0.2	< 0.2	0.2	< 0.2	< 0.2	< 0.2	0
Chromium	910	17	14	20	23	16	16	21	18	16	19	15	14	17	16	16	0
Chromium VI	21	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Copper	2400	65	37	31	91	48	46	155	29	48	17	14	22	19	30	22	0
Lead	200	156	73	75	939	84	123	883	45	84	20	17	34	24	64	42	2
Mercury	40	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	0
Nickel	180	19	16	18	18	14	16	26	18	16	13	12	14	14	13	15	0
Selenium	250	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0
Vanadium	410	33	22	28	30	26	26	29	25	28	29	21	24	23	24	22	0
Zinc	3700	77	60	85	283	63	107	430	65	74	36	53	74	50	61	60	0
Petroleum Hydrocarbons																	
Benzene	0.87	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0
Toluene	660	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	0
Ethylbenzene	260	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.057	< 0.002	< 0.002	< 0.002	0
o-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.160	< 0.002	< 0.002	< 0.002	0
m-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.224	< 0.002	< 0.002	< 0.002	0
p-xylenes	310	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.224	< 0.002	< 0.002	< 0.002	0
Aliphatic EC >5-6	160	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aliphatic EC >6-8	530	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aliphatic EC >8-10	150	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	10	< 2	< 2	< 2	0
Aliphatic EC >10-12	760	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	25	< 2	< 2	< 2	0
Aliphatic EC >12-16	4300	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	118	< 3	< 3	< 3	0
Aliphatic EC >16-21	110000	< 3	< 3	< 3	< 3	< 3	< 3	25	< 3	< 3	< 3	< 3	154	< 3	< 3	< 3	0
Aliphatic EC >21-35	110000	< 10	< 10	< 10	< 10	< 10	< 10	510	< 10	< 10	< 10	< 10	266	< 10	< 10	< 10	0
Aromatic EC >5-7	300	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aromatic EC >7-8	660	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Aromatic EC >8-10	190	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	4	< 2	< 2	< 2	0
Aromatic EC >10-12	380	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	5	< 2	< 2	< 2	0
Aromatic EC >12-16	660	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	24	< 2	< 2	< 2	0
Aromatic EC >16-21	930	< 3	< 3	< 3	< 3	< 3	< 3	18	< 3	< 3	< 3	< 3	34	< 3	< 3	< 3	0
Aromatic EC >21-35	1700	< 10	< 10	< 10	15	< 10	< 10	533	< 10	< 10	< 10	< 10	218	< 10	< 10	< 10	0

Polycyclic Aromatic Hydrocarbons																	
Naphthalene	2.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthylene	210	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Acenaphthene	170	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Fluorene	170	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Phenanthrene	95	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.26	< 0.1	< 0.1	0
Anthracene	2400	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Fluoranthene	280	0.21	< 0.1	< 0.1	0.21	< 0.1	0.15	< 0.1	0.19	0.13	< 0.1	< 0.1	< 0.1	0.53	< 0.1	0.14	0
Pyrene	620	0.21	< 0.1	< 0.1	0.18	< 0.1	0.14	< 0.1	0.18	0.13	< 0.1	< 0.1	< 0.1	0.57	< 0.1	0.13	0
Benzo(a)anthracene	7.2	0.12	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.33	< 0.1	< 0.1	0
Chrysene	15	0.19	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.15	< 0.1	< 0.1	< 0.1	< 0.1	0.36	< 0.1	< 0.1	0
Benzo(a)pyrene	5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.12	< 0.1	< 0.1	< 0.1	< 0.1	0.82	< 0.1	< 0.1	0
Benzo(b)fluoranthene	2.6	0.17	< 0.1	< 0.1	0.15	< 0.1	< 0.1	< 0.1	0.15	< 0.1	< 0.1	< 0.1	< 0.1	0.75	< 0.1	< 0.1	0
Benzo(k)fluoranthene	77	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.26	< 0.1	< 0.1	0
Indeno(1,2,3-cd)pyrene	27	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.53	< 0.1	< 0.1	0
Dibenz(a,h)anthracene	0.24	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0
Benzo(ghi)perylene	320	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.47	< 0.1	< 0.1	0
Phenols																	
Phenol	280	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	0

Based on the above table, three contaminant concentrations were found in exceedance of the screening criteria relevant to a Residential End Use (with plant uptake). These exceedances refer to Arsenic in TP1 (0.20m) and Lead in TP4 (0.50) and TP7 (0.30m).

Asbestos fibres or fragments were not identified in any of the samples tested during this investigation.

8.3 Soil Waste Assessment

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

The results are summarised in Table 14 below and presented in full in Appendix 5.

Table 14: Waste Classification of Soils

Location	Depth (m bgl)	WM3.1 Classification	WAC Classification	Comments
TP1	0.20	Non-Hazardous	Hazardous	Elevated TOC, Loss on Ignition & pH
TP2	0.60	Non-Hazardous	-	-
TP3	0.80	Non-Hazardous	Hazardous	Elevated Loss on Ignition
TP4	0.50	Non-Hazardous	-	-
TP5	0.40	Non-Hazardous	-	-
TP6	0.70	Non-Hazardous	Hazardous	Elevated TOC, Loss on Ignition & pH
TP7	0.30	Non-Hazardous	-	-
TP8	0.50	Non-Hazardous	-	-
TP9	0.20	Non-Hazardous	Hazardous	Elevated TOC, Loss on Ignition & pH
WS1	0.70	Non-Hazardous	-	-
WS4	0.60	Non-Hazardous	-	-
WS8	0.60	Non-Hazardous	-	-
WS9	0.25	Non-Hazardous	-	-
WS10	0.55	Non-Hazardous	-	-

The above table shows that all of the tested samples collected during this investigation have been classified as **Non-Hazardous** in accordance with WM3.1.

Four of the soil samples have been submitted for Waste Acceptance Criteria (WAC) testing and is shown to be classified as **Hazardous waste**.

For Waste Acceptance Criteria (WAC) testing, EEGL have compared solid waste and leachate values with guideline values in Landfill Regulations. The following table summarises the results of the solid waste analysis and leachate testing, together with limit values for Non-Hazardous waste and Hazardous waste as described in the Landfill Regulations.

The results summarised in Table 15, overleaf show that the soil samples retrieved from TP1 (0.20m), TP3 (0.80m), TP6 (0.70m) and TP9 (0.20m) contained a percentage Loss on Ignition above the recommended level for Hazardous Waste.

It should be noted that these samples were taken from topsoil material with a very high organic content, as can be seen in Appendix 4. It is considered that the very high organic content of these samples is the cause of the elevated TOC and Loss on Ignition identified in the WAC testing, particularly considering the lack of PAHs and TPHs in the standard suite of testing.

Therefore, the soils from these areas of the site can be taken to an **Inert Waste** facility if offsite disposal is required.

Further WAC testing on the remaining samples may prove that the material is acceptable as inert waste.

Table 15: Summary of WAC Test Results

Determinand	Landfill Regulations Limits (mg/kg unless otherwise indicated)			TP1 0.20m (mg/kg)	TP3 0.80m (mg/kg)	TP6 0.70m (mg/kg)	TP9 0.20m (mg/kg)
	Inert Waste	Stable Non- Reactive non-hazardous waste	Hazardous Waste				
TOC (%)	3%	5%	6%	7.8	2.5	3.2	4.1
Loss on ignition (%)	-	-	10%	14.80	10.80	10.50	10.10
BTEX (mg/kg)	6	-	-	< 0.05	< 0.05	< 0.05	< 0.05
Sum of PCBs (mg/kg)	1	-	-	< 0.1	< 0.1	< 0.1	< 0.1
Mineral Oil (mg/kg)	500	-	-	< 10	< 10	< 10	< 10
Total PAH (mg/kg)	100	-	-	< 1.7	< 1.7	< 1.7	< 1.7
pH (units)	-	< 6	-	5.1	6.4	5.2	5.6
Acid Neutralisation Capacity (mol/kg)	-	To be evaluated		<1	<1	<1	<1
Arsenic	0.5	2	25	< 0.2	< 0.2	< 0.2	< 0.2
Barium	20	100	300	0.1	< 0.1	0.1	< 0.1
Cadmium	0.04	1	5	< 0.02	< 0.02	< 0.02	< 0.02
Chromium	0.5	10	70	< 0.20	< 0.20	< 0.20	< 0.20
Copper	2	50	100	< 0.5	< 0.5	< 0.5	< 0.5
Mercury	0.01	0.2	2	< 0.005	< 0.005	< 0.005	< 0.005
Molybdenum	0.5	10	30	< 0.1	< 0.1	< 0.1	< 0.1
Nickel	0.4	10	40	< 0.2	< 0.2	< 0.2	< 0.2
Lead	0.5	10	50	< 0.2	< 0.2	< 0.2	< 0.2
Antimony	0.06	0.7	5	< 0.05	< 0.05	< 0.05	< 0.05
Selenium	0.1	0.5	7	< 0.05	< 0.05	< 0.05	< 0.05
Zinc	4	50	200	< 0.2	0.2	< 0.2	< 0.2
Chloride	800	15000	25000	21	25	19	23
Fluoride	10	150	500	< 1	< 1	< 1	< 1
Sulphate	1000	20000	50000	29	25	28	23
Total Dissolved Solids	4000	60000	100000	121	140	153	139
Phenol Index	1	-	-	< 0.5	< 0.5	< 0.5	< 0.5
DOC	500	800	1000	115	135	183	126

9.0 GROUNDWATER MONITORING RESULTS

9.1 Analyses of Results

In the absence of specific UK guidelines regarding groundwater quality in the UK, chemical results obtained by EEG have been compared with the following statutory and non-statutory standards:

- Environmental Quality Standards (EQS); and
- UK Drinking Water standards ⁽²⁰⁰⁰⁾.

EQS values have been derived to protect surface water. Two surface water features have been identified within 250m of the site, with the Rochdale Canal located directly west of the site. Therefore, for the purposes of this report, it is considered the most appropriate EQS data are those established for freshwater.

Several of the EQS values lie just above the method detection limit for parameters and as such, are extremely conservative. In the absence of EQS values, Drinking Water Standards have been used for comparison of results. Again, these standards are highly conservative, especially in this site context.

Groundwater samples were retrieved from three monitoring wells installed in window sample boreholes WS1, WS2, WS6, WS7 and WS9.

A direct comparison was made between the groundwater analyses results and the EQS and Drinking Water Standards, and the results are summarised in Table 16, overleaf.

In general, the laboratory analyses encountered levels of contamination below the EQS and DWQ guidelines.

Table 16: Groundwater Results Comparisons with EQS/Drinking Water Quality Values

Determinand	EQS Value (1)	Drinking Water Quality (DWQ) Value (2)	WS1	WS2	WS6	WS7	WS9	No. of Exceedances
Arsenic	50	10	< 5	< 5	< 5	< 5	< 5	0
Cadmium	0.9	5	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	0
Chromium	50	-	< 5	< 5	< 5	< 5	< 5	0
Copper	10	2000	< 5	< 5	< 5	< 5	< 5	0
Lead	1.2-14	10	< 5	< 5	< 5	< 5	< 5	0
Mercury	0.07	1.0	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	0
Selenium	-	10	< 5	< 5	< 5	< 5	< 5	0
Nickel	50-200	20	< 5	< 5	< 5	< 5	< 5	0
Zinc	75	-	13	8	16	4	3	0
Cyanide	-	50	< 5	< 5	< 5	< 5	< 5	0
Phenol	7.7-46	-	< 10	< 10	< 10	< 10	< 10	0
Sulphate	250000	250000	11	12	7	16	6	0
pH	6 – 9	-	6.6	6.3	6.7	6.4	6.8	0
Naphthalene	10	-	0.06	0.07	< 0.01	0.1	< 0.01	0
Anthracene	0.1	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(a)pyrene	0.27	0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(b)fluoranthene	0.017	0.10	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Benzo(k)fluoranthene	0.017	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Indeno(123cd)pyrene	-	0.10	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Fluoranthene	0.12	-	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0
Aliphatic >C5-C6	15000	-	< 10	< 10	< 10	< 10	< 10	0
Aliphatic >C6-C8	15000	-	< 10	< 10	< 10	< 10	< 10	0
Aliphatic >C8-C10	300	-	< 10	< 10	< 10	< 10	< 10	0
Aliphatic >C10-C12	300	-	< 10	< 10	< 10	< 10	< 10	0
Aliphatic >C12-C16	300	-	< 10	< 10	< 10	< 10	51	0
Aliphatic >C16-C21	-	-	< 10	< 10	< 10	< 10	< 10	0
Aliphatic >C21-C34	-	-	311	219	< 10	< 10	156	0
Aromatic >C5-C7	10	1	< 10	< 10	< 10	< 10	< 10	0
Aromatic >C7-C8	700	-	< 10	< 10	< 10	< 10	< 10	0
Aromatic >C8-C10	300	-	< 10	< 10	< 10	< 10	< 10	0
Aromatic >C10-C12	90	-	< 10	< 10	< 10	< 10	< 10	0
Aromatic >C12-C16	90	-	< 10	< 10	< 10	< 10	20	0
Aromatic >C16-C21	90	-	< 10	< 10	< 10	< 10	< 10	0
Aromatic >C21-C35	90	-	< 10	< 10	< 10	< 10	< 10	0
Benzene	10-50	1	< 1	< 1	< 1	< 1	< 1	0
Toluene	50-380	-	< 5	< 5	< 5	< 5	< 5	0
Ethylbenzene	20-200	-	< 5	< 5	< 5	< 5	< 5	0
Xylenes	30	0.10	< 10	< 10	< 10	< 10	< 10	0

10.0 GROUND GAS AND RADON GAS CONTAMINATION RISK ASSESSMENT

10.1 Radon Gas

The site is not located within a Radon Affected Area as defined by the Health Protection Agency, as 1 - 3% of properties are above the Action Level of exposure and therefore radon protection measures are not necessary.

10.2 Analyses of Monitoring Results

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.

Six monitoring visits were conducted between the 31st of January and the 27th of February 2023. The results recorded methane (CH₄) levels of 0.0% to 0.7% v/v with carbon dioxide (CO₂) levels of 0.1% to 6.0% v/v. Oxygen concentrations of between 22.1% and 14.8% v/v were also recorded.

A maximum flow rate of 0.2 litres/hour was encountered from the boreholes on site. It should be noted the minimum flow rate was recorded as -0.1 litres/hour. For assessment purposes, the steady detection flow rate of 0.1 litres/hour has been used.

Atmospheric pressure was recorded to be between 978mb and 1036mb.

Full results of the monitoring are presented in Appendix 6.

Table 17 overleaf, adapted from Table 1 of the technical paper Risk and Reliability in Gas Protection Design by Card et al. 2019, shows a summary of the 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 steady flow rate of 0.1l/h adopted for assessment purposes.

- Carbon dioxide: maximum flow rate = 0.1 l/hr, max concentration = 6.0%
- Methane: maximum flow rate = 0.1 l/hr, max concentration = 0.7%.

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

- **Carbon Dioxide:** $GSV = 0.1 \times 6.0 / 100 = 0.006 \text{ litres/hour}$
- **Methane:** $GSV = 0.1 \times 0.2 / 100 = 0.0007 \text{ litres/hour}$

The CIRIA guidance document notes that ‘...the GSV is a guideline value and not an absolute threshold’.

The above results suggest the site can be given a Characteristic Situation 2, i.e., ‘low risk’, in accordance with Table 17 overleaf, due to elevated carbon dioxide levels.

Table 17: Characteristic Situation (Wilson et al 2006/2007 modified from Wilson and Card, 1999)

Characteristic Situation	Risk Classification	Gas Screening Value CH₄ or CO₂ (l/hr)	Additional Factors	Typical source of generation
1	Very Low	<0.07	Typically, < 1% methane Typically, < 5% carbon dioxide	Typical made ground
2	Low	<0.7	Borehole air flow rate to not exceed 70l/hr otherwise consider increase to Characteristic Situation 3	Typical made ground
3	Moderate	<3.5		Old landfill, inert waste, flooded mine workings
4	Moderate to High	<15	Quantitative risk assessment	Mine workings susceptible to flooding, completed landfill
5	High Risk	<70		Mineworking unflooded inactive with shallow workings near surface
6	Very High Risk	>70		Recent landfill site

Detailed Assessment

EEG have made reference to *Ground Gas Information Sheet No.1, Using Ternary Plots for Interpretation of Ground Gas Monitoring Results (July 2018)*, which reports that carbon dioxide is widespread in the sub-surface environment at concentrations of up to 21% and is generated by microbial and geochemical processes. Elevated carbon dioxide concentrations are commonly elevated in Glacial Till, Chalk, River Terrace Gravel, Thanet Sand, Lambeth Group and Made Ground.

It is reported that when monitoring wells are installed in these materials, small volumes of organic material are exposed to oxygen, which results in biological respiration or oxidation of the material, resulting in the production of carbon dioxide. Weathering of pyrites and subsequent reactions of acidic pore water with carbonate material can also cause increased concentrations of carbon dioxide in the monitoring well headspace.

Organic material in Made Ground can also degrade to produce carbon dioxide and or methane, in which case the carbon dioxide may be generated so slowly that it will not be emitted from the ground surface in quantities or at a rate that is sufficient to pose a risk to overlying development.

Based on the above information, the gas monitoring data from this investigation has been analysed in respect of methane, carbon dioxide, oxygen, and nitrogen gas ratios, to deduce the potential source of the ground gas, as shown in Figures 8 to 10 overleaf.

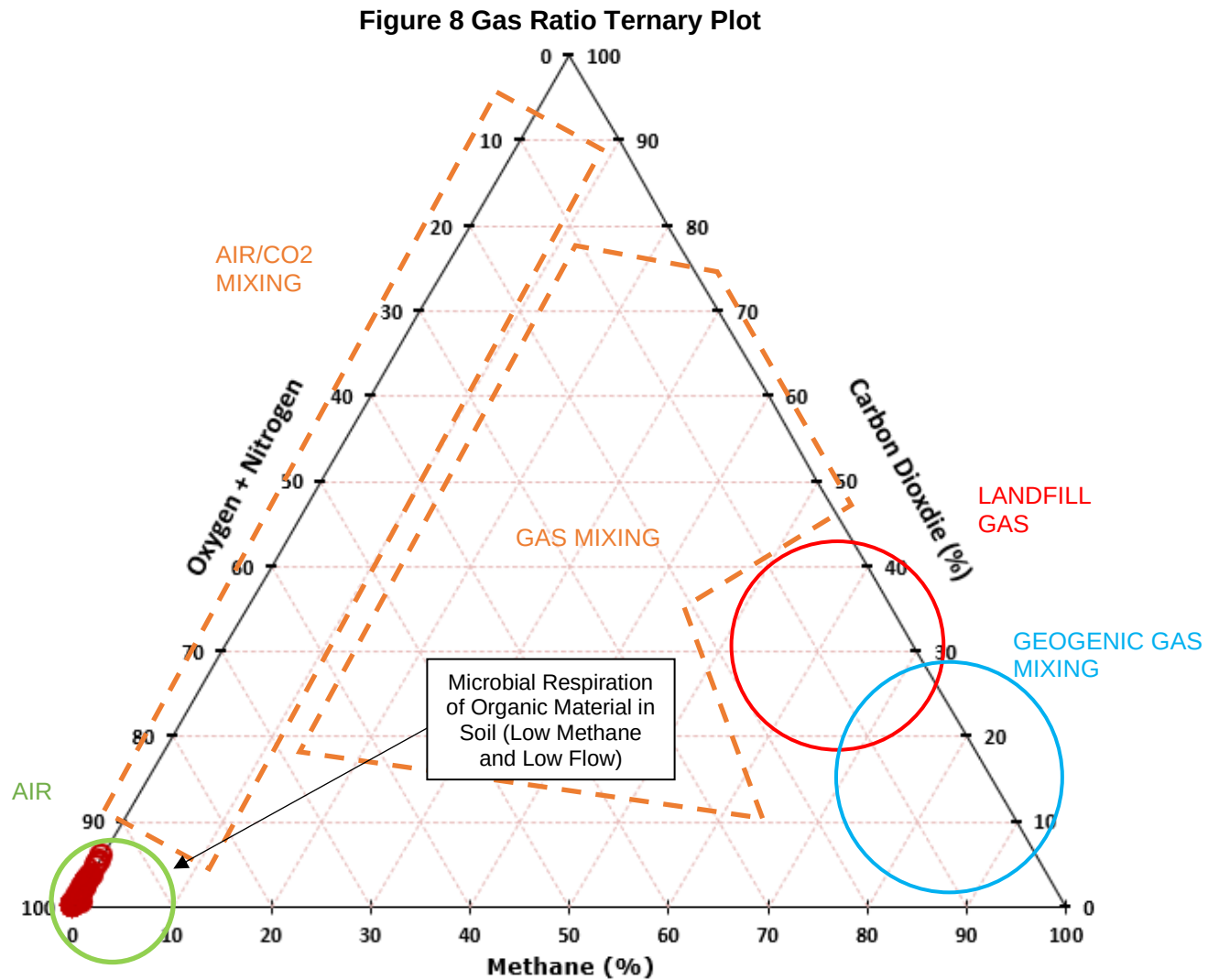


Figure 8 shows the ground gas monitoring results from this site investigation plotted with the gas composition from different sources, adapted from Teasdale et al. 2015. The results show that the gas composition within the monitoring wells at the site is unlikely to be landfill gas. The results generally correspond to air on the gas ratios ternary plot.

Figure 9 Carbon Dioxide: Oxygen Ratio Plot

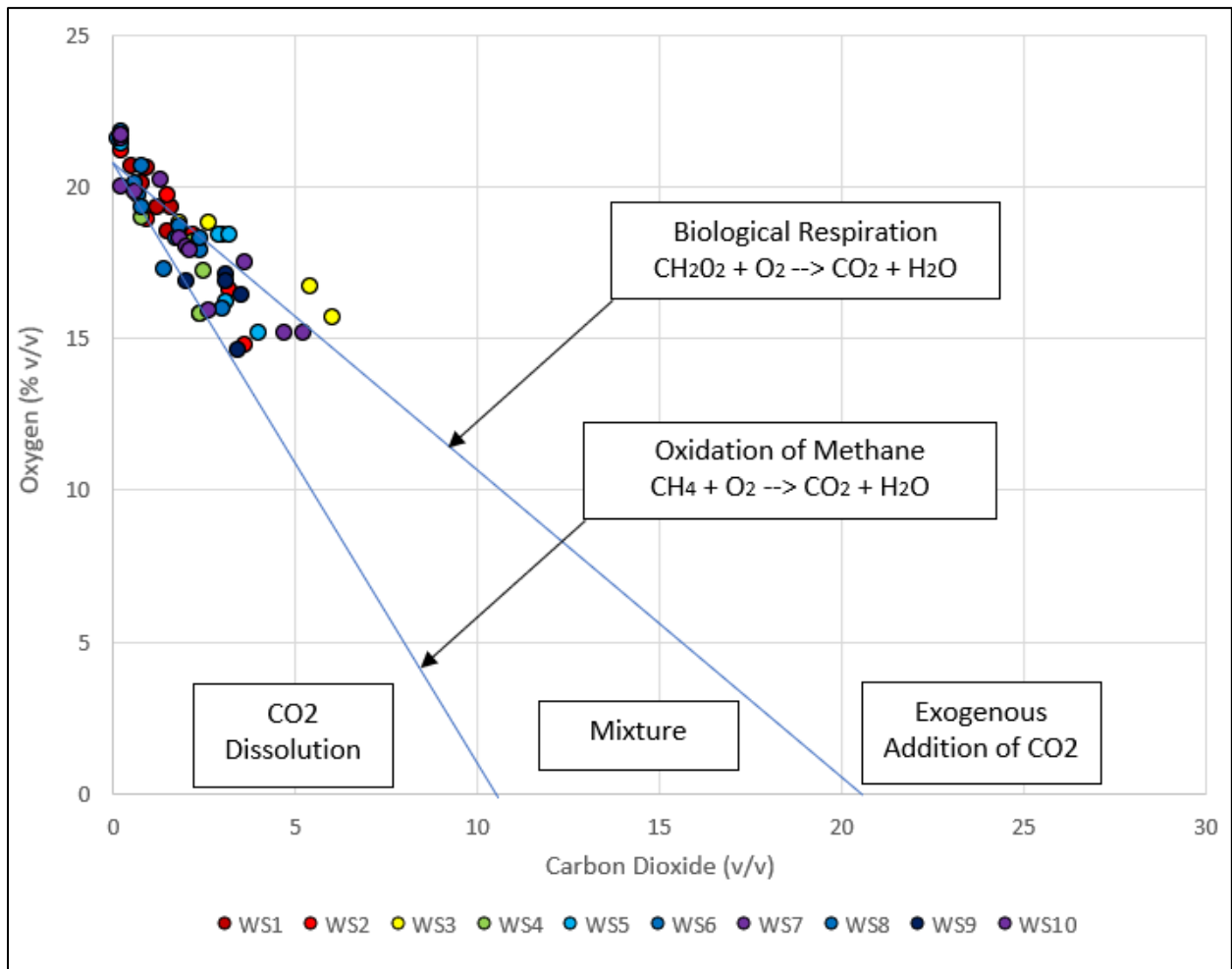


Figure 9 shows that the points that plot to the left of the biological respiration and oxidation of methane lines are caused by dissolution of gas from the ground (or pore) water and from reaction of rainwater with soil. The points to the right of the biological respiration line are caused by biological respiration (i.e., oxidation of organic material in the soil).

None of the data plots to the left of the oxidation of methane line. The data is roughly split either side of the biological respiration line. The data plotted to the right of the biological respiration line indicates that the source of carbon dioxide is likely to be from the oxidation of organic material in the soil, whereas the data plotted to the left indicates a mixture.

Figure 10 Nitrogen/Oxygen: Carbon Dioxide Ratio Plot

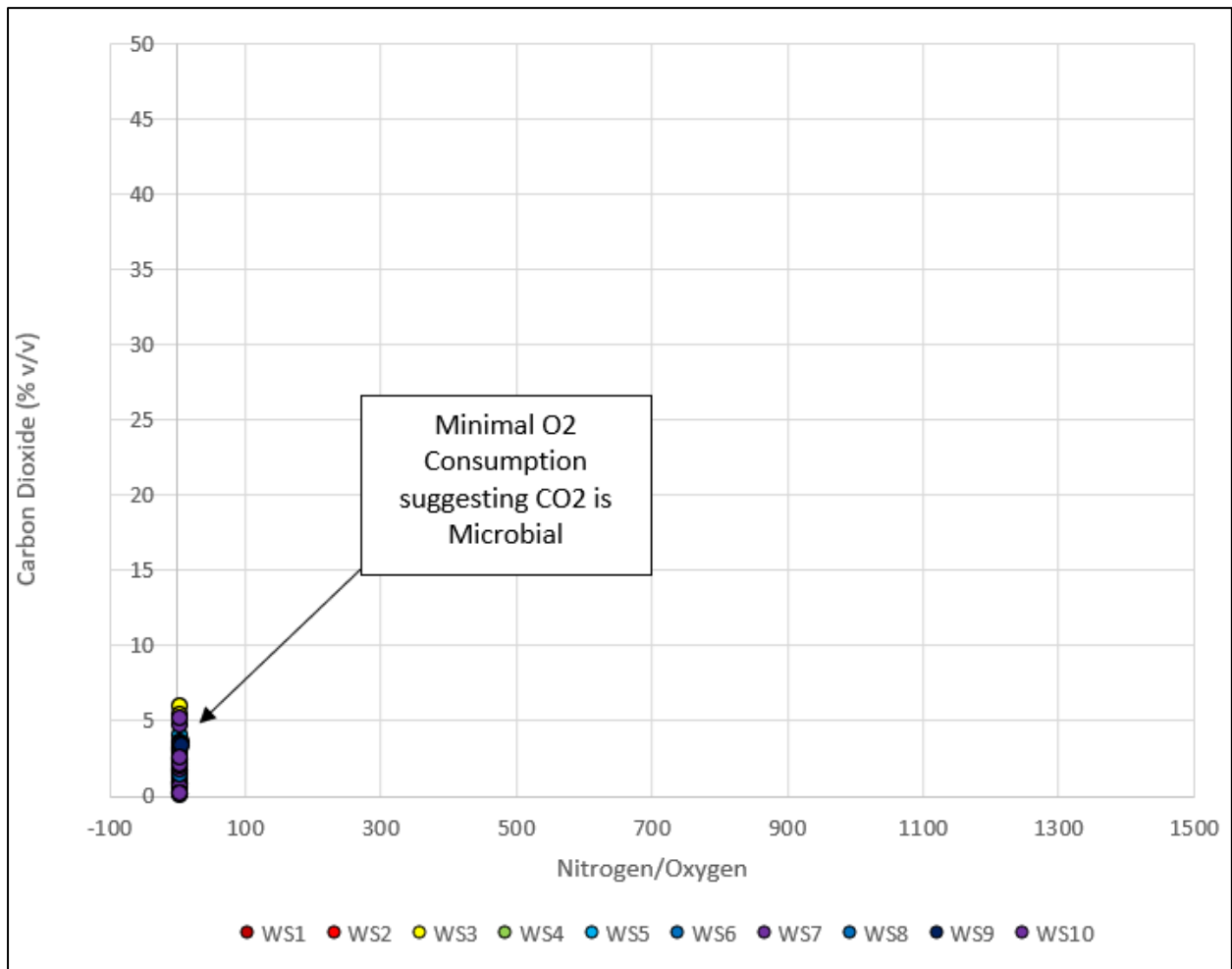


Figure 10 presents an assessment of the nitrogen/oxygen and carbon dioxide ratios. The figure shows all the monitoring results plotted to the left side of the graph, which represents minimal oxygen consumption. There is no data plotting towards the right side of this figure which would suggest methane oxidation.

The above results and assessment suggest the site can be given a Characteristic Situation 1, i.e., 'very low risk', in accordance with Table 17 above.

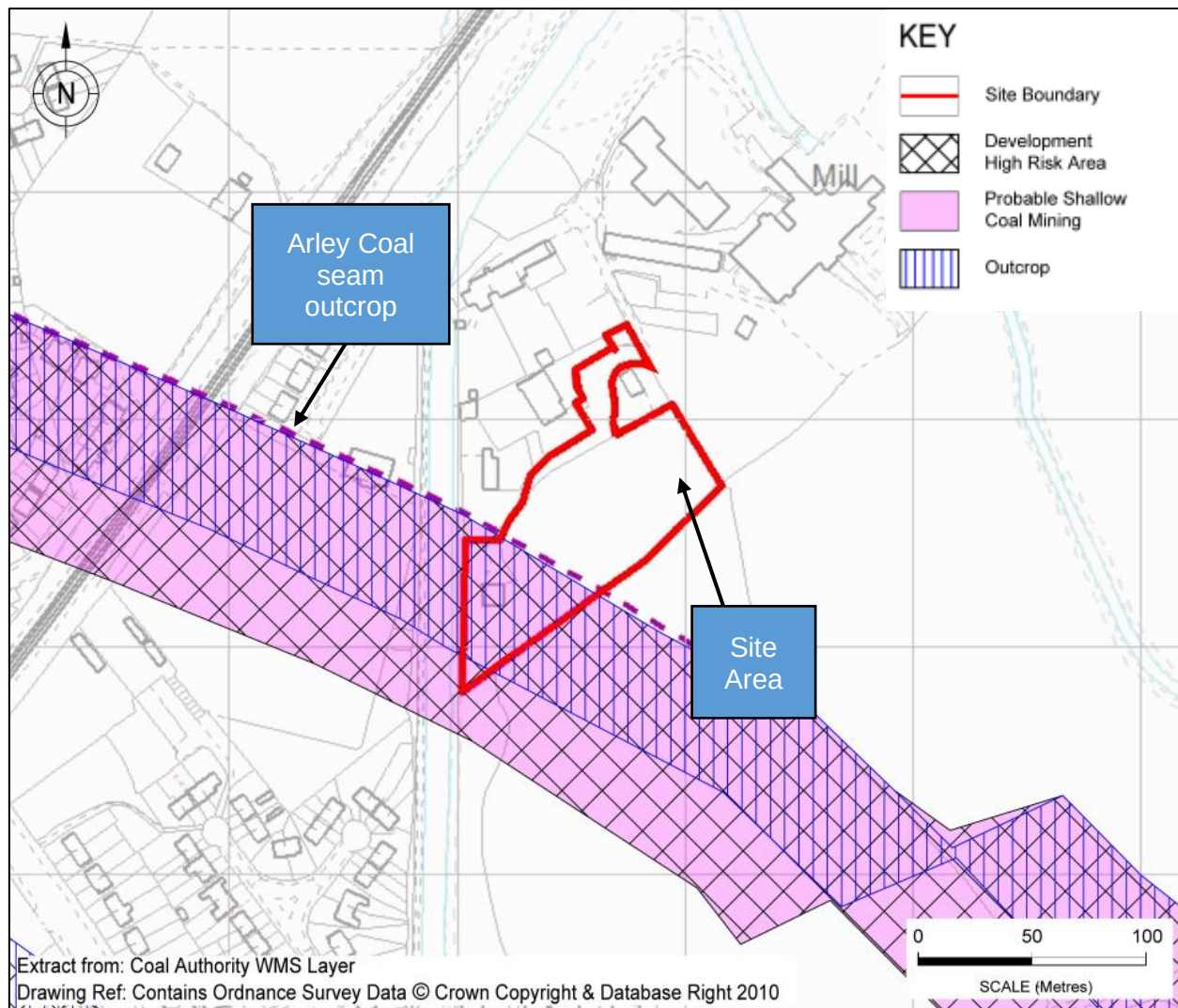
Therefore, ground gas protection measures are not considered necessary for the proposed development at this site.

11.0 COAL MINING RISK ASSESSMENT

Three rotary open hole boreholes were drilled in the southwest of the site as this area lies within a Coal Authority Development High Risk Area due to the locally outcropping and potentially workable Arley coal seam.

Figure 11 (below) presents an extract from LK Consult's Coal Mining Risk Assessment, based on data from the Coal Authority Consultant Mining Report, that shows the location of the locally outcropping Arley seam, along with the Development High Risk area and the area of Probable Shallow Coal Mining.

Figure 11 Extract from LK Consult Coal Mining Risk Assessment



In general, superficial deposits were encountered below the site to approximately 8.00m bgl and were underlain by bedrock comprising a sequence of grey mudstones and sandstones. Occasional thin (<0.10m) bands of competent sandstone were encountered within the mudstones, with thin bands of mudstone encountered within some of the sandstones.

Table 18: Summary of Geology Encountered

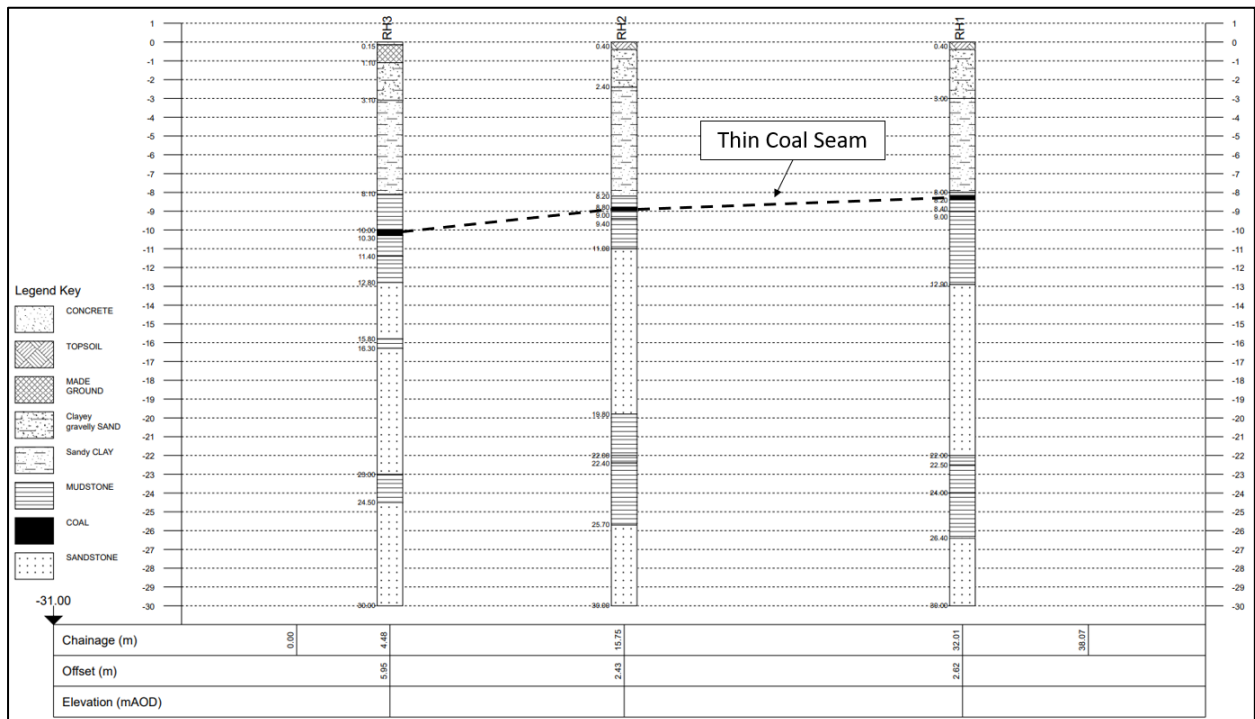
Location	Superficial Deposits/ Made Ground	Mudstone	Coal	Sandstone
RH1	GL - 8.00m	8.00 - 8.20m 8.40 - 12.90m 22.00 - 26.40m	8.20 - 8.40m	12.90 - 22.00m 26.40 - 30.00m
RH2	GL - 8.20m	8.20 - 8.80m 9.00 - 11.00m 19.80 - 25.70m	8.80 - 9.00m	11.00 - 19.80m 25.70 - 30.00m
RH3	GL - 8.10m	8.10 - 10.00m 10.30 - 12.80m 15.80 - 16.30m 23.00 - 24.50m	10.00 - 10.30m	12.80 - 15.80m 16.30 - 23.00m 24.50 - 30.00m

Coal was encountered between 8.20m and 8.40m bgl in RH1, between 8.80m and 9.00m bgl in RH2 and between 10.00m and 10.30m bgl in RH3.

All lithologies were found to be intact. There was no evidence of voiding or broken strata caused by shallow mineworking.

During drilling an infra-red gas analyser (GA2000) was used to measure the borehole annulus for the concentration of methane, carbon-dioxide, carbon monoxide and hydrogen sulphide. No elevated concentrations of any ground gas were detected during the drilling works.

Figure 12 Cross Section (A - A') of Encountered Coal Seams



12.0 CONCLUSIONS & RECOMMENDATIONS

12.1 Soil Contamination

There is a **MODERATE to LOW** potential risk from soil contamination to construction workers and ground workers during development, and appropriate measures such as PPE, site health plans, appropriate disposal of material arisings will mitigate this risk. The groundworks contractor must provide a soil management plan including methods of dealing with unanticipated soil contamination encountered during groundworks.

Based on the results of the chemical testing, three contaminant concentrations were found in exceedance of the screening criteria relevant to a Residential End Use (with plant uptake). These exceedances refer to Arsenic in TP1 (0.20m) and Lead in TP4 (0.50) and TP7 (0.30m). The risk to end users is therefore considered to be **MODERATE to LOW**.

A remediation strategy with therefore need to be developed for the site, including the delineation and potentially removal of the contaminated material.

12.2 Asbestos

Asbestos fibres or fragments were not identified in any of the samples tested during this investigation.

12.3 Groundwater Contamination

Perched water samples have been collected and tested for a wide range of potential contaminants of concern. A preliminary assessment of the measured concentrations, using conservative assessment criteria, reveals that no contaminant concentrations were found in exceedance of the EQS and DWQ guidelines.

The risk to controlled waters is therefore considered **LOW**.

12.4 Foundations

Shallow strip/pad foundations placed in the natural sand should be appropriate for the current proposed development, dependent on allowable bearing pressures and tolerance of structures to settlement.

Should the allowable bearing pressure and settlement prove unfavourable, then alternative foundations options will need to be considered, such as ground improvement and piles.

12.5 Soil Disposal

Soils should be disposed of at a suitable site, registered to take the levels of contamination encountered. All soil samples collected from site have been classified as Non-Hazardous for the purpose of off-site disposal in accordance with Environment Agency guidance WM3.1.

Further Waste Acceptance Criteria (WAC) testing on four of the collected samples showed the material to be classified as Hazardous Waste due to elevated Total Organic Carbon (TOC), Loss on Ignition and pH. However, as the samples were taken from topsoil material, the elevated TOC

and Loss on Ignition has been attributed to the very high organic content of the samples. Acidic pHs are also often associated with natural organic carbon.

It is therefore concluded that the material can be considered Inert Waste for the purpose of offsite disposal.

12.6 Land Gas

Detailed assessment of the data, with specific reference to gas ratios shows that the ground gas composition generally resembles air, not landfill or harmful gas. No oxidation of methane is occurring at the site. The source is likely to be biological respiration (i.e., the oxidation of organic material in the soil) that has been disturbed and released during the drilling process.

Based on this analysis and the low flow rates recorded in the window sample boreholes, the risk of ground gas can be considered “very low” with a characteristic situation of CS1. Therefore, ground gas protection measures are not necessary in the proposed buildings on this site.

12.7 Coal Mining

Three rotary open hole boreholes have been drilled in the southwest of the site, in close proximity to the locally outcropping Arley Coal Seam, to a depth of 30.00m bgl. Coal seams of between 0.20m and 0.30m thick, were encountered across all boreholes, between depths of 8.20m and 10.30m bgl.

All lithologies encountered were found to be intact, with no evidence of loss of flush, voiding or broken strata.

As a result, ground remedial measures such as strengthening of foundations or mine grouting will not be required.

12.8 Risk to Buried (Water) Services

It is considered that due to the low levels of contamination encountered standard materials are likely to be appropriate for new water pipes. Further advice should be sought from the local water company.

Previous guidance on buried water pipes was contained in Water Regulations Advisory Scheme (WRAS) Guidance Note No. 9-04-03⁽²⁰⁰²⁾, however this has been superseded by the UK Water Industry Research Report ‘Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites’ Ref 10/WM/03/21 (January 2011).

12.9 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.

12.10 Other Matters

Due diligence is required during the construction period, and should any further evidence of contamination be found, appropriate investigation and / or action should be taken. The

significance of any contamination not discovered by this investigation is outside the scope of this report.

APPENDIX 1

EXPLORATORY HOLE LOGS

APPENDIX 2

DYNAMIC PROBE RESULTS

APPENDIX 3

GEOTECHNICAL TESTING RESULTS

APPENDIX 4

CHEMICAL TESTING RESULTS

APPENDIX 5

SOIL WASTE ASSESSMENT

APPENDIX 6

GROUND GAS MONITORING DATA

APPENDIX 7

REPORT LIMITATIONS

REPORT LIMITATIONS

This contract was completed by Earth Environmental & Geotechnical Ltd based on 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.

Other than that, expressly contained in the above paragraph, Earth Environmental & Geotechnical Ltd provides no other representation or warranty whether express or implied, is made in relation to the services. Unless otherwise agreed this report has been prepared exclusively for the use and reliance of the client in accordance with generally accepted consulting practices and for the intended purposes as stated in the agreement under which this work was completed. This report may not be relied upon, or transferred to, by any other party without the written agreement of a Director of Earth Environmental & Geotechnical Ltd.

If a third party relies on this report, it does so wholly at its own and sole risk and Earth Environmental & Geotechnical Ltd disclaims any liability to such parties.

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 2023 and should be read considering 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 of 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.