



**EARTH ENVIRONMENTAL
& GEOTECHNICAL**

Phase II GeoEnvironmental Investigation & Coal Mining Risk Assessment

120 Laund Road

Huddersfield

October 2019

On behalf of

**Creative Developments
(Huddersfield) Ltd**



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**PHASE II GEOENVIRONMENTAL
INVESTIGATION & COAL
MINING RISK ASSESSMENT**

**120 LAUND ROAD
HUDDERSFIELD**

**Report Ref: A0697/19/B.0
October 2019**

Prepared on Behalf of:

CREATIVE DEVELOPMENTS (HUDDERSFIELD) LTD

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120 LAUND ROAD, HUDDERSFIELD

Report Reference: A0697/19

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Prepared for: Creative Developments (Huddersfield) Ltd

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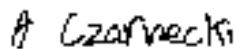
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1.0 INTRODUCTION

1.1 Background

A site investigation has been commissioned by Northern Design Partnership on behalf of the Client, Creative Developments (Huddersfield) Ltd to examine ground conditions for a proposed development at 120 Laund Road, Salendine Nook, Huddersfield, HD3 3TY.

A Phase II site investigation is required to support the planning application to Kirklees Council (reference: 2019/62/90486/W) for the development of the site in accordance with Environmental Health Consultation Response (reference: WK/201903882).

The Coal Authority Interactive Viewer identifies the site as being located within a Development High Risk Area associated with probable shallow coal mine workings. An intrusive investigation into the presence of shallow coal seams, unrecorded workings and the potential for mine gas emissions is also therefore required.

1.2 Previous Site Investigations

1.2.1 ***Earth Environmental & Geotechnical Ltd Coal Mining Risk Assessment (Reference: A0697/G/1, December 2014)***

The British Geological Survey 1:10,000 mapping (Sheet SE11NW) and digital mapping indicate that the site is directly underlain by Rough Rock (sandstone) in the west of the site and Pennine Lower Coal Measures (mudstone, siltstone and sandstone) in the east of the site. No superficial deposits are shown to be present and the regional dip of the strata is indicated to be two degrees to the east.

A marine band and a thin coal (the Pot Clay Coal) are indicated to outcrop immediately west of the site, adjacent Laund Road. A second coal outcrop is also shown close to the south eastern corner of the site.

The Coal Authority Mine Mining Report states that coal may have been mined at shallow (<30m) depth beneath the site, although there are no records for this. There are no shafts on or near to the site on historical mapping, however, excavations are shown in an adjacent field to the north of the site on the mapping dated 1894, which may possibly be coal related.

It was concluded that due to the presence of seams of coal at shallow depths, there is potential for unrecorded shallow mine workings in the form of “bell pits” beneath the site, which could be prone to collapse if not properly backfilled.

It was recommended that trenches be dug in the areas of the proposed foundations to investigate voiding and/or evidence of bell pit workings below the site, and subsequent strengthening of foundations if required.

Following submission of the Coal Mining Risk Assessment, the Coal Authority Consultation Response dated 22nd January 2015 stated that:

‘The proposed mitigation measures may bring to light the presence of bell pit and other shaft openings; however, they do not fully address the potential risk posed to the proposed development from underground coal mining i.e. from the working of coal seams less than 30m deep. It is quite possible that such workings, if present, may have been accessed via mine entries

outside the footprint of the proposed dwellings. A more comprehensive borehole investigation of the south eastern portion of the site would therefore be necessary in order to investigate the presence of shallow coal seams, unrecorded workings and the potential for mine gas emissions.'

1.2.2 Earth Environmental & Geotechnical Ltd Phase I GeoEnvironmental Desk Study (Reference: A0697/17, November 2017)

The desk study highlighted that the site was first developed with a small structure in the early 1900s, which had been demolished and replaced by a larger (residential) structure in the northwest of the site by 1918, followed by the addition of several other small structures in subsequent years.

The house in the northwest was demolished in the early 1960s and replaced by 1993 with the existing bungalow that remains on-site to the present day. By the early 2000s the remaining smaller structures had been demolished leaving only the bungalow.

The walkover identified several small piles of fly-tipped material close to the residential dwelling, which contained plasterboard, wood, empty gas canisters, glass bottles, metal and plastic.

Early mapping showed neighbouring land uses to be predominantly agricultural, with gradual residential development occurring from the 1930s. Nearby industrial land uses are limited to a pottery, mill and works located to the southwest between 1893 and 1993.

Unspecified ground workings are shown 4-5m to the north of the site, together with a clay pit, on mapping dated between 1893 and 1933.

The following potential contamination sources are identified on-site:

- Contaminated made ground associated with the various phases of development on site.
- Ground gas from potentially infilled ground workings in close proximity of the site.
- Asbestos Containing Materials (ACM) in soils.

There was concluded to be a **MEDIUM** risk to end users from potential soil contamination and ground gas. The risk to groundwater and nearby surface water features was concluded to be **LOW**.

1.3 Terms of Reference

Earth Environmental and Geotechnical Ltd (EEG) have been commissioned by Creative Developments (Huddersfield) Ltd, the Client, to undertake an investigation of the site in accordance with proposal A0697/19/V3 dated 15th May 2019.

The objectives of this investigation are as follows:

- *Assessment of the presence and likely extent of any potential environmental hazards (soil, ground gas and groundwater contamination) associated within the areas of the site investigated.*
- *Assessment of the ground conditions for design of foundations.*
- *Assessment of shallow coal mining regime.*
- *Classification of soils for off-site disposal purposes.*

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 trial pits and 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 located northeast of Laund Road at postcode HD3 3TY, approximately 4km northwest of Huddersfield City centre, and around 900m east of Junction 23 of the M62 motorway. The site is roughly L-shaped with maximum approximate dimensions of 70m northwest-southeast by 30m northeast-southwest, occupying an area of 0.25ha. The National Grid Reference for the centre of the site is SE103182 (410379, 418266)

The site is currently occupied by an existing stone-built bungalow, 120 Laund Road, in the northwest of the site, which is set back from Laund Road, and a recently constructed two-storey four-bedroom house fronting Laund Road. The site is accessed from Laund Road via an unnamed road/track which is surfaced with tarmacadam in poor condition.

The remainder of the site comprises the front and rear gardens to 120 Laund Road and a parcel of land in the southeast of the site, which is bordered by mature trees and has become overgrown. At the time of the site investigation, the front garden of the bungalow was used for storage of miscellaneous construction materials and equipment.

The rear garden was observed to be overgrown, elevated and sloping moderately to the west/southwest, with retaining walls along the northwest, northeast and southeast garden boundaries. Due to these obstructions, this part of the site was generally inaccessible for the drilling rigs and machine excavator.

Concrete floor slabs and remains of demolished structures (brick rubble etc) are also present in the southeast of the site, together with a stockpile of surface soil, which is understood to have been stripped from the front garden of 120 Laund Road and the southeastern portion of the site.

The general slope of the surrounding land is down towards the southwest, in the direction of Laund Road. However, the central part of the site itself appears to have been levelled to some extent and sits around 1-2m higher than properties to the southwest the boundary. A retaining wall is present around the rear of the existing bungalow.

The site is bordered by a combination of dry-stone wall, wooden post fencing and mature trees.

The site location is shown in Figure 1, overleaf together with site photographs presented as Figures 2 to 5.

Figure 1 Site Location Plan

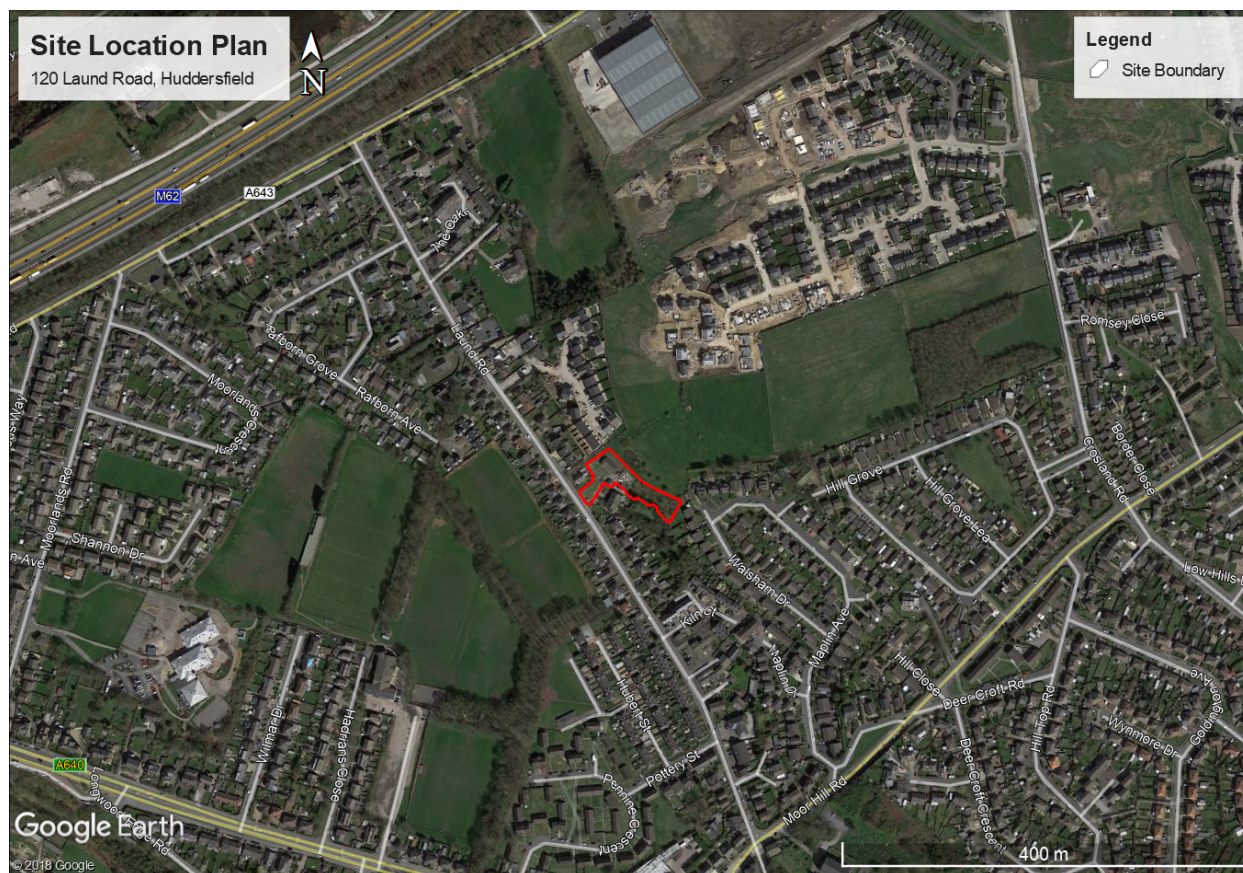


Figure 2 Looking towards the southeastern part of the site



Figure 3 Looking northwest onto the front garden of 120 Laund Road



Figure 4 Overview of the overgrown southeastern part of the site



Figure 5 Looking west along the access track towards Laund Road with new property in view

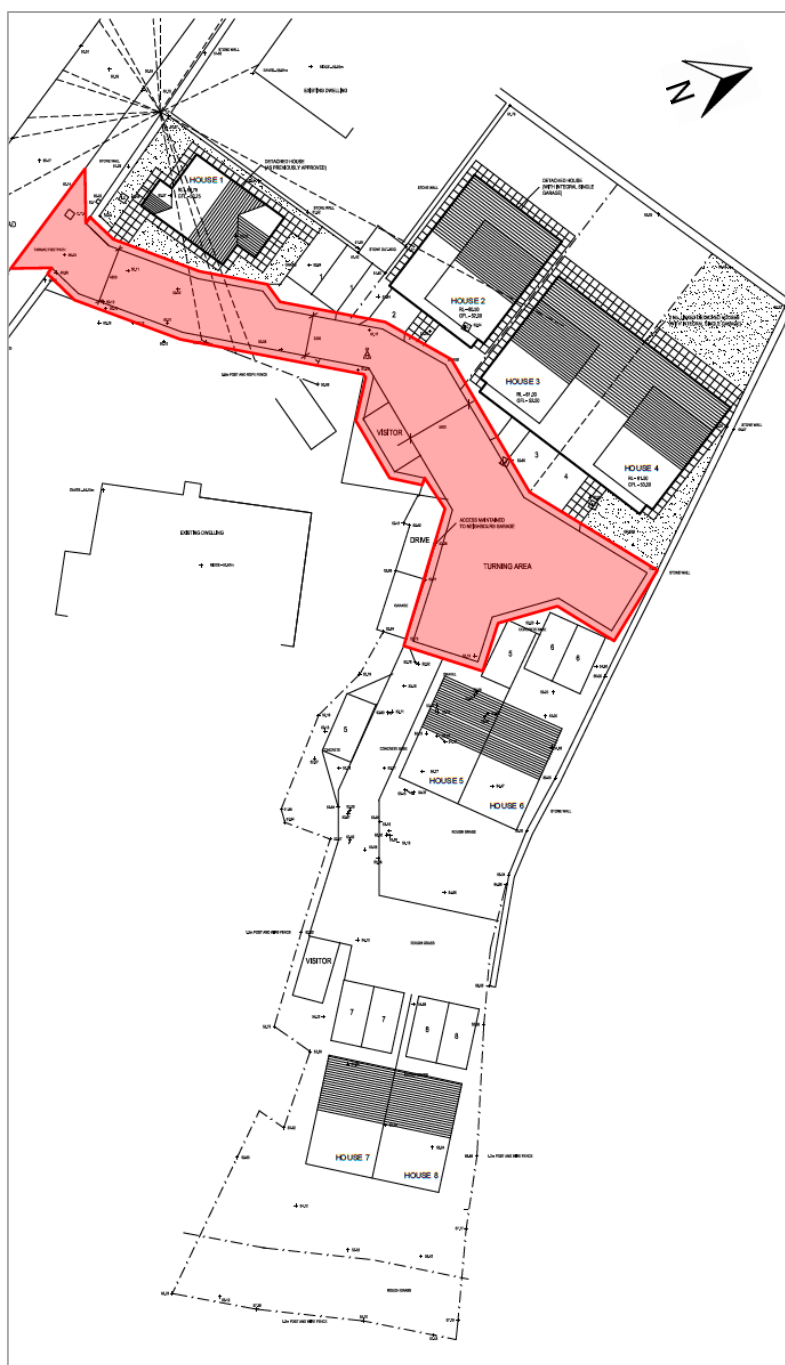


2.1 Proposed Development

It is understood that the client intends to demolish the existing bungalow (120 Laund Road) and construct 8no. new two-storey detached and semi-detached residential houses with parking, private gardens and associated infrastructure.

The proposed development layout is presented in Figure 6, below.

Figure 6 Proposed Development Layout Plan



3.0 SITE INVESTIGATION

3.1 Exploratory Fieldwork

The initial fieldwork was carried out by EEG Ltd between Wednesday 12th and Friday 14th June 2019 and comprised:

- Seven window sample boreholes (designated WS1 to WS7 inclusive) were each sunk to depths of between 2.0m and 2.8m 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.
- Sixteen trial pits (designated TP1-TP8, TP8A and TP9-TP15) were excavated to depths between 0.25m and 3.10m below existing ground level, using a tracked machine excavator. Representative disturbed samples were recovered from the excavated material as pitting proceeded. The trial pits were backfilled immediately on completion of sampling.
- Two rotary open-hole boreholes (designated RO1-RO2) were drilled to depths of 30.0m below existing ground level, using a track-mounted rotary rig. The boreholes were 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 cement bentonite grout.

A secondary site visit was carried out on 4th September 2019 and comprised:

- Five window samples (designated WS01 to WS04) were each sunk to depths between 1.7m and 2.8m below existing ground level.
- On completion, four of the window sample boreholes (WS01A, WS02, WS03 and WS04) were installed with 50mm diameter monitoring standpipes to enable subsequent gas and groundwater monitoring.

Exploratory hole locations were chosen by an EEG engineer based on the proposed layout and also to target potential coal mine workings and potentially contaminative historical features.

Exploratory hole logs are presented in Appendix 1, and exploratory Hole Location Plans (with proposed development plan underlay) are presented as Figures 7 & 8, 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, 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 (June Investigation)

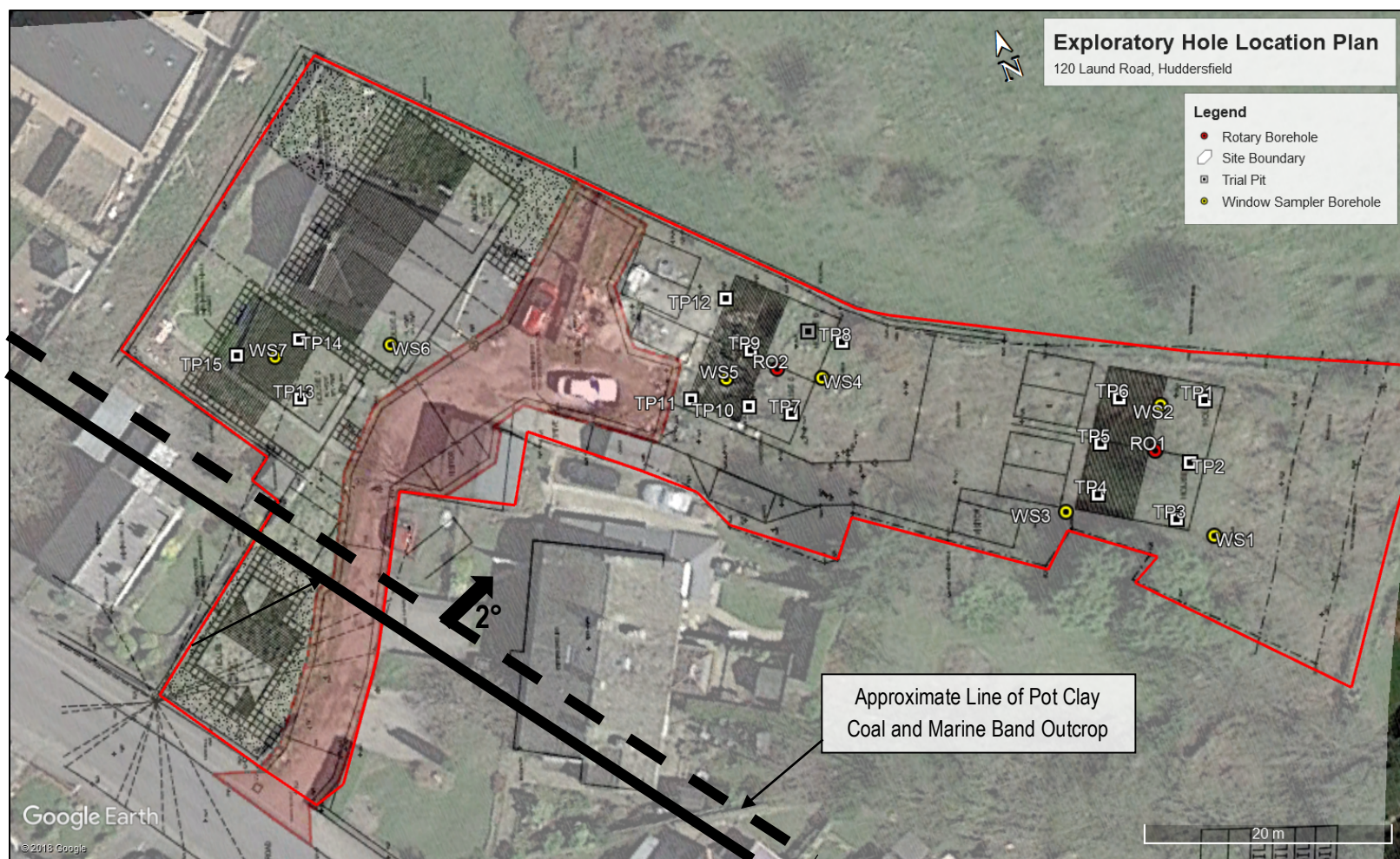
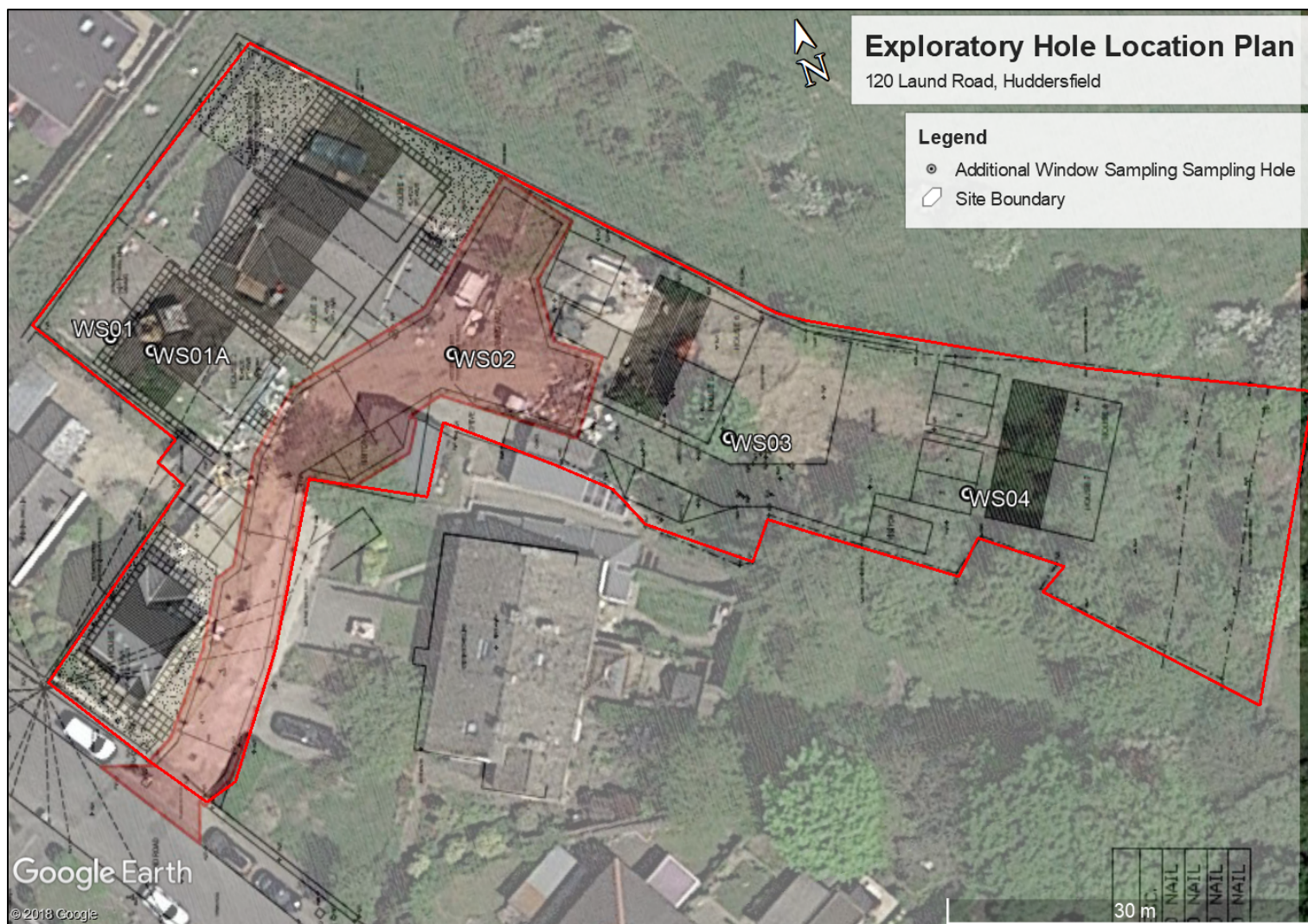


Figure 8 Exploratory Hole Location Plan (September Investigation)



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**
RO1	RO	30.00	12/06/2019	12/06/2019	B/G
RO2	RO	30.00	12/06/2019	12/06/2019	B/G
TP1	TP	2.50	13/06/2019	13/06/2019	A
TP2	TP	2.90	13/06/2019	13/06/2019	A
TP3	TP	2.90	13/06/2019	13/06/2019	A
TP4	TP	3.10	13/06/2019	13/06/2019	A
TP5	TP	3.00	13/06/2019	13/06/2019	A
TP6	TP	3.10	13/06/2019	13/06/2019	A
TP7	TP	2.80	13/06/2019	13/06/2019	A
TP8A	TP	0.25	13/06/2019	13/06/2019	A
TP8	TP	2.90	13/06/2019	13/06/2019	A
TP9	TP	2.80	13/06/2019	13/06/2019	A
TP10	TP	2.80	13/06/2019	13/06/2019	A
TP11	TP	2.70	13/06/2019	13/06/2019	A
TP12	TP	1.50	13/06/2019	13/06/2019	A
TP13	TP	3.00	14/06/2019	14/06/2019	A
TP14	TP	3.00	14/06/2019	14/06/2019	A
TP15	TP	2.70	14/06/2019	14/06/2019	A
WS1	WS	2.00	14/06/2019	14/06/2019	A
WS2	WS	2.00	14/06/2019	14/06/2019	A
WS3	WS	3.00	14/06/2019	14/06/2019	A
WS4	WS	2.00	14/06/2019	14/06/2019	A
WS5	WS	2.00	14/06/2019	14/06/2019	A
WS6	WS	2.00	14/06/2019	14/06/2019	A
WS7	WS	2.80	14/06/2019	14/06/2019	A
WS01	WS	2.60	04/09/2019	04/09/2019	A
WS01A	WS	2.60	04/09/2019	04/09/2019	SP
WS02	WS	1.70	04/09/2019	04/09/2019	SP
WS03	WS	1.70	04/09/2019	04/09/2019	SP
WS04	WS	2.80	04/09/2019	04/09/2019	SP
* RO=Rotary Open Hole Borehole, TP=Triaxial Pit, WS=Window Sampler Borehole					
** A=Arising, B/G=Bentonite/Grout, SP=Monitoring Standpipe					

3.1.1 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 below:

TEST	STANDARD (BS1377:1990)	No.
Liquid Limit, Plastic Limit, Plasticity Index	Part 2, Clause 4 / 5	4
Particle size distribution (wet)	Part 2, Clause 9.5	2
Single Stage Undrained Triaxial Testing	Part 7, Clause 9	1
Sulphate content of 2:1 soil: water extract	Part 3	4
pH value	Part 3	4

The results of the laboratory geotechnical tests are discussed in Section 5 and included in Appendix 3.

3.1.2 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 Laboratory.

Chemical analyses were carried out on 10 soil samples, which 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 speciated Total Petroleum Hydrocarbons (TPH).

Additional Waste Acceptance Criteria (WAC) testing was carried out on 3 soil samples to allow for classification of waste soils for off-site disposal.

Soil leachate analyses were also undertaken on 3 soil samples to assess the risk posed by soil contamination to underlying controlled waters.

The results of the laboratory soil contamination tests are discussed in Section 7 and included in Appendix 2.

4.0 GROUND CONDITIONS ENCOUNTERED

4.1 Soil Profile Encountered

The British Geological Survey 1:10,000 Sheet SE11NW and digital mapping for the area indicate the site to be directly underlain by Carboniferous strata of the Lower Coal Measures, comprising mudstones, sandstones (Soft Bed Flags) and coal seams. Superficial deposits are not shown to be present.

A marine band and a thin coal (Pot Clay Coal) are conjectured to outcrop adjacent Laund Road and dip at a shallow angle (2°) site to the east, beneath the site.

The sequence of strata encountered beneath the site in the Window Sampler Boreholes and Trial Pits was as follows:

- **Topsoil** – encountered in WS1, WS3, RO1 and RO2 to depths of between 0.20m and 0.80m bgl and described as:
 - Grass over brown sandy, gravelly CLAY with roots and gravel of sandstone, mudstone and rare brick and tile inclusions.
- **Made Ground** – encountered at the surface all other exploratory holes to depths of between 0.10m and 2.00m and typically described as:
 - Soft greyish brown, sandy, gravelly CLAY with gravel and cobble sized inclusions of concrete, brick, mudstone, sandstone, coal, clinker, glass, tile, plastic and general miscellaneous fly-tipped waste in variable proportions. Or;
 - Dark brownish black, clayey, gravelly SAND with inclusions as above.
- **Possible Relict Topsoil** – encountered beneath the Made Ground in TP4-TP6 as a 0.40m-0.50m thick horizon of soft brown silty/sandy, slightly gravelly CLAY with roots.
- **Pennine Lower Coal Measures Formation (PLCM)** – encountered beneath the Topsoil or Made Ground in all locations as:
 - Soft to firm greyish brown or orangish brown mottled grey, sandy, gravelly CLAY (destructured/completely weathered).
 - Weakly bedded dark grey mottled orange weathered MUDSTONE recovered as weak shaley gravel with clayey matrix.
 - Yellow, thinly bedded SANDSTONE recovered as silty, sandy gravel.
 - Dull black COAL.
 - Alternating sequence of SILTSTONE and SANDSTONE with depth.
- **Suspected Backfill Material** – encountered in the northwestern part of the site only (TP14, TP15 and WS7) beneath the natural strata at minimum and maximum depths of 1.00m and 2.60m bgl, and described as:
 - Loose, wet, dark grey very clayey/silty fine to coarse, subangular GRAVEL of mudstone.

The depths of the various materials encountered in the window sampler boreholes are summarised in the following table. The materials encountered in the rotary boreholes are presented in more detail in Table 3 of Section 4.6.

Table 2: Summary of Ground Conditions Encountered (Trial Pits & Window Sampler Boreholes)

Hole	Depth to Stratum (m)								Ground Water (m bgl)
	TOPSOIL	MADE GROUND	RELICT TOPSOIL	PENNINE LOWER COAL MEASURES				BACKFILL MATERIAL (Suspected Workings)	
				Sandy Gravelly CLAY (Completely Weathered)	MUDSTONE	SANDSTONE	COAL		
TP1	-	GL-0.10	-	0.10-0.80	0.80-2.50+	-	-	-	-
TP2	-	GL-0.30	-	0.30-0.60	0.60-2.90+	-	-	-	-
TP3	-	GL-0.40	-	0.40-1.30	1.30-2.90+	-	-	-	-
TP4	-	GL-0.60	0.60-1.10	1.10-1.80	1.80-3.10+	-	-	-	-
TP5	-	GL-0.10	0.10-0.50	0.50-1.30	1.30-3.00+	-	-	-	-
TP6	-	GL-0.20	0.20-0.60	0.60-1.20	1.20-3.10+	-	-	-	-
TP7	-	GL-0.70	-	0.70-1.40	1.40-2.80+	-	-	-	-
TP8A*	-	GL-0.25+	-	-	-	-	-	-	-
TP8	-	GL-0.40	-	0.40-1.20	1.20-2.90+	-	-	-	-
TP9	-	GL-0.60	-	0.60-0.90	0.90-2.80+	-	-	-	-
TP10	-	GL-1.00	-	1.00-1.70	1.70-2.80+	-	-	-	-
TP11	-	GL-0.80	-	0.80-1.20	1.20-2.70+	-	-	-	-
TP12	-	GL-0.80	-	0.80-1.50+	-	-	-	-	0.80
TP13	-	GL-0.50	-	0.50-1.10	1.10-1.40 1.70-2.30	2.30-3.00+	1.40-1.70	-	-
TP14	-	GL-0.40	-	0.40-0.60	0.60-1.30 2.10-2.60	2.60-3.00+	1.80-2.10	1.30-1.80	1.50
TP15	-	GL-0.50	-	0.50-1.00	-	2..30-2.70+	-	1.00-2.30	1.20
WS1	GL-0.70	-	-	0.70-1.30	1.30-2.00+	-	-	-	-
WS2		GL-0.60	-	0.60-1.30	1.30-2.00+	-	-	-	-
WS3	GL-0.80	-	-	0.80-1.20	1.20-3.00+	-	-	-	-

Hole	Depth to Stratum (m)								Ground Water (m bgl)
	TOPSOIL	MADE GROUND	RELICT TOPSOIL	PENNINE LOWER COAL MEASURES				BACKFILL MATERIAL (Suspected Workings)	
				Sandy Gravelly CLAY (Completely Weathered)	MUDSTONE	SANDSTONE	COAL		
WS4	-	GL-0.40	-	0.40-1.20	1.20-2.00+	-	-	-	-
WS5	-	GL-0.90	-	0.90-1.50	1.50-2.00+	-	-	-	1.20
WS6	-	GL-1.00	-	-	1.00-1.60 1.80-2.00+	-	1.60-1.80	-	-
WS7	-	GL-1.80	-	-	-	2.60-2.80	-	1.80-2.60	2.00
WS01	-	GI-2.00	-	-	-	2.00-2.60	-	-	-
WS01A	-	GI-1.20		1.20-1.80	-	1.80-2.60	-	-	-
WS02	-	GL-0.55	-	-	0.55-1.70	-	-	-	-
WS03	-	GL-0.30	-	-	0.30-1.70	-	-	-	-
WS04	-	GL-0.80	-	-	0.80-2.80	-	-	-	-
*Concrete slab encountered; trial pit abandoned and relocated (TP8).									

4.2 Observable Indications of Contamination

Abundant inclusions of brick, concrete, coal, clinker, glass, tile, plastic and general miscellaneous fly-tipped materials were noted within the Made Ground soils in variable proportions. However, these inclusions are generally inert and not considered to pose a significant risk of soil contamination.

The surface soils across the majority of the southeastern part of the site appeared to have been recently removed in advance of the pending construction works and stockpiled in the central part of the site (Figure 9). The stockpile was observed to contain building and demolition waste and inclusions as previously described. Fragments of suspected asbestos cement sheeting were also observed (Figure 10).

Figure 9 Stockpile of Building & Demolition Waste



Figure 10 Suspected Asbestos Cement Sheetting



No other visual or olfactory evidence of contamination was identified during the investigation.

4.3 Obstructions

A concrete slab presumed to be the relict floor slab of a former building was encountered in TP8A the central/southeastern part of the site, beneath a surface covering Made Ground soils.

Another concrete slab remains in the central/southeastern part of the site, associated with a structure removed more recently.

Relict foundations, brickwork and masonry were also encountered in TP11 and WS6.

Buried services such as gas, electricity, water, drainage and CATV are known to run along the entrance track in the west of the site from Laund Road. However, the exact routes are uncertain.

Relict buried services, particularly drainage, are considered likely to remain in-situ in the southeastern part of the site.

4.4 Groundwater

Groundwater strikes were recorded during the fieldwork in TP12, TP14, TP15, WS5 and WS7 depths of 0.80m (TP12) to 2.0m bgl (WS7).

Subsequent monitoring of groundwater in standpipes (WS01A, WS02, WS03 and WS04) recorded water levels to be between ground level and 2.37m bgl.

4.5 Rockhead

Shallow bedrock (weathered mudstone) was encountered in the majority of the exploratory holes at depths of between 0.30m (WS03) and 2.00m bgl (WS0110).

4.6 Coal and Suspected Workings

Available information indicates that the Pot Clay coal and Marine Band, which outcrop adjacent Laund Road, are likely to be present at shallow depth (<30m bgl) beneath the site, and may have been worked at some time in the past.

Two rotary boreholes were drilled in the southeastern part of the site as per the recommendations of the Coal Authority. The depths of the various materials encountered in the rotary boreholes are summarised in the following table:

Table 3: Summary of Ground Conditions Encountered (Rotary Boreholes)

HOLE	Depth to Stratum (m bgl)							
	TOPSOIL/ CLAY	PENNINE MIDDLE COAL MEASURES				POTENTIAL WORKINGS		TOTAL DEPTH (m bgl)
		MUDSTONE	SILTSTONE	SANDSTONE	COAL	BROKEN GROUND	VOID	
RO1	GL-1.00	1.00-3.60	3.60-8.40	8.60-30.00	8.40-8.60	-	-	30.00
RO2	GL-1.20	1.20-6.00	6.00-7.20 7.60-8.00	8.00-3.00	7.20-7.60	-	-	30.00

A copy of the Coal Authority Mining Permit (reference no. 18200) is presented in Appendix 5.

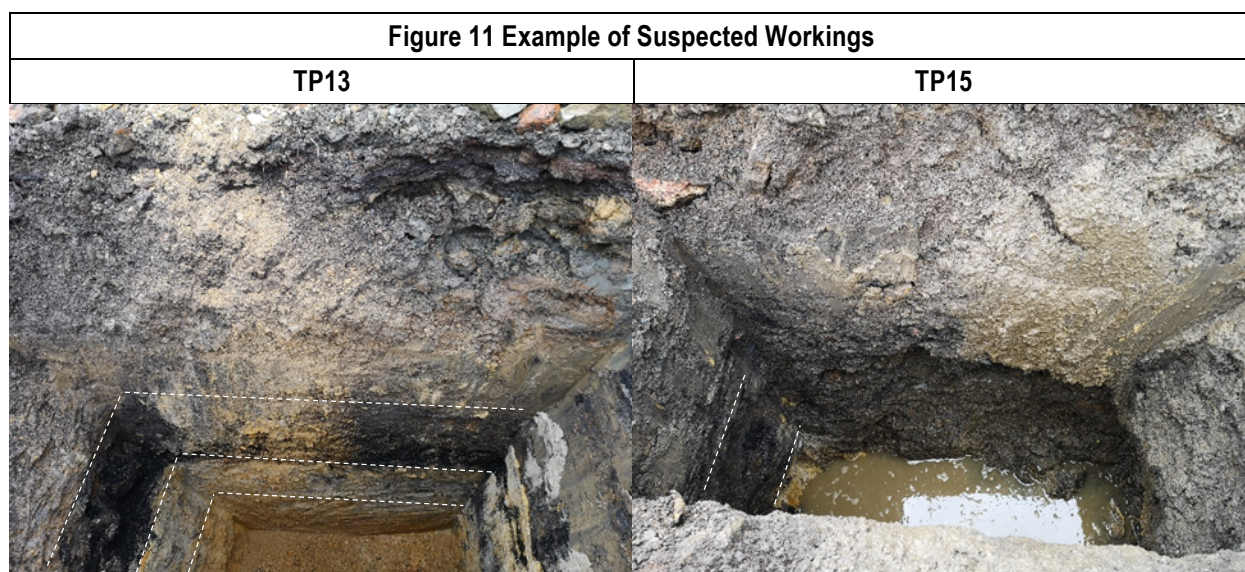
Reference to Table 2 in Section 4.1 shows near surface coal (<5.0m bgl) was encountered at three locations (TP13, TP14 and WS6), at bottom depths of 1.70m (TP13) to 2.10m (TP14), with thickness of 0.20m to 0.30m.

As shown in Table 3, above, deeper coal of similar thickness (0.20m to 0.40m) was also encountered in RO1 and RO2 at bottom depths of 8.60m and 7.60m respectively, inferred to represent the same dipping seam.

No broken ground, voids or suspected workings were encountered in the rotary boreholes.

However, loose wet collapsible deposits (suspected backfill material associated with bell pit mining) were encountered beneath the natural strata in in TP14 (1.30-1.80m bgl), TP15 (1.00-2.30m bgl) and WS6 (1.80-2.60m bgl).

Figure 11, overleaf, compares the soil profile in TP13 and TP15, which were located immediately adjacent each other.



The soil profile in TP13 shows natural strata with fairly distinct layers. The soil profile in TP15 shows solid 'overburden' underlain by very loose collapsing deposits of clayey mudstone gravel, together with the introduction of perched groundwater, which was not present in the neighbouring trial pit.

The short side of TP15 (left-hand side of the image) abuts the short side of TP13 (also left-hand side of image). In TP15 the image shows more distinct layering at this end of the pit, with sandstone just visible at the base, which is synonymous with sequence of strata visible in TP13, indicating that the bell mine workings must have terminated here.

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

Made Ground was encountered across the site to a maximum depth of 2.00m bgl (WS04). Made Ground is not typically considered to be a suitable founding material, and as such, no geotechnical testing was carried out on the material.

Due to the limited depth of the Made Ground, only one SPT test was carried out in the material (WS7 at 1.0m bgl), which resulted in an SPT N value of 3, as shown on the SPT v Depth Plot in the Section 5.3. The results suggest the Made Ground in this location is very soft.

Sulphate content and pH value determination tests were carried out on 10 samples of the Made Ground by the chemical laboratory. The water-soluble sulphate content of the samples ranged between 17 mg/l SO₄ to 478 mg/l SO₄ with pH values of 5.3 to 7.5.

5.2 Suspected Backfill Material

Suspected backfill material was encountered in TP14 (1.30-1.80m bgl), TP15 (1.00-2.30m bgl) and WS6 (1.80-2.60m bgl).

As with the Made Ground no geotechnical testing was carried out on the material.

Again, only one SPT test was carried out in the Suspected Backfill Material (WS7) at 2.0m bgl, which resulted in an SPT N value of 3. The results suggest the material is very loose.

By way of comparison, the SPT test at 2.0m bgl in WS6, located in close proximity of WS7, recorded an SPT N value of 26 in natural mudstone.

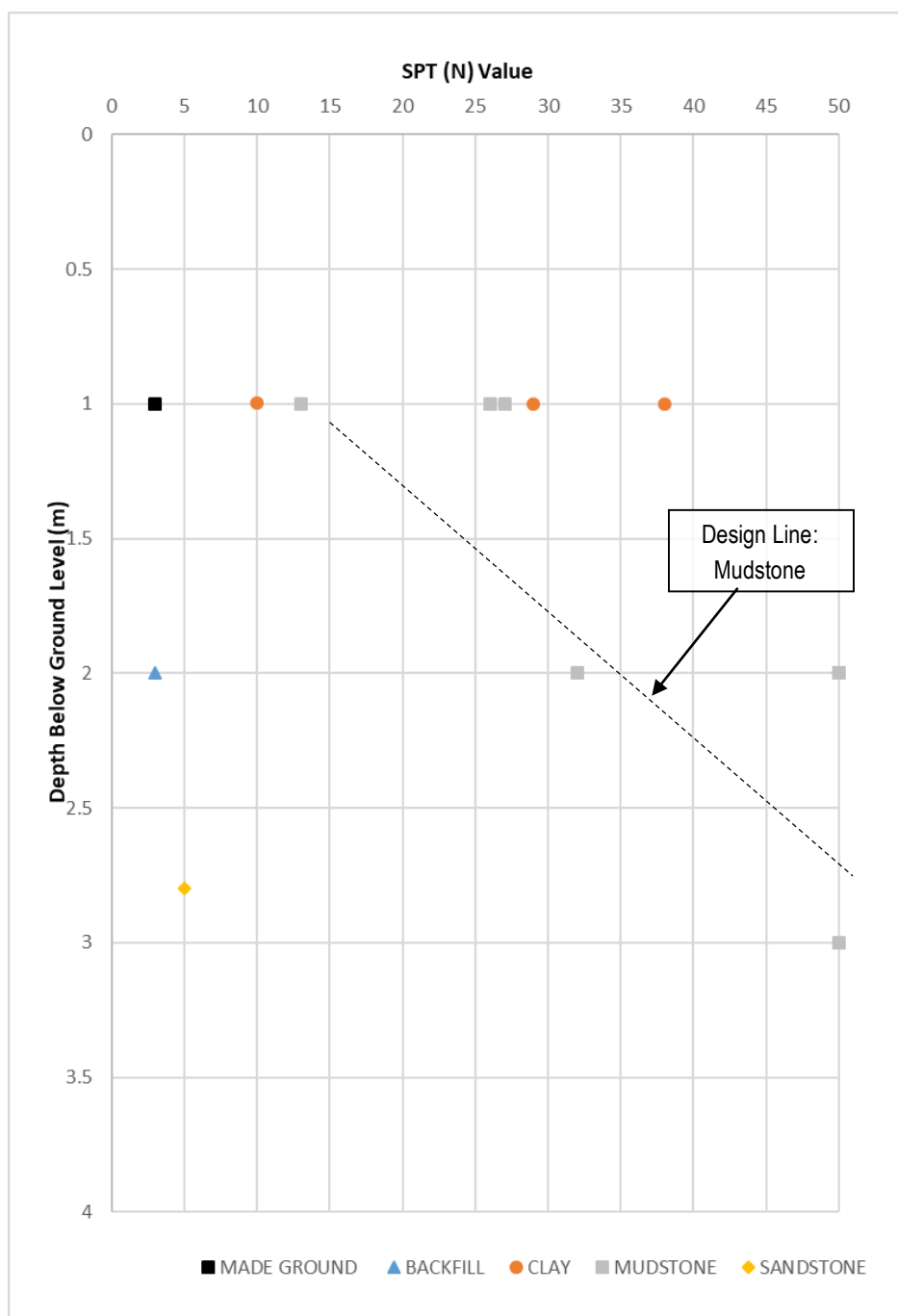
5.3 Sandy Gravelly Clay (Weathered PLCM)

The Sandy Gravelly Clay was encountered beneath the surface soils (Topsoil/Made Ground) in the majority of the exploratory holes, to a maximum depth of 1.80m bgl (TP4). The Clay was absent in WS6 and WS7.

The material generally became weakly laminated and friable with depth, and is inferred to represent destructured/completely weathered PLCM.

SPT tests carried out in the Sandy Gravelly Clay resulted in SPT N values at 1.0m bgl ranging from 10 to 38, as shown on the SPT v Depth Plot overleaf. The results suggest the Sandy Gravelly Clay is firm to very stiff.

Figure 12 SPT v Depth Plot



In-situ hand vane (HV) tests were also carried out on the recovered Clay soils, where possible. The results ranged between 29kN/m^2 and 70kN/m^2 , suggesting the material varied in soil strength from soft to firm.

In addition, one undrained triaxial shear strength test was carried out on the Sandy Gravelly Clay by the laboratory, which resulted in a shear strength value of 34kN/m^2 at 0.7m bgl.

Figure 13, below, shows the derived undrained shear strength of the Clay soils based on in-situ hand vane tests alongside equivalent shear strength from SPT N values based on correlations by Stroud and Butler (1975) and undrained shear strength based on laboratory triaxial testing.

Figure 13 Strength v Depth Plot for Sandy Gravelly Clay

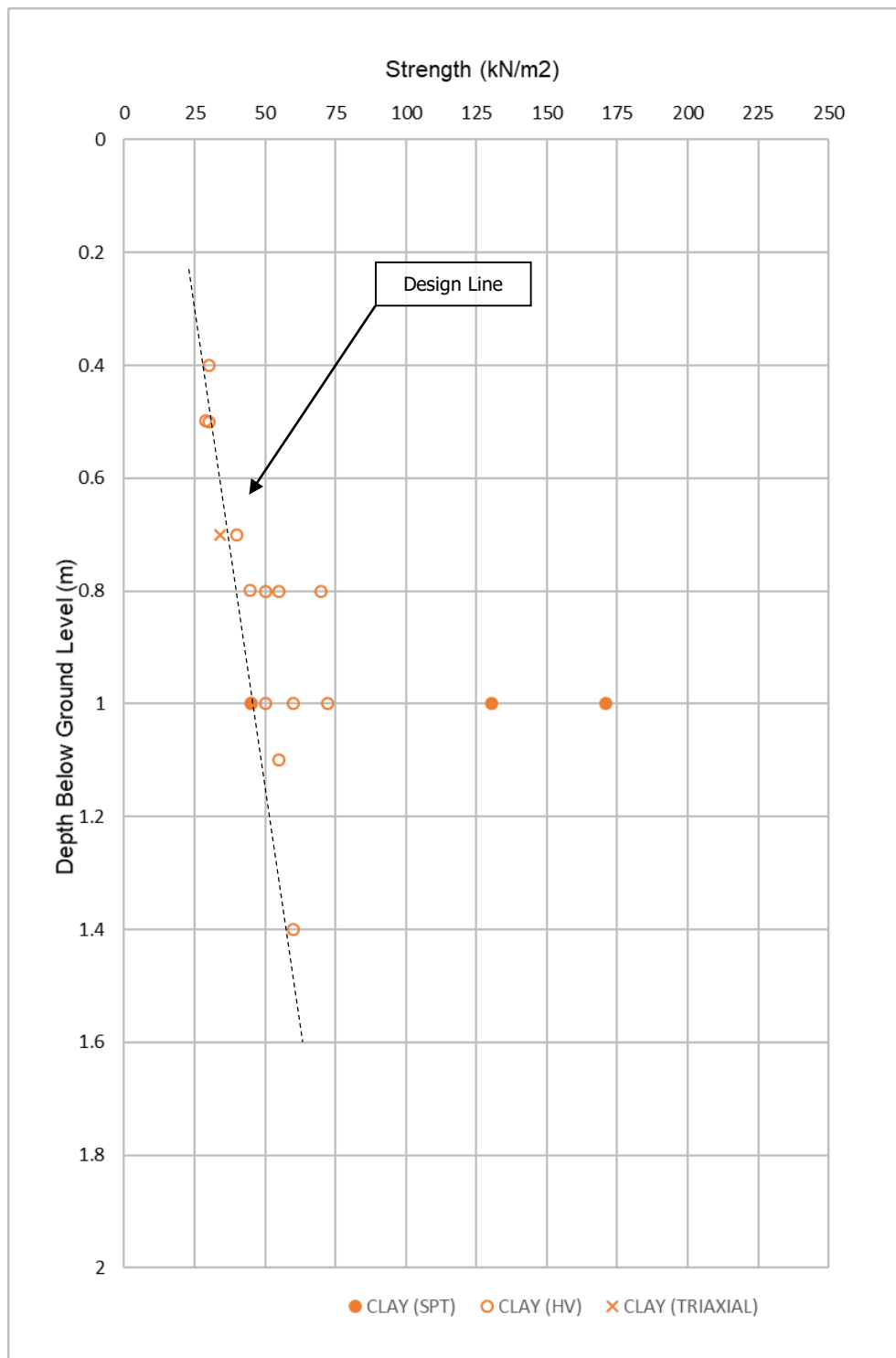


Figure 13 shows there is a general increase in soil strength with depth in the Sandy Gravelly Clay.

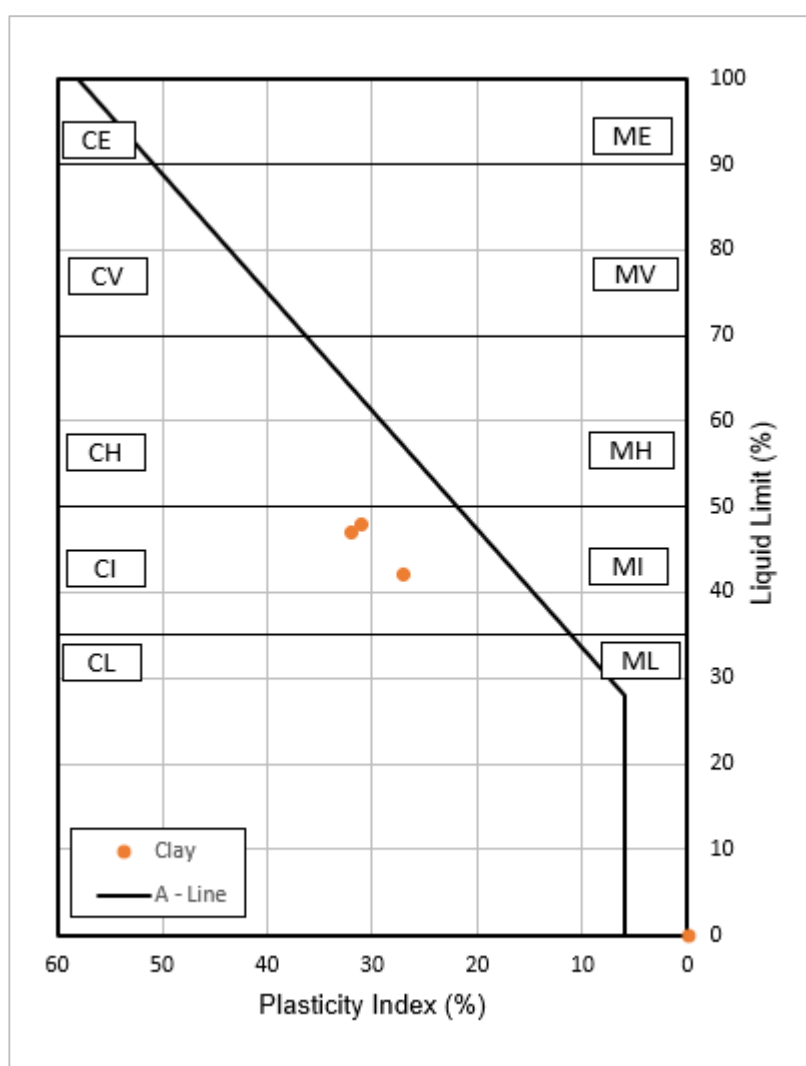
Two Particle Size Distribution (PSD) tests were carried out the Sandy Gravelly Clay. The laboratory described the material to be soft brown, silty, sandy clay with rare/occasional gravel.

Atterberg Limit tests were carried out on four samples of the Sandy Gravelly Clay. Results of the tests reported **liquid limit** values of 42% to 48%, and **plastic limit** values of 15% to 17%, resulting in **plasticity index** values of 27% and 32%. These results suggest the Sandy Gravelly Clay to be of **intermediate plasticity**, with **medium volume change potential**.

One sample of weakly laminated, friable clay, taken from WS6 at 1.50m bgl was found to be non-plastic and described by the lab as a clayey, sandy silt.

Results are shown on the Plasticity Chart below.

Figure 14 Plasticity Chart



For design purposes, a value of plasticity index = 30% 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:

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

I_p' = modified plasticity index,
 I_p = plasticity index.

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. Based on the results of the Atterberg tests, none of the soils showed evidence of desiccation, despite the southeast of the site being overgrown and bordered by mature trees.

It is recommended that for assessing ultimate bearing capacities, where the lower values are critical, the lower quartile value of N values is used. For assessing settlements average ground conditions will give a more realistic value of settlements, and the average of N values should be used.

Recommended N values and derived design values are summarised in the table below.

Table 4: Summary of Design Parameters (Sandy Gravelly Clay)

Depth (m bgl)	SPT N Value Range	Design N Value*	Equivalent Shear Strength** (kN/m ²)	Laboratory Derived Shear Strength (kN/m ²)	Average Hand Vane Shear Strength (kN/m ²)	Coefficient of Volume Compressibility** (mv)
0.5	-	-	-	-	30	0.21
1.0	10-38	20	88	34	50	0.15
1.5	-	-	-	-	60	0.15
*Based on lower quartile N value and correlations						
**Based on correlations by Stroud & Butler ⁽¹⁹⁷⁵⁾						

Based on the above and Figure 13, the results of the in-situ testing (SPT and HV) and laboratory testing at 1.0m bgl do not correlate well, with the SPT test results suggesting that the material exhibits much higher shear strength. Overall, the results indicate the material to be of generally low to medium strength.

The Sandy Gravelly Clay is considered theoretically suitable for conventional shallow foundations at depths greater than 1.0m bgl. It is recommended that a conservative shear strength value of 45kN/m² at 1.0m bgl (firm/medium strength) is applied at the foundation design stage.

However, is considered likely that rockhead (mudstone) will be encountered at depths of around 1.0m to 1.50m bgl and is recommended that foundations be extended to rockhead as this is considered a more suitable founding material.

Sulphate content and pH value determination tests were carried out on two samples of the Sandy Gravelly Clay by geotechnical laboratory. The water-soluble sulphate content of the samples was reported to be 210mg/l SO₄ and 280mg/l SO₄ with pH of 7.0.

5.4 Mudstone

Mudstone was encountered beneath the Clay across the site at depths of between 0.30m (WS03) and 1.80m bgl (TP4) and was observed to be weakly bedded and 'crumbly' based on the material exposed and recovered from the trial pits.

SPT tests carried out in the Mudstone resulted in SPT N values of generally between 13 and 50, as shown on the SPT v Depth Plot (Figure 12), with a general increase in strength with depth.

Recommended N values and derived design values are summarised in the table below.

Table 5: Summary of Design Parameters (Mudstone)

Depth (m bgl)	SPT N Value Range	Design N Value*	Equivalent Shear Strength** (kN/m ²)
1.0	13-27	16.5	75
2.0	13-25	45.5	205
3.0	26-50	50	225
*Based on lower quartile N value and correlations **Based on correlation by Stroud & Butler (1975)			

Based on the above, if Mudstone is encountered at proposed founding depth, the material is considered suitable for conventional mass concrete foundations.

Sulphate content and pH value determination tests were carried out on one sample of Mudstone. The water-soluble sulphate content of the sample was 350mg/l SO₄ with pH value of 7.2.

5.5 Sandstone

Sandstone was generally encountered beneath the Mudstone at depths of 1.80m to 2.60m bgl. The Sandstone was observed to be of moderate strength strong based on the material recovered from the trial pits and window sampler boreholes.

Only one SPT test was carried out in the Sandstone, which resulted in an SPT N value of 50 (refusal), as shown on the SPT v Depth Plot (Figure 12). An equivalent shear strength of 225kN/m² may be applied for foundation design.

5.6 Coal

Near surface coal was encountered in three locations at depths of between 1.40m (TP13) and 1.80m bgl (TP14).

Where coal is present at proposed foundation depth, the designer should satisfy themselves that the foundation load will not cause undue settlement. Consideration should be given to extending foundations beyond the base of the identified shallow coal (maximum depth 2.10m bgl in TP14).

Sulphate content and pH value determination tests were carried out on one sample of coal. The water-soluble sulphate content of the sample was 400mg/l SO₄ with pH value of 6.7.

6.0 GEOTECHNICAL ASSESSMENT

6.1 Proposed Development

It is understood that the client intends to construct 8no. new three and four-bedroom houses with parking, private gardens and associated infrastructure.

Detailed information regarding structural loadings and proposed foundation type was not available, however, we anticipate the loadings to be similar to those of a typical two-storey house (75kN/m^2).

6.2 Ground Conditions Encountered

The exploratory holes generally encountered Made Ground across the site, to depths of between 0.10m and 2.00m bgl (WS01), typically underlain by sandy gravelly clay representative of completely weathered Pennine Lower Coal Measures. Rockhead (weathered mudstone) was encountered at depths of between 0.30m (WS03) and 1.70m bgl (TP10) and sandstone was encountered directly beneath the Made Ground in WS7 at 1.80m bgl and WS01 at 2.00m bgl.

Near surface coal was encountered in three locations (TP13, TP14 and WS6), at bottom depths of 1.70m (TP13) to 2.10m (TP14), with thickness of 0.20m to 0.30m.

Suspected backfill material (loose wet collapsible deposits), indicative of potential 'bell pit' mine workings were also recorded beneath the natural strata in TP14, TP15 and WS7, located in the front garden area of the existing bungalow.

Perched groundwater was recorded in the exploratory holes in TP12, TP14, TP15, WS5 and WS7 depths of 0.80m (TP12) to 2.0m bgl (WS7).

6.3 Coal Mining Regime

The British Geological Survey 1:10,000 Sheet SE11NW shows the Pot Clay coal and Marine Band to outcrop in the southwest of the site, to the rear of House 1, oriented approximately northwest-southeast (parallel to Laund Road) and dipping at 2° from horizontal to the east, beneath the site.

The anticipated depth and depth at which the coal seams were encountered beneath the site are summarised in Table 6, overleaf. The anticipated depth of the coal has been calculated based on the distance and approximate elevation of the exploratory holes from the conjectured outcrop.

Table 6: Depth of Coal Beneath the Site

Location	Anticipated Depth of Seam (m bgl)	Depth Beneath Site (m bgl)	Thickness (m)
TP13	1.50	1.40	0.30
TP14		1.80	0.30
WS6		1.60	0.20
RO1	6.5	8.40	0.20
RO1		7.20	0.40

Based on the above, the anticipated depth of the seam beneath the front garden of 120 Laund Road in the northwestern part of the site (TP13, TP14 and WS6) correlates well with the findings of our investigation.

The depth of coal encountered in the southeastern part of the site is deeper than anticipated, which may be due to the seam dipping unevenly or associated with changes made to the topography/elevation of the site.

No broken ground, voids or suspected workings were encountered in the rotary boreholes. However, loose wet collapsible deposits (suspected backfill material associated with bell pit mining) were encountered beneath the natural strata in in TP14 (1.30-1.80m bgl), TP15 (1.00-2.30m bgl) and WS6 (1.80-2.60m bgl).

As a result, remedial measures will be required, such as deepening foundation to ensure they bear upon competent strata and placing a geogrid over the affected area to stabilize the soils and prevent uneven soil settlement.

Given the likely extent of the suspected workings across this part of the site, short bored piles may be a more economically viable solution.

6.4 Foundation Considerations

Conventional strip/trench foundations are considered suitable for the proposed development, bearing into the natural Pennine Lower Coal Measures (predominantly weathered mudstone).

Short bored piles may be a more suitable alternative foundation solution in the north/northwest of the site where coal and loose wet collapsible deposits (suspected backfill material associated with bell pit mining) have been encountered.

The above foundation options are discussed in the following sections.

6.4.1 Strip/Trench Foundations

Strip/trench foundations should be placed in natural clay (weathered PLCM) at a minimum depth of 1.0m bgl based on a medium volume change potential, providing suitably firm clays are encountered. Although it should be noted that soils shallower than 1.5m bgl were generally low/medium strength.

Furthermore, mature trees (mixed species) border the site, it is unknown whether these will be retained or removed. Although the clays showed no evidence of desiccation, in accordance with

NHBC Chapter 4.2 (2016) guidance, foundations within influencing distance of these trees may need to be extended to depths of up to 2.50m bgl, depending on tree species and proximity.

It is considered likely that rockhead (mudstone) will be encountered at depths of around 1.0m to 1.50m bgl and it is therefore recommended that foundations be extended to rockhead as this is considered a more suitable founding material. The foundation depth may be reduced to minimum depth of 0.75m bgl where suitable rockhead is encountered.

If Made Ground, coal, or loose/soft material is encountered at the proposed foundation level, this should be excavated and replaced with suitable granular fill or the foundation extended at least 500mm into suitable natural strata. Similarly, foundations should be placed in materials of similar bearing and consolidation characteristics to avoid potential differential settlement occurring.

The depth of backfill materials encountered in the north/northwest of the site may preclude the option of conventional foundations and short bored piles may be required (see following section).

The table below summarises anticipated allowable bearing pressures for conventional strip/trench foundations at the site. The bearing capacities are calculated based on Hansen's (1978) method and assuming a factor of safety against bearing capacity failure of 3.

Perched groundwater was encountered in the boreholes during the fieldwork. For the purposes of estimating net safe bearing pressures, we have taken a conservative approach to the depth to groundwater beneath the site and assumed that the water table is at 3.0m bgl.

Table 7: Summary of Allowable Bearing Pressures (Strip/Trench Foundations)

Foundation Depth (m bgl)	Strata	Design Value / Shear Strength (Section 5)	Foundation Width (m)	Allowable Bearing Pressure (kN/m ²)
1.0	Sandy Gravelly CLAY	50kN/m ²	0.60	127
			0.75	124
			0.90	121
1.5	Sandy Gravelly CLAY	60kN/m ²	0.60	161
			0.75	158
			0.90	154
1.0	Weathered MUDSTONE	75kN/m ²	0.60	188
			0.75	182
			0.90	178
1.5		115kN/m ²	0.60	300
			0.75	294
			0.90	288
2.0		205kN/m ²	0.60	544
			0.75	534
			0.90	525

Foundation loadings have been assumed as 75kN/m² and at this bearing pressure, total drained settlements in the clay have been calculated to be within tolerable limits (10-13mm). Settlement in cohesive soils typically comprises a small amount of immediate settlement as loads are applied and a larger proportion of consolidation settlement, which will occur over a longer period of time.

Settlements for other bearing pressures may be estimated on a pro-rata basis. Increased loading may result in settlements above 25mm.

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. Nominal reinforcement/movement joints should be incorporated where foundations cross from one founding strata to another e.g. cohesive to granular or soil to rock, to accommodate the effects of differential settlement.

The clay soils are susceptible to medium volume change due to the influence of trees. Numerous trees remain at along the site boundaries. No evidence of soil desiccation was encountered during the site investigation, however, consideration for deeper foundations in close proximity of boundary trees should be considered in accordance with NHBC Chapter 4.2 (2016) guidance.

6.4.2 Short Bored Piles

Should strip/trench foundations not be viable, for instance in the northwest of the site, short bored piles terminating in the bedrock at a depth no shallower than 3.0m would be a suitable alternative foundation solution.

Bored/Continuous Flight Auger (CFA) piles are considered most suitable for the proposed extension carrying their loads as a combination of skin friction and end bearing.

The noise and vibration associated with the installation of driven piles prevents this type of pile from being selected due to the proximity and sensitivity of the existing structure and neighbouring properties. It should also be noted that driven piles can potentially create preferential pollutant pathways.

Careful consideration should be given to the neighboring electricity substation and any potential live services entering the site.

Because of the various advantages and limitations of each pile type, and the cost implications, advice should be sought from specialist piling contractors to determine the most suitable and cost-effective type. They should also be able to give recommended pile diameters and depths and likely pile capacities, with guaranteed performance. It is recommended a pile test be carried out to confirm pile capacities. In assessing the pile capacities, contractors should make an allowance for the effects of negative skin friction, particularly in any Made Ground.

There may be differential settlement between piled structures and the surrounding ground level areas of pavement/road construction). Provision should, therefore, be made to make up ground levels at threshold positions, vehicle access, doorways, etc. Alternatively, these materials should be removed and replaced in a controlled manner by suitable existing materials or imported engineered fill.

6.5 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. 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.

6.6 Pavement Design

The ground investigation identified the soil type at subgrade level to be Made Ground or clay with average plasticity index of 30%.

Reference should be made to the 'Design Guidance for Road Pavement Foundations', Interim Advice Note 73/06, Revision 1 (2009), when considering the CBR value appropriate for use.

Generally, where Made Ground is present at subgrade level, a conservative design CBR value of 1% should be adopted. However, should natural clay be encountered, an estimated CBR value of 3% is recommended.

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.

Once formation level for the new road pavements has been achieved, proof rolling should be carried out using a heavy roller and any soft areas that are revealed should be excavated and a greater depth of subbase provided.

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.

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.

6.7 Chemical Attack on Buried Concrete

Water soluble sulphate content and pH value determinations have been carried out on the Made Ground and natural soils by both the chemical and geotechnical laboratory.

Based on the assumption of mobile groundwater, the results have been compared to current guidance provided within BRE Special Digest 1 'Concrete in Aggressive Ground' (2005) and the recommended classification for the strata encountered is summarised in the table below:

Table 8: Summary of Concrete Classification for Encountered Soils

Soil Type	Characteristic Sulphate Content (mg/l)	Characteristic pH Value	Design Sulphate Class	Aggressive Chemical Environment for Concrete
Made Ground*	353	5.5	DS-1	AC-2z
Clay	280	7.0	DS-1	AC-1
Weathered Mudstone	350	7.2	DS-1	AC-1

*Based on mean of highest 20% of sulphate concentrations & lowest 20% of pH values in dataset of 10 or more results.

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

6.8 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.

The natural soils are likely to be suitable as structural fill and could be used as such, 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.

6.9 Temporary Works

Formations in the natural soils 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 soft/wet shallow soils & backfill materials may 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 may be encountered in excavations, depending on depth. If required pumping of excavations from a suitable located sump should be adequate 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 9: Summary of Guideline Values for Protection of Workers Development

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	5.8-7.5	A
Arsenic	0 - 30	30 - 50	50 - 100	100 - 500	500	10-72	A-C
Cadmium	0 - 1	1 - 3	3 - 10	10 - 50	50	< 0.2-1.2	A-B
Chromium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	17-37	A
Copper	0 - 100	100 - 200	200 - 500	500 - 2500	2500	38-230	A-B
Lead	0 - 500	500 - 1000	1000 - 2000	2000 - 1%	1.0%	72-501	A-B
Mercury	0 - 1	1 - 3	3 - 10	10 - 50	50	< 1	A
Nickel	0 - 20	20 - 50	50 - 200	200 - 1000	1000	11-58	A-C
Zinc	0 - 250	250 - 500	500 - 1000	1000 - 5000	5000	114-2070	A-D
Boron	0 - 2	2 - 5	5 - 50	50 - 250	250	< 1	A
Beryllium	0 - 5	5 - 10	10 - 20	20 - 50	50	0.7-2.1	A
Vanadium	0 - 100	100 - 200	200 - 500	500 - 2500	2500	25-71	A
Sulphate	0 - 2000	2000 - 5000	5000 - 1%	1% - 5%	5.05%	17-478	A
Sulphide	0 - 10	10 - 20	20 - 100	100 - 500	500	< 5	A
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 results the soils are predominantly a mixture of uncontaminated and slightly contaminated. High concentrations of Zinc suggest the soils may be heavily contaminated in some parts of the site.

There is therefore considered to be 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, appropriate disposal of material arisings will be required to 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 future residential 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 2 and summarised in Table 10, overleaf.

Table 10: Assessment of Soil Chemical Data

Parameter	TP2 0.20m MG	TP4 0.30m MG	TP4 0.70m MG	TP8 0.30m MG	TP11 0.40m MG	TP14 0.30m MG	TP15 0.30m MG	WS1 0.40m MG	WS6 0.50m MG	STOCK PILE MG	Assessment Criteria (mg/kg)
Arsenic	10	19	26	28	35	68	72	24	36	10	37
Boron	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	290
Beryllium	0.8	1.7	1.6	1.3	1.7	1.6	2.1	1.4	1.6	0.7	1.7
Cadmium	< 0.2	< 0.2	< 0.2	0.6	1.2	< 0.2	0.5	< 0.2	< 0.2	< 0.2	11
Chromium	21	28	25	19	17	32	36	29	37	18	910
Free Cyanide	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	41
Hexavalent Chromium	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	21
Copper	38	230	54	51	72	177	155	53	114	38	2400
Lead	100	194	173	265	241	444	246	223	501	72	200
Mercury	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	40
Nickel	17	28	18	20	26	46	58	21	48	11	180
Selenium	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	250
Vanadium	27	44	55	36	38	51	71	46	53	25	410
Zinc	115	230	134	733	500	674	495	271	2070	114	3700
pH	7.5	6.6	5.8	6.5	7.3	6.5	7.3	5.3	5.9	7.1	N/A
Naphthalene	< 0.1	< 0.1	0.2	0.29	3.29	1.13	0.55	0.25	0.28	0.59	2.3
Acenaphthylene	0.19	0.18	< 0.1	< 0.1	< 0.1	< 0.1	0.13	< 0.1	< 0.1	< 0.1	170
Acenaphthene	< 0.1	< 0.1	0.21	0.38	4.16	1.43	0.64	0.18	0.43	1.18	210
Fluorene	0.14	0.16	0.16	0.38	2.72	1.1	0.5	0.14	0.32	0.9	170
Phenanthrene	0.92	1.17	1.39	4.14	24.4	10.5	5.32	1.64	3.62	8.76	95
Anthracene	0.32	0.3	0.24	2.47	3.75	2.34	1.14	0.27	0.71	2.06	2400
Fluoranthene	1.89	2.09	1.53	11.8	19.4	15.7	7.32	2.62	5.03	12.6	280
Pyrene	1.7	1.78	1.28	10.7	11.2	13.2	6.36	2.31	4.37	10.6	620

Parameter	TP2 0.20m MG	TP4 0.30m MG	TP4 0.70m MG	TP8 0.30m MG	TP11 0.40m MG	TP14 0.30m MG	TP15 0.30m MG	WS1 0.40m MG	WS6 0.50m MG	STOCK PILE MG	Assessment Criteria (mg/kg)
Benzo(a)anthracene	1.19	1.05	0.58	6.97	3.95	5.88	3.24	1.03	1.85	4.31	7.2
Chrysene	0.77	0.78	0.76	5.19	4.32	4.83	3.15	1.22	1.83	4.28	15
Benzo(b)fluoranthene	1.28	1.18	0.61	6.53	3.43	5.26	3.31	1.42	1.63	3.79	2.6
Benzo(k)fluoranthene	0.43	0.4	0.24	2.23	1.08	1.53	1.53	0.43	0.5	1.27	77
Benzo(a)pyrene	0.99	0.89	0.42	5.29	2.53	3.65	2.79	1	1.14	2.84	5.0
Indeno(1,2,3-cd)pyrene	0.87	0.74	0.17	2.38	1.13	1.53	1.66	0.53	0.62	1.37	27
Di-benz(a,h)anthracene	< 0.1	< 0.1	< 0.1	0.46	0.22	0.33	0.17	< 0.1	< 0.1	0.25	0.24
Benzo(ghi)perylene	0.61	0.46	0.17	1.95	0.88	1.19	1.51	0.47	0.51	1.11	320
Phenol	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	280
Benzene	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	87
Toluene	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	130
Ethylbenzene	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	47
Xylene	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	60
Aliphatic >C5 - C6	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	78
Aliphatic >C6 - C8	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	230
Aliphatic >C8 - C10	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	65
Aliphatic >C10 - C12	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	330
Aliphatic >C12 - C16	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	2400
Aliphatic >C16 - C21	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	92000
Aliphatic >C21 - C34	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	25	92000
Aromatic >C5 - C7	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	140
Aromatic >C7 - C8	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	290
Aromatic >C8 - C10	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	83
Aromatic >C10 - C12	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	180
Aromatic >C12 - C16	< 2	< 2	< 2	4	18	9	4	< 2	< 2	2	330
Aromatic >C16 - C21	< 3	< 3	< 3	19	53	44	22	< 3	4	30	540
Aromatic >C21 - C35	< 10	< 10	< 10	57	38	46	41	< 10	< 10	86	1500

Parameter	TP2 0.20m MG	TP4 0.30m MG	TP4 0.70m MG	TP8 0.30m MG	TP11 0.40m MG	TP14 0.30m MG	TP15 0.30m MG	WS1 0.40m MG	WS6 0.50m MG	STOCK PILE MG	Assessment Criteria (mg/kg)
Asbestos	D	ND	ND	D	ND	D	ND	ND	ND	ND	-

Notes for Table 10

Concentrations in **red** above assessment criteria based on Residential with Plant Uptake.

Based on Table 10, several of the samples tested contained concentrations of various heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) in exceedance of assessment criteria values relevant to a residential end use with plant uptake.

Asbestos was also detected in three of the samples that underwent testing, as both Chrysotile and Amosite. Quantification of the asbestos revealed concentrations of between < 0.001% wt/wt (trace) and 0.007%.

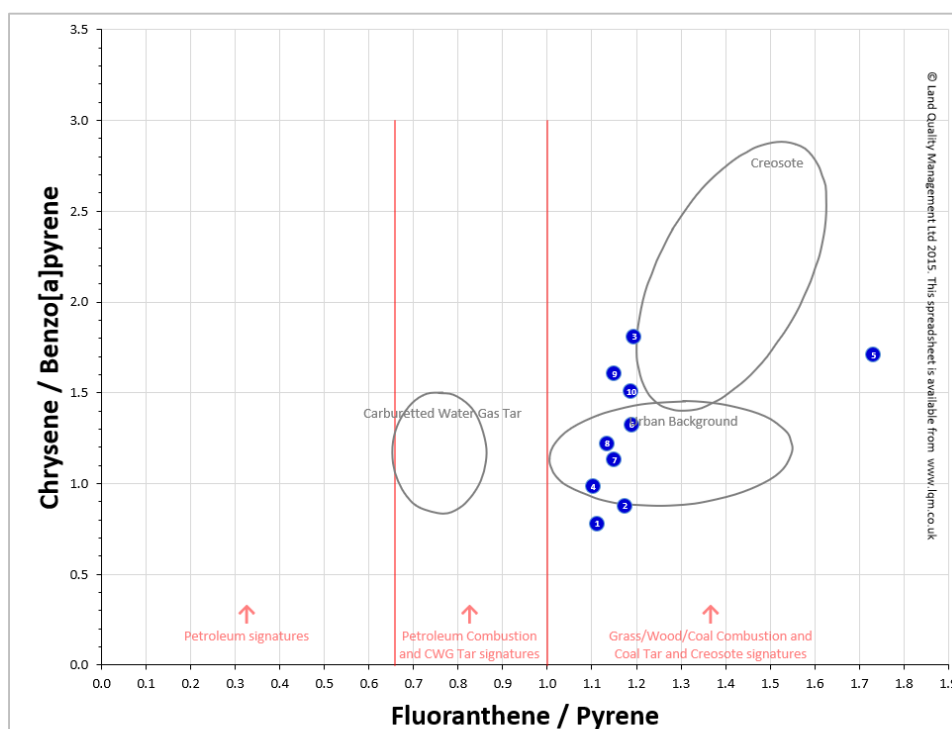
The exploratory holes in which the exceedances were found suggest the soil contamination is wide spread across the development area. A summary of contaminant exceedances at each location is presented in Table 11 overleaf.

Table 11 : Summary of Contamination Found at Each Location

Hole	Contaminant	Type
TP2	Chrysotile	Asbestos
TP8	Lead	Heavy Metal
	Benzo(b)fluoranthene, Benzo(a)pyrene & Di-benz(a,h)anthracene	PAH
	Amosite	Asbestos
TP11	Lead	Heavy Metal
	Naphthalene & Benzo(b)fluoranthene	PAH
TP14	Arsenic & Lead	Heavy Metal
	Benzo(b)fluoranthene & Di-benz(a,h)anthracene	PAH
	Chrysotile	Asbestos
TP15	Arsenic, Lead & Beryllium	Heavy Metal
	Benzo(b)fluoranthene	PAH
WS1	Lead	Heavy Metal
WS6	Lead	Heavy Metal
STOCKPILE	Di-benz(a,h)anthracene	PAH

Based on the PAH ratios contained in the Made Ground, the samples are inferred to contain derivatives of coal and wood combustion, predominantly from an urban background, as shown in the plot below.

Figure 15 PAH Double Ratio Plot



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 each of the samples tested using HazWasteOnline.

Additional Waste Acceptance Criteria (WAC) testing has also been carried out on three of the samples.

Full results of the soil waste assessment are presented in Appendix 4 and summarised in the table below.

Table 12: Soil Waste Assessment

Location	Depth (m bgl)	HazWasteOnline Classification	WAC Classification
TP2	0.20	Non-Hazardous	Inert
TP4	0.30	Non-Hazardous	-
TP4	0.70	Non-Hazardous	-
TP8	0.30	Non-Hazardous	-
TP11	0.40	Non-Hazardous	-
TP14	0.30	Non-Hazardous	-
TP15	0.30	Non-Hazardous	Non-Hazardous
WS1	0.40	Non-Hazardous	-
WS6	0.50	Hazardous	-
STP (Stockpile)	-	Non-Hazardous	Non-Hazardous

The soils have generally been classified as Non-Hazardous for the purpose of off-site disposal. However, soils in the vicinity of WS6 are classified as Hazardous due to a high concentration of Zinc.

7.4 Soil Leachate Risk Assessment with Respect to Controlled Waters

Soil leachate analyses were undertaken on 3 soil samples to assess the risk posed by soil contamination to underlying controlled waters.

Drinking water standards (DWS) have been adopted as reference criteria for the site. Where a DWS is not available, the Environmental Quality Standard (EQS) value for freshwater environments or World Health Organisation (WHO) standards have been adopted.

A summary of the results of the soil leachate analysis can be found in Appendix 2 and summarised in Table 13 (overleaf).

Table 13: Assessment of Soil Leachate Data

Parameter	WS2	WS7	TP5	Assessment Criteria (µg/l)	Source
Arsenic, Dissolved	< 5	9	< 5	10	EQS/UK DWS
Barium, Dissolved	10	28	32	700	EQS/UK DWS
Beryllium, Dissolved	< 3	< 3	< 3	No Standard	No Source
Boron	17	25	10	1000	UK DWS
Cadmium, Dissolved	< 0.4	< 0.4	< 0.4	5	UK DWS
Chromium, Dissolved	< 5	11	< 5	50	UK DWS
Hexavalent Chromium	< 20	< 20	< 20	50	EQS Freshwater
Lead, Dissolved	< 5	< 5	< 5	10	UK DWS
Mercury, Dissolved	< 0.05	< 0.05	< 0.05	1	UK DWS
Nickel, Dissolved	< 5	< 5	< 5	20	UK DWS
Selenium, Dissolved	< 5	< 5	< 5	10	UK DWS
Vanadium, Dissolved	< 5	< 5	< 5	20	EQS Freshwater
Zinc, Dissolved	4	3	7	3000	UK DWS
Benzo(a)pyrene	< 0.01	< 0.01	< 0.01	0.01	UK DWS
Fluoranthene	< 0.01	0.04	0.03	0.1	EQS Freshwater
Naphthalene	< 0.01	0.02	0.07	10	EQS Freshwater
pH	7.0	8.1	7.7	6.5-9.5	UK DWS
Phenol	< 10	< 10	< 10	No Standard	EQS Freshwater
Toluene	< 5	< 5	< 5	700	WHO Drinking Water Guideline
Benzene	< 1	< 1	< 1	10	WHO Drinking Water Guideline
EPH C10 – C40	0.04	0.15	0.21	10	WHO Drinking Water Guideline

Notes for Table 13

Concentrations in **red** above assessment criteria

UKDWS: United Kingdom Drinking Water Standards

EQS Freshwater: Environment Agency Environmental Quality Standard for Freshwater

All assessment criteria derived from EA Chemical Standards Database & CL:AIRE Petroleum Hydrocarbons in Water, Version 1.1, 29th March 2017 and EA Chemicals Standards Database

The above table indicates that measured concentrations of dissolved contaminants in leachate derived from the three soil samples analysed are below the threshold values for the protection of groundwater/drinking water quality.

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 11th September 2019 and 1st October 2019 and the results obtained recorded methane (CH₄) levels of 0.0% to 0.1% by volume (v/v) and carbon dioxide (CO₂) levels ranging from 0.0% to 15.2% v/v. Oxygen concentrations of between 4.2% and 19.3% v/v were also recorded.

Gas flow rates were recorded using a dedicated flow meter. A maximum flow rate of 37.0 l/hr was detected in the boreholes. This elevated flow rate and other similar flow rates have been discounted as they were most likely caused by water entering the boreholes and pressurising the gas that had collected in the installation. This is evidenced by the rapid drop in flow rate, often to 0.0 l/hr. Because of this, the highest steady flow rate of 0.3 l/hr has been selected. Atmospheric pressure was recorded to be between 968mb and 999mb.

Full results of the monitoring to date are presented in Appendix 6.

Table 14 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 maximum flow rate, which represents worst-case scenario conditions

- Carbon dioxide: maximum flow rate = 0.3 l/hr, max concentration = 15.2%
- Methane: maximum flow rate = 0.3 l/hr, max concentration = 0.1%.

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

- **Carbon dioxide:** $GSV = 0.3 \times 15.2 / 100 = 0.0456$ litres/hr
- **Methane:** $GSV = 0.3 \times 0.1 / 100 = 0.0003$ litres/hr

The above results suggest the site can be given a Characteristic Situation-1 (CS-1), i.e. 'Negligible to very low risk' classification, in accordance with Table 14 overleaf. This is due to the GSV values for methane and carbon dioxide being below 1.3 l/h and 7.2 l/hr respectively.

Table 14: Modified Ground Gas Classification Table (Risk and Reliability in Gas Protection Design, 2019)

Characteristic Situation	Pathway vertical permeability (m/s)	GSV CH₄ (l/hr)	GSV CO₂ (l/h)	GSV oxygen deficient gas (Nitrogen) (l/h)	Maximum borehole gauge pressure (Pa)	Limiting sustained gas concentrations in unsaturated zone within 10m of surface	Limitations	Risk level
CS-1	$\leq 1 \times 10^{-7}$ $1 \times 10^{-7} < k < 1 \times 10^{-5}$ $\geq 1 \times 10^{-5}$	< 2 < 1.5 < 7.2	< 11.9 < 9.0 < 7.2	< 217 for all permeability (care when using this value. Usually oxygen deficient gas emissions are sporadic and monitoring should cover suitable situations)	500 (50mm water) – ASTM (2016)	$< 30\%$ methane $< 21\%$ carbon dioxide No limit on oxygen depletion because it is widespread in natural	No nearby Municipal Solid Waste landfills or other credible source of gas. No pathway for migration to the site being considered. No potential high volume gas reservoirs in ground.	Negligible to very low
CS-2	$\leq 1 \times 10^{-7}$ $1 \times 10^{-7} < k < 1 \times 10^{-5}$ $\geq 1 \times 10^{-5}$	≤ 35.6 ≤ 21.7 ≤ 18.2	< 248.8 < 152.0 < 127.0	< 390 < 296 < 238	No limit	$< 30\%$ methane $< 30\%$ carbon dioxide $< 90\%$ combined methane and carbon dioxide	Where oxygen deficient ground gas or carbon dioxide is likely to be emitted from shaft, fractured rock or ground where $k > 1 \times 10^{-4}$ m/s assume CS3 for Type A and B development and CS2 for Type C and D development (or alternatively undertake DQRA)	Low to moderate
CS-3	$\leq 1 \times 10^{-7}$ $1 \times 10^{-7} < k < 1 \times 10^{-5}$ $\geq 1 \times 10^{-5}$	≤ 85.3 ≤ 52.1 ≤ 43.6		No limiting values (site specific check required that gas emission can be managed by protection measures)	No limit	No limit		Moderate to high
CS-4		<100m ³ /h total LFG generation rate	N/A	N/A			Sites that are domestic/commercial landfill sites where gas generation is still managed by extraction systems such as calorific flaring	Very high

9.0 REVIEW OF CONCEPTUAL SITE MODEL

A Preliminary Risk Assessment (PRA) is presented as Table 3 in the EEG Ltd Phase I GeoEnvironmental Desk Study report (A0697/17, November 2017). The findings of which are summarised in Section 1.2.2. The PRA concluded there to be a **MEDIUM** risk to end users from potential soil contamination and ground gas. The risk to groundwater and nearby surface water features was concluded to be **LOW**.

A revised risk assessment and Conceptual Model have been prepared for the site based on the results of the site investigation and subsequent chemical analysis and presented as Table 17, overleaf. The conceptual site model considers the source-pathway-receptor linkages present alongside the likelihood, severity and risk level as defined within Table 15 and Table 16 below. The assessment of probability, a modified risk table, and certain consequence definitions are based on CIRIA C552 and CLR11.

Table 17 considers whether a pollution linkage is potentially present and provides a qualitative assessment of risk based on a proposed residential end use with plant uptake.

Table 15: 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 dependent 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 16: 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 report for the site outlined the potential for the presence contaminated soils associated with the former site land uses and development history, notably:

- Made Ground.
- Ground gas from potentially infilled ground workings in close proximity of the site.
- Asbestos Containing Materials (ACM) in soils.

Made Ground was encountered across the site, to depths of between 0.10m and 1.80m bgl (WS7). A stockpile of waste soil was also present in the central/southeastern portion of the site, which was observed to contain fragments of suspected asbestos containing material (ACM).

In the samples which underwent chemical analysis, 8 samples contained concentrations of various heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs) in exceedance of assessment criteria values relevant to a residential end use with plant uptake. Asbestos was also detected in three of the samples, with a maximum concentration of 0.007% wt/wt.

Soil leachate analysis showed the measured concentrations of dissolved contaminants in leachate derived from the soil samples to be below the threshold values for the protection of groundwater/drinking water quality.

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 and inhalation

- Downward vertical migration of contaminants to groundwater and lateral migration to nearby water courses
- Vertical or lateral migration of ground gas associated with the Made Ground/mining processes

Table 17: Revised Conceptual Model

Source	Pathway	Receptor	Probability	Consequence	Risk	Comment
Contaminated Made Ground & Soil Stockpile (Heavy Metals & PAHs)	Dermal contact, ingestion and inhalation of soils dust	Current Site Users	Likely	Moderate	Moderate	The existing bungalow is currently occupied. The risk to current site users from soil contamination is considered to be MODERATE .
		Adjacent land users	Low Likelihood	Moderate	Moderate to Low	Several soil samples were found to contain concentrations of contaminants in exceedance of assessment criteria. Residential properties border the site to the north and east. Usual dust control measures should be implemented as part of good site working practices during construction to prevent generation/spread of airborne contamination. The risk is considered MODERATE to LOW .
		Future land users	Likely	Moderate	Moderate	Several soil samples were found to contain concentrations of contaminants in exceedance of assessment criteria. The proposed development includes private gardens. The risk to future site users via direct exposure is therefore considered to be MODERATE . Remediation in the form of clean cover soils in proposed garden areas would reduce this risk to LOW .
		Construction Workers	Low Likelihood	Moderate	Moderate to Low	There is a MODERATE to LOW risk to construction workers as they are likely to be exposed to contaminated materials during construction works, however exposure duration will be short-term only, and 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	Soil leachate analysis showed the measured concentrations of dissolved contaminants be below the threshold values for the protection of groundwater/drinking water quality. The risk to groundwater is therefore considered to be LOW .
	Vertical or lateral migration of ground gas associated with Made Ground & Backfilled	Current Site Users	Low Likelihood	Moderate	Moderate	The existing bungalow is currently occupied. GSVs calculated from the ground gas monitoring characterize the site as CS-1. The risk of ground gas to current site users is therefore considered to be LOW .
		Adjacent land users	Unlikely	Moderate	Low risk	Migration of any potential ground gas will be inhibited by the predominantly low permeability of the underlying geology,

Source	Pathway	Receptor	Probability	Consequence	Risk	Comment
	Shallow Mine Workings					The risk to adjacent users from ground gas is considered LOW .
		Future land users	Low Likelihood	Moderate	Moderate to Low	The proposed development will include 8 new residential dwellings. GSVs calculated from the ground gas monitoring characterize the site as CS-1. The risk from ground gas to future site users is therefore considered to be LOW . Modern construction practices will further reduce this risk.
		Construction Workers	Unlikely	Moderate	Low	Construction workers may be exposed to ground gases in excavations. However, the exposure duration will be short. The risk to construction workers from ground gas is considered LOW .
Asbestos up to 0.007% wt/wt.	Inhalation of fibres	Current Site Users	Likely	High	High	Asbestos is only harmful when disturbed and becomes airborne i.e. during construction/excavation works. The existing bungalow is currently occupied. The risk of disturbance and inhalation of fibres is therefore considered to be HIGH .
		Adjacent land users	Low Likelihood	High	Moderate	Soils will be disturbed during construction/excavation works allowing fibres to become airborne. The risk to adjacent land users is therefore considered MODERATE . Implementation of and asbestos management plan and appropriate dust control measures would reduce the risk to adjacent land users during construction works to LOW .
		Future land users	Likely	High	High	The proposed development will include 8 new residential houses with private gardens. The risk of to end users from disturbance and inhalation of fibres is therefore considered to be HIGH . Remediation in the form of clean cover soils in proposed garden areas would reduce this risk to LOW .
		Construction Workers	Unlikely	High	Low risk	Construction workers will be exposed to soils and airborne fibres during the construction phase. The risk is therefore considered HIGH . Implementation of and asbestos management plan and appropriate dust control measures would reduce the risk to LOW .

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

Eight of the ten soil samples taken from across the development area and the on-site stockpile have been found to contain concentrations of contaminants in exceedance of assessment criteria values relevant to a residential end use with plant uptake. Contaminants in exceedance included a selection of Heavy Metals and Polycyclic Aromatic Hydrocarbons (PAHs).

The overall potential risk to residential end users is concluded to be **MODERATE** and remediation will be required to mitigate this risk.

Given the spread of the soil contamination across the site, in order to break potential pollutant linkages to future residential end users, it is recommended that all garden and landscaped areas are capped with a minimum 600mm (450mm in front gardens) of validated clean cover soils, incorporating an appropriate physical barrier at the base of the capping layer, to act as a no dig layer for future residents and to prevent potential bioturbation

There is considered to be a **MODERATE to LOW** 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.

The groundworks contractor must provide a soil management plan including methods of dealing with any unanticipated soil contamination encountered during groundworks.

A Remediation Method Statement should be developed for the site, which would detail the nature of the cover system, chemical testing and validation criteria.

10.2 Asbestos

Asbestos has been identified in samples from TP2, TP8 and TP14 as both Chrysotile and Amosite. Quantification results show that the samples contain < 0.001% (trace) to 0.007 % wt/wt asbestos.

An asbestos management plan will therefore be required. Precautions will include (but are not limited to):

- Ensuring that the risk is communicated to all site personnel at induction stage
- Ensuring all site personnel have suitable training and PPE/RPE
- Ensuring that the soils do not become dry and dusty

As mentioned above, all garden and landscaped areas should be capped with a minimum 600mm of validated clean cover soils, incorporating an appropriate physical barrier at the base of the capping layer.

10.3 Soil Waste Assessment

The soils have generally been classified as Non-Hazardous waste for the purpose of off-site disposal.

However, the soils taken from WS6 have been classified as Hazardous. It is recommended that additional sampling and WAC testing is carried out on soils in the vicinity of WS6 at the time of soil stripping to delineate the area of Hazardous soils, so the material can be disposed of appropriately.

10.4 Groundwater

The measured concentrations of dissolved contaminants in leachate derived from the soils analysed are below the threshold values for the protection of groundwater/drinking water quality.

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

10.5 Ground Gas

GSV values for methane and carbon dioxide have been calculated as being below 1.3 l/h and 7.2 l/hr respectively.

The site has been given a classification of CS 1, and gas protection measures will not be required.

10.6 Coal

Intact Coal was encountered at shallow depth (1.40m to 1.80m bgl) in TP14, TP14 and WS6 in the north/northwestern part of the site, and at depths of 7.20m and 1.40m bgl in the southeastern part of the site, with thickness ranging from 0.20m to 0.40m.

No broken ground, voids or suspected workings were encountered in the rotary boreholes. However, loose wet collapsible deposits (suspected backfill material associated with bell pit mining) were encountered beneath the natural strata in in TP14 (1.30-1.80m bgl), TP15 (1.00-2.30m bgl) and WS6 (1.80-2.60m bgl).

As a result, remedial measures will be required, such as deepening foundation to ensure they bear upon competent strata and placing a geogrid over the affected area to stabilize the soils and prevent uneven soil settlement.

10.7 Foundation Recommendations

The site is underlain by soft to firm, medium volume change potential clay (inferred to be weathered Pennine Lower Coal Measures), which generally overlies weathered mudstone bedrock. Rockhead was encountered at depths of between 0.60m and 1.70m bgl and near surface coal (1.40m to 1.80m bgl) is present in the north/northwest of the site, together with suspected backfilled bell pit workings.

Strip/Trench foundations in the natural clay are likely to be suitable across the southeastern part of the site, at a minimum recommended depth of 1.0m bgl. However, it is considered likely that rockhead (mudstone) will be encountered at depths of less than 2.0m bgl and it is therefore recommended that foundations be extended to rockhead, as this is considered a more suitable founding material. The foundation depth may be reduced to minimum depth of 0.75m bgl where suitable rockhead is encountered.

If Made Ground, coal, or loose/soft backfill material is encountered at the proposed foundation level, this should be excavated and replaced with suitable granular fill or the foundation extended at least 500mm into suitable natural strata.

The depth of backfill materials encountered in the north/northwest of the site may therefore preclude the option of conventional foundations, in which case, short bored piles terminating in competent strata (mudstone/sandstone) at a minimum depth of 3.0m bgl are recommended.

10.8 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.

10.9 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

CHEMICAL TESTING RESULTS

APPENDIX 3

GEOTECHNICAL TESTING RESULTS

APPENDIX 4

SOIL WASTE ASSESSMENT

APPENDIX 5

COAL AUTHORITY PERMIT

APPENDIX 6

MONITORING DATA

APPENDIX 7

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.