Eastwood
CONSULTING ENGINEERS



Geotechnical and Geo-environmental Site Investigation

DARLEY AVENUE, WARD GREEN, WORSBROUGH

ALLERT BUILDING & CONSTRUCTION LTD

30/09/2022

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GEOTECHNICAL AND GEO-ENVIRONMENTAL SITE INVESTIGATION

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FOR

ALLERT BUILDING & CONSTRUCTION LTD

ISSUE 1



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Andrew Kerslake
Technical Director

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1.0 EXECUTIVE SUMMARY

1. The approximately 0.16-hectare site is located to the north of Darley Avenue, Ward Green in Worsbrough, Barnsley. The site is of rough rectangular shape and located at grid reference 434680, 404570. Access to the site can be gained via gate situated on Napier Mount.

2. Historically, the site was occupied by semi-detached residential properties from around 1931. The properties were demolished by 1993 and the site has remained vacant to date. The surrounding area, is predominantly residential in nature.

3. The solid geology beneath the site is expected to comprise mudstone of the Pennine Middle Coal Measures Formation. No superficial deposits are shown to underlie the site.

4. Six trial pits were excavated by ECE. Topsoil and topsoil made ground surface the site to depths of between 0.15 m and 0.5 m bgl. In the south of the site, made ground comprising of gravel of limestone (hardcore) to depths of between 0.3 m and 0.4 m was encountered underlain by stiff slightly sandy gravelly clay, with gravel of brick, slate, coal and limestone to depth of between 0.8 m and 1.1 m bgl. Below the made ground, natural ground comprising of stiff slightly sandy slightly gravelly clay with gravel of mudstone and iron nodules was encountered to depth of between 1.3 m and 2.4 m bgl, followed by a clayey gravel of mudstone and shale to depth of between 2.4 m and 2.7 m bgl, underlain by extremely weak and very weak mudstone bedrock. No groundwater was encountered.

5. A rotary borehole investigation, comprising of three boreholes sunk to 30 m bgl, was undertaken to ascertain the presence and extent of any workings in the Top Beamshaw Coal, The Low Beamshaw Coal and the Kent's Thin coal. A 600 mm to 700 mm thick band of coal was encountered in all three rotary boreholes. The coal was encountered at depths of between 10.4 m and 13 m bgl. Due to the depth and thickness of the coal encountered, the coal is likely the Low Beamshaw Coal seam. No workings were encountered, and we therefore consider that no remedial measures are required for the proposed residential development, due to past mining, across the site.

6. For the proposed low rise housing scheme, the most suitable foundations are considered to be strip or trench fill footings, taken through any made ground, soft or loose ground and into the natural clay. A minimum foundation depth of 900 mm from finished or original ground level, whichever is lower, will apply for foundations within the natural clay. Footings will need to be deepened where trees will have an influence, and heave protection will be required where the footing depth due to trees exceeds 1500mm.

7. Where less than 600 mm of made ground is present, ground bearing slabs will be appropriate. Elsewhere, reinforced suspended slabs or precast concrete floors with a minimum 150 mm high ventilated void should be used, increasing to a 250 mm void where heave protection is needed.

8. Radon precautions are not required for the development.

9. Historical landfill sites are present within 250 m of the site boundary. Gas monitoring is being undertaken due to this. At this stage, due to the maximum carbon dioxide concentration of 5.8% which has been recorded in the initial monitoring visit, CS2 gas protection measures should be allowed for all plots. Further gas monitoring will be required to confirm the gas regime.

10. Elevated concentrations of PAHs were detected in the topsoil and topsoil/made ground. It is therefore recommended that the material is removed from site. The made ground and natural ground were not found to contain any elevated concentrations of contaminants, and if these remain at surface, no remediation would be required, other than the placement of a topsoil growing medium of 150mm minimum thickness.

11. Based on the chemical test results, a design sulphate class of DS-2 and an ACEC class of AC-2 is considered appropriate for concrete in contact with the made ground. No sulphate precautions are required for below ground concrete in contact with the natural ground only.

12. Due to the cohesive natural ground encountered, it is not expected that soakaway drainage will be suitable for this site.

13. The conclusions in this report in relation to contamination are subject to agreement by the approving bodies, such as the Local Authority, and your warranty provider.

2.0 INTRODUCTION

2.1 Terms of Reference

This report presents the findings of a Phase 1 and Phase 2 Geotechnical and Geo-environmental Site Investigation carried out by Eastwood Consulting Engineers for, and on the instructions of, Allert Building and Construction Limited. Any other parties using the information in this report do so at their own risk and any duty of care is excluded.

2.2 Context

Eastwood Consulting Engineers (ECE) are not aware of any previous investigations having been undertaken on the site.

2.3 Aims and Objectives

The aims and objectives of this investigation were as follows:

- Assimilate Phase 1 data to derive an outline conceptual model identifying potential contaminants, pathways and receptors, as well as possible linkages between these;
- Obtain information enabling refinement and subsequent testing of the conceptual model;
- Carry out a tiered risk assessment to establish the likely risks to future receptors, involving the use of generic assessment criteria and where unacceptable risks are identified, site specific assessment criteria within a detailed quantitative risk assessment;
- Identify feasible remediation options if unacceptable risks are highlighted; Develop an appropriate remediation strategy where remediation is required; and
- Detail the ground conditions and their geotechnical properties enabling outline foundation proposals to be made.

2.4 Scope of Investigation

This document is split into two sections. These constitute the findings of the Phase 1 and Phase 2 investigations, consecutively.

2.4.1 Phase 1

The Phase 1 investigation involved a review of information extracted from published documentation as well as that obtained from a site reconnaissance. Information regarding the current and former

land uses both on and surrounding the site, as well as the environmental sensitivity of the site location as determined by factors including geology, hydrogeology and hydrology have been examined.

Information analysed in this section of the report has been obtained from a variety of sources and included the following:

- Envirocheck Report
- Coal Authority Report
- Geological Maps and Associated Geological Memoirs; and
- A site walkover.

2.4.2 Phase 2

This part of the investigation consisted of intrusive works and laboratory analysis. The findings were used to test the conceptual model and produce a final risk assessment. The intrusive works comprised trial pits and rotary boreholes which were undertaken to enable:

- Examination of the shallow ground conditions;
- In situ description of soils, enabling any localised lateral and vertical changes in soil conditions to be logged;
- Assessment of any contamination identified using visual and olfactory methods;
- Collection of soil samples for chemical and Geotechnical testing; and
- An assessment of the likelihood of historical mining below the site at shallow depth.

2.5 Limitations of Investigation

This report is based on the assumption that the site will be developed with residential properties, each with private gardens and areas of hardstanding. The dwellings will be of conventional construction and will be three storeys or less in height, and it is assumed that existing ground levels will not alter significantly. If this is not the case, then the advice given in this report may not be appropriate.

Where assessments of site areas affected in particular ways are given, these are approximate. All information, comments and opinions given in this report are based on the ground conditions encountered during the site work, on the results of laboratory testing carried out as part of the investigation and information gained from a geological and historical desk study. However, there may be conditions at the site that have not been taken into account, such as unpredictable soil strata and water conditions between or below investigation points. It should be noted that groundwater levels vary due to seasonal or other effects, and may at times differ from those measured during the investigation.

This report considers the ground and groundwater and does not cover any buildings or their fabric or the constituents of any existing hardstanding materials. Generally, testing has only been carried out for contaminants identified as potentially present with no assessment made of biological contamination. Risks to ecological receptors, such as bats, have not been considered.

3.0 THE SITE

3.1 Description

The site has an area of approximately 0.16-hectarea and is located to the north of Darley Avenue, Ward Green in Worsbrough, Barnsley. The site is roughly rectangular shape and located at grid reference 434680, 404570. Access to the site can be gained via gate situated on Napier Mount to the east.

The site is currently undeveloped and is surfaced by overgrown grass. A small footpath is present in the north west of the site, which connects Fernbank Close with a footway along the west of the site. Household waste and litter is present along the southern and western boundaries of the site.

The southern boundary is bordered by a low metal bar wooden post fence. An approximately 1-metre-high brick wall borders the north and south west of the site. The eastern and western boundaries are bordered by a 1.8 m high metal palisade fence.

The site slopes to the south, with a gradient of around 1 in 25. The north of the site lies at approximately 129 m AOD, with the south of the site lying at around 128 m AOD.

In the surrounding area, residential properties are present to the north, east, south and west.

3.2 History

Historical Ordnance Survey maps obtained as part of the Envirocheck Report have been studied to assess the previous use of the site. Copies of the maps are presented in Appendix 2.

3.2.1 The Site

The earliest dated map, dated 1855 shows the site is comprised of agricultural fields.

By 1931, the site is occupied six semi-detached houses with associated rear gardens. No changes are then noted until 1960, by which time, a small structure is present north of the houses in the west of the site. The structure is likely a shed/outbuilding.

By 1972, two additional small structures are present on the site, one in the west and one in the east. These are also likely to be sheds. By 1993, the sheds have been demolished. The houses remain at this time.

Aerial photography from 2008 shows the houses on site have been demolished, with the site now shown as vacant.

3.2.2 The Surrounding Area

The earliest dated map 1855 shows the surrounding land is predominately dominated by agricultural land. High Stone Wood is located directly north of the site. High Stone Road is located approximately 25 m east of the site, trending north west to south east. Wells are shown approximately 25 m north east of the site and 80 m north of the site. Mount Vernon Sanatorium was located 260 m north east of the site. The surrounding area is labelled as Ward Green. A number of sandstone quarries are present, one located 275 m north east, one located 450 m north and 475 m east of the site. A number of collieries are present in the wider surrounding are, including Prince Albert Colliery located approximately 800 south west of the site, Victoria Colliery approximately 750 m north west of the site and Bell Ing Colliery approximately 750 m south east.

By 1894 Bell Ing Colliery has been replaced with terrace housing and Highstone Plantation is shown around 240 m north east of the site.

The map dated 1907 shows a number of old air shafts in the surrounding area, suggesting that mine workings are progressing.

By 1932, the surrounding open agricultural has been replaced with housing. Barnsley town centre, located to the north of the site experiences residential expansion. Allotment gardens are located 300 m north east of the site. The sandstone quarries in within the surrounding area are shown to be infilled, and have been replaced by playing fields and buildings.

The map dated 1948 shows the land to the south east to is no longer predominantly agricultural land, having been replaced by residential development. The area is now labelled as Worsbrough. The agricultural land around 100 m north west of the site has also been replaced by residential properties.

By 1978, the Mount Veron Sanatorium has been replaced with a hospital.

During the 1980's, the land to the south east of the site, is developed with residential properties.

By 2021, the hospital located 260 m north east of the site has been demolished and the land is shown to be vacant.

No further significant changes are indicated to the present day.

3.3 Geology

The geological maps, SE30SW and SE30SE (1:10,000 scale), Yorkshire 274 SE (1:10,560 scale), Sheet 87 'Barnsley' (1:50,000), the geological memoirs, and the British Geological Survey (BGS) Online Viewer have been consulted.

The solid geology beneath the site is expected to comprise the Pennine Middle Coal Measures Formation (i.e., interbedded mudstone, siltstone and sandstone with coal seams). Undifferentiated mudstones are indicated to directly underlie the site. The strata are shown to dip to the north east at 4° to 5° in the surrounding area.

No superficial deposits are shown to underlie the site and no faults of other lines of weakness are indicated to cross the site at surface.

There is limited BGS borehole information in the surrounding area, although from information freely available on the planning portal, a borehole investigation was previously undertaken at Highstone Lane, approximately 100 m north east of the site. The investigation generally encountered made ground to depths of up to 1.8 m, followed by mudstone to depths between to 5.4 m, underlain by sandstone to depth of between to 7.7 m, followed by siltstone to a maximum depth of 8.8 m bgl. The investigation encountered 0.7 m to 0.8 m thick band of coal between 7.1 m and 7.7 m bgl.

3.4 Hydrogeology

3.4.1 Groundwater Vulnerability

The underlying bedrock is classified as a Secondary A Aquifer comprising permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

3.4.2 Groundwater Abstractions

There are no groundwater abstractions within 500 m of the site boundary.

3.5 Hydrology

The Envirocheck records the nearest surface water feature lies around 234 m to the south east of the site, the water feature is likely a drain.

Information within the Envirocheck states that the site does not lie within a groundwater Source Protection Zone.

3.6 Extractive Industries

3.6.1 Coal Mining

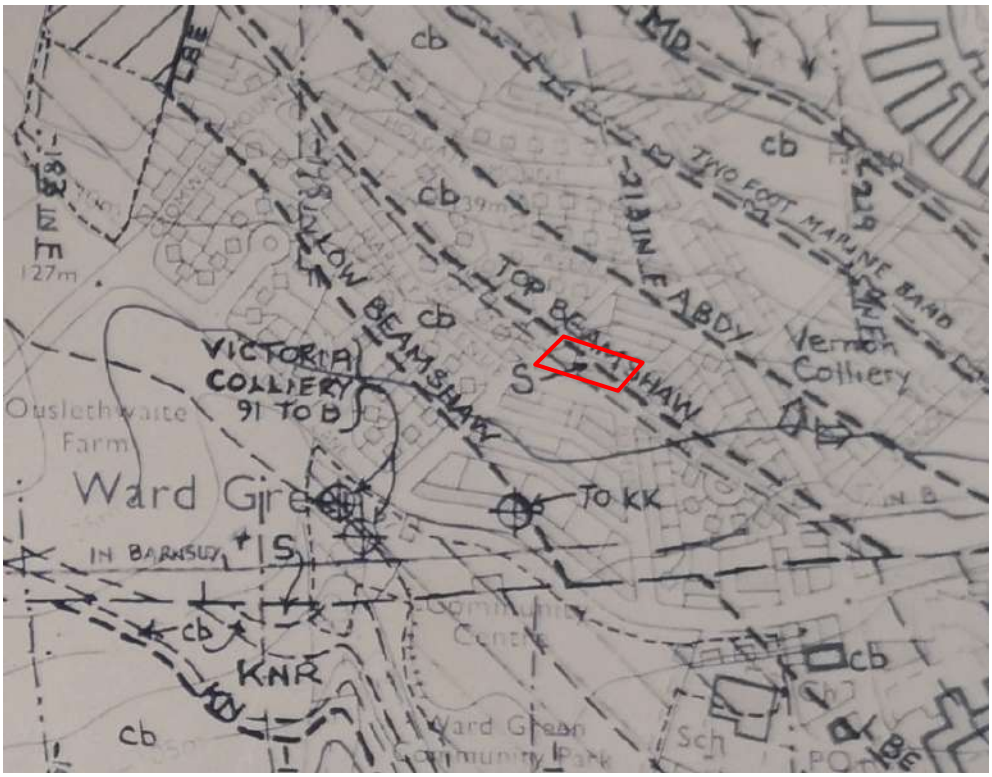
According to the geological maps, a seam of coal is conjectured to outcrop on the site, across the northern half, dipping northwards. This is the Top Beamshaw Coal. According to the geological memoirs for Barnsley, the Top Beamshaw Coal seam is around 0.9 m thick. The memoirs indicate that the seam is sometime worked in the area north of Barnsley, but that around the town centre and to the south, it deteriorates in quality and is rarely exploited.

The next shallowest seam expected below the site is the Low Beamshaw Coal Seam. This seam outcrops approximately 100 m south west of the site. According to the geological maps, the seam is between 0.46 m and 0.61 m thick to the north of Barnsley, but again deteriorates to become mixed with shale southwards, and thus is of little value. Given the dip and direction in strata to the north east, the Low Beamshaw Coal seam is generally expected to underline the site at shallow depth, around 8 to 9 m bgl. Workings are not expected in the seam, however.

For there to be no significant risk to developments from voids caused by mining migrating to the surface, it is generally accepted that there should be ten times the seam thickness of competent ground above the workings and below the proposed foundation level. If workings are present in the Top Beamshaw and Low Beamshaw, there may not be sufficient competent strata above the seams, and thus may present a significant risk to developments on the site.

The next shallowest coal seam is the Kent's Thin Coal, outcrops approximately 350 m south west of the site. According to the geological memoirs the coal is between approximately 0.3 m and 0.6 m thick, the geological maps state the coal is between 0.62 m and 1.52 m thick. Given the dip and direction in strata to the north east, the Kent's Thin Coal seam is expected to underline the site at shallow depth, between 24 m and 30 m bgl. The memoirs do not specifically mention workings in this seam in the vicinity of the site, but note that the coal is persistent in presence, thickness and quality. It is possible that the seam will have been locally worked, but at the expected depth, workings are not likely to affect surface development.

Below is an extract of the geological map SE30SW (10:000), the site has been outlined in red:



A Consultants Coal Mining Report has been obtained and is included in the Appendix.

The report states that the Barnsley Coal, Top Fenton Coal, Parkgate Coal, Middleton Main Coal and Silkstone Coal have been extracted from beneath the site. Details of the extraction are shown below.

Seam	Depth (m)	Dip (degrees) and Direction	Extraction Thickness (m)	Year Last Mined
Barnsley	122	6.1	2.52	1875
Top Fenton	342	6.1	1.07	1955
Parkgate	359	5.7	1.28	1960
Middleton Main	382	5.7	1.40	1938
Silkstone	444	5.0	2.00	1924

Furthermore, the report states that the site does lie within an area with probable unrecorded shallow workings. This maty refer to the Beamshaw Coals, or to the Kents Thin Coal

There are no recorded mine entries on the site. The Coal Authority's records may however, be incomplete and therefore further mine entries could exist of which the Coal Authority has no knowledge. The Coal Authority record five adits and a single mine shaft from approximately 65 m east of the site.

Three abandonment mine plans are recorded to intersect the site boundary. The abandoned mine plans likely detail the extractions of the deep coal seams in the area.

There is one coal mining subsidence claim recorded within 50 m of the site, located directly to the west of the site. The location of this claim is shown on the enquiry boundary map, at the end of the appended Coal Authority report. The mining subsidence claims are likely due to past longwall mining at depth (i.e., extraction of the Parkgate and Silkstone coal seam in the 1960s). As most subsidence from longwall mining occurs within two months after coal extraction, further mining subsidence is not expected to affect the site. There is no current Stop Notice delaying the start of remedial works or repairs to the property.

The Coal Authority is not aware of any request having been made to carry out preventive works before coal is worked under section 33 of the Coal Mining Subsidence Act 1991. There are no records of mine gases within 500 m of the site and there are no mine water treatment schemes within 500 m of the site.

The property is not within 200 m of an area where the Coal Authority has plans to grant a license to remove coal by underground methods.

No notices have been given under section 46 of the Coal Mining Subsidence Act 1991, stating that the land is at risk of subsidence. The property is not in an area where a notice has been given under section 41 of the Coal Industry Act 1994, cancelling the entitlement to withdraw support.

There are no Coal Authority managed tips within 500 m of the site.

Based on the above, the Top and Low Beam shaw coals may be present a risk to the site if tthey have been worked in the past. A borehole investigation is required to confirm. If workings are present wpthin the Kents Thin Coal, these are not expected to affect the development.

3.6.2 Sandstone Quarrying

The 1850s historical maps noted a couple of sandstone quarries within 500 m of the site, notably around 250 m east of the site and 450 m north of the site. Historical maps show the quarries were infilled by the 1930's. N workings are indicated to extend onto the site.

3.7 Ground Gas

Radon

According to the Envirocheck, the site lies within an intermediate probability radon area (1 to 3% of homes are estimated to be at or above the Action Level). Therefore, no radon protective measures are necessary.

Landfill and Other Ground Gases

Historically, the site has been occupied by semi-detached houses with associated areas of soft landscaping. According to historical mapping the houses were demolished by 1993. Since, the site has remained vacant.

The Envirocheck records two landfill sites (historical and Local Authority recorded) within 250 m.

The Envirocheck records the historical landfill to be located 150 m south west of the site. The landfill was active between 1981 and 1989. Inert, industrial and commercial waste was recorded to be deposited within the landfill. The Local Authority Landfill Site is located 169 m south west of the site; however, the deposited waste and years active are unknown. Due to the distance from the site, the historical landfills may pose a risk of ground gas generation to the site

The Envirocheck records three potentially infilled feature within 250 m of the site, located 195 m south west of the site, 210 m south of the site and 239 m north east of the site.

The potentially infilled features located 195 m south west and 210 m south of the site are likely associated with former ponds. The potentially infilled feature located 239 m north east of the site is associated with a former sandstone quarry. According to historical mapping the sandstone quarry was infilled by 1892.

Given the past development on the site, made ground is likely present below the site. However, it is not expected to be of significant thickness and significant amounts of organic and other degradable material are not expected to be present. No significant risk of gas generation should therefore be presented.

The Top Beamshaw is recorded to outcrop across the site. The Low Beamshaw and Kent's Thin Coal seams are anticipated to underlie the site at shallow depths. If shallow mine workings are encountered these could also be a source of ground gas.

Due to the landfills within 250 m of the site, a programme of gas monitoring is considered to be required, to confirm the level of gas precautions necessary, if any, for a residential development.

3.8 Pollution Incidents to Controlled Waters

The Envirocheck records two pollution incidents within 250 m of the site. The incidents occurred in 1989 and 1994, with the incidents located 179 m south east and 245 m south east of the site. Both incidents were classified as Category 2 – Significant Incident. The pollutant was unknown for the incident 179 m south east of the site. The pollutant in incident 245 m south east of the site is listed as mud/clay or soil.

Due to the distance and date of the pollution incidents, these incidents are not considered to pose a significant risk to the site.

3.9 Local Authority Pollution Prevention and Controls

The Envirocheck does not list any controls within 250 m of the site.

3.10 Discharge Consents

According to the Envirocheck, there are three discharge consents within 250 m of the site, relating to storm sewage overflow discharges, dated 1989, 2003 and one undated. The consent dated 1989 was revoked in 2003. These are not expected to affect the site.

3.11 Flooding

Information provided in the Envirocheck Report does not show the site to lie within a flood plain.

The site is not at shown to be at risk from surface water flooding.

3.12 Soil Geochemistry

The Envirocheck estimates the following concentrations of arsenic, cadmium, chromium, nickel and lead to be present in the natural soil at the site. These have been compared to the appropriate assessment value protective of residential human health receptors with homegrown produce:

Contaminant	Estimated Concentration (mg/kg)	Assessment Value (mg/kg)
Arsenic	25 to 35	37
Cadmium	<1.8	11
Chromium	60 to 90	910
Lead	100 to 200	200
Nickel	30 to 45	180

Given the above, no naturally elevated concentrations of metals/metalloids are anticipated.

3.13 Contemporary Trade Directory Entries and Fuel Station Entries

There are three active and inactive contemporary trade directory entries recorded within 250 m of the site. The trade entries include a pest and vermin control company and an oven cleaning company.

There are no fuel stations within 500 m of site.

4.0 OUTLINE CONCEPTUAL MODEL

4.1 Potential Sources of Contamination

Historically, the site was occupied by semidetached residential properties. The properties were built in around 1931 and were demolished by 1993 and the site has remained vacant since.

Any made ground which is present on the site may contain elevated concentrations of metals/metalloids, polycyclic aromatic hydrocarbons (PAHs) and sulphates. Asbestos containing materials would not generally be expected in houses of this age, but may have been introduced during subsequent building works or other refurbishments. Fibres could therefore be present within the soils.

4.2 Ground Gas

No radon protective measures are required.

No significant thickness of made ground is expected on the site. If shallow mine workings are encountered these could be a source of ground gas. Due to the landfills recorded within 250 m of site, a gas monitoring programme is considered to be required to confirm the level of gas precautions necessary, if any, for a residential development.

4.3 Potential Pollutant Linkages

The following table details the possible sources and associated contaminants of concern, pathways and receptors, highlighted by the Phase 1 as potentially present.

Source	Potential Contaminants	Potential Pathways	Potential Receptors
Made ground	Heavy metals/metalloids Asbestos PAHs TPH	Ingestion Inhalation Direct contact Biological uptake Migration through ground	Site residents and visitors to the site Site construction workers Secondary A Aquifer Plants Water supply pipes
	Asbestos	Inhalation of fibres	Site residents and visitors to the site Site construction workers
Made or natural ground	Sulphates Low pH	Direct contact	Below ground concrete
Off-site landfills within 250 m of the site. Shallow mine workings.	Ground gas and mine gas	Migration through ground	Site residents and visitors Construction workers Buildings

5.0 GROUND INVESTIGATION

5.1 Site Works

Eastwood CE visited site on 20 August 2022 and excavated six trial pits (TP01, TP02, TP02A, TP03, TP04 and TP05) and one hand-dug pit (HP01) in order to determine the underlying ground conditions. The trial pits reached depths of between 0.71 m and 3.6 m below ground level (bgl). The hand-dig pit reached a depth of 0.3 m bgl.

Eastwood CE later visited the site on 8 September 2022 and undertook the drilling of three rotary boreholes to 30 m bgl, in order to determine the depth and conditions of the Top Beamshaw Coal, Low Beamshaw Coal and Kent's Thin Coal. The boreholes were completed using water flush drilling as stipulated by the Coal Authority permit which was obtained prior to commencement.

Copies of all trial pit logs are presented in Appendix 4, and their locations are plotted on the Exploratory Hole Location Plan, Drawing number 47287/001 revision A in Appendix 1.

5.2 Laboratory Testing

Three samples of topsoil, two samples of topsoil made ground, four samples of made ground and two samples of natural ground were despatched for chemical testing. Soil samples were taken in 1 kg plastic tubs and 250 ml amber glass jars. All samples were analysed at Eurofins Chemtest Limited, using MCERTs accredited methodologies where available. The chemical test results are presented in Appendix 3 and discussed further in Sections 7 and 8.

Three samples of natural ground were sent to Professional Soils Laboratory for geotechnical testing. The geotechnical test results are presented in Appendix 4 and are discussed in Section 7.0.

6.0 GROUND CONDITIONS

6.1 Surface Covering

The site is surfaced by grass over topsoil and topsoil/made ground to depths of between 0.15 m and 0.5 m bgl. The topsoil comprised slightly gravelly slightly sandy clay with gravel of pottery, glass and brick. The topsoil/made ground generally comprised slightly sandy gravelly clay with gravel of limestone, quartzite, clinker and rare coal.

A small section of the site in the west is surfaced by a concrete slab which is 100 mm in thickness.

6.2 Made Ground

Made ground was encountered in three trial pits, TP01, TP02 and TP02A. The trial pits were located in the south of the site.

The made ground comprised gravel of limestone (hardcore) to depths of between 0.3 m and 0.4 m bgl, followed by stiff slightly sandy gravelly clay, where the gravel included brick, slate, coal and limestone and extended to depths of between 0.8 m and 1.1 m bgl.

Cobbles of brick were encountered in TP02 and TP02A from 0.4 m to 0.6 m bgl, likely associated with foundations of the previous development on the site. No intact footings were encountered, however.

6.3 Natural Ground

Natural ground was encountered in every trial pit.

The natural ground generally comprised stiff slightly sandy slightly gravelly clay, with gravel of mudstone, ironstone nodules and occasional coal to depths of between 1.3 m and 2.4 m bgl. Beneath the stiff clay, clayey gravel of mudstone, shale with occasional ironstone nodules was encountered to depths of between 2.4 m and 2.7 m bgl. Underlain by extremely weak and very weak mudstone bedrock recovered as angular to subangular clayey gravel. Mudstone bedrock with sandstone bands was encountered from depths of between 2 m and 4 m bgl. In BH03, weathered sandstone bedrock was encountered at depths of between 1.5 m and 4 m bgl.

A 300 mm to 500 mm band of mudstone with coal traces was encountered across the site at depths of between 4 m and 6.5 m bgl.

6.4 Coal

A 100 mm thick band of clayey coal was encountered in TP05 at depth of between 2 m and 2.1 m bgl. Due to depths of the coal band, the coal may be the outcropping Top Beamshaw Coal seam.

A 600 mm to 700 mm thick band of coal was encountered in all three rotary boreholes. The coal was encountered at depths of between 10.4 m and 13 m bgl. Due to the depth and thickness of the coal encountered, the coal is likely the Low Beamshaw Coal seam.

Loss of flush was recorded in BH01 from depth of between 21 m bgl. This is not expected to represent mine workings, however, but may be indicative of either a weathered band of material at depth, or fracturing caused by deeper mine workings. The Kent's Thin Coal was not encountered in any of the boreholes. The remaining boreholes recorded no evidence of shallow coal workings (i.e., voids, soft/broken drilling or loss of flush).

6.5 Groundwater

No groundwater was encountered in any of the exploratory holes.

6.6 Evidence of Contamination

Visual or olfactory evidence of possible significant contamination was not identified in any of the exploratory holes. In addition, no evidence of any organic matter was identified in the exploratory holes.

7.0 GEOTECHNICAL APPRAISAL

The proposed development is to comprise six low-rise residential properties of conventional construction, with associated private gardens and driveways.

Topsoil and topsoil/made ground surface the site to depths of between 0.15 m and 0.5 m bgl. In the south of the site, made ground comprising of gravel of limestone (hardcore) to depths of between 0.3 m and 0.4 m was encountered underlain by stiff slightly sandy gravelly clay, with gravel of brick, slate, coal and limestone to depth of between 0.8 m and 1.1 m bgl.

Below the made ground, natural ground comprising of stiff slightly sandy slightly gravelly clay with gravel of mudstone and iron nodules was encountered to depth of between 1.3 m and 2.4 m bgl, followed by a clayey gravel of mudstone and shale to depth of between 2.4 m and 2.7 m bgl, underlain by extremely weak and very weak mudstone bedrock. No groundwater was encountered.

A hand shear vane test was undertaken in the cohesive made ground in TP01, with a shear strength of 146 kN/m2 being recorded, which is indicative of a stiff clay.

Eight hand shear vane tests were undertaken in the natural clay, with shear strengths of 54 kN/m2 and 195 kN/m2 being recorded, which is indicative of firm to very stiff clays.

A bearing capacity 100 kN/m² is considered appropriate for the natural cohesive soils, which will increase with depth.

Three samples of natural cohesive ground were sent for geotechnical testing. The results are enclosed in Appendix 4 (PSL22/4962) and summarised below:

Trial Pit	Depth (m)	Material	Moisture Content (%)	Liquid Limit (%)	Liquid Limit x 0.4 (%)	Potentially desiccated?	Modified Plasticity Index (%)	Volume Change Potential*
TP02	1.2	Slightly sandy CLAY	26	46	18.4	No	26	Medium
TP03	0.7	Slightly gravelly CLAY	23	56	22.4	No	34	Medium
TP04	3.2	MUDSTONE, recovered as gravel	11	43	17.2	Yes	17.4	Low

Assuming a worst-case scenario, given the above, the natural clay at the site should be regarded as being of medium volume change potential in accordance with NHBC Chapter 4.2 guidance.

The Party Wall Act will need to be considered for structures associated with neighbouring properties along the site boundaries.

7.1 Coal Mining Assessment

A rotary borehole investigation has been undertaken to ascertain the presence and extent of any workings in the Top Beamshaw Coal, The Low Beamshaw Coal and the Kent's Thin coal. The Top Beamshaw Coal was expected to outcrop in the east of the site.

A 100 mm thick band of clayey coal was encountered in TP05 at depth of between 2 m and 2.1 m bgl. Due to depths of the coal band, the coal may be the outcropping Top Beamshaw Coal seam.

A 600 mm to 700 mm thick band of coal was encountered in all three rotary boreholes. The coal was encountered at depths of between 10.4 m and 13 m bgl. Due to the depth and thickness of the coal encountered, the coal is likely the Low Beamshaw Coal seam.

Loss of flush was recorded from 21 m in BH01. No voids or broken/soft ground were recorded. The loss of flush may be indicative of deeper collapse workings, or a band of weaker material within the bedrock. Given that no other coal was encountered to 30 m bgl, there is expected to be at least ten times seam thickness of competent cover over any workings that are present within the Kent's Thin Coal.

We therefore consider that no remedial measures are required for the proposed residential development, due to past mining, across the site. Any excavations on the site should be inspected for signs of prior disturbance, which may indicate the presence of shafts, adits or bell pits. Such features will need to be treated, if encountered. This is considered unlikely, however.

7.2 Foundations

For the proposed low rise housing scheme, the most suitable foundations are considered to be strip or trench fill footings, taken through any made ground, soft or loose ground and into the natural firm to stiff clay. A minimum foundation depth of 900 mm from finished or original ground level, whichever is lower, will apply for foundations within the natural clay.

Where foundations are within influencing distance of past, present or proposed trees in or over cohesive ground, the footing depth will need to be increased in accordance with the NHBC Standards Chapter 4.2. Precautions against soil heave due to the influence of past or present trees are likely to be required wherever the footing depth is increased to greater than 1500 mm.

7.3 Ground Floors

Where less than 600 mm of made ground is present, ground bearing slabs can be considered. Elsewhere, reinforced suspended slabs or precast concrete floors with a minimum 150 mm high ventilated void should be used.

If the footings require heave precautions due to trees, a precast concrete floor with a ventilated void will be required. This void should be a minimum of 250 mm high.

7.4 Superstructure Precautions

No additional superstructure precautions will be required due to the ground conditions encountered.

7.5 Excavation Problems and Obstructions

Temporary support will be required in accordance with current Health & Safety Regulations wherever access is required to trenches deeper than 1.2 m or less where there is risk of collapse.

7.6 Surface Water Drainage

Given the cohesive nature of the ground encountered across the site, soakaway drainage is not considered to be a viable form of surface water drainage for the site. A piped discharge will be required, with on site attenuation.

8.0 REFINEMENT OF OUTLINE CONCEPTUAL MODEL

8.1 Source Characterisation

An outline conceptual model, detailing the possible sources and associated contaminants of concern, potential pathways and receptors identified in the phase 1 study was detailed in Section 4.0.

This section of the report documents the works undertaken to obtain information to test and refine this model enabling a risk assessment to be produced and, where significant risks are expected, remediation recommendations.

8.2 Investigation of Potential Contamination Sources

The investigation works undertaken to cover each of the sources of potential contamination outlined in Section 4, are detailed in the table below:

Source	Potential Contaminants	Exploratory hole used to investigate source
Made ground	Heavy metals/metalloids Asbestos PAHs TPH Asbestos	Made ground was encountered in four exploratory holes, TP01, TP02, TP02A and TP03.
Made or natural ground	Sulphates Low pH	Made ground was encountered in four exploratory holes, TP01, TP02, TP02A and TP03. Natural ground was encountered in every exploratory hole.
Off-site landfills within 250 m of the site.	Ground gas	Three ground and gas monitoring wells installed in BH01 to BH03, across the site.
Shallow mine workings.	Mine gas	Three rotary boreholes sunk to confirm the absence of shallow workings.

8.3 Gas Precautions

No radon protective measures are required.

No significant thickness of made ground was encountered on the site.

Shallow mine workings were not recorded in any of the rotary boreholes.

Due to the landfills recorded within 250 m of site, a gas monitoring programme is underway to confirm the level of gas precautions necessary, if any, for a residential development.

Combined gas and groundwater wells have been installed within the rotary boreholes, BH01, BH02 and BH03. Six rounds of gas monitoring are proposed of which one has been completed to date. The results are included in Appendix 4, and summarised below:

- No detectable methane concentrations have been recorded;
- A maximum carbon dioxide concentration of 5.8% has been recorded;
- A maximum carbon monoxide concentration of 7 ppm has been recorded;
- No detectable positive flow rates have been recorded; and
- Groundwater was recorded in BH03 at 2.3 m bgl.

8.4 Unexpected Contamination

No visual or olfactory observations of unexpected contamination were noted.

8.5 Chemical Testing

Three samples of topsoil, two samples of topsoil made ground, four samples of made ground and two samples of natural ground were sent for testing. Each of the samples was analysed for the suite of contaminants listed overleaf.

Contaminant Type	Actual Contaminants
Metals/Metalloids	Arsenic, cadmium, chromium, lead, mercury, nickel, selenium, copper and zinc
pH	pH
PAHs	Speciated PAH
Sulphates*	Water soluble sulphate, acid soluble sulphate, total sulphur
Asbestos**	Fibres

*Made and natural ground samples only

** topsoil and made ground samples only

In addition to the above testing the samples of made ground and natural ground were analysed for water soluble sulphate, acid soluble sulphate and sulphur. One sample of made ground was analysed for TPH CWG.

Testing was undertaken by Chemtest, using MCERTs accredited methodologies, where available.

8.6 Assessment Criteria

The proposed development of the site is to be residential with associated gardens. Therefore, the assessment criteria relating to a residential end use with homegrown produce have been used.

Tables detailing the relevant assessment concentrations used are included in Appendix 5.

8.7 Chemical Test Results

The test results (Chemtest report 22-27789-1) are presented in Appendix 5.

8.7.1 Topsoil and Topsoil/Made Ground

Three samples of topsoil, TP04 at 0.25 m, TP05 at 0.4 m and HP01 at 0.15 m, and two samples of topsoil made ground, TP01 at 0.1 m and TP03 at 0.2 m, were sent for chemical testing.

All five samples recorded concentrations of PAHs above their respective assessment values. A summary is provided in the table below.

Contaminant	Assessment Value ((1% SOM) (mg/kg)	Sample/Concentration (mg/kg)				
		TP04 0.25 m	TP05 0.4 m	HP01 0.15 m	TP01 0.1 m	TP03 0.2 m
Benzo(a)anthracene	7.2	19	5.7	4.2	8.2	5.0
Chrysene	15	18	5.3	4.0	8.5	3.8
Benzo(b)fluoranthene	2.6	21	7.2	5.8	8.4	5.1
Benzo(a)pyrene	2.2	19	6.7	5.4	<0.10	<0.10
Dibenz(a,h)Anthracene	0.24	2.1	0.71	0.60	<0.10	<0.10

No other elevated concentrations were recorded. No asbestos fibres were detected in any of the samples tested.

8.7.2 Made Ground

Three samples of made ground, TP01 at 0.3 m, TP01 at 0.8 m and TP02 at 0.5 m, were submitted for testing.

None of the samples recorded elevated concentrations of contaminates above their respective assessment values for human health or phytotoxicity.

TP01 at 0.8 m was also analysed for TPH CWG due to the presence of ashy material. All of the TPH concentrations were below the limit of detection.

No asbestos fibres were detected in any of the samples.

8.7.3 Natural Ground

Two samples of made ground, TP01 at 1.4 m and TP04 at 2 m were sent for chemical testing.

None of the samples recorded elevated concentrations of contaminates above their respective assessment values for human health or phytotoxicity.

8.7.4 Sulphates

In accordance with BRE Special Digest 1, the site comes under the classification of 'brownfield' and groundwater is expected to be mobile.

The following table displays the results of the made ground and natural ground samples tested:

Made Ground	**Range of Results**
Water Soluble Sulphate (mg/l)	10 to 16
Total Sulphur (%)	0.05 to 0.09
Total Potential Sulphate (%)	0.15 to 0.27
pH	8.1 to 9.2
Natural Ground	**Range of Results**
Water Soluble Sulphate (mg/l)	< 10 to 46
Total Sulphur (%)	0.031 to 0.060
Total Potential Sulphate (%)	0.093 to 0.18
pH	6.9 to 8.2

8.8 Significant Pollutant Linkages

The significant pollutant linkages consequently identified are thus documented in the following table:

Source	Pathway	Receptor
Elevated concentrations of PAHs in the topsoil.	Ingestion, inhalation, direct contact	Site residents and visitors Construction workers
Sulphates in the made ground	Direct contact	Below ground concrete
Off-site landfills within 250 m of the site	Migration through ground	Site residents and visitors Construction workers Buildings

9.0 RISK ASSESSMENT

9.1 Human Health: Future Site Users

No asbestos fibres were detected within any of the materials sampled.

Elevated concentrations of PAHs were detected in the topsoil and topsoil/made ground across the site. The concentrations were locally significantly above the respective assessment values. The topsoil materials are therefore not considered to be suitable for re-use.

Due to the limited site area, it is considered that the most practical course of action will be to strip the topsoil and topsoil/made ground form the site and to remove it to a suitable recycling facility.

The underlying made ground is considered to be chemically suitable to remain in situ. However, some extraneous materials were present within the made ground, and it is not aesthetically suitable to remain at surface. Where made ground is present in the garden and landscaped areas, it is recommended that a visual inspection is undertaken, with hand picking of any sharp fragments (i.e., glass or wire) and cobbles of extraneous material such as brick and concrete, before the addition of a minimum 150 mm thickness of topsoil to act as a growing medium for plants and grass. Landscapers may also ask for an increased thickness of cover over the made ground, in areas of proposed shrubbery or trees.

The natural ground is considered suitable for re-use in the residential development.

Alternatively, the existing topsoil and topsoil/made ground could be left in situ, with a capping layer of further inert topsoil placed above it. The capping layer would need to be a minimum of 600 mm thick, and would need to be separated from the existing material by a geotextile membrane to prevent soil mixing. The inert soil would need to be imported to site.

9.2 Human Health: During Construction

Groundworkers employed during the construction phase of the development are most at risk of harm due to them having direct contact with the affected soils. However, the contact is generally of short duration, and all competent ground workers will be aware of the potential risks associated with the made ground soils. Therefore, the overall risk to the health of construction workers is considered to be low.

Normal site procedures, such as the wearing of gloves when handling soils and the washing of hands prior to eating, should be implemented at all times.

9.3 Plants

None of the topsoil, made ground or natural ground samples recorded concentrations of phytotoxic metals elevated above the respective assessment values. Therefore, there is no significant risk to plant health.

A growing medium of inert topsoil is required in all gardens and soft landscaping areas. This layer is to be at least 150 mm thick.

9.4 Ground Gas

No radon protective measures are required.

A gas monitoring programme is currently ongoing. One round of monitoring, out of six, have been undertaken so far. The results are included in Appendix 5.

To date no detectable methane concentrations have been recorded. A maximum steady state concentration of carbon dioxide of 5.8% has been recorded, with a negligible gas flow rate. Using a maximum flow of 0.1 l/hr, gas screening values (GSVs) of 0.0 l/hr and 0.0058 l/hr are calculated (in accordance with BS8485 (2015) + A1 (2019)) for methane and carbon dioxide, respectively. The GSVs are below the upper threshold for 'CS1' characterisation. However, the maximum carbon dioxide concentration slightly exceeds the upper threshold for CS1 of 5%

At this stage, due to the maximum carbon dioxide concentration, we anticipate CS2 gas measures would be required for all plots. This would require the incorporation of a fully lapped and sealed gas resistant membrane within the plot's substructure. Further gas monitoring will be required to confirm this.

9.5 Construction Materials

Based on the chemical test results, using highest total potential sulphate results (0.27%), a design sulphate class of DS-2 and an ACEC class of AC-2 is considered appropriate for concrete in contact with the made ground.

For the natural ground, a design sulphate class of DS-1 and ACEC class of AC-1 is considered appropriate. Therefore, no sulphate precautions are required for below ground concrete in contact with the natural ground only.

The results of the chemical testing will need to be forwarded to the water company, so that appropriate water supply pipes can be selected.

9.6 Controlled Waters

The site does not lie within a Groundwater Source Protection Zone, the bedrock is classed as a Secondary A Aquifer, with the nearest surface water feature lies around 234 m to the south east of the site.

The elevated concentrations of PAHs within the topsoil and topsoil/made ground do not appear to be leaching or migrating into the underlying soils. The topsoil is expected to be removed from site.

A very low risk to controlled waters is therefore presented.

Standard good site practice during the construction phase of the development must still be adhered to in terms of surface water run-off control measures, to ensure there is no risk to controlled waters.

9.7 Unexpected Contamination

It is possible given the past use of the site, that there are areas of the site which are more significantly contaminated than areas of the site investigated to date.

Should any unusual, brightly coloured, ashy, fibrous or odorous material or material suspected of containing asbestos be encountered during construction this should be brought to the attention of the site staff and investigated.

9.8 Disposal of Material

If material needs to be removed, it should to be taken to a suitably licensed landfill or waste treatment facility. The costs of disposal and landfill tax can be substantial. The disposal of material should therefore be seen as a last resort with options such as treatment and reuse either on-site or off-site considered where possible.

The category of landfill which can accept the waste (inert, non-hazardous or hazardous) would need to be determined and will also have a significant effect on the costs. Additional testing may be required by the landfill operator and the acceptance of material is generally at their discretion.