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OCTOBER 2015

GEOENVIRONMENTAL APPRAISAL

of land off
CARRS LANE, CUDWORTH, BARNSLEY

prepared for
BARRATT & DAVID WILSON HOMES

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EXECUTIVE SUMMARY

Introduction	Sirius Geotechnical and Environmental Ltd (Sirius) were commissioned by Barratt & David Wilson Homes (BDW), to undertake a geoenvironmental appraisal at land off Carrs Lane, Cudworth, Barnsley, South Yorkshire (the "site"), to assist with planning, design and abnormal cost assessment. It is understood that BDW are considering developing the site for a low-rise residential end-use, comprising 263 two storey residential properties and 15 bungalows, with private gardens, areas of soft landscaping, Public Open Space (POS), areas of hardstanding, and highways. No loadings or development levels were known at the time of writing. **Sirius has previously compiled a geoenvironmental appraisal for the site in October 2014 (Report Ref: C6138A). Since the issue of the report the development layout, including the south eastern and south western site boundaries, have altered slightly and subsequently the development area has reduced. This current report makes reference to the updated development layout, however the conclusions and recommendations given within are based on the original, larger development area. Therefore this desk study should be read with consideration to the revised development layout plan.**
Site Details	The site forms an irregular shaped plot of land, which broadly slopes downwards from north to south east, with an elevation difference of up to c. 23m. The north western part of the site slopes downward from north to south west. The site generally comprises a set of agricultural fields defined by a combination of semi-mature / mature trees and low-lying shrubs. A set of electricity pylons are recorded within the southern portion of the site, aligned east to west and north to south. An unknown brick structure was identified to the sites north eastern portion during the initial walkover survey in September 2014. Upon closer inspection during the recent intrusive investigation, it is considered that this may be representative of a well. Along the sites northern and north eastern perimeters, are a number of areas of fly-tipped material including wood, soil, plastic, fabrics, glass, brick and concrete. The sites western and north western flanks are formed by retaining walls and a quarry high wall.
Site History	Review of historical Ordnance Survey maps indicates that the site has been agricultural fields since at least 1854. A number of buildings and a pump (latterly demolished) were shown to the sites south eastern portion between 1854 and 1955. Significant off-site features include a former railway line, with historic associated airshaft / mine entry, gasometer and goods shed to the immediate west of the site. In addition, to the west / north west was a quarry. A reservoir was shown to the immediate north west of the site between c. 1906 and 1984, which was later infilled and is referred to as a historical landfill site.
Fieldwork	Fieldwork was undertaken between 16th and 24th September 2014 and comprised: • Boring of 10 window sample boreholes (WS1 to WS10) to a maximum depth of 4.50m bgl. • Eight openhole rotary probes (RO1 to RO7, and RO1A), drilled to a maximum depth of 30.00m bgl using a combination of water and air flush techniques. • Excavation of 37 trial pits (TP1 to TP37) and six trial trenches (TT1 to TT6), to a maximum depth of 3.50m bgl. • Soakaway tests undertaken within five trial pits (SA1 – SA5), excavated to a maximum depth of 2.50m bgl, to determine the suitability of the soils for soakaways. Permanent monitoring installations for both groundwater and ground gas monitoring were installed within selected window sample boreholes, namely WS1, WS2, WS3, WS4, WS5, WS6 and WS7, all sealed into the made ground.
Laboratory	Samples of soil and soil leachate were submitted for analysis of a range of metals, other inorganic and organic components. Geotechnical testing was scheduled on selected samples.

Testing	All testing was undertaken at accredited laboratories.
Ground Conditions	Reworked topsoil, and locally made ground, was encountered across the site to depths between 0.15m and 0.55m bgl, which was found to be underlain by, in the main, granular residual soils. Cohesive residual soils were encountered in the eastern and south eastern parts of the site. Residual granular soils were generally described as medium dense to dense gravelly sand / sandy gravel / sand and gravel / gravelly clayey sand, of sandstone. The residual cohesive soils were described as firm to very stiff, generally medium to high strength, slightly sandy clay, with occasional gravel of sandstone, siltstone and locally mudstone. Bedrock, generally described as extremely / very weak and weak sandstone, with interbeds of siltstone, mudstone and coal, was proven at depths between 0.50m and 2.80m bgl. Locally, within WS3, WS4 and WS5, at depths between 1.40m and 4.20m bgl, very weak thinly bedded siltstone was recorded. Rotary drilling undertaken at the site has identified one coal seam, considered representative of the Sharlston Low Coal. The coal seam was proven to be worked in one of the eight boreholes drilled. This investigation has proven that potentially workable coal exists within influencing distance of the surface in the western part of the site. Elsewhere the coal should, even if worked, be too deep to affect surface stability.
Ground Stability	Based on published geological information, a mining report and the results of rotary drilling, it is considered that there is a risk of surface subsidence as a result of potential shallow coal mining in the western portion of the site. A supplementary rotary probing investigation is recommended to confirm the presence / absence of mine workings beneath this part of the site. If workings are found within influencing distance of the surface, drilling and grouting will be required (or coal removal), with appropriate precautions taken in foundations. For adoptable highways, the scope of works would need to be approved by the local highways department. A strip to natural ground is recommended as part of the enabling works to inspect for any disturbed ground associated with possible historic bell pits / mine entries / shallow crop workings. Inspection of historical OS plans has revealed the presence of a former quarry / quarry high wall to the sites north western / western perimeter. The possibility of encountering unrecorded quarries on site cannot be wholly discounted. It is therefore recommended that all excavations be examined for evidence of such features. If evidence of these features is suspected works should cease and the advice sought of a suitably qualified consultant. Furthermore with regards to the quarry high wall it would be prudent to undertake a visual assessment of the rock face by a suitably qualified Engineer in order to ascertain the stability of the feature and the potential risk of impacting the development site.
Foundations and Floor Slabs	**The recommendations provided below are based on the assumption that appropriate treatment of shallow mine workings (i.e. drilling and pressure grouting) will be undertaken, if proven necessary.** Reinforced spread foundations (strip/trench fill) are considered generally appropriate, taken through reworked topsoil and made ground to found within the underlying cohesive or granular residual soils of adequate bearing capacity. If foundation excavations encounter bedrock, all foundations should be placed within this material. Alternative foundation solutions may be required where deep made ground exists or very shallow coal mine workings are proven/treated. If coal is encountered in foundation excavations, the foundation excavation should be extended through the coal seam into competent strata below. At this stage ground bearing slabs are anticipated across the majority of the site, but this will need to be confirmed following completion of a tree survey, and when gas monitoring is completed and final levels established.
Sulphate Class	DS-1 and an ACEC Class of AC-1.
Contamination	No specific remedial measures are anticipated for a proposed residential end-use.
Gas Protection	Based on the gas monitoring results recorded to date, it is considered that in accordance with Table 2 presented in BS8485:2015, the soil gas regime can be classed as Characterisitc Situation (CS) 1. For the proposed residential development,

	CS1 does not require special precautions with regards to ground gas. The above assessment should be regarded as interim only however, prior to completion of the monitoring programme. A further five gas/groundwater monitoring visits are programmed prior to finalising gas protective measures. Radon protection measures are not required for the proposed development.
HS2	The property is located a short distance to the east of the proposed HS2 network railway line, the position of which is still to be confirmed. BDW should be cognisant of the proposed rail line in any future transaction for the site, and it would be prudent to take legal advice in determining its implication on the proposed development.

The executive summary is an overview of the key findings and conclusions of the report. There may be other information contained in the body of the report which puts into context the findings of the executive summary. No reliance should be placed on the executive summary in isolation, particularly when deriving design detail/abnormal costs.

1. INTRODUCTION

Sirius Geotechnical and Environmental Ltd (Sirius) were commissioned by Barratt & David Wilson Homes (BDW), to undertake a geoenvironmental appraisal of land off Carrs Lane, Cudworth, Barnsley, South Yorkshire (the "site"), to assist with planning purposes, design and abnormal cost assessment.

It is understood that BDW are considering developing the site for a low-rise residential end-use, comprising 263 two storey residential properties and 15 bungalows, with private gardens, areas of soft landscaping, Public Open Space (POS), areas of hardstanding, and highways. A proposed development layout plan (as reproduced from Urban Design Revision D, dated 23rd September 2015) is included in Appendix A, as Drawing No. C6138/02. No loadings or development levels were known at the time of writing.

The geoenvironmental appraisal has been undertaken in two phases; an initial preliminary appraisal (desk study), followed by an intrusive investigation. The desk study was completed by Sirius in October 2015 (Sirius Report Ref. C6138 Rev 1) and included an assessment of information provided by Landmark Information Group (LIG), the Coal Authority (CA) and the British Geological Survey (BGS). The desk study presented an initial conceptual site model (CSM) from which the intrusive investigation rationale was derived.

Sirius has previously compiled a geoenvironmental appraisal for the site in October 2014 (Report Ref: C6138A). Since the issue of the report the development layout, including the south eastern and south western site boundaries, have altered slightly and subsequently the development area has reduced. This current report makes reference to the updated development layout, however the conclusions and recommendations given within are based on the original, larger development area. Therefore this desk study should be read with consideration to the revised development layout plan.

This report details the results of the intrusive investigation and makes recommendations relating to the proposed development. This report should be read in conjunction with the Sirius desk study. The objectives of this appraisal were to:

- Summarise the historical development and environmental setting of the site and surrounding area from a review of a previous desk study report;
- Investigate near surface soil and groundwater conditions;

- Determine the potential risks posed by any ground contamination and provide recommendations on remedial measures to manage such risks;
- Determine the potential risk to the development from hazardous ground gas sources, including radon;
- Evaluate whether past mining or other extractive industries could have an influence on the surface stability of the site;
- To determine infiltration characteristics of shallow soils to enable others to design soakaways, if viable; and,
- Provide recommendations for foundations, floor slabs and highway/pavement design for the proposed development.

Fieldworks undertaken by Sirius comprised the boring of 10 window sample boreholes, the drilling of eight open hole rotary probeholes, the excavation of 37 trial pits, six trial trenches and an additional five trial pits to enable soakaway tests to be completed. The fieldwork was undertaken by Sirius between 16th and 24th September 2014.

This report presents the factual information available during this appraisal, interpretation of the data obtained and recommendations relevant to the defined objectives.

It has been assumed in the production of this report that the site is to be developed for a low-rise (two storey) residential with gardens end-use. In addition, it is assumed that ground levels will not change significantly from those described in this report. If this is not the case, then amendments to the recommendations made in this report may be required.

Where the report refers to the potential presence of invasive plants (such as Japanese Knotweed) or asbestos-containing materials (ACMs), such observations are for information only and should be verified by a suitably qualified expert.

The comments and opinions presented in this report are based on the findings of a previous desk study, ground conditions encountered during intrusive investigation works performed by Sirius and the results of tests carried out within one or more laboratories. There may be other conditions prevailing on the site, which have not been revealed by this investigation and which have not been taken into account by this report. Responsibility cannot be accepted for any conditions not revealed by this investigation. Any diagram or opinion on the possible configuration of strata, contamination or other spatially variable features between or beyond investigation positions is conjectural and given for guidance only. Confirmation of ground conditions between exploratory holes should be

undertaken if deemed necessary. Evaluation of ground gas and groundwater is based on observations made at the time of the investigation and subsequent monitoring visits. It should be noted that ground gas, groundwater levels and quality may vary due to seasonal variations and other effects.

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2. SITE DETAILS AND DESCRIPTION

Table 2.1 Current Site Overview

Location	The site is located off Carrs Lane, Cudworth, approximately 4km north east of Barnsley town centre. A site location plan is included as Drawing No. C6138A/01 within Appendix A.
National Grid Reference (NGR)	438650mE, 408150mN.
Topography and Features	The site forms an irregular shape, with its long axis running north to south. The site broadly slopes downwards from north to south east, with an approximate elevation difference of up to 23m. Locally, within the northern part of the site, there is an approximate elevation difference of between 9-16m, with the downward slope recorded from the central portion of the site to the east and west. The north western perimeter of the site forms part of a presumed historical quarry high wall; vertical remnants of the quarry high wall are visible. The quarry high wall has an elevation difference of between c. 1.50m and 20m between the site and the base of the quarry / former dismantled railway line to the west. In addition, along part of the sites western / north western boundary is a c. 0.50m to c. 1.50m high brick retaining wall. The retaining wall was noted to be in relatively 'good' condition, apart from some minor evidence of cracking. Access to the site is via Carrs Lane, to the south east and Newlands Avenue to the north west, both by vehicular traffic. A rough footpath is recorded off Newland Avenue, aligned north to south, from the residential estate to the former dismantled railway line. The site generally comprises a set of agricultural fields, defined by a combination of semi-mature / mature trees and low-lying shrubs. A set of electricity pylons are recorded within the southern portion of the

	site, aligned east to west and north to south. A Yorkshire Water manhole cover was identified within the north western portion of the site. An unknown brick structure was identified to the sites north eastern portion, within an area of dense vegetation. On closer inspection, during the fieldworks, it was considered this feature could be representative of a former well, although there is no evidence within any historical OS mapping. Along the northern and north eastern perimeters of the site, in close proximity to the off-site residential properties, are a number of areas of fly-tipped materials including wood, soil, plastic, fabrics, glass, brick, concrete etc. In addition, to the south eastern perimeter were a number of discarded telegraph poles. Evidence of a small bonfire was noted to the sites northern perimeter.
Approximate Site Area	12.4 hectares.
Site Boundaries	The site boundaries are generally delineated by a combination of wooden panelled and metal palisade fencing, brick, stone and concrete walls, and semi-mature and mature trees, hedges and shrubs. The site is predominantly surrounded by residential dwellings to the north and east. To the sites southern boundary is a large grassed field, beyond which is Small Bridge Dike, aligned north west to south east. Ring Farm, a stable's, is recorded to the south east. To the west of the site is a dismantled railway line, which is currently utilised as a public footpath. This feature is in a cutting to the north and an embankment to the south.
Current Land Use	Agricultural fields.
Invasive Plant Species	None noted. An ecological survey should be carried out to confirm if any invasive plant species are present, most specifically around the perimeter of the site and where the fields are delineated by dense vegetation.

The main existing and historical site features are shown on Drawing No. C6138A/03 within Appendix A.

3. ENVIRONMENTAL SETTING

3.1. Introduction

Published environmental, geological and historical data relating to the site were reviewed as part of the previous preliminary appraisal (desk study). A summary of salient information is provided below. However, the previous desk study report should be referred to for further detail.

3.2. Site History

Review of historical Ordnance Survey maps indicates that the site has been occupied by agricultural fields since at least 1854. A number of buildings and a pump (latterly demolished/removed) were shown to the sites south eastern portion between 1854 and 1955.

Significant off-site features include a former railway line, with historic associated airshaft / mine entry, gasometer and goods shed to the immediate west of the site. In addition, to the west / north west was a quarry. A reservoir was shown to the immediate north west of the site between c. 1906 and 1984, which was later infilled and is referred to as a historical landfill site and has since been developed upon with housing.

3.3. Published Geological Information

Published geological information indicates the site to be underlain by a combination of sandstone (Glass Houghton Rock) and undifferentiated strata (Pennine Middle Coal Measures). The Glass Houghton Rock is recorded across the majority of the site, with the Pennine Middle Coal Measures shown within the western portion of the site.

Although no made ground is indicated on the geological plans, localised made ground deposits are likely to be encountered within the south eastern portion of the site owing to the former presence of a number of buildings.

A number of areas of worked and made ground are recorded within 500m of the site. Made Ground forming part of the dismantled railway line is shown along the western boundary of the site. Further areas of made / worked ground are identified along the former railway line, between c. 350m and 450m. Worked ground comprising “mainly railway and road cuttings, quarries and brick pits” is shown c. 200m to the north east of the site, which may be associated with a number of former quarries.

A further area of worked / made / infilled ground comprising "backfilled opencast coal sites and quarries" is shown c. 400m to the north east of the site.

No superficial deposits are shown to underlie the site; however the BGS map sheet does indicate the presence of Alluvial Deposits in the vicinity of the Small Bridge Dike c. 20m, to the west (at its nearest point) to the site.

An un-named fault, aligned approximately south west / north east, is conjectured within the north western portion of the site, downthrowing strata to the north west.

The Sharlston Low Coal Seam (reported to be 0.30m to 0.48m thick on the vertical section provided within the 1:10,000 scale map for the area) is conjectured to outcrop within the western portion of the site dipping to the east (below the site).

The Sharlston Top Coal Seam (reported to be 0.69m to 1.07m thick on the vertical section of the 1:10,000 scale map) is shown to outcrop on and / or around the eastern boundary of the site again dipping to the east (away from the site).

No workable coal seams are recorded at shallow depth below the Sharlston Low Coal Seam.

The CA mining report obtained for the site records the following salient information:

- *The property is in the likely zone of influence from workings in 7 seams of coal at 250m to 660m depth, last worked in 1991. Any ground movement from these coal workings should have stopped by now.*
- ***The property is in an area where the CA believes there is coal at or close to the surface. This may have been worked at some time in the past.***
- *There is 1 known coal mine entry within, or within 20 metres of, the boundary of the property.* This feature is recorded c. 20m to the south west of the site and coincides with a former airshaft, as seen within historical OS mapping. *There is no record of what steps, if any have been taken to treat the mine entry. Records may therefore be incomplete. Consequently, there may exist in the local area mine entries of which the CA has no knowledge.*
- *The CA is aware of 1 damage notice or claim for alleged subsidence damage to a property to the immediate east of the site (40 Carrs Lane, Cudworth) in September 1995. However, the claim was rejected*. A further two claims are recorded within c. 50m to the east of the site boundary.

From historical OS maps several presumed sandstone quarries have been noted within c. 100m and 1km of the site. In addition, to the immediate north west / west of the site, in proximity to the former Cudworth railway station is a former quarry.

The LIG Envirocheck report confirms the presence of a number of ceased sandstone quarries; the nearest is located 195m to the north east (opencast).

3.4. Hydrology and Hydrogeology

The nearest Environment Agency (EA) GQA Classified watercourse is Small Bridge Dike, located 41m to the south west of the site. Review of the EA website indicates that the current ecological quality of the watercourse is classified as 'bad'. The ecological quality is predicted for 2015 to improve to 'moderate'.

There are four unclassified watercourses recorded within 500m of the site. These features relate to a number of tributaries and drainage channels associated with Small Bridge Dike. The closest feature is recorded 181m to the west, and relates to a 'Tertiary River'.

The solid geology across the site and the Alluvial Deposits recorded in proximity to Small Bridge Dike are both classified as Secondary A Aquifers. The site is not located within an EA Source Protection Zone (SPZ).

There are no active/current surface water and / or groundwater abstraction licenses within 1km of the site.

The site is not indicated within the LIG Envirocheck report and EA website as being located within an indicative Zone 2 or Zone 3 floodplain. However, the site is located c. 29m to the north east of an indicative floodplain at risk from flooding from river and sea (Zone 2 and 3). This is associated with Small Bridge Dike.

3.5. Landfilling and Waste Management

According to information provided within the LIG Envirocheck report, there are three historical landfill sites within 1km of the property. The closest record is shown 1m to the west of the property and is referred to as 'Newlands Avenue', in the location of the former reservoir. The waste materials deposited are not known. This area has now been developed with housing.

There is one landfill site recorded 29m to the south west of the property and is referred to as 'former Cudworth railway station', which deposited inert material.

A further record is shown 285m to the south east of the property, which deposited wastes including inert, commercial/industrial and household materials.

There are 10 Local Authority Landfill Sites within 1km of the property. The closest is recorded on the site boundary, to the immediate west, presumably associated with the former reservoir.

There are six registered landfill sites within 1km of the property; the closest facility is located 103m to the west, referred to as 'former Cudworth railway station', which accepted wastes including inert non-combustible construction / demolition wastes.

There is one inactive Licensed Waste Management Facility recorded within 500m of the property, this is associated with the 'former Cudworth railway station'.

In addition, historical OS mapping indicates the presence of a number of areas of infilled land off-site, including deep made ground associated with the infilled railway cutting, infilled reservoir, infilled quarries and infilled ponds (some of which are licensed landfills). All of which could present a potential gas source / risk to the site.

Other potential gas sources include; mine gases associated with the presence of shallow coal seams on site and marsh gases associated with the alluvial/organic soils recorded to the west of the site.

3.6. Radon Risk

The site lies within an area in which **no radon protective measures are required**.

3.7. Other

Other potentially contaminative activities or environmental constraints identified as part of the previous desk study are listed below. The entries relate to activities within approximately 250m of the site, with the exception of Control of Major Accident Hazard (COMAH) facilities and Notification of Installations Handling Hazardous Substances (NIHHS) facilities where the assessment was extended to a distance of approximately 1km from the site.

- There are three discharge consents within 250m of the site; the closest is located 64m to the south east of the property and relates to sewage discharge – storm water overflow / storm tank (water company) to a freshwater stream / river, namely Small Bridge Dike. The license is referred to as 'revoked'.

- There is one local authority pollution prevention and control within 250m of the site. The entry is recorded to the immediate west of the site, for a mobile screening and crushing processes. The license is referred to as 'permitted'.

- There are 16 pollution incidents to controlled waters within 250m of the property. The closest, which involved mud / clay / soil, occurred at a location 90m south east of the site in 1993 and was described as "Category 3 - Minor Incident".

- There are no active trades within 250m of the site. There are, however, three inactive trades within 250m of the property, these include a printers, automation systems and equipment and electrical engineers.

- The south western portion of the site is located within an area of adopted green belt.

3.8. Preliminary Conceptual Site Model

A combined preliminary conceptual site model and conceptual exposure model (PCSM) was developed for the proposed future land use (residential with gardens) as part of the October 2015 desk study.

The PCSM is presented in schematic form as Drawing No. C6138A/04, in Appendix A.

In summary, the preliminary CSM identified the following potential pollutant linkages which could result in an unacceptable risk to the proposed end-use:

- Ingestion, inhalation of dust and dermal contact with potential heavy metals, asbestos fibres, hydrocarbons (including Polycyclic Aromatic Hydrocarbons – PAH / Total Petroleum Hydrocarbons - TPH) and pesticides in topsoil and locally made ground posing a **low to moderate** risk to site end users, adjacent site users and construction workers.

- Possible leachable (and mobile) heavy metals and organic contaminants in topsoil and locally made ground posing a **low** risk to controlled waters (underlying Secondary A Aquifer and Small Bridge Dike).

- Risk from hazardous ground gas sources including mine gases and marsh gases, located both on and off-site, posing a **moderate** risk to site end-users and construction workers.

4. PREVIOUS INVESTIGATION FINDINGS

No previous site investigation reports relating to this property have been made available.

5. FIELDWORK

5.1. Scope of Investigation

The information contained in this report is limited to areas of land accessible during the investigation within the site boundary, as indicated on the site plan, presented within Appendix A as Drawing No. C6138A/05.

Sirius scoped the intrusive ground investigation, using guidance presented in BS 5930:1999+A2:2010, BS10175:2011+A1:2013 and BS EN ISO 1997:2004 and 2007.

The investigation, which was supervised by a Sirius Geoenvironmental Engineer, took place between 16th and 24th September 2014 and comprised:

- Boring of 10 window sample boreholes (WS1 to WS10) to a maximum depth of 4.50m bgl.
- Eight openhole rotary probes (RO1 to RO7, and RO1A) drilled to a maximum depth of 30.00m bgl using a combination of water and air flush techniques.
- Excavation of 37 trial pits (TP1 to TP37) and six trial trenches (TT1 to TT6) to a maximum depth of 3.20m bgl.
- Soakaway tests were undertaken within five trial pits (SA1 – SA5), excavated to a maximum depth of 2.50m bgl, to determine the suitability of the soils for soakaways.

Gas and groundwater monitoring wells were installed within seven selected window sample boreholes (WS1, WS2, WS3, WS4, WS5, WS6 and WS7), all sealed into natural strata.

5.2. Strata Description

Detailed descriptions of strata and groundwater observations made during investigation works, together with samples recovered, are presented on the Engineer's exploratory hole records in Appendix B.

Standard strata descriptions are compliant with BS EN ISO 14688:2002 and 2004 and BS EN ISO 14689:2003. The depths of strata on the record sheets are recorded from current ground levels at each location, unless indicated otherwise.

5.3. Exploratory Hole Locations

The exploratory hole locations were based on the findings of the preliminary conceptual site model in order to target specific areas of interest and achieve a general site coverage. Procedures and principles recommended in CLR4, BS10175:2011+A1:2013 and BS EN ISO 1997:2004 and 2007 were followed when determining exploratory hole locations.

Table 5.1 details the exploratory hole rationale:

Table 5.1 Exploratory Hole Rationale

Exploratory Hole	Rationale
TP1 – TP37	General site coverage based on a c. 50m grid, with the exception of TP14 and TP22, which were targeted within areas where a number of former buildings were positioned.
TT1 – TT6	Positioned to try to ascertain the location of the conjectured outcrop of the Sharlston Low Coal Seam and the un-named geological fault.
SA1 – SA5	Soakaways completed across the site, to provide general site coverage, based on the geological conditions encountered within TP1 – TP37.
R01 – R07 (inclusive of R01A)	To confirm the shallow stratigraphy below the site, and the presence of workable coal within influencing distance of the surface.
WS1 –WS10	Positioned across the site to allow derivation of geotechnical parameters for the shallow soil, and selected locations for gas well installation. • WS1 positioned to target the off-site gas source of the infilled reservoir. • WS2, 3 & 7 positioned to target the off-site gas sources of the infilled railway cutting, historic gasometer, historical airshaft / mine entry and potentially the Alluvial Deposits. • WS4 positioned to target the potential off-site gas source of an infilled quarry. All wells were also to be used to monitor for mines gas.

Exploratory hole locations are shown on Drawing No. C6138A/05, within Appendix A of this report.

5.4. Geotechnical Testing

Geotechnical laboratory testing was carried out on selected samples in accordance with techniques outlined in BS 1377:1990 “Methods of Test for Soils for Civil Engineering Purposes” at the laboratory of Professional Soils Laboratory (PSL), a UKAS accredited laboratory.

Geotechnical and geochemical test results are included within Appendix C of this report.

5.5. Chemical Testing

Selected samples of soil and soil leachate were tested for a range of potential contaminants under subcontract with Derwentside Environmental Testing Services (DETS), a UKAS and MCERTS accredited laboratory.

The potential contaminants of concern identified by the preliminary conceptual site model were selected as the analytes for analysis, for the samples recovered from the site. The results of soil and leachate analysis, as received from the laboratory, are presented within Appendix C of this report.

6. GROUND CONDITIONS AND MATERIAL PROPERTIES

6.1. Strata Profile

A summary of the strata profile is provided in Table 6.1 below.

Table 6.1 Strata Profile

Strata	Depth Range (Thickness Range)	Description and Comments
Reworked Topsoil	Ground Level (0.15 to 0.55m)	Reworked topsoil was encountered within all the exploratory holes, comprising sandy silt with rare gravel sized fragments of coal.
Made Ground	0.20m to 0.30m (0.20m)	Made ground was encountered locally within the western and eastern portions of the site, namely WS2 and TP14, respectively, comprising clayey fine to coarse sand with gravel sized fragments of sandstone and rare coal, brick and pottery.
Residual Soils (weathered bedrock)	0.15m to 0.55m (0.20m to 3.65m)	Natural strata was encountered below the reworked topsoil / made ground soils within all of the exploratory holes, comprising granular, and locally cohesive, residual soils Granular residual soils were described as medium dense to dense, gravelly sand/sandy gravel/sand and gravel/gravelly clayey sand. The gravel fraction comprising angular sandstone and rare coal and siltstone. Locally, the granular deposits were recorded as loose material in the upper 2.00m of WS3, to the western portion of the site. Cohesive residual soils were recorded within a number of the exploratory holes to the sites south eastern / eastern portions, and, on occasion, on the western boundary (WS3). Cohesive residual soils were recorded to depths between 1.40m and 3.85m bgl, described as firm to very stiff, medium to high strength, slightly sandy clay, with gravel of sandstone, siltstone and locally mudstone. Within WS3 a 0.35m thick seam of very weak coal was encountered at a depth of 3.85m bgl (33.68m above ordnance Datum (AOD)), below the cohesive residual soils and above the competent bedrock.
Bedrock	0.50m to 4.20m (NR)	Bedrock was recorded at depths of between 0.50m and 4.20m bgl. Bedrock was generally recorded as very weak and weak, weathered sandstone, with interbeds of siltstone, mudstone and coal seams. Locally, within WS3, WS4 and WS5, to the eastern and

Strata	Depth Range (Thickness Range)	Description and Comments
		western portions of the site, the competent bedrock comprised extremely / very weak thinly bedded siltstone, at depths of between 1.40m and 4.20m bgl. The competent strata were proven to a maximum depth of 30.00m bgl within the rotary boreholes.

NR - not recorded

6.2. Subsurface Mine Workings

Rotary drilling undertaken at the site has identified one coal seam, considered likely to represent the Sharlston Low Coal Seam.

The Sharlston Low Coal Seam was encountered at depths of between 3.85m and 26.80m bgl (at levels of between 25.19m and 35.25m AOD) within four test holes (namely R02, R04, R07 and WS3), with recorded thicknesses of between 0.35m and 0.70m.

Based on the rotary drilling completed, the Sharlston Low Coal Seam is near to crop to the sites western boundary, with coal recorded at depths of between 3.85m bgl (33.68m AOD) and 5.80m bgl (34.59m AOD).

Triangulation of the rotary hole data indicates the Sharlston Low Coal Seam to be dipping at approximately 3.5° to 4.0° to the south east.

0.8m broken ground was recorded at the anticipated depth of the Sharlston Low Coal seam in R03 (28m bgl~26.7mAOD), in the north eastern corner of the site.

Based on the estimated dip, and the associated strike lines, the absence of coal from R05 and R06 is thought to be because the coal is beyond the base of the boreholes

Within RO1 and RO1A a zone of broken and soft ground was encountered at a depth of 5.00m to 9.00m bgl and 4.50m to 4.80m bgl, respectively. The cause of this anomaly is currently unknown.

Based on the findings of this investigation it is appears that the Sharlston Low Coal seam has been worked, however it only has the potential to affect surface stability along the western flank of the site; as shown broadly on Drawing No. C6128A/05, presented in Appendix A. This area should be further investigated to determine the presence/absence of mine workings and the need, or

otherwise for drilling and grouting. At this stage the area potentially at risk from shallow coal mining has been extended to include R01 and R01A, due to the recorded anomaly in the ground conditions at this location.

6.3. Trial Trenching

Six trial trenches were excavated, within the north western / western and central portions of the site, in order to try to locate an un-named fault and a shallow coal seam (Sharlston Low), which is recorded to outcrop along the sites western flank. The trial trenches did not however indicate any distinguishable features.

6.4. Material Properties

Reworked Topsoil

Water soluble sulphate (SO_4) concentrations recorded from four samples taken in the reworked topsoil recorded concentrations of between <10mg/l and 19mg/l, together with pH conditions of between 6.5 and 6.8. These results indicate a design sulphate class of DS-1 and an ACEC class of AC-1, in accordance with BRE Special Digest 1 (2005) for the design of buried concrete in made ground soils, based on brownfield site designation and mobile groundwater conditions.

Made Ground

Water soluble sulphate (SO_4) concentrations recorded from two samples taken in the made ground recorded concentrations of between 16mg/l and 25mg/l, together with pH conditions of between 6.5 and 7.2. These results indicate a design sulphate class of DS-1 and an ACEC class of AC-1, in accordance with BRE Special Digest 1 (2005) for the design of buried concrete in made ground soils, based on brownfield site designation and mobile groundwater conditions.

Residual Soils

Water soluble sulphate (SO_4) concentrations recorded from four samples taken in the residual soils recorded concentrations of between 13mg/l and 29mg/l, together with pH conditions of between 5.2 and 7.6. These results indicate a design sulphate class of DS-1 and an ACEC class of AC-1, in accordance with BRE Special Digest 1 (2005) for the design of buried concrete in natural soils, assuming mobile groundwater conditions.

Atterberg limit determinations undertaken on five samples of the cohesive residual soils revealed liquid limits of between 28% and 45%, plastic limits of between 16% and 23% and plasticity indices

of between 10% and 22%. This data indicates the material tested to be clay of low to intermediate plasticity.

Calculation of the modified Plasticity Index indicates the residual cohesive soils strata to have a low to medium volume change potential.

Hand shear vane tests undertaken (in the field) within the cohesive residual soils recorded undrained shear strengths ranging between 44kN/m^2 to 130kN/m^2, indicative of medium to high strength material. The mean and median undrained shear strength was calculated to be 77kN/m^2 and 75kN/m^2, respectively, giving a characteristic shear strength in the high strength range.

SPTs undertaken within the cohesive residual soils recorded uncorrected 'N' values of between 14 and 18 (mean and median N value of 16).

Indicative undrained shear strengths of cohesive soils can be derived by applying a correlation to SPT 'N' values according to the material's plasticity, after Stroud (1975)[1]. Based on a plasticity index of 20% for the cohesive residual soils, a correlation factor of 5 can be derived. Using Stroud's correlation the SPT 'N' values indicate undrained shear strengths of between 70kN/m^2 and 90kN/m^2, indicating the cohesive residual soils tested to be of medium and high strength.

Eight SPTs undertaken within the granular residual soils recorded uncorrected 'N' values of between 7 and 35 (mean and median N value of 21 and 19, respectively), indicative of loose to dense material.

A Particle Size Distribution (PSD) test was undertaken on one selected sample of residual granular soils obtained from TP17 between 0.60 – 0.70m bgl. The results of the laboratory tests are summarised on the PSD plots, included within Appendix C.

California Bearing Ratio (CBR) tests were undertaken in the laboratory on compacted bulk samples of granular residual soils obtained from TP27 at 0.60m – 0.80m bgl and TP35 at 0.40m – 0.60m bgl. The results of the laboratory CBR tests recorded a moisture content of 11 and 12% respectively, a bulk density of between 2.07 - 2.16Mg/m^3, a dry density of between 1.86 - 1.94Mg/m^3, and a CBR value of between 67.8 – 90.6% top and between 55.8 - 81.3% bottom.

[1] Stroud, M. A. The standard penetration test in insensitive clays and soft rocks, *Proceedings of the European Symposium on Penetration Testing,* 2, 367 – 375 (1975)

Competent Bedrock

Water soluble sulphate (SO_4) concentrations recorded from two samples taken in competent bedrock recorded concentrations of between <10mg/l and 32mg/l, together with pH conditions of between 6.6 and 7.4. These results indicate a design sulphate class of DS-1 and an ACEC class of AC-1, in accordance with BRE Special Digest 1 (2005) for the design of buried concrete in natural soils, assuming mobile groundwater conditions.

SPTs undertaken in the competent bedrock recorded uncorrected 'N' values of 50 blows for between 40mm and 295mm penetration, indicative of very dense soil/extremely weak rock.

6.5. Groundwater

No significant ingresses of groundwater were noted during the drilling of the window sample boreholes or the excavation of the trial pits / trial trenches.

It should be noted that due to the nature of the rotary drilling method (water flush) undertaken in RO1, RO1A, RO3 and RO6 it was not possible to detect seepages or low flow water strikes. However, within the holes where air flush techniques were used, RO2 and RO5 identified groundwater at 27.00m bgl and 18.30m bgl, respectively.

One subsequent groundwater monitoring visit completed to date has recorded the majority of the wells to be 'dry', with the exception of WS3 and WS4, to the north eastern and western portions of the site, with standing water levels recorded between 1.30m and 2.92m bgl.

6.6. Stability

All the trial pits / trenches excavated as part of this intrusive investigation were stable in the short term.

6.7. Soakaway Infiltration Tests

Soakaway tests were carried out in five trial pits (SA1 – SA5) in general accordance with the test method specified in BRE Digest 365 - Soakaway Design. Water was added to the excavation, to fill the test zone, using 1,000 litre water containers. Due to the slow speed of infiltration and time restraints, soakaway tests were not repeated three times in all locations as defined within BRE 365, with the exception of SA5.

Soakaway tests were completed within both the granular and cohesive residual soils / completely weathered bedrock and the underlying bedrock i.e. sandstone and sandstone with interbedded siltstone.

The soakaway tests were completed to provide an indication as to the potential use / installation of soakaways on site.

Plots of water level against time are provided on the soakaway result sheets, contained within Appendix D of this report.

6.8. Visual / Olfactory Evidence of Contamination

No visual or olfactory evidence of hydrocarbon contamination was noted during the fieldwork.

6.9. Ground Gas

Table 6.2 Summary of Gas Monitoring (1 visit to date)

Well	Methane (range) %v/v	Carbon Dioxide (range) %v/v	Oxygen (range) %v/v	Flow (range) l/hr
WS1	ND	0.1	21.2	ND
WS2	ND	0.9	20.3	0.5
WS3	ND	1.6 – 1.7	19.9	ND
WS4	ND	1.3	20.0	ND
WS5	ND	1.4 – 1.5	21.5	ND
WS6	ND	1.8	19.7	ND
WS7	ND	2.1 – 2.2	19.8	0.5

Results received to date (1 visit); ND Not Detected. Gas monitoring is currently on-going.

Low / background concentrations of hydrogen sulphide and carbon monoxide were detected, with maximum recorded concentrations of 2ppm and 4ppm in comparison to Generic Assessment Criteria (GAC) based on HSE Workplace Exposure Limits of 5ppm and 30ppm, respectively.

The monitoring programme includes six visits over a three month period (five visits remaining over a three month period). On completion of the monitoring, a full set of results will be issued in an addendum letter.

A copy of the gas and groundwater monitoring data received to date is presented in Appendix E.

7. RESULTS OF CHEMICAL TESTING

7.1. Assessment Methodology

The results of the laboratory testing have been compared against generic assessment criteria (GAC) values, the derivations of which are detailed in Appendix F.

Usually statistical testing is undertaken for the Planning Scenario by the methods described in CL:AIRE & CIEH "Guidance on Comparing Soil Contamination Data with a Critical Concentration", May 2008. This statistical testing is undertaken to determine whether there was sufficient evidence that the true mean concentration of each determinand was less than the relevant critical concentration for that component. However, as all the results are significantly less than the GAC values no further assessment has been carried out.

7.2. Soil Analysis

Results of chemical analysis as received from the laboratory are presented in full within Appendix C.

For this site, measured values were compared to GACs derived for a residential with plant uptake end use. The chemical analysis results (for five topsoil samples and one made ground sample) and screening criteria are summarised in Table 7.1.

Table 7.1 Summary of Total Soil Concentrations

Determinand	No. of Samples Tested	Range of Results (mg/kg unless specified)	GAC (1% SOM)	No. of Samples >GAC	Sample Exceeding GAC
Metals					
Arsenic (inorganic)	6	8.4 – 28	37	0	
Cadmium	6	0.3 – 0.9	11	0	
Chromium (III)	6	17 – 32	910	0	
Copper	6	21 – 55	200	0	
Lead	6	22 – 76	200	0	
Mercury (inorganic)	6	<0.05 – 0.29	40	0	
Nickel	6	16 – 25	180	0	
Selenium	6	<0.5 – 0.7	250	0	

Determinand	No. of Samples Tested	Range of Results (mg/kg unless specified)	GAC (1% SOM)	No. of Samples >GAC	Sample Exceeding GAC
Zinc	6	44 – 110	450	0	
Inorganics					
pH	12	5.2 – 7.6	<5 or >9	0	
Total Sulphate	6	300 – 1300	2400	0	
Water Sol. Sulphate	12	<0.01 – 0.029	0.5 g/l	0	
Speciated PAH					
Acenaphthene	6	<0.1	200	0	
Anthracene	6	<0.1 – 0.3	2300	0	
Acenaphthylene	6	< 0.1	170	0	
*Benzo(a)anthracene**	6	<0.1 – 0.9	*b(a)p**	0	
*Benzo(b)fluoranthene**	6	<0.1 – 0.9	*b(a)p**	0	
*Benzo(k)fluoranthene**	6	<0.1 – 0.5	*b(a)p**	0	
*Benzo(g,h,i)perylene**	6	<0.1	*b(a)p**	0	
Benzo(a)pyrene	6	<0.1 – 0.9	2.1	0	
*Chrysene**	6	<0.1 – 1.0	*b(a)p**	0	
*Dibenzo(a,h)anthracene**	6	<0.1	*b(a)p**	0	
Fluoranthene	6	<0.1 – 1.6	280	0	
Fluorene	6	<0.1 – 0.2	170	0	
Indeno(1,2,3-cd)pyrene	6	<0.1	*b(a)p**	0	
Naphthalene	6	<0.1 – 0.3	1.0	0	
Pyrene	6	<0.1 – 1.5	620	0	
Phenanthrene	6	<0.1 – 0.6	95	0	
TPH					
Aliphatic EC 5-6	2	<0.01	24	0	
Aliphatic EC >6-8	2	<0.01	53	0	
Aliphatic EC >8-10	2	<0.01	13	0	
Aliphatic EC >10-12	2	<1.5	62	0	
Aliphatic EC >12-16	2	<1.2	510	0	
Aliphatic EC >16-35	2	<4.9	41000	0	
Aromatic EC 5-7	2	<0.01	53	0	
Aromatic EC >7-8	2	<0.01	100	0	
Aromatic EC >8-10	2	<0.01	20	0	
Aromatic EC >10-12	2	<0.9	63	0	
Aromatic EC >12-16	2	<0.5	140	0	
Aromatic EC >16-21	2	<0.6	260	0	
Aromatic EC >21-35	2	<1.4	1100	0	

Determinand	No. of Samples Tested	Range of Results (mg/kg unless specified)	GAC (1% SOM)	No. of Samples >GAC	Sample Exceeding GAC
Others					
Phenol	6	<0.3 – 0.8	110	0	
TOC	6	0.7 – 3.6 w/w%	3 w/w%	1	WS5 at 0.10m bgl
Calorific Value	3	<1.0 – 1.3MJ/kg	2MJ/kg	0	
Asbestos	3	NAD	Fibres present	0	

Table based on a Residential with Gardens end-use.
* assessed using benzo(a)pyrene as a surrogate marker.
# Laboratory detection limits are higher than GAC values; GAC -generic assessment criterion; NAD – No Asbestos Detected: NA - not applicable; LoD – Limit of detection.

None of the determinands tested for within the selected soil samples exceeded the relevant GACs, with the exception of Total Organic Carbon (TOC).

TOC was recorded at a concentration marginally exceeding the relevant GAC within one sample of reworked topsoil obtained from WS5 at 0.10m bgl. The GAC for TOC is based on the Hazardous Waste (England and Wales) Regulations 2005. TOC content in itself does not represent a potential risk to human health. This GAC is provided for indicative assessment of disposal options, in the case that off-site landfill of soil is undertaken. This GAC is specified at the 'Inert' waste threshold and should therefore be considered as for information purposes only.

In addition to the above soil analyses, one sample of reworked topsoil (TP2 at 0.10m bgl) was analysed for a range of pesticide compounds. The results have returned all determinands below the laboratory's limit of detection.

7.3. Leachability Testing

Given the environmental setting of the site, consideration has been taken of both groundwater and surface water as potential controlled water receptors of contamination. Hence, the results of leachate analysis have been evaluated against both Drinking Water Standards (DWS) and Inland Waters Environmental Quality Standards (EQS) levels. For EQS levels where a threshold concentration is determined from the hardness of the receiving waters, the most conservative hardness value has been used, as the receiving waters themselves have not been tested.

The derivation of the GAC values is described in Appendix F.

The analytical results for leachate samples and the outcome of screening are summarised in Table 7.2.

Table 7.2 Summary of Total Leachate Concentrations

Determinand	No. of Samples Tested	No. Samples Above Limit of Detection	Range of Results (µg/l unless specified)	GAC value (µg/l unless specified)		No. of Samples >GAC
Metals				**EQS (Note 1)**	**DWS (Note 2)**	
Arsenic	3	3	1.1 – 2.2	50	10	0
Cadmium +	3	0	<0.03	0.08	5	0
Chromium	3	0	<0.25	4.7	50	0
Lead	3	3	0.45 – 1.1	7.2	10	0
Mercury	3	0	<0.01	0.05	1	0
Copper +	3	3	2.5 – 3.7	1	2000	3 (EQS)
Nickel	3	1	<0.5 – 0.6	20	20	0
Zinc +	3	3	1.93 – 3.78	8	5000	0
Organics						
Naphthalene	3	0	<0.01	2.4	NA	0
Benzo(a)pyrene	3	1	<0.01 – 0.01	0.05	0.01	0
Anthracene	3	0	<0.01	0.1	NA	0
Fluoranthene	3	1	<0.01 – 0.02	0.1	NA	0
Sum of benzo(b)fluoranthene and benzo(k)fluoranthene	3	1	<0.02 – 0.03	0.03	NA	0
Sum of benzo(ghi)perylene and indeno(1,2,3-cd)pyrene	3	0	<0.02*	0.002	NA	0
Sum of four PAHs benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene	3	1	<0.04 – 0.05	NA	0.1	0
Phenol	3	0	<0.50	7.7	0.5	0

+ – EQS is hardness related; 1 – Inlands Waters EQS values; 2 – DWS values; * – Laboratory detection limits are higher than EQS value; # – Laboratory detection limits are higher than DWS value.

None of the determinands tested for within the selected soil leachate samples exceeded the relevant GACs, with the exception of leachable copper.

Marginally elevated concentrations of leachable copper were detected within three samples tested in comparison to the most conservative EQS values.

It is considered that laboratory leachate testing is not truly reflective of natural hydraulic processes, but represents a much more aggressive process often resulting in elevated concentrations of leachable determinands being identified. With this in mind, the marginal nature of exceedances, the “greenfield” history of the site, and its environmental setting, the identified concentrations are considered to pose a negligible risk to controlled waters. These elevated concentrations are therefore not considered further.

8. REVISED CONCEPTUAL SITE MODEL AND GENERIC QUANTITATIVE RISK ASSESSMENT OF POLLUTANT LINKAGES

The preliminary combined conceptual site model and conceptual exposure model, developed as part of the 2014 desk study and summarised in Section 3.8, has been revised in light of the ground investigation and the chemical analysis results presented above.

The revised conceptual site model has been developed for the proposed future land use (residential with gardens). This summarises the understanding of surface and sub-surface features, the potential contaminant sources, transport pathways and receptors.

The revised conceptual site model is presented in schematic form in Appendix A, as Drawing No. C6138A/06.

8.1. Summary of Identified Pollutant Linkages

In summary, the revised CSM has identified the following potential pollutant linkages which could result in an unacceptable risk to the proposed end-use:

- Risk from hazardous ground gas sources, including mine gases and marsh gases, located both on and off-site, posing a **low to moderate** risk to site end-users and construction workers. A fully risk assessment will be provided upon completion of the remaining monitoring visits, presented in an addendum letter report.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. General

This geoenvironmental appraisal has been performed at land off Carrs Lane, Cudworth, Barnsley, in order to assist with planning purposes, design and abnormal cost assessment.

It is understood that BDW are considering developing the site for a low-rise residential end-use, comprising 263 two storey residential properties and 15 bungalows, with private gardens, areas of soft landscaping, Public Open Space (POS), areas of hardstanding, and highways. No loadings or development levels were known at the time of writing.

This report has been compiled to assist with planning purposes for the proposed residential end-use, assuming development levels will remain broadly as existed at the time of the preliminary investigation.

9.2. Flood Risk

According to the LIG Envirocheck report and the EA website, the site does not lie within an indicative flood plain (zone 2 or 3) at risk of flooding from rivers or sea.

9.3. Geotechnical

Mining

This investigation has proven that potentially workable coal exists within influencing distance of the surface within the western portion of the site; ie in the vicinity of WS3 and RO7, and potentially around R01 and R01A (see Drawing No. C6138A/4). Elsewhere the coal should, even if / where worked, be too deep to affect surface stability.

A supplementary rotary probing investigation is recommended to confirm the presence / absence of mine workings beneath the site, concentrated where insufficient rock cover has been identified (ie the western flank). If workings are found within influencing distance of the surface, drilling and grouting will be required (or coal removal) with appropriate precautions taken in foundations. For adoptable highways, the scope of works would need to be approved by the local highways department.

The CA mining report records that no mine entries are known to exist on the site (although one is shown 20m to the south west), but warns of their potential unrecorded presence. It is therefore

recommended that as part of the enabling works the site be stripped back to natural strata in order to inspect for mine entries / bell pits / crop workings. If evidence of a mine entry, bell pit, coal workings or ground disturbance is suspected, advice regarding treatment / foundation precautions should be sought from a suitably qualified engineer.

At this stage a contingency should be included for drilling and pressure grouting potential mine workings (including potential crop workings) below the western part of the site, and, in addition, treating yet unproven mine entries (i.e. shafts, adits and / or bell pits).

Inspection of historical OS plans has revealed evidence of a former quarry / quarry high wall to the sites north western / western perimeter, in addition to a number of former sandstone quarries within the vicinity of the site. As such the possibility of encountering unrecorded quarries on site cannot be wholly discounted. It is recommended that all excavations be examined for evidence of such features. If evidence of an infilled quarry is suspected works should cease and the advice sought of a suitably qualified consultant.

With regards to the former quarry high wall located to the sites north western boundary it would be prudent to undertake a visual assessment of the rock face by a suitably qualified Engineer in order to ascertain the stability of the feature, particularly owing to the ground conditions identified within RO1 and RO1A i.e. broken / soft ground and the potential risk of impacting the development site, particularly if residential properties are proposed in its proximity.

Foundations

The recommendations provided below are based on the assumption that the surface stability of the site is not affected by shallow mine workings. If this proves not to be the case, the recommendations will need to be revised; including treatment of shallow mine workings, and modification to foundation design.

Reworked topsoil, and locally made ground soils, were encountered to depths of between 0.15m and 0.55m bgl, underlain by, across the majority of the site, granular residual soils, and in the east and south east, cohesive residual soils.

Granular residual soils were proven to depths of between 0.50m and 2.80m bgl, recorded as comprising medium dense to dense (locally loose within WS3) gravelly sand / sandy gravel / sand and gravel / and gravelly clayey sand, of sandstone, with rare coal and siltstone. Cohesive residual soils were proven to depths between 1.40m and 3.85m bgl, recorded as firm to very stiff,

generally medium to high strength, slightly sandy clay with gravel of sandstone, siltstone and locally mudstone.

Bedrock was generally described as very / extremely weak and weak weathered sandstone, with, on occasion, interbeds of siltstone, mudstone and coal. Locally, within WS3, WS4 and WS5, the residual soils were underlain by extremely weak / very weak siltstone bedrock at depths between 1.40m and 4.20m bgl.

Groundwater monitoring, undertaken by Sirius (to date), of the standpipes installed within selected window sample boreholes revealed groundwater levels, to be standing between 1.30m and 2.92m bgl within only WS3 and WS4, all other installed wells were recorded as 'dry'.

The reworked topsoil and made ground soils are considered unsuitable as bearing strata using conventional spread foundations due to the potential for excessive total and differential settlements. It is considered that structural loads associated with the proposed development could be supported on reinforced spread foundations (such as strip / trench fill) taken down through any reworked topsoil / made ground into the underlying natural ground of adequate bearing capacity. If shallow coal requires consolidation, overlying foundations may need to be rafts or piles.

For preliminary foundation design a 0.60m wide strip footing within the granular residual soils identified across the majority of the site (based on a typical SPT N-value of 10 (medium dense) and a minimum angle of shearing resistance (Φ') of 30º) at 1.00m bgl, is assumed to support a design load of 80kN/m run, with settlements being below 25mm.

In the eastern and south eastern part of the site, beneath the reworked topsoil / made ground soils are cohesive soils. The settlement characteristics of sand / gravel and clay are different. It would be prudent for all foundations to bear upon one consistent stratum i.e. granular residual soils or cohesive soils, in order to prevent differential settlements occurring between foundations.

The residual cohesive soils (of at least medium strength) are considered to have an characteristic undrained shear strength (C_u) of 50kPa at a founding depth of 1.00m bgl. By way of example, calculations indicate a 0.60m wide strip bearing on the cohesive medium to high strength residual soils at a depth of 1.00m bgl, can impose a maximum line load of 80kN/m run. The application of such a pressure would keep settlements to 25mm or less.

If foundations encounter bedrock all of the foundation should be placed in this material in order to limit the potential for unacceptable differential settlements. By way example and in accordance with

Eurocode 7, for a 0.60m wide strip founded on competent bedrock placed at 2.00m depth, a design load of 150kN/m^2, can be assumed for the very weak sandstone / siltstone.

Locally, loose granular residual soils were encountered within WS3. It is considered that within this area spread foundations may have to be locally deepened in order to found onto competent strata and / or thickened, widened and strengthened to accommodate variations in ground conditions.

If foundations are to bear upon a mix of residual soils (cohesive and granular), it is recommended that settlement performance between the foundation types be calculated / assessed. Reinforcement of foundations to cater for potential differential settlement of the residual should be anticipated.

The above calculations for the proposed residential development are based on theoretical foundations. The loading regime and settlement of foundations is dependent on foundation loadings, and dimensions. It is therefore recommended that foundation settlements are reviewed by a qualified engineer once final loading arrangements and foundation sizes are known.

If shallow coal is encountered during foundation excavations, the foundation excavation should be extended through the coal seam into competent strata below. If the depth to the base of coal increases to greater than 2.50m bgl within the foundation excavation, then an alternative engineer designed foundation may be required. In addition, if foundations extend through any shallow coal seams these will require protection from potential spread of fire; this typically involves the installation of a sacrificial concrete barrier to the external faces of foundations. Advice should be sought from a suitably qualified engineer.

Further rotary probing is required to confirm the presence / absence of mine workings beneath the western most part of the site. Following this, appropriate treatment and foundation design can be determined in this area.

Trial trenching undertaken as part of this investigation to attempt to locate a conjectured fault and / or a shallow coal seam (Sharlston Low) did not generally identify any distinguishable features. As a precaution against residual movement along the fault plan, foundations over and within say 25m either side of its conjectured position, should be reinforced. Reinforcement should be detailed by an appropriately qualified Engineer.

The natural cohesive soils have been found to be of low to medium volume change potential in accordance with NHBC Standards Chapter 4.2. Foundations placed into natural insitu clay soils should be a minimum of 900mm deep (from existing or finished ground level, whichever is the

lower of the two), deepened / protected within the zone of influence of existing or proposed trees in accordance with NHBC guidance. A tree survey was beyond the scope of this investigation but should be undertaken to enable production of a detailed plot specific foundation schedule. The removal of trees during development of the site may cause heave of cohesive soils and heave protection measures should be adopted in foundation design where appropriate.

Foundations placed into granular deposits and bedrock should be at least 500mm below finished or original ground level (whichever is the lower of the two), to alleviate any affects arising from frost heave.

Foundations should be taken below a line drawn up at 45° from the base of any existing or proposed services, including a sewer which is understood to cross the site. Consultation should be undertaken with the appropriate regulator to determine the implication of the sewer on development plans.

It should be noted that locally (WS3), groundwater has been encountered at shallow depth beneath the site. This may have an adverse effect on foundation construction and performance, particularly in winter months. This should be considered when designing foundations.

Other Geotechnical Considerations

Assessment of the suitability / stability of the retaining wall structure recorded to the sites western / north western perimeter (if maintained and incorporated into the proposed development) within the context of the proposed development levels is recommended.

As mentioned within Section 2, an unknown brick structure was identified to the sites north eastern flank, within an area of dense vegetation. On closer inspection, it may be possible that the feature is representative of a former well, although there is no evidence of such a feature on historical OS mapping. In addition, historical OS mapping has identified a former pump to the sites south eastern portion; trial pitting and window sampling completed within its proximity did not reveal any significant evidence of this feature. As such it is recommended as part of the enabling works that further investigations are undertaken in the vicinity of both features. This may comprise of a small surface strip to confirm the presence / absence of these features and if present, determine the construction details and size. Treatment will be subject to the findings, development proposals in the affected areas and regulatory requirements.

Floors

In accordance with NHBC Standards 2008 (Chapters 4.2, 4.6 and 5.1), suspended ground floor slabs are required in the following situations:

- Made ground greater than 600mm thick.
- Where soil swelling may occur.
- Where vibratory ground improvement has been carried out.
- Where the ground has insufficient bearing capacity.

On the basis of the above, and assuming that gas measures are not required in buildings (which is still to be confirmed) ground bearing slabs should be feasible across the majority of the site. Suspended slabs will be required where trees are present and soils are cohesive.

Floor design should be confirmed when final site levels are known, a tree survey is competed and gas measures are finalised.

Sulphate Attack

Based on the samples tested, a Design Sulphate Class of DS-1 and an ACEC Class of AC-1 should be used for buried concrete structures in contact with both reworked topsoil/made ground and natural soils.

Groundworks, Excavation Stability and Groundwater Dewatering

Excavations into existing reworked topsoil/made ground and the underlying natural soils should be assumed to be unstable. No man entry into unsupported excavations should be allowed without an appropriate risk assessment. Reference to CIRIA report 97 should be made to establish suitable means of support or battering of excavation sides.

Based on the results of this investigation, significant groundwater flow into shallow excavations (<1.50m) is not be expected. If groundwater is encountered at shallow depth it should be possible to deal with these seepages through normal site pumping practices for any shallow excavations open for short periods of time. Disposal/discharge of water will require appropriate treatment/consent.

It is recommended that an adequate drainage system for surface water be installed by a competent contractor, in order to prevent surface water ponding or collecting both during and post construction, as this may lead to deterioration of the founding stratum.

It is recommended that in order to reduce the possibility of softening or swelling of cohesive soils at the base of foundation trenches, it should be suitably blinded with concrete.

Competent bedrock strata will be identified at relatively shallow depth. For deep excavations, for example, for services, competent bedrock may require breaking-out using heavy mechanical plant.

Soakaways

Soakaway tests were undertaken within five trial pits (SA1 to SA5) to determine infiltration rates.

At the time of the intrusive works, the invert level of the soakaway discharge pipe or soakaway base was not known.

The infiltration rate is calculated from the gradient of the graph between 75% and 25% effective depth. The water level in soakaway tests SA3 and SA4 did not fall to below 75% and 50% of their effective depth, respectively. As a result a soil infiltration rate was not calculated for these soakaway tests.

The results of the soakaway tests are summarised below:

Table 9.1 Soakaway Results

Trial Pit	Test Number	Soil Infiltration Rate (m/s)	Stratum
SA1	1	5.31×10^{-5}	Residual granular soils/Sandstone
	2	6.84×10^{-5}	
SA2	1	7.82×10^{-5}	Sandstone
	2	6.10×10^{-5}	
SA3	1	N/A Water level did not fall below 75% effective depth within 5.15 hours	Residual cohesive soils/Sandstone with interbedded siltstone
SA4	1	N/A Water level did not fall below 50% effective depth within 2.55 hours	Residual granular soils/Sandstone
SA5	1	4.42×10^{-4}	Residual granular soils/Sandstone
	2	1.59×10^{-4}	
	3	8.74×10^{-5}	

N/A – Not Applicable

Final soakaway design is to be undertaken by others, based on the infiltration rates provided. The size of the required soakaway is a function of the area to be drained, anticipated rainfall and soil infiltration rate.

The low infiltration rates recorded in a number of the soakaway trial pits is thought likely to be a result of the fines content / cohesive nature of the soils.

It should be borne in mind that water levels are likely to fluctuate with seasonal/rainfall and may therefore be substantially higher at wetter times of year and subsequently reduce the capacity of soakaways.

It is recommended that the EA be consulted with respect to soakaway drainage for the site, as the underlying bedrock (Glass Houghton Sandstone) is classified as a Secondary A Aquifer.

Pavements and Highways

Based on a visual examination of the shallow soils and Atterberg test results, a CBR value of 3% is suggested for the natural residual cohesive soils.

Laboratory CBR tests undertaken on two samples of the residual granular soils indicates a CBR value of between 56% and 91%. For preliminary design purposes in these materials it is suggested that 10% is assumed.

It is recommended that insitu CBR testing is carried out during the enabling works, when final site levels will be known, to confirm design. An allowance should be included for proof-rolling of roads and car park formations, and excavation of any identified soft-spots and replacement with granular materials placed and compacted in layers.

All road design should be discussed with the relevant local authority if highways are to be subject to a Section 38 agreement.

Should supplementary rotary probing prove shallow mine workings within influential distance of the surface, it is recommended that an allowance be made for the consolidation/treatment of mine workings beneath proposed highways.

Advice should be sought from an appropriately qualified Highway Engineer to assess the impact of the site gradient on the development aspirations.