PRELIMINARY GEOENVIRONMENTAL GROUND INVESTIGATION

Employment Land
Barnsley West

Reference	**4848-JPG-SW-XX-RP-G-0609-S2-P02**
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Revision	Date	Revision Details	Status	Author(s)	Approved
P01	04.05.2023	Issue to Client	Preliminary	DMH	JBW
P02	09.10.2023	Proposed Earthworks Levels Drawing updated	For Information	JBW	JDM

EXECUTIVE SUMMARY

Site Address	**Employment Land, Barnsley West**
NGR	Approximate NGR 431833, 406683.
Current Site Use & Proposed Development	The site is irregular in shape and occupies an area of approximately 37 hectares. Ground levels are approximately 146m AOD in the west, generally falling to approximately 120m AOD in the north east. The site generally consists of sloping arable and grazing land, which is divided into fields by hedgerows, fences and small watercourses. The Hunters Cottage Open Cast Coal Site (OCCS) is located in the central and southeastern parts of the site. The Hunters Cottage Extension OCCS is located in the north western part of the site. It is proposed to develop the site for commercial end use.
Previous Reports & Investigation	JPG have completed a desk study and a preliminary geoenvironmental ground investigation report for the overall Barnsley West development site and a coal mining risk assessment and coal recovery report for the employment land only.
Fieldwork	Fieldwork comprised the drilling of six rotary openhole boreholes and the excavation of four trial pits. Samples of soil were obtained and submitted for chemical and geotechnical analysis. A groundwater and gas monitoring well was installed in BH109A and monitored on six occasions. One extensometer was installed in BH109 and monitored on seven occasions.
Ground and Groundwater Conditions	The ground conditions outside the OCCSs comprised topsoil overlying cohesive made ground to a maximum proven depth of 2.80m bgl, firm to stiff medium strength residual soils to a maximum proven depth of 3.40m bgl and extremely weak mudstone, sandstone and coal of the Pennine Middle Coal Measures Formation to a maximum proven depth of 40.00m bgl. The ground conditions inside the OCCSs comprised topsoil overlying cohesive and granular colliery spoil to a maximum proven depth of 13.00m bgl, overlying extremely weak mudstone, sandstone and coal of the Pennine Middle Coal Measures Formation to a maximum proven depth of 27.00m bgl. BH108, BH109 and BH109A were drilled inside the OCCS to target the base of the opencast and underlying coal seam, Low Haigh Moor coal seam. None of the boreholes encountered any underground coal workings. BH121, BH122 and BH125 were drilled outside the OCCS to target the underlying coal seams, Dunsil, Gawber, Thin, Swallow Wood, the Top Haigh Moor and the Low Haigh Moor coal seams. None of the boreholes encountered underground coal workings. Perched groundwater was encountered in trial pits at depths between 1.00m bgl and 3.00m bgl. Groundwater strikes were recorded in the boreholes at depths between 5.10m bgl and 5.20m bgl. The groundwater installation in BH109A was recorded as dry for the whole monitoring period.
Geotechnical and Engineering Assessment	**Foundations and Ground Floor Construction** – Outside of the backfilled opencast site, it is considered likely that shallow foundations could be utilised within the firm to stiff residual soil or onto the bedrock. If shallow coal seams are encountered in foundation excavations, the coal should be removed at least 1.0m from the face of the foundation. Inside of the backfilled opencast site, it is recommended that in-situ ground improvement, e.g. Dynamic Compaction, is carried out on the backfilled opencast materials to achieve the required allowable bearing capacity and limits on settlement for the proposed development. Any ground improvement will require validation in order to confirm that the allowable bearing capacity and acceptable limits on settlement have been achieved. Alternatively, consideration could also be given to placing the foundations and ground floor slab on controlled modulus columns (CMCs) or utilising a piled foundation solution. **Earthworks** – The granular colliery spoil, cohesive made ground and residual soil are considered suitable for re-use in earthworks. The results of the laboratory testing also indicates that the cohesive colliery spoil material may be too wet to achieve suitable compaction. Further testing of the colliery spoil made ground is required to confirm its suitability for earthworks and compaction requirements. If the material is still too wet to be effectively compacted, consideration should be given to the addition of lime and/or cement to improve the material for re-use. **Control of Groundwater** - Control of groundwater and surface water control will be required as part of the earthworks. Significant (fast) inflows into boreholes, BH108, BH109A, BH122 and BH125 suggest that control by pumping from sumps might not be possible in the area around the former Hunters Cottage Opencast site. **Settlement** – The completion of re-soiling, following opencast abstraction, at Hunters Cottage (including extensions) was completed in January 1950. If development on the site was to commence in 2025, then 75 years will have passed since the most recent backfilling. Consequently, most creep (self-weight) will have already occurred. Based on the time since pumping ceased, it is likely that the water levels within the OCCS will have fully rebounded by now. However, this will need to be confirmed by further groundwater monitoring/assessment. Extensometer monitoring has been carried out on seven occasions and does not indicate any ongoing downward movement. Two models (worst case: deepest part of the Hunters Cottage OCCS is 19.0m) has been set up in Settle 3 which includes 3.0m of re-engineered colliery spoil, overlying 5.0m of cohesive colliery spoil and 11.0m of granular colliery spoil. The first model assumes a pad foundation with dimensions of 2.0m by 2.0m at 2.0m depth with a design load of 120kN/m^2 and the

	second model assumes a ground-bearing slab with dimensions of 100m by 50m and a design load of 50kN/m². Total predicted settlements for the first model is 50.8mm and for the second model is 151mm. Total differential settlement for a ground bearing floor slab for a large commercial unit has been calculated as approximately 25mm (1:4,000). **Roads, Pavements and Hardstanding Surfaces** – Laboratory CBR values for the residual soil are typically >5%. At this stage, it is recommended that a design CBR of 3% is adopted for pavement design for the engineered colliery spoil, assuming any soft spots at formation level are removed. **Excavations** - On completion of the earthworks, excavations through the compacted materials and exposed natural ground are likely to be unstable over the construction period and temporary side support is likely to be required. **Obstructions** – It is noted that the colliery spoil includes boulders from the historically excavated bedrock material. An allowance for excavation and processing of this material for re-use on site should be made. **Chemical Attack on Buried Concrete** - It is recommended that concrete should be designed to Aggressive Chemical Environment for Concrete (ACEC) Design Sulphate Class DS-1 and ACEC Class AC-1. **Coal Mining Constraints** –Based on the coal seam depths, seam thicknesses, seam quality and other recorded information, the Gawber, Thin, Swallow Wood, Top Haigh Moor and Low Haigh Moor coal seams are all considered to pose a low or low to moderate risk of unrecorded underground coal workings. No underground coal workings, either outwith or below the base of the OCCS, have been proven to-date. There are no recorded mine entries on the site, although there remains a residual risk of unrecorded mine entries.
Environmental Risk Assessment	Based on the identified potential sources of contamination and available pathways and receptors, the following linkage assessments have been considered. This assessment is based on current site conditions and does not consider exposure pathways following any remediation of the site. **Sources** – The following potential sources of contamination are considered to be present on the site: • Potentially combustible cohesive made ground. **Mitigation Measures** – In order to mitigate the risk posed by the potential contaminants which are present on the site, consideration should be given to the following mitigation measures. **Development and Maintenance Workers** • Site workers involved in groundworks should take the necessary measures to ensure that all works in excavations and confined spaces are carried out in accordance with best practice in order to prevent exposure to potentially hazardous gases. • Site workers involved in groundworks should use appropriate PPE, i.e. overalls and gloves. Appropriate health and safety measures, e.g. washing hands prior to eating or drinking, should also be enforced. • During development of the site, all workers should remain vigilant to the possible risk of encountering areas of potentially contaminated material. Should potentially contaminated material be encountered, site management should be informed. Further testing may then be required to assess the risk to health and safety of the site workers and the environment. • All employers involved in works at the site should produce an appropriate method statement and risk assessment, to which all employees should comply, e.g. working in confined spaces and encountering combustible made ground soils. Reference should also be made to the appropriate HSE and other guidance for working on contaminated and potentially contaminated sites. **Future Site Users** • No made ground soils with elevated calorific value (>2MJ/kg) shall remain within 1.00m of finished ground level in any soft landscaping. Confirmatory testing will be required as part the earthworks in order to confirm that the soils retained within 1.00m of the finished surface are not potentially combustible. • It is recommended that a sufficient thickness of clean cover soils, i.e. 300mm, is placed in future landscaped areas. Preliminary chemical test results indicate that the existing topsoil is suitable for re-use on the site. • It is recommended that further topsoil sampling and testing is undertaken in order to confirm the topsoil's suitability for re-use onsite. **Classification of Materials for Disposal Off-Site** – In total, seven samples, comprising four topsoil, one made ground, two colliery spoil samples were classified as Non-Hazardous using HazWasteOnline™. The laboratory certificates and assessment should be forwarded to the landfill operator to confirm this classification and provide a price for disposal should soils be removed from site.
Hazardous Gas	**Ground Gas Risk** – Based on the gas results, in accordance with BS8485:2015, the site is classified as Characteristic Situation (CS) 1, therefore no gas protection measures required. However, additional ground investigative works and ground gas monitoring is required in order to confirm the ground gas regime and the requirement for ground gas protection measures. **Radon Risk** –No radon protective measures are required.
Further Work Required	It is recommended that further ground investigation is carried out. The recommended scope of works Is set out below. • Rotary boreholes to confirm the coal mining legacy of the site and the requirement for drill and

	grout treatment. • Delineation of the opencast highwalls using a combination of geophysics, rotary open hole boreholes and/or trial trenching. • Trial pits to obtain samples of the made and natural ground to submit for chemical and geotechnical testing. • Cable percussion boreholes with in-situ testing, to obtain geotechnical parameters and undisturbed geotechnical samples for testing. Gas and groundwater monitoring wells to be installed in selected boreholes. • Quarterly monitoring of BH109 extensometer to be continued as long as possible to inform creep settlement assessment. • Static cone penetration testing to assess the in-situ geotechnical parameters. • Slope stability assessment of the existing slopes, especially those which will be subject to cut and fill, potentially exposing slip surfaces, or surcharging of unstable slopes. • Chemical analysis of made and natural ground material and groundwater in order to confirm the concentrations of potential contamination on the site and classify selected materials for re-use onsite and disposal offsite. • Geotechnical and chemical testing to classify materials and inform foundation design. • Ground gas monitoring of monitoring installations over a six week period. • Assessment of the groundwater regime below the site, in order to understand the site's groundwater regime and to assist with inundation settlement analysis. • Additional of the groundwater regime below the site, in order to understand the site's groundwater regime and to assist with inundation settlement analysis.
This sheet is intended as a summary only of the assessment of the site in relation to ground condition. It does not provide a definitive engineering analysis.	

1.0 INTRODUCTION

1.1 Instruction

JPG (Leeds) Limited has been instructed by Strata Sterling Barnsley West Limited to carry out a preliminary geoenvironmental ground investigation for the proposed employment land at the Barnsley West development site.

1.2 Objectives

The objective of the preliminary geotechnical ground investigation was to identify potential geotechnical and environmental issues that may represent constraints to the proposed development of the site.

1.3 Location

The site is located approximately 3km to the west of Barnsley town centre. The approximate centre of the site is located at NGR 431833, 406683. The site is located to the northeast of the M1 motorway and to the south of Hermit Lane.

A site location plan is presented as Figure 1 in Appendix A.

1.4 Site Description and Topography

The site is irregular in shape and occupies an area of approximately 37 hectares. Ground levels are approximately 146m AOD in the west, generally falling to approximately 120m AOD in the north east. The site generally consists of sloping arable and grazing land, which is divided into fields by hedgerows, fences and small watercourses.

The Hunters Cottage Open Cast Coal Site (OCCS) is located in the central and south eastern parts of the site. The Hunters Cottage Extension OCCS is located in the north western part of the site.

A steep valley with a drainage ditch at its base extends northwards from the south east; the drainage ditch is culverted where it passes below Hermit Lane. A second steep sided valley is present in the centre of the site and trends to the north.

The northern boundary is defined by Hermit Lane, beyond which is undeveloped farmland. A raised plateau of grassland is present to the east of the site, beyond which is the town of Pogmoor. The southern boundary is defined by the M1 motorway, beyond which is the town of Dodworth and the western boundary is defined by Higham Lane and the M1 motorway.

An aerial photograph of the site is presented as Figure 2 in Appendix A.

1.5 Development Proposals

It is proposed to develop the site for commercial end use. A plan outlining the proposed commercial red line boundary is referenced below and provided in Appendix A.

- JPG Leeds Limited. Commercial Boundary Plan. Barnsley West. Drawing Ref: 4848-JPG-ZZ-ZZ-DR-C-1001.

1.6 Previous Reports

JPG have completed a desk study and a preliminary geoenvironmental ground investigation report for the overall Barnsley West development site and a coal mining risk assessment and coal recovery report for the employment land only. Furthermore, a geoenvironmental ground investigation report was also completed for a parcel of land adjacent to the western boundary of the site where a roundabout is to be constructed. These reports are referenced below and should be read in conjunction with this report.

- JPG (Leeds) Limited. Geoenvironmental Desk Study Report. Barnsley West. Report Ref. 4848-JPG-XX-XX-RP-G-0604-S2-P04. Dated July 2019 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Preliminary Geoenvironmental Ground Investigation. Barnsley West. Report Ref: 4848-JPG-SW-XX-RP-G-0603-S2-P02. Dated July 2019 for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Coal Mining Risk Assessment and Coal Recovery Report. Employment Land, Barnsley West. Report Ref: 4848-JPG-Z2-XX-RP-G-1102-S2-P03. Dated August 2019, for Strata Sterling Barnsley West Limited.
- JPG (Leeds) Limited. Geoenvironmental Ground Investigation. Higham Common Road Roundabout, Barnsley West. Report Ref: 4848-JPG-HC-XX-RP-G-0603-S2-P02. Dated October 2020 for Strata Sterling Barnsley West Limited.

In addition, a review of the following report was included in the July 2019 desk study report.

- Eastwood and Partners Consulting Engineers. Geotechnical and Geo-Environmental Site Appraisal Commentary. Barnsley West. Report Ref. 36284. Dated 4 October 2013 for Strata.

1.7 Limitations

The general limitations to the nature of the investigation are outlined in Appendix G.

2.0 FIELDWORK

The intrusive investigation was designed to provide a preliminary assessment of the properties of the opencast backfill, the potential underground coal workings and the general ground, groundwater and hazardous gas conditions at the site.

The rationale behind each exploratory location is summarised in Table 2.0 below.

Table 2.0 – Exploratory Hole Rationale

Potential Issue	Exploratory Holes
Boreholes and trail pits targeting the Hunters Cottage OCCS and proposed cut areas	BH108, BH109, BH109A and TP112
Boreholes and trail pits targeting the proposed cut areas and the areas outside the opencast	BH121, BH122, BH125 and TP108 to TP110

It was not possible to access a parcel of land adjacent to the southern boundary of the site due to landownership issues, which were not known to JPG ahead of the fieldwork.

2.1 Fieldwork

The fieldwork was carried out from 11 March to 8 April 2019 and on 16 May 2019. The works undertaken are summarised in Table 2.1 below.

Table 2.1 – Summary of Ground Investigation Works

Investigation Method	No of Positions	Maximum Depth (m bgl)	Monitoring Wells	Monitoring
Trial Pits.	4	3.40	-	-
Rotary Open Hole Boreholes.	6	40.00	1 x 50 mm.	GG, WL.
			1 x Ext	Set

bgl – below ground level.
Ext – Extensometers.
Set – Settlement within the Hunters Cottage OCCS.
GG – ground gas monitoring (methane, carbon dioxide, oxygen, hydrogen sulphide, gas flow and atmospheric pressure using a portable gas meter).
WL – standing groundwater level using an electric contact dip meter.

The ground investigation has been undertaken in general accordance with the techniques outlined in BS5930:2015 Code of Practice for Site Investigations. An exploratory hole location plan is contained in Appendix A and exploratory hole records are presented in Appendix B. The investigation was carried out under the full-time supervision of an engineer from JPG.

2.2 Surveying

The exploratory locations were set out using a hand-held GPS unit. As-built locations were surveyed using a using Leica GPS equipment (accuracy +/- 10mm). The surveyed positions were then transferred onto the survey drawing.

3.0 LABORATORY TESTING

3.1 Chemical Analysis

The chemical analysis suite was designed to:

- Characterise near surface contamination levels to provide an assessment of the risks associated with direct contact with soils on site in its current state.
- Provide information on the general contamination concentrations in the various strata across the site; and
- Provide information on the solubility of contaminants and therefore the potential for impact to controlled waters.

The sampling and testing carried out comprises an initial assessment and that no targeted sampling has taken place to-date.

Chemical testing was carried out for the following determinands by Derwentside Environmental Testing Services Limited (DETS) in County Durham. Chemical analysis certificates are provided in Appendix C.

Soils – General

Selected samples of soil were analysed for the following potential contaminants on a total concentration basis:

Arsenic	Mercury	Copper
Cadmium	Lead	Nickel
Chromium	Zinc	Selenium
Cyanide (free)	Phenol	
Speciated Poly Aromatic Hydrocarbons (PAHs)		
Soil Organic Matter		
Sulphate (water soluble) and pH		
Asbestos Screen		

In addition, selected samples were submitted for the following analysis:

- Hexavalent chromium, total chloride, total sulphate, total sulphide and ammoniacal nitrogen; and
- Calorific Value Testing.

Selected samples of soil leachate were analysed for the following potential contaminants:

Arsenic	Mercury	Copper
Cadmium	Lead	Nickel
Chromium	Zinc	Selenium
Cyanide (free)	Total Cyanide	Phenol
Speciated Poly Aromatic Hydrocarbons (PAH)		
Sulphate and pH		

3.2 Geotechnical Testing

Laboratory geotechnical testing was carried out by Professional Soils Laboratory (PSL) in Doncaster in order to determine the physical characteristics of the soils and comprised the following:

- Moisture content, Atterberg limits and particle size distributions (PSDs)/sedimentations to confirm the field descriptions of the soils encountered.
- Compaction tests (2.5kg and 4.5kg rammer) and particle density to determine the compaction properties of the soils.
- California Bearing Ratio (CBR) test (2.5kg and 4.5kg rammer) to determine the bearing characteristics of the proposed fill material.
- Moisture Condition Value 5 and 1 point.
- pH, 2:1 water soluble sulphate, acid soluble sulphate and total sulphur.
- Organic content.

The geotechnical testing was carried out in accordance with BS1377:1990, "*Methods of Test for Soils for Civil Engineering Purposes*". The results of the geotechnical testing are provided in Appendix D.

4.0 GROUND AND GROUNDWATER CONDITIONS

4.1 Introduction

The ground conditions encountered during the investigation were consistent with the anticipated sequence of strata indicated by the desk study information and previous ground investigation report.

4.2 Ground Conditions

Topsoil, generally comprising soft to stiff dark brown, slightly sandy, slightly gravelly clay with rootlets was encountered in TP108 to TP110, TP112, BH108, BH109, BH109A, BH121, BH122 and BH125 to depths of between 0.10m bgl in TP108 and 0.50m bgl in BH122, an average of 0.25m.

The made ground within and immediately surrounding the Hunters Cottage OCCS typically comprised colliery spoil, which was recorded as compact or stiff in the rotary boreholes and as soft to firm, dark greyish brown, sandy, gravelly clay and/or dark brownish grey, clayey, sandy gravel in the trail pits. The colliery spoil was encountered in TP109, TP110, TP112, BH108, BH109 and BH109A to depths of between 1.50m bgl in TP109 and 13.00m bgl in BH108.

The made ground outside the Hunters Cottage OCCS, typically comprised brown clay fill in the rotary boreholes and soft to stiff, greyish brown and orangish brown sandy, gravelly clay. The cohesive made ground was encountered in TP108 and BH121 to depths of 2.80m bgl and 0.50m bgl, respectively. The made ground encountered in TP108 could potentially be arisings associated with the construction of the M1 motorway to the south.

Residual soils, typically comprising firm to stiff, medium strength, orangish brown and grey, sandy, gravelly clay was encountered in TP108, TP109, TP110 and BH122 to depths of 3.40m bgl, 2.90m bgl, 2.90m bgl and 1.10m bgl, respectively.

The underlying bedrock geology comprised the Pennine Middle Coal Measures. The bedrock geology was recorded as thinly laminated, light grey, occasionally brown, de-structured mudstone to a depth of 3.30m bgl in TP109 and as grey and brown, interbedded mudstone, sandstone and coal seams to a maximum proven depth of 40.00m bgl in BH121.

4.3 Coal Mining Assessment

BH108 and BH109A were carried out within Hunters Cottage OCCS, in which the Top Haigh Moor coal seam was the deepest coal seam extracted by opencast techniques; these boreholes were extended below the base of the opencast to establish the rock cover over the underlying Low Haigh Moor coal seam. BH108 proved the base of the OCCS at 13.00m bgl and the base of the Low Haigh Moor coal seam at 23.40m bgl (0.80m thick). BH109A proved the base of the opencast at 11.20m bgl and the base of the Low Haigh Moor coal seam at 18.70m bgl (0.40m thick). Neither borehole encountered any underground coal workings. In both boreholes there is sufficient rock cover over the Low Haigh Moor coal seam so that if coal workings were present, they would not affect the surface stability of the site.

BH121, BH122 and BH125 were drilled outside the Hunters Cottage OCCS. None of the boreholes encountered underground coal workings.

BH121, drilled close to the western boundary of the proposed employment land, encountered coal seams between 6.30m and 8.00m (1.70m thick), between 14.60m and 15.00m bgl (0.40m thick), between 16.00m and 16.50m bgl, and between 29.20m and 29.50m bgl (0.30m thick). These coal seams have been interpreted as the Top Haigh Moor, the Low Haigh Moor (two leaves) and a thin coal seam. Based on the depths and thicknesses of the coal seams, if underground coal workings were present in the Top Haigh Moor, remedial action would be required. In addition, if both leaves of the Low Haigh Moor coal seam have been worked, remedial action will be required.

Based on the findings of the Higham Common Road Roundabout investigation located immediately to the west of the commercial area, five rotary boreholes were drilled with the Top Haigh Moor proven in all five boreholes and the Low Haigh Moor proven in four boreholes. In each borehole, the coal seams were proven to be intact. This provides more confidence that the shallow coal seams on the western flank have not been worked by underground means.

BH122 was drilled close to the northern boundary of the employment land. A very thin coal seam (0.10m thick) was encountered at 8.10m bgl. A thick bed of coal (2.30m thick) was encountered between 15.40m and 17.70m bgl and may represent either the Gawber or Top Haigh Moor coal seam, the uncertainty due to the nearby fault.

BH125 was drilled close to the eastern boundary of the employment land. Coal seams were encountered between 3.30m and 4.30m bgl (1.00m thick), between 15.50m and 15.80m bgl (0.30m thick), between 23.90m and 24.00m bgl (0.10m thick), between 25.10m and 25.50m bgl (0.40m thick) and between 36.60m and 36.90m bgl (0.30m thick). The coal seams are considered to represent the Gawber, a thin seam, the Swallow Wood (two leaves) and the Top Haigh Moor. Only the Gawber coal seam poses a potential risk to the surface stability of the site, based on coal seam thickness and depth at this location.

To-date only intact coal seams have been encountered beyond the extent of the opencast and beneath the base of Hunters Cottage OCCS. The majority of the intact coal seams proven as part of this preliminary investigation indicate thicknesses similar to those recorded on the BGS 1:10,000 scale geological map, the abandonment plans and those stated within the South Yorkshire Mining Advisory Service (SYMAS) report.

The site-wide coal seam information is summarised in Table 4.3.1.

Table 4.3.1: Coal Seam Succession and Relevant Information

Coal Seam (Youngest to Oldest)	BGS Thicknesses (m)	Recorded Thickness (m) (Abandonment Plans)	Proven Thickness (m) (JPG SI - 2019)		Proven Depth Range (m) (JPG SI – 2019)		Maximum Proven Seam Thickness (m)	Average Seam thickness according to SYMAS (m)	Coal Seam Thickness used on models (m)
Dunsil Coal	0.46 - 0.81	N/A	0.10* (BH122 Only)		8.10 – 8.20		0.10	0.60	0.60
Thin coal/unnamed	N/A	N/A	N/A		N/A		N/A	<0.40	0.40
Gawber Coal	0.72 - 0.76	0.76 - 0.90	2.30* (BH122 Only)	1.00	15.40 – 17.70 (BH122 Only)	3.30 – 4.30	1.00 (Excluding BH122)	0.70	1.00
Thin coal	0.38	0.34 - 0.38	0.30		15.50 – 15.80		0.30	<0.40	0.30
Swallow Wood Coal	0.30 - 1.15	0.36 - 0.91	0.10* (BH122 Only)		8.10 – 8.20		0.10	0.90	0.90
Top Haigh Moor	0.69 - 1.19	0.91 - 1.12	2.30* (BH122 Only)	0.30 – 1.70	15.40 – 17.70 (BH122 Only)	6.30 -36.90	1.70 (Excluding BH122)	1.10	1.70
Low Haigh Moor	0.43 - 1.02	0.89	0.40 - 1.90**		14.60 – 23.40		1.90**	0.80	0.80
Thin coal/unnamed	N/A	N/A	0.30		29.20 – 29.50		0.30	N/A	0.30

N/A: Not applicable – seam not encountered.
* - Could potentially be a different coal seam, dependent on fault line position. Additional investigative works required to locate the fault line. BH122 only.
** - Including partings and 2nd leaf

Based on the information in Table 4.3.1, a series of conceptual ground models, including a coal mining constraints plan and illustrative geological cross sections have been produced. The proven coal seams vary in thickness across the site. Therefore, for the models, the maximum proven thickness was generally applied for a preliminary assessment. If the coal seam was not encountered during the ground investigation, the maximum recorded thickness by SYMAS was applied.

Additional ground investigative works is required to delineate the areas where underground coal workings may be present.

A plan and cross sections showing areas of residual risk from underground coal mining has been prepared by JPG and is referenced below.

- JPG (Leeds) Limited. Conceptual Ground Model - Coal Mining Risks Level Assessment. Barnsley West. Drawing Ref: 4848-JPG-SW-XX-DR-G-1307-S2-P05. Dated July 2019.
- JPG (Leeds) Limited. Conceptual Ground Model – Illustrative Cross Sections, Cross Sections A-A', B-B' & C-C'. Barnsley West. Drawing Ref: 4848-JPG-SW-00-DR-G-1304-S2-P03. Dated June 2019.

4.4 Laboratory Testing

Three samples of natural ground (residual soil), three samples of made ground and three samples of colliery spoil were submitted for laboratory testing. The testing suite was designed to classify the materials and assess the suitability of the materials for re-use in earthworks.

Moisture Content and Atterberg Limit Testing

Seven samples were submitted for moisture content testing and five samples were also submitted for Atterberg Limit testing. The results are summarised in Table 4.4.1 below.

Table 4.4.1 – Summary of Moisture Content and Atterberg Limit Testing

Material	Moisture Content (%)		Atterberg Limits Modified Plasticity Index (%)	
	No of samples	Range	No of samples	Range
Cohesive Made Ground	3	11 to 14	2	15.04 to 16.15
Cohesive Residual Soil	2	17 to 18	1	24.75
Cohesive Colliery Spoil	2	16 to 18	2	20.24 to 21.60

The results of the Atterberg limits testing indicate the materials to be of low to intermediate plasticity with a low to medium volume change potential.

Particle Size Distribution

Particle size distribution/sedimentation testing was carried out on one made ground sample in order to confirm the field descriptions of the material and determine the proportion of clay minerals in the material. The result is summarised in Table 4.4.2.

Table 4.4.2 – Summary of Particle Side Distribution/Sedimentation Testing

Exp Hole	Depth (m bgl)	Material	Cobbles (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
TP108	2.50 – 2.60	Cohesive Made Ground	0	33	22	24	21

Compaction Testing

One sample of cohesive colliery spoil, one sample of granular colliery spoil, one sample of cohesive made ground and one sample of residual soil were submitted for dry density/moisture content relationship testing. The compaction tests were carried out using a 2.5kg and a 4.5kg hammer. The results are summarised in Table 4.4.3 below.

Table 4.4.3 – Summary of Compaction Test Results

Exp. Hole	Depth (m bgl)	Material	Weight of Rammer	Natural Moisture Content (NMC)	Max. Dry Density (Mg/m3)	Optimum Moisture Content (OMC)	Suitability for Compaction and Range of Acceptable Moisture Contents
TP108	2.50 – 2.60	Cohesive Made Ground	2.5kg	13	1.91	13	Suitable, 12.5 – 17.5%
			4.5kg		2.05	10	Suitable, 9.0 – 14.0%
TP109	1.50 – 1.90	Residual Soil	2.5kg	17	1.80	17	Suitable, 16.0 – 21.0%
			4.5kg		1.90	14	Suitable, 13.0 – 17.5%
TP110	2.00 – 2.50	Cohesive Colliery Spoil	4.5kg	18	1.97	12	Unsuitable, 11.0% - 16.0% (Too Wet)
TP112	2.50 – 2.80	Granular Colliery Spoil	4.5kg	10	2.09	8	Suitable, 8.0% to 12.0%

Suitability for compaction is defined as achieving greater than 95% of the maximum dry density and less than 5% air voids.

Based on the results of the compaction and moisture content testing, the cohesive made ground and residual soil materials indicate that suitable compaction can be achieved with both the 2.5kg and 4.5kg rammers.

The results for the colliery spoil material vary, with suitable compaction with a 4.5kg rammer being achieved for the granular material but not for the cohesive material, which is indicated to be too wet to achieve suitable compaction (based on one sample tested only).

California Bearing Ratio Testing

One sample of residual soil was submitted for laboratory California Bearing Ratio (CBR) testing. The results are summarised in Table 4.4.4 below.

Table 4.4.4 – Summary of California Bearing Ratio Results

Exp. Hole	Depth (m bgl)	Material	Compaction Conditions	As Received Moisture Content (%)	CBR Value (%)		Average CBR (%)*
					Sample Top	Sample Base	
TP109	1.50 – 1.90	Residual soil	2.5kg	17	9.7	10.1	9.90
			4.5kg	17	10.7	11.2	10.95

* If the results for the top and base of the sample are within +/-10% of the mean value, then the average result may be reported.

The laboratory CBR test results for the residual soil ranged between 9.7% and 11.2%.

Moisture Condition Value

Moisture condition values (MCV) below 8.5 may be indicative of soils which would be too wet to compact and MCV values above 12 may be indicative of soils which are too dry to achieve adequate compaction.

Two single-point moisture condition value (MCV) calibrations were carried out on one sample of cohesive made ground and one sample of residual soil. The MCV result for the cohesive made ground was 9.9 and the result for the residual soil was 9.5. Both results indicate suitable compaction could be achieved.

Two 5-point MCV calibrations were carried out on one sample of cohesive colliery spoil and one sample of granular colliery spoil. Based on the MCV results, the cohesive colliery spoil is considered too wet and the granular colliery spoil is considered too dry to achieve suitable compaction.

4.5 Groundwater

During the site investigation, perched groundwater was noted in TP109 at 1.00m bgl, 1.50m bgl and 3.00m bgl and in TP110 from 2.50m bgl. Groundwater strikes were noted in BH108 at 5.10m bgl, rising to 4.20m bgl after 20 minutes, BH109A at 5.10m bgl, BH122 at 5.20m bgl and BH125 at 4.80m bgl.

A monitoring well was installed and sealed within the colliery spoil in BH109A. No groundwater was recorded in this well during the six week monitoring period.

It should be noted that the groundwater conditions recorded are based on observations made at the time that site work was carried out. Groundwater levels will vary owing to seasonal and weather-related effects.

4.6 Ground Gas

Ground gas monitoring has been undertaken on six occasions. The works were carried out using a portable gas meter (Geotech GA5000) in accordance with the standard JPG methodology and included measurements of methane, carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide, gas flows and atmospheric pressure. The results of the gas monitoring are presented in Appendix F and discussed in Section 6.7 of this report.

4.7 Extensometer (Settlement) Monitoring

An extensometer was installed in BH109 and was monitored by JPG on seven occasions, 11 April and 18 April 2019, 14 June 2019, 13 September 2019, 21 January 2020, 28 May 2020, 20 November 2020 and 28 April 2021. The monitoring was carried out using a reed switch probe. The results are presented in Table 4.7.1.

Table 4.7.1 – Summary of Extensometer Results for BH109

	Depth to Extensometer Magnet (m bgl)			O/A Difference Between Top & Bottom Magnets (m)
Date Surveyed	**1**	**2**	**3 (Base Magnet)**	**3 - 1**
18.04.19	2.231	7.070	14.251	12.020
14.06.19	2.232	7.069	14.250	12.018
13.09.19	2.230	7.069	14.250	12.020
21.01.20	2.231	7.069	14.254	12.023
28.05.20	2.231	7.071	14.252	12.021
20.11.20	2.232	7.070	14.253	12.021
28.04.21	2.232	7.071	14.254	12.022
Difference (mm)	1	1	3	
Overall Difference – Top and Bottom Magnets (mm)				2

A negative change in difference between the top and bottom magnets indicate the magnets are getting further apart, however a positive difference could confirm the magnets are getting closer together and therefore could potentially indicate settlement.

The overall change in difference between the top and bottom magnets in BH109 has been calculated as 2mm. The variation recorded on these visits is attributed to accuracy of the readings.

Assessment of the results of extensometer monitoring to date does not highlight any general settlement trends, either downward or upward.

An assessment of future self-weight settlement is included in Section 5.5 of this report.

5.0 GEOTECHNICAL AND ENGINEERING ASSESSMENT

5.1 Development Proposals

It is proposed to develop the site for commercial end use. A plan outlining the proposed commercial red line boundary is referenced below and provided in Appendix A.

- JPG Leeds Limited. Commercial Boundary Plan. Barnsley West. Drawing Ref: 4848-JPG-ZZ-ZZ-DR-C-1001-S2-P02. Dated March 2023.

5.2 Foundations and Ground Floor Construction

It is proposed to carry out large-scale earthworks across the site in order to create four development plateaus. A drawing outlining the four plateaus is referenced below and provided in Appendix A.

- JPG Leeds Limited. Proposed Earthwork Levels. Barnsley West. Drawing Ref: 4848-JPG-ZZ-ZZ-DR-C-1200-S2-P04. Dated March 2023.

A large area of the site is underlain by significant thicknesses of non-engineered colliery spoil associated with the backfilled Hunters Cottage OCCS, furthermore the northern boundary of the site also encroaches onto the highwall of the Hunters Cottage Extension OCCSs. Outside of the backfilled opencast sites, the natural strata comprise residual soil and interbedded mudstone and sandstone of the Pennine Middle Coal Measures Formation (bedrock) with locally shallow coal seams.

The deep colliery spoil in its current condition is considered unsuitable for the support of structural loads, due to the variation in geotechnical properties. If shallow foundations were to be used, the colliery spoil would become over-stressed, leading to significant settlement.

Outside of the backfilled opencast sites, it Is considered likely that shallow foundations could be utilised within the firm to stiff residual soil or onto the bedrock. If shallow coal seams are encountered in foundation excavations, the coal should be removed at least 1.0m from the face of the foundation.

At this stage, based on the findings of the preliminary ground investigation, the proposed development plateaus and proposed large-scale earthworks, it is recommended that in-situ ground improvement, e.g. Dynamic Compaction, is carried out on the backfilled opencast materials to achieve the required allowable bearing capacity and limits on settlement for the proposed development. Any ground improvement will require validation in order to confirm that the allowable bearing capacity and acceptable limits on settlement have been achieved.

Alternatively, consideration could also be given to placing the foundations and ground floor slab on controlled modulus columns (CMCs) or utilising a piled foundation solution.

The advice of a specialist piling and/or ground improvement contractor will be required to confirm that ground conditions are suitable for these techniques.

Where foundations are to span over the highwall and therefore different strata, precautions will be required to limit potential differential settlement. It is recommended that sections of the highwall, up to 5m, are removed where they are present at shallow depth below the development platform in order to minimise the differential settlement.

Additional ground investigative works are required in order to facilitate the design of foundations and ground floor construction. These works could be carried out as part of the site preparation/earthworks contract.

5.3 Earthworks

Based on the limited earthworks testing results, the granular colliery spoil, cohesive made ground and residual soil are considered suitable for re-use in earthworks.

The results of the laboratory testing also indicates that the cohesive colliery spoil material may be too wet to achieve suitable compaction (based on limited laboratory testing undertaken to date). Further testing of the colliery spoil made ground is required to confirm its suitability for earthworks and compaction requirements. If the material is still too wet to be effectively compacted, consideration should be given to the addition of lime and/or cement to improve the material for re-use.

The following document provides guidance on the suitability of materials for improvement or stabilisation by the addition of lime and/or cement:

- The Highways Agency Design Manual for Roads and Bridges, Advice Note HA 74/07, Volume 4, Section 1, Part 6, 'Treatment of Fill and Capping Materials Using Either Lime or Cement or Both' (HA74/07).

Proper selection and control will be required as part of the earthworks. The materials should not be allowed to deteriorate during excavation and compaction and must be sufficiently protected from traffic after placement.

A detailed Earthworks Specification is required prior to commencement of works onsite.

5.4 Control of Groundwater

The ground investigative works indicate groundwater at shallow depths during the early summer months, especially within the backfilled opencast. Control of groundwater and surface water control will be required as part of the earthworks. Significant (fast) inflows into boreholes, BH108, BH109A, BH122 and BH125 suggest that control by pumping from sumps might not be possible in the area around the former Hunters Cottage OCCS.

Reference should be made to guidance given in the Manual of Contract Documents for Highway Works, Volume 1: Specification for Highway Works, Series 600 Earthworks. In particular the following recommendations are made with respect to the control of surface water and shallow groundwater.

The contractor shall keep earthworks free of water including:

- Arranging for the rapid removal of water which is shed on the earthworks or enter the earthworks from any source.
- Lowering and maintaining by appropriate measures, the water level in excavations sufficiently to enable the permanent works to be constructed.

In order to keep the site free of water the contractor shall do the following:

- Form and maintain cuttings, embankments and other areas of fill with appropriate falls, gradients and sealed surfaces.
- Provide where necessary temporary watercourses, drains, and pumping.
- Discharge accumulated water and groundwater into the permanent outfalls of the drainage system where practicable; and
- Provide adequate means for trapping silt on temporary systems discharging into permanent drainage systems.

5.5 Settlement

The completion of re-soiling at Hunters Cottage and Hunters Cottage extensions OCCSs was completed in January 1950. If development on the site was to commence in 2025, then 75 years will have passed since the most recent backfilling.

To evaluate the settlement within the backfilled opencast sites, assumed parameters based on published literature have been used. Generally, guidance given in BRE document FB 75 '*Building on fill: geotechnical aspects*' (Third edition, 2015) has been followed.

Settlement Following Placement of Engineered Fill
Where ground levels are to be raised, settlement will be induced in the underlying untreated colliery spoil. The settlement will be a combination of consolidation and self-weight settlement, assuming that any immediate settlement will be accommodated during the earthworks.

Future Settlement

After the completion of the development platforms, settlement within the backfilled opencasts will be the result of the following processes:

- Immediate settlement: This is assumed to take place at the time of or shortly after placing the load on the fill.

- Primary (consolidation) settlement: This will occur in the cohesive fill due to loading of the development. This can be calculated based on the applied static and/or live loads and the material properties of the backfilled material within the zone of influence of the applied load.
- Secondary (creep) settlement: This is due to longer-term self-weight settlement of the re-engineered fill and the untreated backfilled material.
- Inundation settlement: Rebound of the groundwater within the backfilled material to the natural level. Water ingress into the fill material can change the equilibrium and cause the soil void spaces to collapse, thus leading to settlement.

It is understood that some form of ground improvement and/or piled foundation solution will be utilised in order to accommodate the foundations and ground-bearing floor slabs.

Immediate Settlement

Immediate settlement is determined using deformation (secant) modulus (E). Empirical values of Young's modulus were taken from Table 11.7 in *Handbook of Geotechnical Investigation and Design Tables* (Look, B. 2014. Second edition, 2014).

The placement of the fill material in areas where site levels are to be raised could bear onto untreated colliery spoil thus potentially causing immediate settlement.

As the proposed pad foundations and ground-bearing floor slab could potentially bear onto re-engineered colliery spoil (stiff clay), an E of 13.5MPa is considered acceptable. However, the underlying untreated colliery spoil (firm cohesive colliery spoil and medium dense granular colliery spoil), an E of 5MPa and 25MPa, respectively, is considered acceptable.

Two models (worst case: deepest part of the Hunters Cottage OCCS is 19.0m) has been set up in Settle 3 which includes 3.0m of re-engineered colliery spoil, overlying 5.0m of cohesive colliery spoil and 11.0m of granular colliery spoil. The first model assumes a pad foundation with dimensions of 2.0m by 2.0m at 2.0m depth with a design load of 120kN/m^2 and the second model assumes a ground-bearing slab with dimensions of 100m by 50m and a design load of 50kN/m^2.

An immediate settlement of approximately 18mm was calculated in the first model and approximately 45mm in the second model. These models are provided in Appendix E.

It is considered that majority of the immediate settlement will be accommodated during the earthworks.

Primary (Consolidation) Settlement

Due to the absence of in situ testing or laboratory data in relation to compressibility, the SPT N values and the plasticity index, retrieved from the wider JPG Geoenvironmental Ground Investigation Report, dated 2019, and the Eastwood and Partners Consulting Engineers Report, dated October 2013, can be used to obtain a value for the coefficient of compressibility (Mv) after Stroud. Where the Stroud correlation cannot be used, empirical values for Mv have been taken from Table 2.11 in *Foundation Design and Construction* (Tomlinson, M.J. 7th edition, 2001).

Based on empirical values for firm clay and medium dense granular colliery spoil, assumed Mv of 0.20 m^2/MN and 0.05 m^2/MN, respectively, are considered acceptable. An assumed Mv of 0.10 m^2/MN has been used for the re-engineered colliery spoil, this is considered acceptable.

Based on the same models detailed above, a consolidation settlement of approximately 12mm was calculated for first model and approximately 75mm for second model. These models are provided in Appendix E.

Additional ground investigative works is required to obtain in-situ and laboratory data of the underlying colliery spoil and residual soils in order to refine the above assessment.

Secondary (Creep) Settlement

The colliery spoil below the footprint of the proposed foundations is to be improved by re-engineering, rapid dynamic compaction and/or dynamic compaction.

Where the colliery spoil is not subject to treatment, it is anticipated that further creep settlement will occur within the untreated materials.

Sowers Method, used to estimate the creep settlement within each backfilled opencast, is expressed as the following equation:

$S = \alpha (\log t_2 - \log t_1)$.

Where:

α is alpha.
t_1 is time since infilling.
t_2 is time since development start.

For the treated colliery spoil, the creep settlement can be calculated using an assumed alpha of 0.2 (based on the Institution of Civil Engineers, *Earthworks: A guide*, second edition, 2015). The predicted creep settlement for different thicknesses of treated fill over the 50-year design life (commercial) for Hunters Cottage OCCS is presented in the Table 5.5.1 below.

Table 5.5.1: Creep Settlement (α = 0.2%) for Treated Fill Thickness – Hunters Cottage OCCS

Time Since Treatment		Settlement (%)	Settlement (mm) for Thickness of Treated Fill (m) as below				
Years	Months		1	5	10	15	20
0	1	-					
1	12	0.22	2	11	22	32	43
2	24	0.28	3	14	28	41	55
5	60	0.36	4	18	36	53	71
10	120	0.42	4	21	42	62	83
20	240	0.48	5	24	48	71	95
30	360	0.54	5	26	51	77	102
50	600	0.59	6	28	56	83	11
Estimated Future Creep Settlement (mm)			**3**	**17**	**34**	**51**	**68**

It is anticipated that most of the creep compression in the untreated material beneath the treated zone will have already occurred due to the time since infilling. However, where ground levels are to be raised in particular, further self-weight settlement may occur.

At this stage, accurate alpha values for the untreated colliery spoil are not possible to calculate as there is no reliable settlement data, i.e. the extensometers have not been the ground for a significant period of time, and they have not (to-date) given any indication of ongoing settlement. Therefore, assumed parameters from published literature have been used in the assessments below.

Taking t1 as January 1950, t2 as January 2025, and an assumed initial alpha as 0.8 for uncompacted fill. The creep settlement that has already occurred for the untreated fill and the remaining creep settlement predicted for the 50 years past the development start date for differing thicknesses of colliery spoil is presented in Table 5.5.2 below.

Table 5.5.2: Creep Settlement (α = 0.8%) for Untreated Fill Thickness – Hunters Cottage OCCS

Time Since Development Start	Time Since Infilling		Settlement (%)	Settlement (mm) for Thickness of Untreated Fill (m) as below					
Years	Years	Months		3	6	9	12	15	18
-	0	1	-						
0	75	900	2.36	71	142	213	284	355	425
5	80	960	2.39	72	143	215	286	358	429
10	85	1020	2.41	72	144	217	289	361	433
20	95	1140	2.45	73	147	220	293	367	440
30	105	1260	2.48	74	149	223	298	372	446
50	125	1500	2.54	76	152	229	305	381	457
Estimated Future Creep Settlement (mm)				**5**	**11**	**16**	**21**	**27**	**32**

The alpha value used for these calculations is considered conservative and the same alpha value has been used for the full thickness of colliery spoil. The estimated future creep settlement ranges between 5mm for 3.0m of untreated fill to 32mm for 18m of untreated fill.

With the information to date, alpha has been altered with thickness of colliery spoil, to estimate a more realistic creep settlement. Table 5.5.3 below shows variations in alpha with different thicknesses of colliery spoil.

Table 5.5.3 Creep Settlement (α = variable) for Untreated Fill Thickness – Hunters Cottage OCCS

Time Since Development Start	Time Since Infilling		Settlement (mm) for Thickness of Untreated Fill (m) as below					
Years	Years	Months	3	6	9	12	15	18
-	0	1						
0	75	900	71	124	160	177	195	213
5	80	960	72	125	161	179	197	215
10	85	1020	72	126	162	181	199	217
20	95	1140	73	128	165	183	202	220
30	105	1260	74	130	167	186	205	223
50	125	1500	76	133	172	191	210	229
Assumed α over depth range			**0.8**	**0.6**	**0.4**	**0.2**	**0.2**	**0.2**
Estimated Future Creep Settlement (mm)			**5**	**9**	**12**	**13**	**15**	**16**

It is considered that the alpha values used in the tables above are more reflective of the conditions present on the site. The estimated future creep settlement with a range of alpha values ranging from 0.8 to 0.2, decreasing with depth, ranges between 5mm with 3.0m of fill and 16mm with 18.0m of fill.

It is recommended further monitoring of the extensometers should be carried out for as long as possible, to provide more accurate alpha values for the site. However, due to the time of backfill in Hunters Cottage OCCS is 75 years, it is assumed that majority of self-weight settlement will have occurred.

Inundation Settlement

Only one monitoring well (BH109A) was installed in the Hunters Cottage OCCS. No monitoring wells were installed outside of the opencast and a groundwater level was not determined in BH109A. Therefore, it is unclear whether the groundwater level has rebounded post backfill. However, due to the time of backfill in Hunters Cottage OCCS is 75 years, it is assumed that majority of the inundation settlement will have occurred.

It is recommended that additional monitoring wells are installed inside and outside of Hunters Cottage OCCS in order to monitor the groundwater and identify whether the groundwater level has rebounded.

Total Predicted Settlement

Total settlement is the combined results of immediate, consolidation and creep settlement. The settlement results for each OCCS are presented in Tables 5.5.4 and 5.5.5.

Table 5.5.4 – Settlement Results for Hunters Cottage OCCS – First Model

Immediate Settlement (mm)	Secondary (Consolidation) Settlement (mm)	Secondary (Creep) Settlement * (mm)	Secondary (Creep) Settlement (Varied α) ** (mm)	Total Predicted Settlement
17.9	11.9	5	16	**50.8**

*** - Creep settlement in treated colliery spoil (assumed 3.00m of treated material).**
**** - Creep settlement in untreated colliery spoil**

Table 5.5.5– Settlement Results for Hunters Cottage OCCS – Second Model

Immediate Settlement (mm)	Secondary (Consolidation) Settlement (mm)	Secondary (Creep) Settlement * (mm)	Secondary (Creep) Settlement (Varied α) ** (mm)	Total Predicted Settlement
45.7	75.2	5	16	**151**

*** - Creep settlement in treated colliery spoil (assumed 3.00m of treated material).**
**** - Creep settlement in untreated colliery spoil**

Differential Settlement over Buried Highwalls

Where highwalls are present, there is the potential for differential settlement. Depth to the highwall varies onsite, differential creep settlement of the fill needs to be considered. Differential consolidation settlement also needs to be considered for the ground bearing floor slabs of the commercial units.

The total differential settlement for a ground floor slab combines the differential consolidation settlement and the worst-case differential creep settlement. It is assumed that the differential immediate settlement will be accommodated during the earthworks. Total differential settlement for a ground bearing floor slab has been calculated as approximately 25mm (1:4,000).

Additional ground investigative works is required to identify the OCCS highwalls in order to calculate the differential settlement for any future proposed commercial units.

5.6 Roads, Pavements and Hardstanding Surfaces

Laboratory CBR values for the residual soil are typically >5%. At this stage, it is recommended that a design CBR of 3% is adopted for pavement design for the engineered colliery spoil, assuming any soft spots at formation level are removed.

Considering majority of the site comprises colliery spoil or made ground, it is recommended that additional ground investigative works is carried in order to assess the onsite materials.

It is likely that for adoptable highways (Section 38 and Section 278), the local authority will require at least 3m of colliery spoil to be engineered below the footprint.

5.7 Excavations

On completion of the earthworks, excavations through the compacted materials and exposed natural ground are likely to be unstable over the construction period and temporary side support is likely to be required.

Occasional perched groundwater has been encountered at shallow depth within the southern half of the site and could potentially be encountered in excavations.

Good working practice with respect to drainage of excavations and formations will be required to protect materials. Any excavation for structural foundations must be covered without delay with blinding concrete to prevent softening by water.

The requirement for temporary support of excavations should be assessed on an individual basis and in any case, excavations of greater than 1.20m depth requiring man entry will require temporary support in accordance with HSE guidance. Alternatively, the sides of the excavation will need to be battered back for the safety of operatives. Guidance on safe batter slopes can be obtained from CIRIA Report 97 Trenching Practice.

5.8 Obstructions

It is noted that the colliery spoil includes boulders from the historically excavated bedrock material. An allowance for excavation and processing of this material for re-use on site should be made.

5.9 Chemical Attack on Buried Concrete

Laboratory testing has been undertaken on samples of the topsoil, colliery spoil, made ground and residual soil to determine the sulphate content and acidity and hence the concrete class required for buried concrete.

Laboratory testing in the topsoil, colliery spoil and made ground recorded water-soluble sulphate contents ranging between 21mg/l and 250mg/l and pH values between 6.7 and 8.4.

Laboratory testing in the residual soil, recorded a water-soluble sulphate content of 51mg/l and pH values of 8.1.

The site has been assessed in accordance with BRE Special Digest 1:2005 'Concrete in Aggressive Ground'. It has been assessed in accordance with the requirements for brownfield locations.

Foundations are likely to come into contact with both the made ground and underlying natural ground. On this basis it is recommended that concrete should be designed to Aggressive Chemical Environment for Concrete (ACEC) Design Sulphate Class DS-1 and ACEC Class AC-1. This assessment has been made in accordance with BRE Special Digest 1: 2005, entitled 'Concrete in Aggressive Ground'.

Additional samples should be obtained from the underlying made ground, natural ground and groundwater in order to thoroughly review the concrete design classification.

5.10 Coal Mining Constraints

The coal seams which are within influencing distance of the surface are indicated on the illustrative cross sections A-A' to C-C' and also the coal mining risks plan. These cross sections are presented in Appendix A. The assessment does not consider future changes in levels at the site, i.e. where significant areas of cut are required, the thickness of competent rock cover over the coal seam may be reduced. Therefore, this assessment should be repeated once final cut – fill levels are known.

Based on the proven coal seam information and recorded seam quality the likelihood of any underground workings is shown in Table 5.10.1 below.

Table 5.10.1: Likelihood of Underground Workings – Employment Land

Seams	Min Seam Depth (m)	Max Seam Thickness (m)	Seam Quality - based on SYMAS report	Likelihood of Underground Workings Affecting Surface Stability of Site (Low/Moderate/High)
Gawber	3.30	1.00 (Excluding BH122)	Inferior/ medium	Low to Moderate
Thin	15.50	0.30	Inferior	Low
Swallow Wood	8.10	0.10	Good	Low
Top Haigh Moor	6.30	1.70 (Excluding BH122)	Medium/Good	Low to Moderate
Low Haigh Moor	14.60	1.90*	Medium/Good	Low (below Hunters Cottage OCCS) Low to Moderate (to west of Hunters Cottage OCCS)

*** - Including partings and the 2nd leaf**

Based on the information to date, the Gawber, Swallow Wood, Top Haigh Moor and Low Haigh Moor coal seams are all considered to pose a low to moderate risk of unrecorded underground workings and more investigation is required to confirm the presence or absence of workings in these seams outside the Hunters Cottage OCCS. The Coal Authority abandonment plan for the Hunters Cottage OCCS records old workings in the Top Haigh Moor coal seam (annotated as Swallow Wood Bottom) approximately 150m to the south east of the site. No evidence of coal workings has been identified to date in any of the aforementioned coal seams.

The typical proven thickness of the Top Haigh Moor across the area is between 0.30m in BH125 and 1.70m in BH121. As there is some uncertainty over the coal seam encountered in BH122, this has been left out of this preliminary assessment.

Additional ground investigative works will be required in the area immediately to the north of the Hunters Cottage OCCS in order to access which geological sequence of coal seams have been encountered, i.e. . either the Dunsil and the Gawber coal seams or the Shallow Wood and Top Haigh Moor coal seams.

The Low Haigh Moor is shown to split into two leaves towards the western boundary of the site in BH121. The possibility of both coal leaves having been extracted by underground methods cannot be dismissed at this stage. Based on the recorded thicknesses of the Low Haigh Moor below the base of the Hunters Cottage OCCS, any coal workings (if present) would not have the potential to affect the surface stability of the site. However, it would be prudent to drill further boreholes to confirm that the Low Haigh Moor does not come within influencing depth.

Additional ground investigative works should be carried out to the east and west of the Hunters Cottage OCCS to confirm the absence of workings in the aforementioned coal seams.

There are no recorded mine entries on the site, although there remains a residual risk of unrecorded mine entries. Should an unrecorded mine entry be encountered, a suitably qualified person should be consulted.

5.11 Geotechnical Risk Register

Table 5.11.4 shows details of the Geotechnical Risk Register for the remediation and construction for the entire site.

A risk register uses a qualitative approach and the following equation to determine the degree of risk per hazard.

Degree of Risk = Likelihood x Effect:

The likelihood and the scale of effect are determined using tables 5.11.1 and 5.11.2 respectively, which together provide the degree of risk, table 5.11.3.

Table 5.11.1: Scale of Likelihood

Likelihood (L)	Scale
Very Likely	4
Likely	3
Unlikely	2
Negligible	1

Table 5.11.2: Scale of Effects

Effect (E)	Scale
Very High	4
High	3
Low	2
Very Low	1

Table 5.11.3: Degree of Risk

Degree of Risk	Risk Level	Recommended Response
1 to 4	Trivial	None
5 to 8	Significant	Consider attention
9 to 12	Substantial	Attention required
16	Intolerable	Work must not start until risk is reduced

Table 5.11.4: Geotechnical Risk Register – Based on Preliminary Findings

No.	Hazard	Risk/ undesirable consequence	Risk assessment (current)				Practicable mitigation	Risk assessment (mitigation)			
			L	E	R	Risk level		L	E	R	Risk level
1	Deep untreated colliery spoil.	Damage caused by consolidation, creep and differential settlement of proposed structures.	3	3	9	Substantial	Treatment/re-engineering of the full thickness or partial thickness of the colliery spoil should reduce the effects of settlement. Consideration should be given to other treatment options, e.g. rapid dynamic compaction and/or dynamic compaction, in order to reduce the risk further.	2	2	4	Trivial
2	Rebounding groundwater	Damage caused by inundation settlement.	2	3	6	Significant	Further assessment required. Additional monitoring wells should be installed inside and outside of the OCCS.	1	3	3	Trivial
3a	Shallow Groundwater	Excavations becoming unstable, softening of materials and moisture content of site won materials increasing.	2	3	6	Significant	Measures put in place to control water and protect the formation from water. Observation of cut faces for any seepages, if noted slope drainage is required.	1	2	2	Trivial
3b		Failure of slopes	2	3	6	Significant		1	3	3	Trivial
4	Coal mining	Unrecorded underground mine workings / mine entries (shafts and adits)	3	3	9	Substantial	Additional ground investigative works is recommended. If coal workings / mine entries encountered, they would require to be treated / capped. Near surface coal seams to be removed as part of the earthworks.	1	2	2	Trivial
5	Unexpected strata	Unexpected ground conditions may require a change in design approach.	2	3	6	Significant	Additional ground investigative works required.	1	3	3	Trivial
6	Fill material not achieving desired strength/density	Damage to foundations due to settlement (total and differential) and/or failures of slopes/embankments	3	3	6	Significant	Additional ground investigative works required. Further assessment of material properties. An earthworks specification should be produced and followed.	1	3	3	Trivial

6.0 ENVIRONMENTAL RISK ASSESSMENT

6.1 Introduction

The statutory definition of contaminated land is given in the Environmental Protection Act, Part IIA, Section 78, 1990, which was introduced by the Environment Act, Section 57, Department of Environment, 1995 and is defined as:

Land which appears to the Local Authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land that:

- Significant harm is being caused or there is a significant possibility of such harm being caused (where harm is defined as harm to health of living organisms or other interference with the ecological systems of which they form a part and in the case of man, includes harm to his property); and/or
- Significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused (by the land).

The presence of contaminated materials on a site is generally only of concern if an actual or potentially unacceptable risk exists. The potential for harm to occur requires three conditions to be satisfied:

- **Sources** – The presence of substances (potential contaminants/pollutants), in or under the ground, that may cause harm or pollution.
- **Receptors** - The presence of a receptor which may be harmed, e.g., the water environment or humans, buildings, fauna and flora; and
- **Pathway** - The existence of a linkage between the Source and the Receptor.

In summary, the presence of measurable concentrations of contaminants within the ground and subsurface environment does not automatically imply that a contamination problem exists, since contamination must be defined in terms of pollutant linkages and an unacceptable risk of harm to available receptors.

The nature and importance of both pathways and receptors, which are relevant to a particular site, will vary according to the sensitivity of the intended end use of the site and the sites characteristics and environmental setting.

Legislation and guidance on the assessment of contaminated sites acknowledges the need for a tiered risk-based approach. This is set out in the Environment Agency's manual *Land contamination: risk management* (published in October 2020 and last updated on 19 April 2021) and comprises the following stages of risk assessment:

Tier 1: Preliminary risk assessment (PRA)	As part of this assessment, the overall site objectives are defined. Current and historical information about the site and the potential contaminants expected to be present are assessed and an outline conceptual model (CM) is developed. The risks are assessed qualitatively, and the findings reported in the PRA (or desk study). The report recommends what further works would be required in order to assess whether the site is suitable for its proposed use.
Tier 2: Generic quantitative risk assessment (GQRA)	The GQRA uses Generic Assessment Criteria and a standard set of generic assumptions based on specific end uses in order to assess the risks to receptors. It includes the collection of more detailed information including laboratory analysis of soil and water samples in order to inform and assess the risks.
Tier 3: Detailed quantitative risk assessment (DQRA)	If pollutant linkages are confirmed as part of the GQRA, these are known as relevant pollutant linkages (RPLs) and further detailed assessment is required. At this tier, detailed site-specific information is collected to estimate the risk or to develop site-specific assessment criteria (SSAC). This may include collecting information about the receptor.

A Tier 1 Assessment has been prepared for the site by JPG and reported in the Geoenvironmental Desk Study Report, referenced 4848-JPG-XX-XX-RP-G-0601-S2-P04 and dated July 2019.

This environmental risk assessment undertaken by JPG constitutes a Tier 2 Generic Quantitative Risk Assessment (GQRA) and has been carried out in accordance with the Environment Agency's *Land contamination: risk management guidance*.

6.2 Assessment Approach

The results of the chemical analysis for each determinand will be assessed against their respective GAC.

Human Health

These include the LQM/CIEH Suitable 4 Use Levels (S4UL) and Category 4 Screening Levels (C4SL) which were developed using the UK Contaminated Land Exposure Assessment (CLEA) Framework Documents and Software.

The CLEA model uses generic assumptions about the fate and transport of chemicals in the environment and a generic conceptual model (referred to as generic land use scenarios) for site conditions and human behaviour, to estimate child and adult exposures to soil contaminants for those living, working and/or playing on contaminated sites over long time periods.

The S4UL and C4SL screening levels have been derived for a variety of land uses including residential, allotments, commercial and public open space.

In the absence of S4UL and C4SL for potential contaminants, appropriate alternative GAC will be used.

Controlled Waters

Based on the environmental setting of the site, the leachate and groundwater chemical testing results have been compared against Generic Assessment Criteria (GAC) threshold values based on the Water Supply (Water Quality) Regulations (Drinking Water Standards) and the Water Framework Directive threshold values.

An exceedance of a threshold value does not directly imply there is an unacceptable risk, however, it indicates that the exceedance should be further assessed via the qualitative source-pathway-receptor approach.

6.3 Evaluation of Soils Analysis

Initially, the results of the chemical analysis for each potential contaminant will be compared directly with their respective GAC. Based on the current development proposals for the site, i.e. commercial, the results of the chemical analysis for the soil samples have been assessed against GAC for a commercial end use.

If any significant exceedances of the GAC are noted, then the results will be subject to statistical analysis if appropriate. An outline of the methodology of the statistical analysis is presented in the Appendix C.

Human Health – Soils

In total, seven samples, comprising four topsoil, two colliery spoil and one made ground, were submitted for chemical analysis. The results have been compared directly with their respective GAC. The results are summarised in Table 6.3.1.

Table 6.3.1 – Summary of Chemical Analysis Results

Determinand	GAC for Commercial End Use (mg/kg)	Sample Mean (mg/kg)	Range of Results (mg/kg)	Do any samples exceed the GAC?
Metals and Metalloids				
Arsenic	640(1)	9.03	2.7 to 17	No
Cadmium	190(1)	0.13	0.1 to 0.2	No
Chromium	8600(1)	16.71	15 to 19	No
Hexavalent Chromium	33(1)	All <1.00	All <1.00	No
Copper	68,000(1)	28.71	21 to 36	No
Lead	2,330(2)	29.29	17 to 51	No
Mercury (Inorganic)	1,100(1)	0.06	0.05 to 0.13	No
Nickel	980(1)	25.57	13 to 35	No
Selenium	12,000(1)	All <0.50	All <0.50	No
Zinc	730,000(1)	98.29	81 to 150	No
Inorganics				
Cyanide (free)	20(2)	0.20	0.1 to 0.5	No
Phenols				
Total Phenols	440*(1)	0.39	0.3 to 0.9	No
Poly Aromatic Hydrocarbons				
Naphthalene	190*(1)	All <0.10	All <0.1	No
Acenaphthylene	83,000*(1)	All <0.10	All <0.1	No
Acenaphthene	84,000*(1)	All <0.10	All <0.1	No
Fluorene	63,000*(1)	All <0.10	All <0.1	No
Phenanthrene	22,000*(1)	All <0.10	All <0.1	No
Anthracene	520,000*(1)	All <0.10	All <0.1	No
Fluoranthene	23,000*(1)	0.13	0.1 to 0.3	No
Pyrene	54,000*(1)	0.14	0.10 to 0.3	No
Benzo(a)anthracene	170*(1)	All <0.10	All <0.1	No
Chrysene	350*(1)	All <0.10	All <0.1	No
Benzo(b)fluoranthene	44*(1)	All <0.10	All <0.1	No
Benzo(k)fluoranthene	1,200*(1)	All <0.10	All <0.1	No
Benzo(a)pyrene	35*(1)	All <0.10	All <0.1	No
Indeno(123-cd) pyrene	500*(1)	All <0.10	All <0.1	No
Dibenzo(ah)anthracene	3.5*(1)	All <0.10	All <0.1	No
Benzo(ghi)perylene	3,900*(1)	All <0.10	All <0.1	No

(1) S4UL * BASED ON 1% SOM, (2) C4SL

None of the above determinands were detected at concentrations in excess of their respective GAC.

Three samples were submitted for an asbestos screen. No asbestos fibres or asbestos containing materials were detected in any of them samples.

Calorific value (CV) tests were carried out on one sample of made ground (TP108 2.70-2.80m bgl) and two samples of colliery spoil (TP109 1.50-1.60m bgl and TP110 2.00-2.10m bgl). The test results ranged between <1.0MJ/kg and 7.1MJ/kg. Soils with a CV of greater than 10MJ/kg are almost certainly combustible. Soils with values below 2MJ/kg are unlikely to burn. The sample of made ground recorded a CV of greater than 2MJ/kg and is therefore deemed to be potentially combustible.

Evaluation of Controlled Waters Analysis

Two samples were submitted for leachability analysis. The result for each determinand was compared directly against their respective GAC. The results are summarised in Table 6.3.2 on the following page.

Table 6.3.2 – Summary of Leachability Results

Determinand	**GAC (µg/l)**	TP108 2.60-2.70m	TP112 2.20-2.40m
Metals and Metalloids			
Arsenic	10 (1)	0.19	0.28
Cadmium	5 (1)	<0.03	<0.03
Chromium	50 (1)	<0.25	<0.25
Copper	2000 (1)	<0.4	<0.4
Lead	10 (1)	<0.09	<0.09
Mercury	1 (1)	<0.01	<0.01
Nickel	20 (1)	0.50	<0.50
Selenium	10 (1)	<0.25	<0.25
Zinc	5000 (1)*	4.2	2.8
Inorganics			
pH	6.5-9.5	7.6	8.7
Cyanide Free	50 (1)	<20	<20
Sulphate	250,000	24000	3600
Poly Aromatic Hydrocarbons			
Naphthalene	4.24 (2)	0.06	0.05
Anthracene	0.193 (2)	<0.01	<0.01
Fluoranthene	0.0122 (2)	<0.01	0.01
Benzo (a) pyrene	0.01 (1)	<0.01	<0.01
Sum of: Benzo (b) fluoranthene, Benzo (k) fluoranthene, Indeno (1,2,3-c,d) pyrene, and; Benzo (g,h,i) perylene	0.1 (1)	<0.01	<0.01
Phenols			
Phenol	14.9 (2)	<0.50	<0.50

(1) Water Supply (Water Quality) Regulations *Historical 1989 Threshold Value.
(2) Water Framework Directive 2015, Surface Water, Maximum Threshold Value.

None of the above determinands were detected at concentrations in excess of their respective GAC.

6.4 Evaluation of Hazardous Gases

Based on the desk study information and ground conditions encountered, i.e. topsoil overlying colliery spoil, residual soil and bedrock with shallow coal seams, it is considered that there is potential for the presence of hazardous gases on the site.

In order to assess the potential risks posed to the proposed development from hazardous gases, a monitoring well was installed and sealed within the colliery spoil in BH109A.

Ground gas monitoring has been undertaken on six occasions. The works were carried out using a portable infrared gas meter (Geotech GA5000) in accordance with the standard JPG methodology and included the measurement of methane, carbon dioxide, oxygen, hydrogen sulphide, carbon monoxide, gas flows and atmospheric pressure.

6.5 Summary of Results

The results of the gas monitoring for BH109A are presented on the site visit record sheets in Appendix F and are summarised below:

- A maximum peak methane concentration of 0.1% v/v was recorded during the sixth monitoring visit.
- A maximum steady carbon dioxide concentration of 3.9% was recorded during the fifth monitoring visit.
- No reduced oxygen concentrations (i.e. <16% v/v) were recorded. Oxygen concentrations of between 16.6% v/v and 20.4% v/v during the monitoring period.
- Concentrations of hydrogen sulphide of 1ppm were recorded during the fourth and fifth monitoring visits.
- Concentrations of carbon monoxide were recorded during first, second and fourth monitoring visits. Concentrations ranged between 1ppm and 6ppm.
- A maximum peak and steady flow of 0.1 l/hr was recorded in third, fifth and sixth monitoring visits.

Four of the monitoring visits were carried out during periods of regionally falling atmospheric pressure, the remaining two were carried out during periods of regionally rising atmospheric pressure. Barometric pressures during the monitoring period ranged between 979mB and 1012mB.

6.6 Requirements for Gas Protection Measures

The results of the gas monitoring have been assessed in accordance with the following:

- BS8485:2015+A1:2019, 'Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

Based on the maximum peak and steady concentrations of CH_4 and CO_2 and the calculated Gas Screening Values (GSV), for CH_4 is 0.0001l/hr and CO_2 is 0.0039l/hr, the site is classified as Characteristic Situation (CS) 1 in accordance with BS8485:2015+A1:2019 requiring ground gas protection measures. This assessment is based on one monitoring well only.

Additional ground investigative works and ground gas monitoring is required in order to confirm the ground gas regime and the requirement for ground gas protection measures.

6.7 Radon Risks

The site is located in a radon affected area with between 1% and 3% of properties above the action level. Based on this information, no radon protective measures are therefore required in the construction of new buildings.

6.8 Summary of Sources, Pathways and Receptors

Sources

Based on the results of the analysis carried out, the following potential sources of contamination are considered to be present on the site:

- Potentially combustible cohesive made ground.

Pathways

Based on the available information and the proposed development of the site for a mixed end use, the following potential exposure pathways will require consideration, both during the development works and on completion of the construction.

- Potential for combustion of made ground as a result of heat/ignition sources within areas of soft landscaping.

Receptors

The potential receptors are considered to be:

- Future end users of the site (e.g. employees); and
- Buildings and services.

6.9 Source – Pathway – Receptor Linkages

Based on the above sources, pathways and receptors, the following linkage assessments have been considered.

This assessment is based on current site conditions (unless stated) and does not consider exposure pathways following any remediation of the site.

Future End Users of the Site

There is potential for exposure to the following:

- Potentially combustible made ground.

Buildings and Services

Recommendations with respect to the chemical attack on buried concrete are given section 5.8.

6.10 Conceptual Site Model & Risk Rating

The preliminary conceptual site model (CSM) has been updated following completion of this ground investigation and the assessment of the results of the chemical analysis and the hazardous ground gas risk assessment.

The revised CSM has been developed for a future commercial end-use. This summarises the understanding of surface and sub-surface features, the potential contaminant sources, transport pathways and receptors, and attributes a risk rating and mitigation measures for each pollutant linkage identified.

The updated conceptual model is summarised in Table 6.10.

Table 6.10 Conceptual Model

Source	Pathway	Receptor	Risk Rating	Mitigation Measures
Potentially combustible made ground.	Potential for combustion of the made ground, as a result of heat/ignition.	Future End Users, e.g., Employees	Low to Moderate	No made ground soils with elevated calorific value, >2MJ/kg, shall remain within 1.00m of finished ground level in soft landscaping. It is recommended that a sufficient thickness of clean cover soils, i.e. 300mm, is placed in future landscaped areas.

6.11 Risk Classification

Based on the updated conceptual site model, the site should be considered to be **low to moderate risk** with respect to potentially combustible made ground soils and provisionally low risk with respect to soils and ground gas. Further testing and monitoring is required to confirm any remedial requirements.

6.12 Mitigation Measures

In order to mitigate the risks posed by the potential contaminants which are present on the site, consideration should be given to the following mitigation measures.

Development and Maintenance Workers

- Site workers involved in groundworks should take the necessary measures to ensure that all works in excavations and confined spaces are carried out in accordance with best practice in order to prevent exposure to potentially hazardous gases.
- Site workers involved in groundworks should use appropriate PPE, i.e. overalls and gloves. Appropriate health and safety measures, e.g. washing hands prior to eating or drinking, should also be enforced.
- During development of the site, all workers should remain vigilant to the possible risk of encountering areas of potentially contaminated material. Should potentially contaminated material be encountered, site management should be informed. Further testing may then be required to assess the risk to health and safety of the site workers and the environment.
- All employers involved in works at the site should produce an appropriate method statement and risk assessment, to which all employees should comply, e.g. working in confined spaces and encountering combustible made ground soils. Reference should also be made to the appropriate HSE and other guidance for working on contaminated and potentially contaminated sites.

Future Site Users

- No made ground soils with elevated calorific value (>2MJ/kg) shall remain within 1.00m of finished ground level in any soft landscaping. Confirmatory testing will be required as part the earthworks in order to confirm that the soils retained within 1.00m of the finished surface are not potentially combustible.
- It is recommended that a sufficient thickness of clean cover soils, i.e. 300mm, is placed in future landscaped areas. Preliminary chemical test results indicate that the existing topsoil is suitable for re-use on the site.
- It is recommended that further topsoil sampling and testing is undertaken in order to confirm the topsoil's suitability for re-use onsite.

6.13 Classification of Materials for Disposal Off-Site

In total, seven samples, comprising four topsoil, one made ground, two colliery spoil samples, were assessed using HazWasteOnline^{tm} in order to determine the classification of the materials for disposal off-site.

Based on the results of the chemical analysis, all the samples can be classified as non-hazardous.

Details of the classification generated by HazWasteOnline^{tm}, is presented in Appendix C.

The results of the chemical analysis and the waste classification should be forwarded to the landfill operator to confirm this assessment and provide a price for disposal.

7.0 FURTHER WORKS

It is recommended that further ground investigative works are to be carried out in order to further assess potential environmental and geotechnical constraints to the development and confirm the preliminary recommendations set out in this report.

The scope of works below is designed to provide a more detailed review of the site and to target areas of concern identified within this preliminary investigation.

- Rotary boreholes to confirm the coal mining legacy of the site and the requirement for drill and grout treatment.
- Delineation of the opencast highwalls using a combination of geophysics, rotary open hole boreholes and/or trial trenching.
- Trial pits to obtain samples of the made and natural ground to submit for chemical and geotechnical testing.
- Cable percussion boreholes with in-situ testing, to obtain geotechnical parameters and undisturbed geotechnical samples for testing. Gas and groundwater monitoring wells to be installed in selected boreholes.
- Quarterly monitoring of BH109 extensometer to be continued as long as possible to inform creep settlement assessment.
- Static cone penetration testing to assess the in-situ geotechnical parameters.
- Slope stability assessment of the existing slopes, especially those which will be subject to cut and fill, potentially exposing slip surfaces, or surcharging of unstable slopes.
- Chemical analysis of made and natural ground material and groundwater in order to confirm the concentrations of potential contamination on the site and classify selected materials for re-use onsite and disposal offsite.
- Geotechnical and chemical testing to classify materials and inform foundation design.
- Ground gas monitoring of monitoring installations over a six week period.
- Assessment of the groundwater regime below the site, in order to understand the site's groundwater regime and to assist with inundation settlement analysis.
- Additional t of the groundwater regime below the site, in order to understand the site's groundwater regime and to assist with inundation settlement analysis.

Appendix A Figures/Drawings

Figure 1 – Site Location Plan	
Site	**Barnsley West – Employment Land**
Client	**Strata Sterling Barnsley West Limited**
Job Number	**4848**
Scale	**NTS**

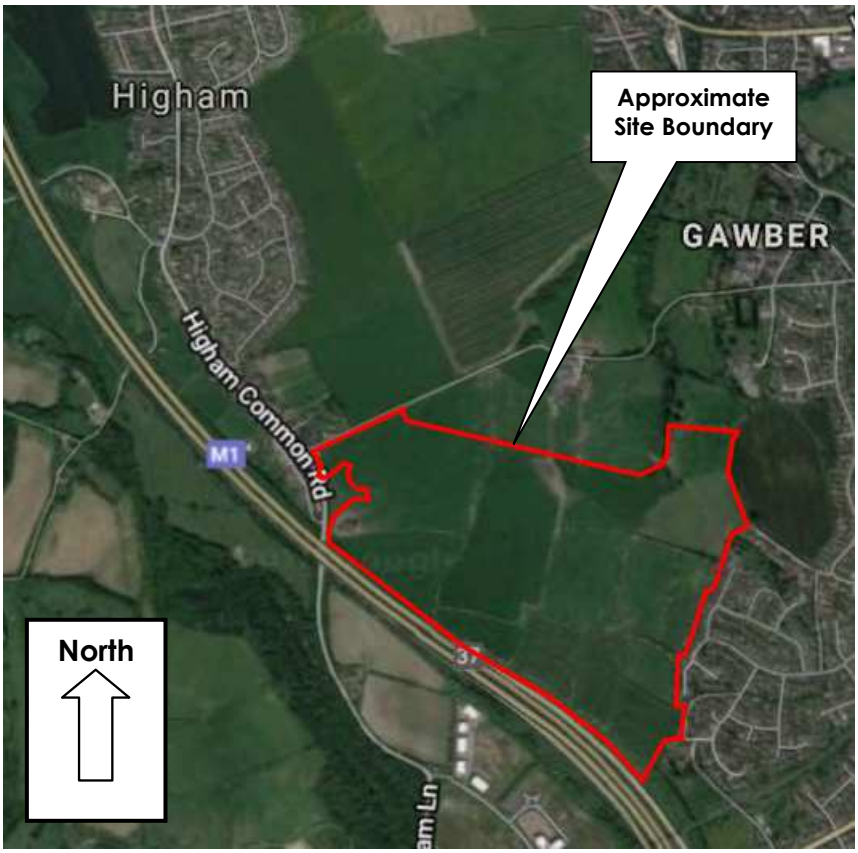

Figure 2 – Aerial Photograph	
Site	**Barnsley West – Employment Land**
Client	**Strata Sterling Barnsley West Limited**
Job Number	**4848**
Scale	**NTS**

DO NOT SCALE (A1)

NOTES

GENERAL NOTES

1. ALL MATERIALS AND WORKMANSHIP IS TO COMPLY WITH JPG CONSULTANTS STANDARD SPECIFICATION & ALL RELEVANT BRITISH & EUROPEAN STANDARDS.
2. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS, M & E CONSULTANTS AND JPG CONSULTANTS DRAWINGS.
3. ANY DISCREPANCIES SHOULD BE REPORTED TO THE ENGINEER IMMEDIATELY SO THAT CLARIFICATION CAN BE SOUGHT PRIOR TO COMMENCEMENT OF WORKS.

LEGEND

COMMERCIAL BOUNDARY

0m 50m 100m

SCALE 1:2000

REV	DESCRIPTION	DATE	CHK	BY
P02	REDLINE BOUNDARY UPDATED	10/10/23	JDM	LSG
P01	FIRST ISSUE.	30.03.23	JDM	EBH

Project
BARNSLEY WEST

Drawing Title
COMMERCIAL BOUNDARY PLAN

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4848-JPG-ZZ-ZZ-DR-C-1001 | S2 | **P02**