



Harworth Estates Investments Limited

J36 Phase 2 and Phase 3 Rockingham

Phase 2 Geo-environmental and Geotechnical Site
Investigation

322368-R02 (01)

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RSK GENERAL NOTES

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Title: Phase 2 Geo-environmental and Geotechnical Site Investigation : J36 Phase 2, and Phase 3 Rockingham

Client: Harworth Estates Investments Limited

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Office: RSK, 172 Chester Road, Helsby, WA6 0AR , Tel.: 44 01928 726006, Contact: Alex Cox

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Author	<u>Arkaash Bennett / Alex Cox</u>	Technical reviewer	<u>Gary McGuicken</u>
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Signature

Date:


May 2020

Signature

Date:


May 2020

Project manager	<u>Alex Cox</u>	Quality reviewer	<u>Ang Wallis</u>
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Signature

Date:


May 2020

Signature

Date:


May 2020

Revision control sheet

Revision reference	Date	Reason for revision
Rev 00	March 2020	First issue
Rev 01	May 2020	Amendments to gas risk assessment and ground treatment

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Where field investigations have been carried out, these have been restricted to a level of detail required to achieve the stated objectives of the work.

This work has been undertaken in accordance with the quality management system of RSK Environment Ltd.

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1 INTRODUCTION

1.1 Commissioning

RSK Environment Limited (RSK) was commissioned by Harworth Estates investment Limited (Harworth Estates) to carry out a Geoenvironmental and Geotechnical Site Investigation of the land referred to as Junction 36 (J36) which is further subdivided into two development areas; Phase 2, to the south of the Dearne Valley Parkway and Phase 3 to the north of the Dearne Valley Parkway at Rockingham, Hoyland, south of Barnsley. The project was carried out to an agreed brief as set out in RSK's proposals (Ref. 322638TL01, dated 9 September 2019 and 322638TL02, dated 6 January 2020).

This report is subject to the RSK service constraints given in Appendix A and limitations that may be described through this document.

1.2 Proposed development

The Site in question is being considered for re-development for a commercial end use. The planned layout of the site is shown in Appendix B and a site location plan is provided as Figure 1.

1.3 Objectives

The objective of the work is primarily to resolve the data gaps and uncertainties highlighted within the Preliminary Risk Assessment and Coal Mining Risk Assessment as well as those within the previous intrusive investigation reports in order to facilitate the proposed redevelopment.

The following items were identified as requiring further work:

- to investigate the potential coal mining legacy risks to the proposed development
- to reassess the data from a load test constructed in 2016 and in-situ testing information in order to predict settlement from proposed building and earthworks loads
- to identify whether or not self-weight settlement of the fill materials used to backfill the old open cast pit is ongoing or has ceased
- to gain further understanding of the geology and groundwater at the site
- to update the ground gas risk assessment for the site with up to date monitoring information
- to provide the information necessary to allow selection of the most appropriate geotechnical ground treatment options
- to identify any land contamination and/or geotechnical constraints to the proposed development not previously identified and to support discharge of relevant planning conditions

- to identify the need for any additional investigation or remediation works to demonstrate that the site is suitable for its proposed use.

1.4 Scope of works

The scope of this assessment has been developed in accordance with relevant British Standards and authoritative technical guidance as referenced through the report. The assessment of the contamination status of the site is in line with the technical approach presented in CLR 11 Model Procedures for the Management of Land Contamination (Environment Agency, 2004) and in general accordance with BS 10175: 2011 + A2 2017 (BSI, 2017). It is also compliant with relevant planning policy and guidance.

The scope of the intrusive investigation has been designed in line with the recommendations of BS5930: 2015 Code of practice for ground investigations (BSi, 2016), which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. It has also been developed in general accordance with BS 10175: 2011 + A2 2017. Ground gas assessment has been undertaken in general accordance with BS8756: 2013 and BS 8485:2015+A1:2019.

A brief summary of relevant legislation and policy relating to contaminated land is given in Appendix C.

The scope of works for the assessment has included the following:

Intrusive Investigation

- design and implementation of an intrusive investigation, in situ testing, soil sampling, laboratory geo-environmental and geotechnical testing, groundwater and ground gas monitoring of installed boreholes
- interpretation of data to develop a refined conceptual site model (CSM)
- generic quantitative risk assessment (GQRA) to evaluate potentially complete contaminant linkages identified in the refined CSM
- identification of the need for further action, e.g. supplementary intrusive investigations/ monitoring, remediation works or other mitigation, if any
- interpretation of ground conditions and geotechnical data to provide preliminary recommendations with respect to foundations and infrastructure design
- preparation of this factual and interpretative report with recommendations for further works.

1.5 Existing reports

The following reports have been produced by RSK that all relate in some extent to ground conditions on various parts of the site:

- RSK Report Reference 321393 – R1 (01), dated July 2013: Rockingham, South Yorkshire: Appraisal of Ground Conditions and Coal Mining Review
- RSK Report Reference 321393 – R5 (00), dated June 2014: Rockingham, South Yorkshire: Appraisal of Wentworth Estates Land

- RSK Report Reference 321393 – R3 (01), dated April 2015: Geo-environmental Site Assessment: Rockingham 2 East
- RSK Report Reference 321393 – R4 (01), dated April 2015: Geo-environmental Site Assessment: Rockingham 3
- RSK Report Reference 321393 – R6 (01), dated April 2015: Geo-environmental Site Assessment: Rockingham 2 West
- RSK Report Reference 322494-R1 (00), dated February 2019; Preliminary Risk Assessment and Coal Mining Risk Assessment: J36 Phase 2, Rockingham.

A Preliminary Risk Assessment and Coal Mining Risk Assessment for the current development proposal has also been prepared and submitted as part of the outline planning application:

- RSK Report Reference 322638-R1 (01), dated December 2019; Preliminary Risk Assessment and Coal Mining Risk Assessment: J36 Phase 2 Phase 2B and Phase 3, Rockingham.

Pertinent information from these reports has been summarised in Section 2.

1.6 Limitations

The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows may vary from those reported due to seasonal, or other, effects and the limitations stated in the data should be recognised.

Preliminary geotechnical recommendations are presented, and these should be verified in a Geotechnical Design Report once proposed construction and structural design proposals are confirmed.

2 SITE DETAILS

2.1 Site location and description

The site, which is referred to as J36 is divided into three development areas (phases). Phase 2A lies to the immediate south of the Dearne Valley Parkway, Phase 2B in the adjacent area to the south and further up-hill and Phase 3 located to the north of the Dearne Valley Parkway between two existing commercial developments; Shortwood Business Park to the east and Rockingham 1 (a Harworth development plot) to the west. The site is located at Rockingham, Hoyland, South Yorkshire, at National Grid reference 434810, 401210, as shown on Figure 1.

In total the J36 site covers approximately 38.5 hectares with Phase 2 comprising approximately 28.2 hectares and Phase 3 comprising approximately 10.3 hectares.

The Phase 2 site lies generally at an elevation of between 100m and 163m above Ordnance Datum (AOD), sloping from south to north and comprises predominantly agricultural land, with a farm track at the perimeter and fenced areas of semi-mature trees defining field boundaries.

The Phase 3 site lies generally at an elevation of between 120m and 130m AOD, and comprises predominantly agricultural land, with several tracks and field boundaries crossing the site. There are also significant areas of semi-mature trees on the eastern site area, and it is crossed by several footpaths.

The site boundary plan is shown on Figure 2.

The site surroundings for Phase 2 and Phase 3 of the site are detailed in Tables 1 and 2.

Table 1 Site surroundings for Phase 2

To the north:	Dearne Valley Parkway (road) with agricultural land beyond
To the east:	Residential housing, farm buildings and commercial units
To the south:	Agricultural land and residential properties
To the west:	Agricultural land with commercial units (Rockingham 1) and residential housing beyond

Table 2 Site surroundings for Phase 3

To the north:	Agricultural land and residential properties
To the east:	Industrial/commercial units (Shortwood Business Park)
To the south:	Dearne Valley Parkway (road) with agricultural land beyond
To the west:	Pond within an area of rough vegetation and industrial/commercial units beyond (Rockingham 1 at the south), and agricultural land (at the north)

2.2 Development plans

The proposed layout of the site, at the time of preparing this report, is shown in Appendix B.

The site is being considered for redevelopment for commercial purposes, comprising several light industrial units with associated roads and infrastructure. In order to bring the site, forward a scheme of earthworks is required, cutting material from the south and filling to the north to create the development platforms. The latest received cut and fill models are included in Appendix B.

There is an active planning application pertaining to the proposed redevelopment of the site, as viewed on the Barnsley Metropolitan Borough Council website, Application Number: 2019/1573.

3 DESK-BASED ASSESSMENT

The full desk-based assessment can be found in RSK report reference 322638 R01 (01). Below is a summary of the pertinent information.

3.1 Site history

The site was part of the Rockingham Colliery, used for open cast mining from 1991 to 1995. The site was backfilled and restored by 2002 (the backfill was not controlled or engineered).

The fill materials used to backfill the opencast voids are thought to largely include materials moved locally to minimise haulage and are generally considered unlikely to have been exposed to significant contamination sources.

This backfill material is recorded as being placed in an uncontrolled manor raising some concerns for its geotechnical stability.

3.1.1 Site services

Buried utility services and their backfill can provide preferential pathways for gas, vapour or groundwater to migrate along to another part of the site or to a receptor. They can also represent significant constraints to development.

Service plans obtained from utility companies by RSK that may affect the site are contained in Appendix D; these are dated 10 October 2019. Buried services present on-site or located adjacent to site boundaries that could represent a pathway for migration of groundwater and gases/ vapours comprise:

- a Yorkshire Water foul sewer running in a north easterly direction through the Phase 3 site.

3.2 Site geology

As a result of the former opencast extraction of coal a significant thickness of made ground covers the majority of the site. This comprises the excavated overburden material replaced to fill the voids created by coal extraction. As mentioned above this is recorded to be primarily uncontrolled fill though engineered fill was placed to support the Dearne Valley Parkway and is recorded to have been built up from the base of the pit. The batters from this may extend onto the site at depth.

The underlying bedrock is recorded as being Pennine Middle Coal Measures Formation, comprising mudstone, siltstone and sandstone with coal seams. The bedrock units comprise a Secondary A aquifer. Substantial underground and opencast mining activity have previously occurred on site. Although there are several recorded mine entries all bar two shafts in the Rockingham 3 site are recorded by the Coal Authority as having been removed by the opencast workings.

3.3 Mining and quarrying

The majority of the site has been subject to opencast coal mining however some areas outside of the opencast pit may have been locally worked and an investigation for potentially worked shallow seams is required.

There are records of three mineshafts (435401-001, 435401-002 and 435401-003) potentially still present beneath the open cast excavation in the coal authority reports however shaft 435401-001 is thought to have been an air shaft and to have been removed by the open cast excavation. Shafts 435401-002 and 435401-003 are recorded to have been treated and capped approximately 30m below the ground surface however no construction details for the caps were available at the Coal Authority archives.

3.4 Sensitive land uses

The environmental database report shows the following sensitive land uses:

- an area of anticipated green belt is located across Phase 2
- an area of anticipated green belt is located across Phase 3. A Nitrite Vulnerable Zone surface water feature is located in the north eastern extent of Phase 3.

4 PREVIOUS INTRUSIVE INVESTIGATIONS AND GEOTECHNICAL ASSESSMENT

Sections 4.1 and 4.2 provide a summary of the site investigation reports previously produced by RSK that relate to the Phase 2 and 3 areas at Rockingham site under Harworth Estate's ownership.

In Section 4.3 we present an outline geotechnical assessment of the key findings of these investigations in relation to the proposed development of the site. In particular this considers potential settlement mechanisms and other issues related to the identified ground conditions.

RSK have also completed detailed investigations and assessment work for the Rockingham 1 area, however as the ground conditions in this area are different from Phase 2 and 3 it is not presented here. Further details can be obtained from RSK reports 321393 R2, dated November 2013 and 321393 R7, dated March 2015.

4.1 Phase 2

4.1.1 RSK intrusive site investigation 2015

RSK have previously produced the following reports for the now Phase 2 area:

- Rockingham 2 East, South Yorkshire; Geo-environmental Site Assessment: RSK Report 321393-R3 (01) April 2015
- Rockingham 2 West, South Yorkshire; Geo-environmental Site Assessment: RSK Report 321393-R6 (01) April 2015.

The reports provide details of the site investigation for which a staged approach was adopted. Stage one comprised the drilling of four boreholes and five trial pits in the western area and nine boreholes and twelve trial pits in the eastern area. Samples were collected for chemical and geotechnical testing and monitoring for ground gas and groundwater was undertaken. The second stage comprised the drilling of 3 rotary boreholes in the eastern area.

An environmental and geotechnical assessment of the Phase 2 site is provided across the two reports based on the initial investigation undertaken.

The ground conditions were found to comprise made ground ranging in thickness from 1.2m to greater than 20.5m over interbedded mudstones, siltstones and sandstones in the eastern area. In the western area made ground was recorded to a maximum depth of 68.7m underlain by mudstone, siltstone and sandstone bedrock.

No visual or olfactory evidence of significant contamination was observed in any of the boreholes or trial pits. The fill comprised reworked natural materials and anthropogenic materials were not generally encountered. No asbestos fibres were detected during laboratory screening of soil samples.

Chemical testing identified no exceedances of the generic assessment criteria (GAC) against which the recorded values were compared. As such no potentially significant risks

associated with soil contamination were identified. More anthropogenic materials were identified in the west, however screening also confirmed that no potentially significant risks associated with soil contamination were present.

Groundwater was not encountered in any of the boreholes drilled.

Ground gas spot monitoring undertaken over 6 monitoring visits identified a maximum steady state methane concentration of 2.9% in the east and 0.1% in the west. Maximum carbon dioxide concentrations were reported as 14.0% in the east and 12.1% in the west with flow rates recorded at a maximum of 0.4l/hr and 2.0l/hr respectively. CS2 standard gas protective measures were recommended for the eastern site area and CS1 for the west.

A number of standard penetration tests (SPT) were undertaken within the backfill in cable percussive boreholes, at depths from 1.2m to 19.0m and typically confirmed medium dense to very dense soils.

36 surface permanent ground marker (PGM) surveying pins were installed in the western area and 32 in the eastern area. These were monitored for a 15-month period between October 2013 until March 2015. The results recorded were variable, and whilst averaged values indicated the possibility of ongoing self-weight settlement, further monitoring was required to complete the assessment.

4.2 Phase 3

4.2.1 RSK intrusive site investigation 2015

- Rockingham 3, South Yorkshire; Geo-environmental Site Assessment: RSK Report 321393-R4 (01) April 2015.

RSK undertook an intrusive site investigation of a parcel of land identified as Rockingham 3. The purpose of this assessment was to investigate existing ground conditions and assess the contamination status of the site and the ground treatment required to enable the proposed redevelopment of the land for commercial end use. The lateral coverage of the investigation works was constrained by the presence of dense vegetation and semi-mature trees preventing access to the south eastern part of the site.

The investigation generally confirmed the expected presence of a variable thickness of opencast backfill across the area, ranging between around 20m in the west and 55m in the east. The fill comprised an upper layer (ranging from 0.3m to 1.7m thick) of apparent re-worked natural slightly gravelly clay. The re-worked clay layer was underlain by made ground generally comprising firm to stiff friable clay with a significant proportion of granular material. Gravels, cobbles and boulders encountered were generally angular to subangular grey mudstone, sandstone and siltstone. Coal fragments were occasionally encountered throughout the stratum. In one location there was a layer of burnt orange shale gravels with coal and dark grey siltstone. All of the cable percussive boreholes were terminated due to obstructions thought to be mudstone boulders within the made ground.

Three rotary boreholes were advanced to rockhead to confirm the full thickness of fill. These were used to validate the depth of previous opencast workings recorded on abandonment plans. In two of the boreholes the depth to the base of the fill was consistent

with that estimated from the plans, but in the third there was significant variation, suggesting that the historic plans may not always provide accurate depths.

Groundwater was not encountered in any of the boreholes or trial pits. Subsequent monitoring of installed boreholes recorded the presence of groundwater at a range of depths. The monitoring did not indicate the presence of a continuous water body.

No visual or olfactory evidence of significant contamination was observed in any of the boreholes or trial pits. The fill comprised reworked natural materials and anthropogenic materials were not generally encountered. No asbestos fibres were detected during laboratory screening of soil samples.

Limited laboratory analyses of soil samples for a range of chemical contaminants did not record any significantly elevated concentration (there was negligible risk to human health as a result of direct contact with the soils). However, further assessment may be required in respect of future water supply pipes. It was indicated that the possibility remains that localised areas of significant soils contamination could be encountered at the site.

Laboratory analysis of groundwater samples was undertaken and recorded negligible impact. The risk assessment completed indicated that a potential contaminant linkage between subsurface contaminants and groundwater in the underlying secondary A aquifer is discounted, due to the minimal impact in groundwater on site, no identified contamination source within shallow soils and no continuous groundwater body.

Six rounds of ground gas monitoring of the installed boreholes were undertaken. This monitoring indicated that the site should be classified as CS2 in respect of ground gases. As such, appropriate gas protective measures may be required in the proposed buildings at the site. It was not considered that off-site migration of hazardous ground gases presented a significant risk to the adjacent residential and commercial properties.

A total organic content of 16% was reported in one soil sample. Considering the risks of combustible materials in the subsurface, further assessment total organic carbon and calorific value was recommended.

A number of SPT tests were undertaken within the backfill in cable percussive boreholes, at depths from 1.0m to 6.7m bgl, and these recorded medium dense to very dense conditions. The density of backfill materials below 6.7m bgl was not tested. A laboratory compaction test undertaken on a sample of the backfill material revealed a maximum dry density of 1.93Mg/m³ and an optimum moisture content of 10.0%.

Several surface PGM markers were installed across the site, and these were monitored for a 19-month period. The results recorded were variable, and whilst averaged values indicated the possibility of ongoing self-weight settlement, further monitoring was required to complete the assessment.

4.2.2 RSK load test and settlement monitoring 2016

Subsequent to the intrusive works detailed above, in 2016 RSK undertook a surcharge load test and continued to monitor a number of PGMs distributed around the Phase 3 area.

4.2.2.1 Load test

RSK carried out a surcharge load test on the western part of Phase 3. This comprised the construction of a surcharge soil mound with dimensions of approximately 40m by 55m in plan (plus sloping sides) and 5.0m in height. This was designed to apply a load of approximately 100kN/m² across a broad ground surface, which would apply stress to the full depth of opencast backfill. The test was designed to mimic the area and load expected to be exerted by a typical light industrial or commercial building.

To facilitate settlement monitoring two hydrostatic profile gauge (HPG) access pipes were installed at the site surface before the surcharge mound was constructed. These passed across the plan footprint of the surcharge mound in two directions and were identified as L1 and L2. The HPG monitoring consists of a probe which traverses a length of the access tubes, and readings are taken at regular intervals. Each round of monitoring is referenced to a datum, and subsequent settlement monitoring readings are reduced to an elevation height (m AOD). The datum is surveyed at regular intervals during the monitoring period and therefore any potential change in level of the datum is taken into account. HPG monitoring measures settlement in a horizontal plane immediately beneath the surcharge mound and does not monitor settlement through a vertical profile.

In addition, a borehole extensometer was installed close to the proposed mound's centre, and this was extended upwards through the mound as it was built up. This system uses magnets installed at various depths within the borehole which can move vertically to record settlement at different depths as the surcharge mound is constructed and during subsequent monitoring. The extensometer was installed with five spider magnets at approximate 2.0m depth intervals between 2.4m and 10.4m bgl (prior to mound construction), and three magnets installed between 13.4m and 20.2m bgl. The datum magnet was installed within bedrock at around 30m bgl.

Monitoring of the induced settlement began with baseline monitoring (prior to mound construction) taking place at the end of February 2016. Monitoring continued whilst the mound was being constructed throughout March, with the last of the material added by mid-April. Following construction of the mound settlement was monitored for a period of approximately nine months.

HPG Monitoring

Monitoring within both pipes L1 and L2 generally show a pattern of settlement as would be expected, with a higher rate of initial settlement recorded at the start of the test, during surcharge mound construction, and a much slower rate of ongoing settlement thereafter. For both pipes, the slow ongoing settlement suggests that further settlement would have been recorded had the monitoring period been extended.

The maximum settlements recorded are around 200mm, and as would be expected, the highest settlements were recorded toward the centre of the surcharge mound.

Borehole Extensometer

The extensometer installation suffered from vandalism and this is likely to have significantly affected some of the results, which must be viewed with some caution.

The results for the shallow magnets do appear to generally show a pattern of rapid settlement during the mound construction, followed by stability once the mound was complete. A broad summary of results is as follows:

- M1 and M2 (at depths of 2.4m and 4.3m) recorded total settlements of between 60mm and 68mm
- M3 (at 6.3m) recorded total settlements of 38mm
- M4 (at 8.8m) recorded settlements of between 10mm and 20mm
- M5 (at 10.4m) recorded settlements of between zero and 10mm
- M5 to M8 (between 13m to 20m) all recorded marginal heave (up to 10mm).

The settlement recorded from these magnets is greater in the shallower horizons, which is as would be expected. Little settlement was recorded at or below 10.4m depth (M5).

4.2.2.2 PGM monitoring

During 2016, RSK undertook additional topographical elevation monitoring of the available PGMs from those that had been previously installed at the site as part of the Rockingham 3 site works in 2015.

Monitoring of the PGMs across the Phase 3 area took place over a 10-month period.

The results of the monitoring across Phase 3 recorded a possible reduction in the elevation of all of the PGMs however this may be attributed to update of the OSGB geoid which occurred between the 2015 and 2016 monitoring.

4.3 Geotechnical assessment

The investigation works completed have identified that across most of the site significant thicknesses of opencast backfill are present and around the perimeter of the opencast areas steep interfaces (highwalls) between the underlying bedrock and overlying opencast backfill will be present. These represent potential constraints to future development and require full assessment, part of which has been completed by the work undertaken by RSK in recent years. In this section we consider the key issues and how these need to be addressed.

4.3.1 Mechanisms of ground settlement

The site is predominantly underlain by significant thicknesses of opencast backfill and such materials may be susceptible to a number of settlement mechanisms. These are listed and described below (with comments on how they are being assessed in brackets):

- self-weight settlement – poorly consolidated backfill materials may settle under their own weight. The timescale is dependent on grain size and is generally short-term in granular soils and long-term in fine grained/cohesive soils (establishment of surface PGMs and long-term monitoring)
- inundation settlement – water entering loosely placed fill can induce significant settlement as particles are softened and collapse into the interstitial voids. The mechanism is most likely in loosely placed backfill with large sized weak fragments

and would not be expected in backfill placed as an engineered fill. Water inundation may be from either rising groundwater from the base of the backfill or from surface water infiltration (surface inundation soakage tests and a long-term programme of monitoring of deep groundwater levels)

- construction and loading induced settlement – loose or weak backfill would be susceptible to settlement induced by loading from new structures, or from fill placed to provide a development platform (large scale load tests and geotechnical settlement modelling).

4.3.2 Assessment of settlement mechanisms

The PGM monitoring has been carried out in a number of phases, with breaks between and consequently a complete monitoring dataset is not available. At some locations it appears that some ongoing settlement may be occurring, however at other locations negligible ground movement has been recorded and there is some uncertainty over the surveying accuracy of some of the data. In order to progress the site, it is fundamental that stable ground conditions are confirmed, it is therefore recommended that a regular accurate monitoring programme is established. This should include all existing PGMs (that remain operable) but should be supplemented by additional pins where required. These should be re-established and monitored monthly for 3 months then quarterly for a further 12-month period.

To assess the potential for inundation settlement it will be necessary to carry out plot specific surface inundation tests and to confirm the long-term resting levels of deep groundwater. In respect of deep groundwater, a number of installations are present, and these have been monitored periodically by RSK. It is recommended that more regular groundwater monitoring is carried out over a long period (comparable to the recommended PGM in the paragraph above). If recovery of water levels is indicated (i.e. rising levels in deep installations) then consideration would have to be given to adding further monitoring installations.

The large load test in Phase 3 recorded settlements of the order of 200mm from an approximate load of 100kPa. This confirms that the opencast backfill will be susceptible to significant settlements from the proposed development construction loads. In order to address this some form of ground treatment will be required. Details of this would be dependent on the size and structural loads of the proposed development and a range of treatment methods may be suitable (including for example surcharging).

Outside of the areas of opencast mining it is expected that competent natural soils and/or bedrock will be present at shallow depth and these settlement mechanisms will not be relevant. In such areas conventional shallow strip or pad spread foundations and ground-bearing floor slabs are likely to be possible (however in these areas shallow coal seams may be present, which may have been worked underground requiring further assessment).

4.3.3 Highwalls

A highwall associated with the Elsecar Fault is present at the location as estimated on Figure 3. At this stage the variation in thickness of fill across the highwall is not fully

understood, and it would usually be advised that the highwalls be considered no-build zones. However, they could be used for roads, car parking and landscaping with appropriate engineering controls. If building over or across highwalls is proposed this could only be considered following additional site-specific investigation work, loading tests and assessment work.

4.3.4 Geotechnical conclusions

The opencast backfill is not currently considered to be a suitable founding stratum for the building development, and so it will require treatment to improve its bearing capacity. A range of ground treatment options might be considered including surcharging which has been successfully adopted locally on the neighbouring Shortwood Business Park.

5 PRELIMINARY GEOTECHNICAL CONSTRAINTS

5.1 Design class

BS EN 1997-1 defines three different Geotechnical Categories that structures may fall into, which are summarised as follows:

- Category 1: Small and relatively simple structures for which it is possible to ensure that the fundamental requirements will be satisfied on the basis of experience and qualitative geotechnical investigations; with negligible risk
- Category 2: Conventional types of structure and foundation with no exceptional risk or difficult ground or loading conditions
- Category 3: Structures or part of structures, which fall outside limits of Geotechnical Categories 1 and 2. Examples include very large or unusual structures; structures involving abnormal risks, or unusual or exceptionally difficult ground or loading conditions; structures in highly seismic areas; structures in areas of probable site instability or persistent ground movements that require separate investigation or special measures.

Based on the information provided above on the proposed development and in view of the anticipated ground conditions, a Geotechnical Category of Category 3 has been assumed for the purposes of designing the geotechnical investigation. This should be reviewed at all stages of the investigation and revised where necessary.

5.2 Preliminary geotechnical hazards assessment

A summary of commonly occurring geotechnical hazards associated with the anticipated geology outlined in Section 3 above is given in Table 3 together with an assessment of whether the site may be affected by each of the stated hazards.

Table 3 Summary of preliminary geotechnical risks that may affect site

Hazard category	Hazard status based on desk study findings and proposed development		Engineering considerations if hazard affects site
	Could be present and/or affect site	Unlikely to be present and/or affect site	
Sudden lateral changes in ground conditions	☒	☐	Likely to affect ground engineering and foundation design and construction
Shrinkable clay soils	☒	☐	Design to NHBC Standards Chapter 4 or similar

Hazard category	Hazard status based on desk study findings and proposed development		Engineering considerations if hazard affects site
	Could be present and/or affect site	Unlikely to be present and/or affect site	
Highly compressible and low bearing capacity soils, (including peat and soft clay)	☒	☐	Likely to affect ground engineering and foundation design and construction
Silt-rich soils susceptible to rapid loss of strength in wet conditions	☒	☐	Likely to affect ground engineering and foundation design and construction
Running sand at and below water table	☐	☒	Likely to affect ground engineering and foundation design and construction
Karstic dissolution features (including 'swallow holes' in Chalk terrain)	☐	☒	May affect ground engineering and foundation design and construction – refer to Section 4.1.2
Evaporite dissolution features and/or subsidence	☐	☒	May affect ground engineering and foundation design and construction
Ground subject to or at risk from landslides	☐	☒	Likely to require special stabilisation measures
Ground subject to peri-glacial valley cambering with gulls possibly present	☐	☒	Likely to affect ground engineering and foundation design and construction
Ground subject to or at risk from coastal or river erosion	☐	☒	Likely to require special protection/stabilisation measures
High groundwater table (including waterlogged ground)	☒	☐	May affect temporary and permanent works
Rising groundwater table due to diminishing abstraction in urban area	☒	☐	May affect deep foundations, basements and tunnels
Underground mining	☒	☐	Likely to require special stabilisation measures
Effects of extreme temperature (e.g. cold stores or brick kilns/furnaces)	☐	☒	Likely to affect ground engineering and foundation design and construction
Existing sub-structures (e.g. tunnels, foundations, basements, and adjacent sub-structures)	☐	☒	Likely to affect ground engineering and foundation design and construction

Hazard category	Hazard status based on desk study findings and proposed development		Engineering considerations if hazard affects site
	Could be present and/or affect site	Unlikely to be present and/or affect site	
Filled and made ground (including embankments, infilled ponds and quarries)	☒	☐	Likely to affect ground engineering and foundation design and construction
Adverse ground chemistry (including expansive slags and weathering of sulphides to sulphates)	☒	☐	May affect ground engineering and foundation design and construction
Site topography	☒	☐	May affect ground engineering and foundation design and construction
Note: Seismicity is not included in the above table as this is not normally a design consideration in the UK.			

6 CONCEPTUAL SITE MODEL

In line with CLR11 (Environment Agency, 2004) and BS 10175: 2011 + A2 2017 (BSI, 2017), RSK has used the information obtained during the desk study to identify sources of contaminants, receptors that may be impacted and plausible linking pathways. Where all three are present this is termed a potentially complete contaminant linkage and a qualitative risk estimation is made. The resulting potential pollutant linkages are considered in Section 5.5. The risk classification has been estimated in accordance with information in Appendix E.

6.1 Summary of potential contaminant sources

Potential sources and contaminants of concern are summarised in Table 4.

Table 4 Potential sources and types of contamination

Potential sources	Contaminants of concern
On-site historical	
Potential for localised contamination in vicinity of buildings associated with deep mining activities, coke manufacture, railway and the sawmill. Potential for ashy materials, oil and fuel leakages and minor spillages from machinery and equipment, etc. Also, possible made ground containing demolition materials. It is possible that such localised contamination was relocated during the subsequent opencast mining of the site and incorporated into the backfill materials.	Fuel oils, lubricating oils, polycyclic aromatic hydrocarbons (PAHs), ash (PAHs and heavy metals), asbestos.
On-site present day	
Opencast backfill to the surface mine, likely to include reworked overburden and bedrock. Possibility of some contaminated materials from historical industrial on-site activities.	Fuel oils, lubricating oils, polycyclic aromatic hydrocarbons (PAHs), ash (PAHs and heavy metals), asbestos.
Off-site	
Opencast backfill extends off site to south, east and west, same potential impacted as on-site fills.	Fuel oils, lubricating oils, polycyclic aromatic hydrocarbons (PAHs), ash (PAHs and heavy metals), asbestos.
Gas sources	
Opencast backfill, likely to be predominantly inert. Underlying Coal Measures Bedrock and deeper mining including mine shafts.	Carbon dioxide, methane and trace gases. Previous assessment of ground gases has found concentrations and flows to be lower than expected with monitoring completed thus far suggesting CS2 protective measures may be required.

RSK considers that contaminated soils may be present within the backfill materials in the former opencast voids on site. These could have resulted from inclusion within the backfill of localised contaminated soils from in and around the former colliery and associated industries on site. However, it is considered unlikely that this contamination is significant given the environmental site setting and the proposed end-use. Given the thickness of made ground and deeper mining sources at the site risks from hazardous ground gases need to be considered for the western site area. However, it is considered that the majority of the made ground will be inert with very low gas generation potential.

6.2 Sensitive receptors

Sensitive receptors identified at the site (following redevelopment) include:

- future site workers on commercial development
- adjacent site users
- users of the public footpaths crossing the site
- proposed buildings, infrastructure and services
- potable water supply pipes
- groundwater beneath the site (secondary A aquifer comprising the Pennine Lower Coal Measures Formation bedrock)
- surface watercourses (stream on site, Blacker Dike to the north).

Please note that construction workers have not been identified in the conceptual model as receptors because risks are considered to be managed through health and safety procedures including CDM regulations.

6.3 Summary of plausible pathways

The plausible pathways for identified for the site are summarised below:

- direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation)
- ground gas and soil gas accumulation and/or inhalation
- vertical and lateral migration including leaching
- root uptake
- permeation of plastic water supply pipes.

6.4 Data gaps and uncertainties

The composition of fill within the former opencast voids has been found in previous investigations to comprise predominantly reworked overburden and bedrock materials that are chemically suitable for the proposed end use. Though it is not expected, there is potential given the volume of fill for contaminated soils to be locally present.

The thickness of fill materials, though roughly defined by the seam extraction records, is not fully understood. This is particularly the case around the high walls of the former pits.

Ground gas monitoring was last undertaken at the site in September 2014 and as such there is potential for the conditions to have altered.

6.5 Potentially complete pollutant linkages

The outline CSM has identified several potentially complete pollutant linkages and these, along with an estimate of the risk associated with each linkage, are presented in Table 5. The risk classification has been undertaken in accordance with CIRIA guidance, a summary of which is included in Appendix E.

Table 5 Risk estimation for potentially complete pollutant linkages

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
Possible contamination in soils placed within opencast backfill (materials originally from areas around former colliery and associated infrastructure, colliery spoil, and possible demolition rubble). (on-site sources)	Future workers in commercial development	Direct contact (soil, dust and vegetable ingestion, dermal contact, dust and fibre inhalation)	Unlikely	Medium	Low: Prior to being excavated as part of opencast operations, overburden soils and bedrock may have been locally contaminated due to the former presence of a colliery on site. Demolition materials from the former buildings (potentially including asbestos) may have been mixed with the overburden materials however no evidence of this was identified during the initial intrusive investigation. Should evidence of significant visual or olfactory evidence of contamination be identified this pollutant linkage may need to be reintroduced.
	Residents/users of adjacent commercial and residential areas	Direct contact with windblown dust	Unlikely	Medium	Low: If contamination is present on site it is unlikely to significantly impact residents/users off-site. It is expected that during the construction phase dust generated from soils will be controlled as required by CDM regulations.
	Future workers in commercial development	Permeation of water supply pipes	Low likelihood	Medium	Moderate / Low: If organic contamination is present there is a potential for quality of water supply pipes to be affected.
	Secondary 'A' aquifer in Pennine Lower Coal Measures	Vertical and lateral migration of contaminants into underlying bedrock aquifer	Unlikely	Medium	Low: Though it is possible that any contamination within the filled voids on site could leach and impact the aquifer there has not been any continuous groundwater body identified and no significant source within shallow soils.
	Surface watercourse (ditch on-site and Blacker Dike)	Surface water run-off, lateral migration of contaminants	Unlikely	Medium	Low: It is possible that any contamination within the shallow soils on site could leach and migrate to the nearby stream, though the stream is likely to be perched above the groundwater within the filled voids.
Ground gases from opencast backfill (and from underlying Coal Measures)	Future workers in commercial development	Vertical and lateral migration and build-up of methane in confined spaces, leading to explosion,	Low likelihood	Severe	Moderate: Given the considerable depth of infilled voids there is potential for gas generation, but the fill is likely to comprise mostly inert materials. Significant ground gas generation has not been recorded on the site however elevated carbon dioxide concentrations did lead to a recommendation for ground gas protective measures in the east of Phase 2 during the previous site investigation.

Potential Contaminant	Potential receptor	Possible pathway	Likelihood	Severity	Risk and justification
	Off-site occupants of nearby residential and commercial properties.	or inhalation of carbon dioxide in confined spaces, resulting in suffocation.	Unlikely	Severe	Moderate/Low: Given the considerable depth of opencast backfill (and underlying Coal Measures) there is potential for gas generation, but the backfill is likely to comprise almost entirely inert materials. Off-site properties are less likely to be affected than those on site.
	Proposed buildings and infrastructure		Low likelihood	Medium	Moderate/Low: Given the considerable depth of opencast backfill (and underlying Coal Measures) there is potential for gas generation, but the backfill is likely to comprise almost entirely inert materials. Proposed commercial buildings and infrastructure are a less sensitive receptor.

The potential pollutant linkages with a risk of moderate/low or above that may drive site investigation and assessment works are:

1. permeation of water supply pipes by contaminants in soils and subsequent ingestion by workers in the proposed on-site commercial buildings – **Moderate/Low risk**
2. vertical and lateral migration of ground gas into enclosed spaces which would affect future workers on-site (and possibly workers/residents on adjacent sites and future buildings on site) – **Moderate risk**.

7 SITE INVESTIGATION STRATEGY & METHODOLOGY

7.1 Introduction

RSK carried out intrusive investigation works and subsequent monitoring of boreholes across the Phase 2 and Phase 3 areas at the Rockingham site between October 2019 and February 2020.

Prior to conducting intrusive works, utility service plans were obtained, and buried service clearance undertaken in line with RSK's health and safety procedures. Copies of the statutory service records obtained by RSK as part of the agreed scope of works that were recorded as affecting the site are provided in Appendix D. The full dataset of responses from utility providers is available on request.

7.2 Objectives

The specific objectives of the investigation were as follows:

- to establish the ground conditions underlying the site including the extent and thickness of any made ground
- to determine groundwater depth and flow direction
- to determine the ground gas regime underlying the site
- to assess geotechnical properties of soils
- to address data gaps identified in section 6.4.

7.3 Selection of investigation methods

The techniques adopted for the investigation were chosen with consideration of the objectives and site constraints, which are described below.

Cable percussion drilling was chosen based on the targeted drill depth, requirement for in-situ geotechnical data (standard penetration tests – SPT's), the opportunity to collect both disturbed and undisturbed samples and install monitoring wells.

This was supplemented by mechanically excavated trial pitting to obtain a number of investigation locations, allow collection of large bulk geotechnical samples for the classification of cut and fill materials and achieve greater visibility of the Made Ground.

Rotary drilling techniques, including rotary open hole and rotary coring, were utilised to investigate coal mining legacy issues, as well as targeting any potential groundwater within the bedrock.

Probe holes using windowless sampling techniques were also utilised in some areas to confirm depth to shallow bedrock, as well as provide further in situ (SPT) data within the shallow soils in the area of the proposed access roads.

7.4 Investigation strategy

The ground investigation was carried out using intrusive ground investigation techniques in general accordance with the recommendations of BS5930: 2015 Code of practice for ground investigations, which maintains compliance with BS EN 1997-1 and 1997-2 and their related standards. Whilst every attempt was made to record full details of the strata encountered in the boreholes, techniques of hole formation and sampling will inevitably lead to disturbance, mixing or loss of material in some soils and rocks.

The investigation strategy involved targeted and non-targeted boreholes, probeholes and trial pits with those targeted locations positioned for geotechnical rather than environmental purposes. The investigation comprised a supplementary investigation, focussing on the Phase 2 and Phase 3 areas of the site.

The constraints to the investigation were as follows:

- Yorkshire Water Sewer
- existing surcharge mound
- areas of woodland
- boulders within the open cast backfill.

In order to gain access to the densely wooded area to the north east of Phase 3 an area of approximately 1000m² was cleared over the course of three days by a three-man chainsaw and chipping team under the guidance of an arborist and ecologist.

Details of the investigation locations, installations and rationale are presented in Table 6. 25 machine excavated trial pits were dug to a maximum depth of 5.50m bgl before being backfilled with arisings. 36 cable percussive boreholes were drilled to a maximum depth of 20.45m bgl and selected boreholes were installed with a combined gas and groundwater monitoring wells, 8 windowless sample probeholes were drilled to a maximum depth of 5.45m bgl and 22 rotary boreholes were drilled to a maximum depth of 63.00m.

Table 6 Exploratory hole and monitoring well location rationale

Investigation type	Number	Designation	Monitoring well installation	Rationale examples below
Boreholes by cable percussive methods	36	BH501 to BH504, BH506 to BH517, BH519 to BH535, BH535A, BH536 and BH537	Gas and groundwater	To obtain in-situ geotechnical data, environmental and geotechnical samples and confirm the geological sequence as well as allow installation of monitoring wells.
Boreholes by dynamic/windowless sampling methods	5	WS101 to WS105	N/A	To provide in-situ geotechnical test data along the proposed entrance road.

Investigation type	Number	Designation	Monitoring well installation	Rationale examples below
Boreholes by dynamic/windowless sampling methods	3	WS106 to WS108	N/A	To confirm the presence or absence of shallow bedrock and to provide in-situ geotechnical test data.
Trial-pits excavated by mechanical excavator	25	TP501 to TP515, TP517 to TP526	N/A	To accurately log the upper strata in targeted and non-targeted locations beneath the site. Collect samples from the shallow made ground soils.
Borehole by rotary open hole and rotary coring methods	22	BH518, BH530 (rotary follow on), RBH501 to RBH518, RBH520 and RBH521	Groundwater	To investigate the bedrock/made ground contact, progress past boulders encountered in the cable percussive drilling as well as allow installation of deep groundwater monitoring wells and investigate for potential shallow worked coal seams.

7.4.1 Implementation of investigation works

The exploratory holes were logged by an engineer in general accordance with the recommendations of BS 5930:2015 (which incorporates the requirements of BS EN ISO 14688-1, 14688-2 and 14689-1), with the exception of holes progressed by rotary open hole methodologies whereby arisings are limited.

The monitoring well construction and associated response zones are detailed on the exploratory hole records in Appendix F. The response zones were either installed to target identified gas generation sources or migration pathways detailed in the CSM, or to target potentially water bearing strata across the site. 50mm I.D HDPE pipework was installed into the boreholes with 1mm slotted and geo-wrapped sections used in the targeted response zone. A washed gravel annulus was utilised for the screened section with the remainder sealed with hydrated bentonite pellets. Monitoring wells were capped with a rubber bung and dual gas taps with concreted raised headworks.

The soil sampling and analysis strategy was designed to enhance the existing assessment of the potential contaminant linkages identified within previous reports and investigate the geotechnical characteristics. In addition, samples were taken to allow for geo-environmental and geotechnical testing to be undertaken.

Soils collected for laboratory analysis were placed in a variety of containers appropriate to the anticipated testing suite required. They were dispatched to the laboratory in cool boxes under chain of custody documentation. Samples were stored in accordance with

the RSK quality procedures to maintain sample integrity and preservation and to minimise the chance of cross contamination.

7.5 Monitoring programme

7.5.1 Ground gas monitoring

In line with the initial CSM, response zones were installed to target the sources or pathways as detailed in the CSM. Dual gas taps were installed in line with BS8576.

A programme of ground gas monitoring has been completed at the site. Six monitoring rounds have been undertaken to date to provide data to support refining of the CSM. The number of monitoring rounds carried out has been undertaken in general accordance with the decision matrix presented as Figure 6 of BS8576.

An infrared gas meter was used to measure gas flow, concentrations of carbon dioxide (CO₂), methane (CH₄) and oxygen (O₂) in percentage by volume, while hydrogen sulphide (H₂S) and carbon monoxide (CO) were recorded in parts per million.

Initial and steady state concentrations were recorded.

The atmospheric pressure before and during monitoring, together with the weather conditions, were recorded. The monitoring included periods of falling atmospheric pressures and after/during rainfall.

All ground gas monitoring results together with the temporal conditions are contained within Appendix G.

7.5.2 Groundwater gauging

Four rounds of groundwater gauging were undertaken over a 4-month period in order to better understand the groundwater regime at the site. A summary of the gauging records, including dates, is provided in Appendix H.

Development of the monitoring wells following installation was undertaken comprising the removal of three well volumes using a bailer.

Depths to groundwater were recorded using an electronic dip meter on each of the visits.

7.6 Laboratory testing

Laboratory testing was undertaken at a UKAS accredited laboratory with ISO17025 and MCERTS accredited test methods were specified where applicable for contamination testing and as shown in the laboratory test certificates appended.

7.6.1 Chemical analysis of soil samples

The soil sampling strategy was designed to supplement the work completed during the previous investigations of the site, aiding characterisation of the made ground. The CSM had only identified a moderate/low risk of contamination to water pipelines from organic contaminants and as such sampling was limited unless visual or olfactory evidence of contaminants were identified during the supplementary site investigation.

The programme of chemical tests undertaken on soil samples obtained from this intrusive investigation is presented in Table 7 with the laboratory testing results contained in Appendix I.

Table 7 Summary of supplementary chemical testing of soil samples

Stratum	Tests undertaken	No. of tests
Made ground	BRE Brownfield Pyritic suite comprising pH, sulphate, ws sulphate, sulphur	12
Made ground	Environmental suite comprising speciated PAHs, TPHs, pH, metals, sulphate, ws sulphate	2
Made ground	TPHs	6
Made ground	Metals (9)	16
Made ground	PAHs	2
Made ground	pH	18
Made ground	Total Organic Carbon	10
Made ground	Calorific Value	3
Made ground	SVOC	7

No visual or olfactory evidence of organic contaminants, aside from a wood fragment with a creosote odour found in TP525 at 4.10m depth below ground level, were identified during the investigation and as such the samples collected were non-targeted. No asbestos containing materials were identified during the site investigation.

7.6.2 Geotechnical analysis of soils

Where appropriate disturbed, bulk and undisturbed soil samples were taken for geotechnical classification testing with the depth and nature of samples detailed within the exploratory hole records.

Testing was undertaken in accordance with BS 1377:1990 Method of Tests for Soils for Civil Engineering Purposes or, where superseded, by the relevant part of BS EN ISO 17892:2014 Geotechnical investigation and testing - Laboratory Testing of Soil. Tests carried out in order to classify the concrete class required on-site have been undertaken following the procedures within BRE SD1:2005.

The programme of geotechnical tests undertaken on samples obtained from the intrusive investigation to date is presented in Table 8. The results and UKAS accreditation of tests methods are shown in Appendix J.

Table 8 Summary of geotechnical testing undertaken

Strata	Tests undertaken	No. of tests
Made ground & weathered Pennine Middle Coal Measures	Moisture content %	8

Strata	Tests undertaken	No. of tests
Made ground	Liquid/ plastic limits	8
Made ground	Sieve analysis	12
Made ground	Compaction – dry density moisture content relationship test (4.5kg rammer)	5

The geotechnical analysis described above is supplementary to that undertaken as part of the RSK 2014/2015 investigation (reports referenced in Section 1.5, testing certificates included in Appendix J for ease of reference). As of the date of issue of this draft report the full suite of scheduled geotechnical tests has not been made available by the laboratory and as such they will be provided within the final issue of this document.

8 SITE INVESTIGATION FACTUAL FINDINGS

The preliminary results of the geo-environmental and geotechnical intrusive investigation are detailed below. This report summarises the site data collected in 2019 and 2020 and presents them in the context of the findings to date.

8.1 Ground conditions encountered

The descriptions of the strata encountered, notes regarding visual or olfactory evidence of contamination, list of samples taken, field observations of soil and groundwater, in-situ testing and details of monitoring well installations are included on the exploratory hole records presented in Appendix F.

The exploratory holes revealed that the site is underlain by a variable thickness of made ground (backfill of the former opencast pit) directly overlying an interbedded series of mudstones, siltstones, sandstones and coal seams of the Pennine Middle Coal Measures Formation. This appears to confirm the stratigraphical succession described within the CSM with no superficial deposits evident across the site. The Elsecar Fault is shown to influence bedrock geology in the proposed development area, trending through Phase 2 and Phase 3 in an approximately north-west to south-easterly direction, downthrown by between 60m and 70m on the north eastern side. The bedrock has also been disturbed by the open cast mining across the site resulting in significant variations in depth.

For the purpose of discussion, the ground conditions encountered during the fieldworks are summarised in Table 9 with the strata discussed in subsequent subsections. A selection of cross sections covering the site are provided as Figures 5, 6 and 7.

Table 9 General succession of strata encountered

Stratum	Exploratory holes encountered	Depth to top of stratum m bgl	Proven thickness (m)
Made Ground	All exploratory holes	0.00	1.50 – 54.00
Pennine Middle Coal Measures	BH502, BH509, BH514 to BH519, BH534, RBH501, RBH503, RBH504, RBH507, RBH509 to RBH512, RBH514 to RBH518	1.50 – 54.00	N/A

8.1.1 Made ground

The made ground generally comprised a cohesive soil with a significant proportion of granular material (gravel, cobbles and boulders) within the matrix. A surface layer of made ground ranging from 0.10m to 0.55m in thickness was encountered in all exploratory locations acting as a growing media for the grassed fields. This layer exhibited properties resembling that of topsoil in terms of appearance and structure and should be considered as a soft compressible layer across the site surface. The made ground ranged in thickness from 0.80m to 54.0m, with the latter extent found in RBH503, located in an area of deep opencast extraction. The deepest deposits of opencast backfilled identified at the site to date was 69m in RBH405. From the available historic records, in-situ testing and load test

results it is evident that the opencast backfill material has not been placed as an engineered fill, however some material placed under engineering control may extend beneath parts of the site adjacent to the Dearne Valley Parkway.

The made ground largely comprised reworked natural materials including mudstone, sandstone, siltstone with occasional coal fragments as would be expected from the backfill of the opencast pit with excavated material. Other materials encountered included rare brick fragments and burnt shale, which are consistent with the former site use as a colliery with spoil materials.

A summary of the in-situ and laboratory test results recorded in the stratum are presented in Table 10.

Table 10 Summary of in-situ and laboratory test results for made ground

Soil parameters	Min. Value	Max. Value	Reference
Moisture content (%)	11	24	Appendix J
Liquid limit (%)	34	40	Appendix J
Plasticity limit (%)	19	19	Appendix J
Plasticity index (%)	15	21	Appendix J
Modified plasticity index (%)	10.80	12.81	Appendix J
Plasticity term	Low	Intermediate	Appendix J
Volume change potential	Low	Low	Appendix J
SPT 'N' values	4	>50	Appendix F
Undrained shear strength inferred from SPT 'N' values (kN/m ²)	20	>250	Appendix F
Undrained shear strength measured by shear vane testing (kN/m ²)	72	>130	Appendix F
Consistency term from field description	Very soft	Very stiff	Appendix F

Significant local variation in soil composition and strength has been encountered in the made ground during the site investigation, although it would be generally be the case that strength and relative density increased with depth.

Where high SPT N values (>50) were recorded at shallow depths these are likely to represent obstructions on coarser fractions (boulders and cobbles) within the soil.

The presence of coarser soil fractions (cobbles and boulders) are likely to be underrepresented in the site logging of boreholes and window samples as a result of limited sample volumes.

8.1.2 Pennine Middle Coal Measures Formation

This stratum comprised an interbedded series of dark brown to dark grey mudstones, siltstones and sandstones with coal seams (usually weathered at the upper surface) and was encountered at a depth of between 1.5m and 54.0m below ground level.

A summary of the in-situ and laboratory test results recorded in the stratum are presented in Table 11.

Table 11 Summary of in-situ test results for Pennine Middle Coal Measures Formation

Soil parameters	Min. Value	Max. Value	Reference
SPT 'N' values	53	333	Appendix F
Undrained shear strength inferred from SPT 'N' values (kN/m ²)	265	1665	Appendix F
Strength term from rock logging	Extremely weak	Medium strong	Appendix F

8.1.3 Visual/olfactory evidence of soil contamination

No visual or olfactory evidence of contamination was identified within made ground deposits aside from a fragment of wood with a creosote odour in TP525. No evidence was identified in underlying natural strata.

No visual evidence of asbestos was encountered.

8.2 Groundwater and surface water

8.2.1 Groundwater encountered during intrusive works

Groundwater was encountered during the intrusive investigation works as detailed on the logs in Appendix F.

The water entries occurred as sporadic seepages within the made ground, possibly representing pathways from interconnected granular lenses allowing surface water and perched water on the more cohesive made ground.

Deeper water strikes were also recorded and are thought to represent perched water at the interface between the made ground and bedrock at the base of the former open cast pit.

8.2.2 Groundwater encountered during monitoring

Resting groundwater levels recorded during the monitoring programme are summarised in Appendix H.

From the monitoring undertaken to date groundwater has been recorded at elevations of between 91.64m AOD (above ordinance datum) and 101.82m AOD in the west of the site, within the larger RJB Mining opencast pit and between 141.59m AOD and 151.16m AOD within the shallower eastern pit.

For context the ground levels range from ~119m AOD in the far north to ~148m AOD in the south (western pit) to ~138m AOD in the north to ~160m AOD in the south for the eastern pit.

8.2.3 Visual/olfactory evidence of groundwater contamination

There was an absence of visual or olfactory evidence of contamination in groundwater during well development.

8.3 Chemical laboratory results

The soil testing results are presented in Appendix I and discussed in Section 10.3.

8.4 Geotechnical laboratory results

The results of the geotechnical testing of soil samples available to date are presented in Appendix J and discussed in Section 11.

8.5 Ground gas monitoring

The results of the ground gas monitoring and testing carried out are given in Appendix G and discussed in Section 10.4.

9 COAL MINING RISK ASSESSMENT

A Coal Mining Risk Assessment (CMRA) was completed as part of the Phase 1 Desk Study Report for the site, RSK reference: 322638 R01 (01).

Based on the information available this report concluded that some potentially unacceptable risks from the coal mining legacy of the site remained to the proposed developed.

These included:

- self-weight settlement of the opencast backfills
- inundation settlement
- settlement of deep areas of opencast backfill under the proposed building and earthworks loads
- sharp variations in backfill thickness potentially leading to differential settlement (highwalls)
- possible unrecorded worked coal seams
- mine entries
- naturally occurring concentrations of sulphates, pyrites and acid conditions within reworked Coal Measures deposits.

In addition, despite the best efforts of RSK and the Coal Authority no records could be recovered for the capping and treatment details for shafts 435401-002 and 435401-003.

These are discussed in turn in the sub sections below based on the findings of the 2019/2020 RSK ground investigation.

9.1 Self-weight settlement

RSK's preliminary risk assessment identified the potential for poorly consolidated backfill materials to settle under their own weight.

The timescale for this is dependent on grain size and is generally shorter in granular soils and longer in fine grained/cohesive soils.

In order to observe whether self-weight settlement was active at the site precise levelling of those ground markers still intact as placed in 2013 was resumed after cessation of monitoring in 2016. Additional ground markers were also installed in areas not previously accessible (woodland on Rockingham 3).

Up to 14 monitoring visits were completed between 1 August 2013 and 9 June 2016, after which no further readings were obtained until the recent work commenced on 17 October 2019. Since October 2019 RSK have obtained a further 3 rounds of monitoring data with the latest round completed on 27 February 2020.

The current monitoring programme is due to run for another 6 months in order to allow meaningful conclusions to be drawn.

9.2 Inundation settlement and collapse compression

Two plausible mechanisms for inundation settlement are possible at the site given the type and quality of soil encountered during the investigation.

The first is related to surface infiltration of water from rainfall. A surface inundation test was performed on the engineered soils of the Rockingham 1 site which identified no significant settlement however the soils of the Rockingham 2 and 3 sites were not engineered and as such inundation settlement cannot be discounted. Additional plot specific testing will have to be conducted to assess the potential for inundation from surface infiltration. This could be undertaken during the proposed regrading earthworks when near final ground levels are achieved.

The second mechanism is from recovering or rising groundwater levels at the base of the opencast backfill. In this case rising groundwater could soften the backfill materials at the base of the opencast backfill and allow collapse which could then migrate upwards. The potential for this can be assessed by direct borehole investigation to inspect the soils for any evidence of potentially soft, weakened or voided material and then by installing deep groundwater monitoring installations and monitoring these to measure standing water levels and any groundwater movements or recovery (for example post mining) over a significant period of time. This approach has been followed on site with deep boreholes with groundwater monitoring standpipes installed within both the made ground of the former opencast pit and within the bedrock outside of it.

The monitoring installations on site have been monitored periodically by RSK between 20 February 2014 and 11 February 2020 and no consistent groundwater elevation has been determined. Water strikes, where they were encountered, were variable in depth though possibly have some correlation to the structure of the former opencast workings.

The results from the monitoring as completed by 2016 have been reported previously, with the latest work adding an additional 4 monitoring visits between 7 October 2019 and 11 February 2020 to this dataset. Recent monitoring included all serviceable wells from the previous investigation as well as the additional monitoring wells installed during the recent (2019/2020) investigation. The relevant data (those monitoring installations that have recorded water to be present) is summarised in graphical form in Appendix H.

By comparing the recent groundwater monitoring results with those recorded at the site from 2014 it can be seen that water levels are largely stable. At two positions a rise of approximately 8m has been recorded [in RBH305 (Rockingham 3) and RBH404 (Rockingham 2)]. Both positions are installed to the base of the former opencast pit in areas of deep made ground to the west of the Elsecar fault. This was not replicated in other boreholes and no significant variations were recorded in the shallower eastern pit.

In RBH404 the rise was recorded between 15 August 2014 and 29 August 2014 with subsequent monitoring visits on 10 September 2014 and 24 November 2014 showing no further rise in groundwater level. This sudden and rapid rise, which then stabilised very quickly is thought to represent some failure of the monitoring installation seal.

At RBH305 the rise in groundwater level was recorded between the last 2014 monitoring visit (24 November) and the first visit of the recent investigation on 7 October 2019. Groundwater levels within this monitoring installation have subsequently fluctuated dropping 3.5m between 7 October 2019 and 13 January 2020 before having been

recorded to rise back to the original level of 101m AOD on 11 February 2020. It should be noted that groundwater levels might fluctuate for a number of reasons including seasonal variations, however these fluctuations have been largely absent in the data collected thus far.

Bi-monthly groundwater monitoring visits are continuing for a further six months to determine whether any rise in ground water level can be perceived. If water levels are indicated as rising (not evident to date), then further monitoring and assessment would be required.

9.3 Settlement under proposed loads

In order to characterise potential ground settlement under the assumed design loads the settlement data from the load test on Rockingham 3 has been back analysed to produce characteristic stiffness values for the non-engineered made ground. These have then been verified against the in-situ SPT results from the recent investigation.

The resultant stiffness values have then been used to model the structural loads on pad foundations and ground bearing slabs under three scenarios representative of the different ground conditions straddled by the proposed Units on site.

Details of this assessment is provided in Appendix O and discussed further in Section 11.

9.4 Variations in backfill thickness

To better understand the variable thickness of made ground at the site RSK have produced a 3D geological model of the Rockingham 2 and Rockingham 3 sites.

The model has been built up using the RJB Mining coal seam extraction records, Mott Macdonald engineering report and borehole information from RSK's investigations and now provides a powerful tool for estimating the ground conditions beneath the proposed units and visualising these.

A link to this model is available on request to RSK following approval by Harworth Estates.

9.5 Possible unrecorded worked coal seams

Previous reporting had highlighted the potential for coal seams to have been worked outside of the areas of recorded opencast extraction.

In order to assess this risk 16 rotary boreholes were extended into the bedrock. No voided or broken ground was identified however intact coal seams were located as detailed in Table 12 below.

Table 12 Summary of in-situ test results for Pennine Middle Coal Measures Formation

BH ID	Ground Level (m AOD)	Borehole Depth (m)	Depth to Rockhead (m)	Top of Seam (m bgl)	Base of Seam (m bgl)	Comments
RBH501	141.06	8.30	3.10	-	-	No seam encountered

BH ID	Ground Level (m AOD)	Borehole Depth (m)	Depth to Rockhead (m)	Top of Seam (m bgl)	Base of Seam (m bgl)	Comments
RBH503	144.66	63.00	54.00	-	-	No seam encountered
RBH504	142.47	41.50	5.10	24.20	24.40	Too thin, no broken ground
RBH505	141.73	40.00	4.90	21.60	21.80	Too thin to affect the surface
RBH505	141.73	40.00	4.90	24.10	25.00	Sufficient rock cover not to represent a risk to ground surface
RBH506	141.85	40.00	3.00	16.50	16.70	Too thin to affect the surface
RBH506	141.85	40.00	3.00	20.30	21.10	Sufficient rock cover not to represent a risk to ground surface
RBH506	141.85	40.00	3.00	30.30	30.60	Too thin to affect the surface
RBH507	145.60	40.00	3.10	24.50	24.70	Too thin to affect the surface
RBH507	145.60	40.00	3.10	28.00	28.80	Sufficient rock cover not to represent a risk to ground surface
RBH508	143.12	40.00	3.00	28.10	28.80	Too thin to affect the surface
RBH510	144.39	40.00	2.30	22.60	23.25	Sufficient rock cover not to represent a risk to ground surface
RBH511	141.32	37.00	24.00	>37.00	-	No coal, no broken ground or voids
RBH512	143.48	50.60	19.40	>50.60	-	No coal, no broken ground or voids
RBH513	148.50	32.50	8.50	26.00	26.30	Too thin to affect the surface
RBH514	148.49	41.00	11.60	27.50	27.70	Too thin to affect the surface
RBH514	148.49	41.00	11.60	30.80	31.50	Sufficient rock cover not to represent a risk to ground surface
RBH515	152.46	32.50	10.80	27.30	27.50	Too thin to affect the surface
RBH515	152.46	32.50	10.80	30.10	31.00	Sufficient rock cover not to represent a risk to ground surface
RBH516	154.12	40.00	19.70	31.30	31.60	Too thin to affect the surface
RBH517	147.95	40.00	7.10	19.70	20.30	Sufficient rock cover not to represent a risk to ground surface
RBH517	147.95	40.00	7.10	23.40	24.70	Sufficient rock cover not to represent a risk to ground surface
RBH518	153.77	50.00	13.70	-	-	No return between 22.60m and 34.40m. Drilling resistance did not suggest a void or broken ground.
Notes: m bgl – meters below ground level, all seams thicknesses recorded as intersected, actual thicknesses may vary.						

Although coal seams were recorded, which are of a thickness which may have been worked underground, there is no evidence of workings within these seams (this would have been evident for example by the presence of voids, broken ground, loss of flush and rapid penetration). At the borehole locations drilled there was sufficient thickness of rock

cover above the seams encountered to accommodate any localised collapse if the seam had been worked. It is considered that the risk from unrecorded shallow worked seams is low unless further evidence is discovered to the contrary through the process of development in which case RSK should be informed immediately.

9.6 Mine entries

Mine entries that remain in place and untreated represent a risk to development due to the potential for collapse. The Coal Authority records and RSK's interpretation of that data within the Coal Mining Risk Assessment (RSK report reference: 322638-R01) indicate that two mineshafts shafts are of potential concern:

- shaft 435401-002, plugged at the depth of the Flockton seam in 1990, partially removed by opencast mining and capped at the base of the opencast workings in June 1992
- shaft 435401-003, was filled in 1990, partially removed by opencast mining and capped at the base of the opencast workings in June 1992.

Although the above data was provided by the Coal Authority, they were unable to provide any details on the caps and requested that presence of the caps were proven at the recorded locations by additional borehole drilling.

As part of the recent investigation work RSK have drilled two rotary boreholes in the vicinity of shaft 435401-003. These include RBH520 (location based off an RJB mining seam plan) and RBH521 (the CA recorded location of shaft ref: 435401-003), both drilled in an attempt to confirm the shaft cap position. RBH521 successfully located the cap as proved by an obstruction at 23.8m depth as detailed on the borehole log provided in Appendix F. Upon completion, the borehole was dipped using a 50m measuring tape which extended to its full length. This suggests that a void is present beneath the cap to a depth of at least 48m below ground level.

A standpipe was installed in the borehole to facilitate subsequent monitoring, however monitoring visits have so far been unsuccessful in extending beyond the cap level. The full depth of the void has therefore not been determined.

Although a rotary borehole (RBH519) was planned directly above the 435401-002 shaft, access to the location was prevented by the presence of the surcharge mound.

10 GEO-ENVIRONMENTAL ASSESSMENT

10.1 Refinement of initial CSM

The conceptual site model (CSM) presented in Section 6 identified two potential pollutant linkages with a risk of moderate/low or above that may drive site investigation and assessment works (see Section 6.5). These include:

1. permeation of water supply pipes by contaminants in soils and subsequent ingestion by workers in the proposed on-site commercial buildings – **Moderate/Low risk**
2. vertical and lateral migration of ground gas into enclosed spaces which would affect future workers on-site (and possibly workers/residents on adjacent sites and future buildings on site) – **Moderate risk**.

No visual or olfactory evidence of contamination was encountered during the intrusive investigation works and the ground conditions and groundwater encountered were as anticipated from the CSM. Consequently, no significant changes are required to the environmental model and the two potential pollutant linkages are still considered valid and require assessment.

Testing was carried out on representative samples to assess the potential for spontaneous combustion of the opencast backfill materials. This is discussed in the Section 10.6.

10.2 Linkages for assessment

In line with CLR11 (Environment Agency, 2004), there are two stages of quantitative risk assessment, generic (GQRA) and detailed (DQRA). The GQRA comprises the comparison of soil, groundwater, soil gas and ground gas results with generic assessment criteria (GAC) that are appropriate to the linkage being assessed. This comparison can be undertaken directly against the laboratory results or following statistical analysis depending upon the sampling procedure that was adopted.

Following the refinement of the initial CSM, the potentially complete contaminant linkages that require further assessment and the methodology of assessment are presented in Table 13.

Table 13 Linkages for GQRA

Potentially relevant contaminant linkage	Assessment method
Soil	
1. Contaminants permeating potable water supply pipes	Comparison of soil data to GAC in Appendix L for plastic water supply pipes using UKWIR (2010) guidance.
Ground Gas	
2. Concentrations of methane and carbon dioxide in ground gas entering and accumulating in enclosed spaces or small rooms in new buildings, which could affect	Gas screening values (GSV) have been calculated using maximum methane and carbon dioxide concentrations with maximum flow rates recorded at the site. The GSV have

Potentially relevant contaminant linkage	Assessment method
future site users. For methane this could create a potentially explosive atmosphere, while death by asphyxiation could result from carbon dioxide.	been compared with the revised Wilson and Card classification presented in BS8485.

Though not identified as a specific pollutant linkage further analysis of TOC and calorific value has been undertaken as recommended in the PRA. These results are also summarised below.

10.3 Methodology and assessment of soil results

The assessment of laboratory results relating to soil samples submitted for testing is included in the following sections and a summary of the soil chemical testing results is provided in Appendix I. These have been screened against RSK's commercial GAC for human health provided in Appendix K to demonstrate that no additional linkages need to be added to the assessment based on the latest testing results.

10.4 Impact of organic contaminants on potable water supply pipes

For initial assessment purposes, the results of the investigation have been compared with the GAC presented in Appendix L for this linkage, which are reproduced from *UKWIR Report 10/WM/03/21. Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites* (UKWIR, 2010).

The results indicate that a relevant linkage is unlikely to exist associated with organic contaminants and therefore pollutant polyethylene (PE) and/or polyvinyl chloride (PVC) water supply pipes are expected to be suitable for use on the development.

It should be noted that at the time of this investigation the future routes of water supply pipes had not been established, hence the investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling/analytical strategy may be required, at a later date, once the route(s) of the supply pipes are known. In addition, it is recommended that the relevant water supply company be contacted at an early stage to confirm its requirements for assessment, which may not necessarily be the same as those recommended by UKWIR.

10.5 Ground gas risk assessment

10.5.1 Appropriate guidance

The risks to development from ground gases have been assessed in accordance with BS 8485:2015, which provides guidance on ground gas (methane and carbon dioxide) characterisation and hazard assessment, as well as a framework for the prescription of protection measures within new buildings.

The process involves characterising the gas hazard from combining the qualitative assessment of risk (using the conceptual site model) with ground investigation data so

that a 'characteristic situation' (CS) can be derived for the site. Characteristic situations range from CS1 to CS6, the higher the CS the higher the hazard potential. Protection measures within new buildings can be prescribed using a point scoring system, taking into consideration the CS and the proposed building type.

BS 8485 indicates that the gas hazard can be characterised using the following methods:

- an empirical semi-quantitative approach using gas monitoring data to determine the 'characteristic situation' of the site (or zones of the site) and subsequent protective measures (Wilson and Card approach)
- an empirical semi-quantitative approach using TOC data to determine the 'characteristic situation' of the site (or zones of the site) and subsequent protective measures (CL:AIRE RB17 approach)
- detailed quantitative assessment methodologies.

For the purpose of this assessment, the first approach listed above has been used to characterise the gas hazard and provide advice on the protective measures likely to be required within new buildings at the site as the CSM has identified potential gas sources aside from the deep made ground.

10.5.2 Summary of the refined conceptual site model for ground gas

In the assessment of risks and selection of appropriate mitigation measures, BS 8485 highlights the importance of the conceptual model. In summary, potential sources of ground gas within influencing distance of the site identified in Section 6.5 comprise:

- made ground from backfill of the former opencast colliery
- underlying coal measures bedrock and any former workings there within.

After completion of the site investigation the highlighted potential sources are still thought to be relevant. For the purposes of assessment, the site will be divided in two halves representing the two phases (Phase 2 and Phase 3) as separated by the engineered backfill beneath the Dearne Valley Parkway.

Pathways and receptors for ground gas were identified in Section 6.1. It is understood that building foundations are likely to be pads with a ground bearing floor slab.

This assessment has been undertaken to assess risks to building structures and proposed end users. The assessment has not taken into consideration the health and safety of construction workers however some advice is provided at the end of Section 10.5.2.1.

The risk assessment has been undertaken based on the current understanding of the CSM.

10.5.3 Empirical semi-quantitative approach using borehole monitoring data (Wilson and Card approach)

10.5.3.1 Permanent gases – methane and carbon dioxide

The empirical semi quantitative approach using gas monitoring data is based on calculations of the gas screening value (GSV). BS 8485 defines the GSV as the '*flow rate (l/hr) of a specific hazardous gas representative of a site or zone, derived from*

assessment of borehole concentration and flow rate measurements and taking account of all other influencing factors, in accordance with a conceptual site model'.

Once derived for both methane and carbon dioxide the GSVs are compared to the thresholds presented in Table 2 of BS 8485, so that a CS can be determined for the site, or a zone. It is important to note that the GSV thresholds are guideline values and not absolute. The GSV thresholds may be exceeded in certain circumstances, if the site conceptual model indicates it is safe to do so. Similarly, consideration of additional factors such as very high concentrations of methane, should lead to consideration of the need to adopt a higher risk classification than the GSV threshold alone may indicate.

The results of the ground gas monitoring and testing undertaken at the site between 2019 and 2020 are given in Appendix N.

The maximum results recorded are summarised in Table 14 and have been subdivided according to the development phases. This is justifiable as the areas are separated by the dual carriageway corridor, which is formed from well compacted engineered fill.

The range of atmospheric pressure over the six monitoring rounds completed was 964-1008 mbar and this was recorded to be falling at the time of the first and second monitoring rounds.

Table 14 Summary of ground gas monitoring results

Borehole	Response zone (m) / stratum	Development Phase	Number of monitoring visits	Max Methane (%)	Max Carbon dioxide (%)	Min Oxygen (%)	Max Flow rate (l/hr)	Water level – 11/02/2020 / 12/02/2020 (mb TOP)
BH204	1.00 – 3.70 MG	2	3	<0.1	4.1	9.1	0.1	-
BH208	1.00 – 13.00 MG	2	5	0.1	2.8	9.9	0.3	11.09
BH302	3.00 – 6.00 MG	3	6	<0.1	6.6	0.7	1.8	4.79
BH402	6.00 – 19.00 MG	2	6	0.1	6.3	14.8	0.4	Dry
BH501D	9.00 – 13.00 MG	3	6	<0.1	23.0	<0.1	0.4	Dry
BH501S	1.00 – 3.00 MG	3	6	<0.1	15.9	3.3	0.6	Dry
BH502	2.00 – 6.00 MG	3	6	<0.1	16.6	1.7	0.6	Dry
BH503	17.00 – 19.00 MG	3	6	<0.1	23.6	0.4	0.6	Dry
BH506	10.50 – 18.50 MG	3	5	<0.1	24.6	0.7	0.4	Dry
BH507	10.00 – 20.00 MG	3	3	<0.1	18.7	2.5	0.6	Dry
BH508	5.00 – 7.00 MG	2	6	0.2	7.5	3.5	0.2	5.22
BH511	7.40 – 13.40 MG	2	6	0.1	12.4	<0.1	0.5	10.01
BH516	2.00 – 2.50 MG	2	6	1.9	10.8	<0.1	2.4	Dry
BH519	1.00 – 5.00 MG	2	6	0.1	5.0	17.1	0.2	Dry

Borehole	Response zone (m) / stratum	Development Phase	Number of monitoring visits	Max Methane (%)	Max Carbon dioxide (%)	Min Oxygen (%)	Max Flow rate (l/hr)	Water level – 11/02/2020 / 12/02/2020 (mb TOP)
BH520	3.00 – 8.00 MG	2	1	<0.1	<0.1	20.9	<0.1	Dry
BH521	3.00 – 6.00 MG	2	6	<0.1	11.7	9.7	0.3	Dry
BH522	6.00 – 11.00 MG	2	6	0.1	22.5	0.2	0.2	Dry
BH523	3.00 – 11.50 MG	2	6	0.1	17.4	<0.1	0.3	Dry
BH524	14.00 – 20.00 MG	2	6	0.1	20.7	<0.1	0.4	Dry
BH535A	4.70 – 14.70 MG	2	2	<0.1	1.2	17.8	0.3	13.82
RBH209	3.00 – 24.00 MG	2	6	<0.1	13.6	0.9	0.3	23.51
RBH210	3.00 – 20.00 MG	2	6	<0.1	16.9	1.2	0.4	13.34
RBH211	3.00 – 15.00 MG	2	6	<0.1	5.4	12.3	0.4	14.33
RBH305	3.00 – 39.00 MG	3	5	<0.1	24.1	0.3	0.6	29.14
RBH306	6.00 – 36.00 MG	3	6	<0.1	19.8	6.8	0.4	27.12
RBH307	2.00 – 21.00 MG + PMCM	3	6	0.1	21.5	<0.1	0.4	23.24
RBH405	3.00 – 57.00 MG	2	5	<0.1	9.9	1.5	0.9	Dry
RBH503	40.00 – 54.00 MG	2	6	0.1	15.3	5.4	1.3	46.10
RBH504	20.00 – 40.00 PMCM	2	4	<0.1	1.0	19.0	0.3	18.33*
MG – made ground, PMCM – Pennine Middle Coal Measures, mb TOP – measured to the top of the monitoring pipe. Worst case values are recorded above for each well (lowest oxygen, highest carbon dioxide, methane and flow rates). Screened section submerged (*) – gas readings have reduced reliability.								

The ground gas monitoring has recorded the ground gas concentrations across both phases of development, primarily from within the opencast backfill that was highlighted in the CSM as being the likely principal gas source. The CSM also indicated the potential for the underlying Coal Measures and any workings to contribute to the gas risk. This could be present in either the bedrock or by migration into the opencast backfill. This has been assessed by including monitoring standpipes installed into bedrock and into the deepest areas of backfill.

BS 8485 suggests that the GSV should be derived by multiplying the worse credible (worst case) recorded flow value in any standpipe in that strata or zone with the maximum gas concentration in any other standpipe in that strata or zone. Further guidance is given in BS 8485 section 6.3.

A spreadsheet showing the calculated hazardous gas flow rates per borehole is provided in Appendix N. Based on the gas monitoring results the following maximum GSVs have been derived for Phase 2 of the site:

- methane GSV (0.046 l/hr) = methane concentration (1.9 % v/v)/100 x flow rate (2.4 l/hr)
- carbon dioxide GSV (0.54 l/hr) = carbon dioxide concentration (22.5 % v/v)/100 x flow rate (2.4 l/hr).

Based on the gas monitoring results the following maximum GSVs have been derived for Phase 3 of the site:

- methane GSV (0.002 l/hr) = methane concentration (0.1 % v/v)/100 x flow rate (1.8 l/hr)
- carbon dioxide GSV (0.44 l/hr) = carbon dioxide concentration (24.6 % v/v)/100 x flow rate (1.8 l/hr).

Based on the GSVs derived and the method for determining the CS presented within Table 2 of BS 8485, the site would be characterised as CS2. This classification is seen to be appropriate given the gas sources identified and gas concentrations recorded during the programme however may be reviewed on a plot specific basis at the detailed design stage ahead of construction.

It should be noted that on disturbance of the ground during drilling, pockets of ground gas within the made ground were disturbed in two boreholes. On disturbance, greater gas flows than were recorded during the monitoring exercise were detected at ground level.

During construction, workers need to be cognisant of the risks, specific risk assessments will be necessary and should be followed. As a minimum, no man entry should be permitted into excavations unless continuous monitoring is undertaken, and suitable equipment and emergency measures are in place.

10.5.3.2 Trace gases

Gas monitoring included the collection of data for carbon monoxide and hydrogen sulphide and based on the maximum concentrations recorded (7 ppm and 1 ppm, respectively), these are not thought to pose a risk to the development.

10.5.4 Design requirements

Ground gas protective measures within buildings include a combination of structural barriers, ventilation systems and gas resistant membranes. Section 7 of BS 8485 provides a point scoring system for ground gas protective measures, whereby different barriers (i.e. structural barriers, ventilation systems, and gas resistant membranes) are assigned different point scores. A combination of protective measures (minimum of 2 types) can be used to achieve a total minimum gas protection point score, the total minimum point score required is determined based on the building type (see Table 3 in BS 8485) and the risk classification.

Considering the CS determined for the site (CS2) and the proposed buildings type (commercial) a minimum point score (see Table 4 in BS8485) of 2.5pts is likely to be required to achieve an adequate level of protection. As an example, a ground bearing floor

slab (score of 0.5) and a proprietary gas resistant membrane (score of 2) would provide a total point score of 2.5, which may be considered adequate for the proposed development when combined with suitable ventilation of the subfloor.

It should be noted that for membranes to achieve a point score greater than zero they should be:

- sufficiently impervious to methane and carbon dioxide
- capable after installation of providing a complete barrier to the entry of the relevant gas
- sufficiently durable to remain serviceable for the anticipated life of the building and duration of gas emissions
- sufficiently strong to withstand in service stresses (e.g. due to ground settlement if placed below a floor slab)
- sufficiently strong to withstand the installation process and following construction activities until covered (e.g. penetration from steel fibres in fibre reinforced concrete, penetration of reinforcement ties, tearing due to working above it, and dropping tools)
- chemically resistant to degradation by other contaminants that might be present
- verified in accordance with CIRIA C735.

A detailed design report (which is not presented in this report) should be prepared detailing the proposed mitigation measures and should be provided to and agreed with the local authority and relevant warranty providers prior to construction works commencing. The design report should include a combination of the following:

- gas conceptualisation (severity of gas regime and sensitivity of land use)
- building and construction related details such as floor slab, wall construction, ground conditions and any complex detailing
- gas protection design sufficient to mitigate the gas risk and be practically installed given the building and construction related details. Likely to include venting calculations, product specifications, installation methodology and installer qualifications/experience
- verification plan (prepared in accordance with CIRIA C735) to identify the verification tasks, frequency of such tasks and by whom they should be undertaken, regulatory requirement and contingency plans. The verification measures required will be dependent on a number of factors including the gas regime, the qualifications of the installers, the complexity of the design and the number of plots.

10.5.5 Implications of ground improvement or foundation design

Pad foundations with a ground bearing slab are being considered for the development. However, before development can proceed ground improvement will be required, which may include placement of engineered fill, surface compaction treatment and surcharging.

Where such works may create preferential pathways for ground gas migration to the surface, this needs to be considered through the design process, such as through a foundation works risk assessment.

Should foundation solutions or building design change within the design process then the gas risk assessment and mitigation should be reviewed and where applicable updated.

10.6 Assessment of soil combustibility

The total organic carbon values were tested for in 10 samples, with results ranging from 0.66% w/w to 7.57% w/w. The calorific value was also measured for three samples including the sample with the highest total organic content (BH512 at 10m depth). The calorific value of the samples tested ranged from 0.4 MJ/kg to 3.4 MJ/kg.

The minimum ignition energy for coal dust in air is ~30MJ. It would therefore be required for ~10kg of soil dust to instantly combust for a spontaneous combustion risk of other coal bearing materials to begin to be realised. The minimum ignition temperature of coal dust is ~150°C which is unlikely to be generated spontaneously.

On this basis the combustion risk is considered to be extremely low.

10.7 Uncertainties and implications in refined CSM and GQRA

In accordance with good practice, data gaps and uncertainties in the refined CSM have been identified at this stage. These are summarised in Table 15 along with the likely implications.

Table 15 Data gaps and uncertainties

Data gap/ uncertainty	Details	Implications
Wooded areas were largely inaccessible along with the area beneath the surcharge mound in Phase 3.	In the case of the wooded areas data gaps are thought to be of little consequence however the Coal Authority records indicate that a capped mineshaft is present beneath the surcharge mound which could not be confirmed by this investigation.	There is a gap in coverage for these areas and uncertainty remains over the location and condition of shaft (Coal Authority Reference: 435401-002)
Asbestos not found in made ground samples tested	Although not encountered to date, asbestos containing material (ACM) could still be present in discrete locations	Vigilance should be maintained for any potential ACM or fibrous material during below ground works
There is a gap of ~5 years between the water monitoring data collected as part of this assessment and that collected in 2014.	There may be seasonal variations or annual trends in water levels that could affect the direction of groundwater flow and susceptibility of the site to inundation settlement.	Bi-monthly monitoring should be maintained for at least another 2 months to allow an assessment of the groundwater elevations.
Monitoring of PGM ground markers to investigate self-weight settlement was not maintained between 2016 and 2019.	Data availability is reduced	Further monitoring to be completed as scheduled.

Data gap/ uncertainty	Details	Implications
Engineers logs based on rotary open hole drilling have less certainty on interpreted ground conditions	Due to the limited and destructured sample return interpretation of rotary open hole boreholes can be difficult	Greater weight should be placed on the interpretation from rotary cored boreholes and allowance made for discrepancies between the rotary open hole borehole logs and actual ground conditions.
Large boulders, boulders and cobbles are likely to be underrepresented in the investigation logging	Due to the limited sample window of boreholes there may be a greater frequency of coarse soils than recorded. Large boulders are thought to have prevented progress at a number of locations.	Coarse soils may hinder excavation for earthworks foundations and infrastructure

11 GEOTECHNICAL ASSESSMENT

In this section we consider the nature of the proposed development and the potential geotechnical constraints that the recorded ground conditions pose to it. We then provide comment on the ground treatment that is needed to address some of these issues and an outline of the requirements for the building development.

11.1 Proposed development

It is understood that the proposed development is to involve the construction of several large commercial properties with dimensions ranging from approximately 35m by 80m to 175m by 225m along with associated infrastructure.

A scheme of earthworks, designed by JPG, is planned to create level development platforms for these proposed buildings, the layout of which is provided in Appendix B. This will require significant earthworks across the site to include areas where several metres of material are cut and others where several metres of fill have to be placed. Where these earthworks include areas of fill the materials to be used will be placed as an engineered fill under strict supervision and control. For the Phase 2 site 332,520 m³ of cut (inclusive of 5% bulking factor) and 324,956 m³ of fill is proposed. For the Phase 3 site 112,673 m³ of cut (inclusive of 5% bulking factor) and 112,156 m³ of fill is proposed. This includes a maximum cut of -7.63m and a maximum fill of 8.32m.

At this stage no specific information relating to building structural loads have been provided and it is expected that floor slabs will have to support a time averaged loading of 35 kN/m².

11.2 Geotechnical hazards/development constraints

The key risks identified from the available ground investigation data are presented in Table 16 together with the section of the report where they are assessed and commented upon.

Table 16 Geotechnical constraints and their assessment

Geotechnical constraint	Assessment and comment
Self-weight settlement	Section 11.3
Load induced settlement of opencast backfill (from earthworks and building loads)	Section 11.4
Collapse compression/inundation settlement	Section 11.5
Differential settlement as a result of adjacent areas of shallow bedrock and deep made ground (highwalls and faults)	Section 11.6
Coal mining related settlement issues (instability from shafts and shallow coal seams)	Section 11.7
Adverse ground chemistry due to elevated sulphates in the Pennine Middle Coal Measures/Colliery Spoil	Section 11.9.7

11.3 Self-weight settlement

RSK have undertaken periodic PGM monitoring (see Figure 4) across the Rockingham Phase 2 and 3 sites since August 2013 to determine if self-weight settlement of the opencast backfill is ongoing. The monitoring work was paused in March 2015 for Phase 2 and June 2016 for Phase 3 before restarting across both Phases in October 2019. The latest monitoring round was undertaken in February 2020 and a further 3 monitoring visits are scheduled over the next 6 months.

The results of the monitoring are difficult to interpret owing to the use of different surveying techniques and changes to the OSGB geoid in 2015. The precise levelling technique adopted for all monitoring visits since 2019 has a reported accuracy of $\pm 4\text{mm}$, taking into account the conditions at the site.

The 2019 readings across the Phase 3 area and Phase 2 area to the east of the Elsecar Fault are comparable to those recorded in 2015 with any changes in level across the majority of monitoring points within the measuring accuracy of the instrumentation. Variation in level between 2019 and 2020 readings have been minimal; averaging to approximately 2mm a year (though this is within the measurement error of the technique). RSK do not consider there to be an issue from ongoing self-weight settlement in these areas from the available data.

To the west of the Elsecar Fault in Phase 2 the monitoring points have shown a variable but sometimes large decrease in level between 2015 and 2019. Firm conclusions cannot be drawn at this stage as the discrepancy may be as a result of the improvement in surveying technique adopted in 2019. Between the October 2019 and February 2020 extrapolation of the readings indicate an ongoing settlement of between 4mm and 12mm per year. The highest settlement was recorded at pin 69, recording 7mm of settlement in 133 days.

Further monitoring is required to determine whether self-weight settlement is continuing on the Phase 2 site to the west of the Elsecar Fault.

If self-weight settlement is still an active settlement mechanism it would require the whole area to be treated by the placement of surcharge, together with settlement monitoring and further modelling and data analysis.

11.4 Load induced settlement

The previously reported large scale load test (see Section 4.2 of this report) has confirmed that the opencast backfill is susceptible to significant settlement when loaded. In this section we present the findings of geotechnical modelling work that has been undertaken in order to determine the anticipated settlements which will be induced from the proposed development.

11.4.1 Settlement modelling

The large load test carried out at Rockingham 3 has confirmed that the opencast backfill is susceptible to settlement on loading. The proposed development will impose additional loading from (1) placement of engineered fill in parts of the site to provide level development platforms, and (2) construction of the new buildings.

In order to assess the settlement which can be expected from these loads RSK have undertaken settlement modelling. This included back analysing the settlement data from the existing load test and using SPT profile data from the drilling records at the site to form a ground model including a stiffness depth profile. This model was then modified to add surface loads and additional surface layers to mimic the proposed development loads and for these scenarios the induced settlement was calculated from computer modelling. This was carried out using the OASYS PDISP 20.0.0.2 software package. Full details of this modelling work is provided in Appendix O.

Based on the results of the large-scale loading test and the settlement modelling presented in Appendix O, significant settlements can be expected to be induced from future loading in areas both where ground levels are to be raised and from the structural loads of the new buildings. In order to permit development, the anticipated settlements will have to be induced in advance of construction by ground treatment. In most areas this can only be practically achieved by placement of surcharge materials to effectively pre-load the development areas.

11.5 Collapse compression/inundation settlement

The groundwater monitoring undertaken at the site to date has shown no evidence of recovering deep groundwater and as such this mechanism of groundwater entry causing inundation settlement is not thought to be feasible.

Surface infiltration causing settlement is a possible mechanism on the uncompacted opencast backfill – the existing surface has been exposed for almost 20 years and although no visual evidence of localised settlement is present it has not yet been tested.

The material which would be most susceptible would likely be the opencast backfill at a few metres depth (beneath any topsoil, soil forming material or zone already influenced by shallow surface water entry). Such materials will be exposed in areas of cut operations during the proposed regrading works. Surface inundation tests should be completed on these materials when exposed during the proposed earthworks.

If surface testing did record settlements, this could be addressed by compacting the surface material to reduce void space and the ability of surface water entry, either by re-engineering a surface layer and/or by surface compaction treatment.

11.6 Differential settlement

Modelling has indicated that variation in thickness of opencast backfill will only result in significant differential settlements where bedrock is shallow and this can be addressed by increasing surcharge thicknesses to induce a significant proportion of the anticipated differential settlement so that any residual settlement (post surcharging) will be of a tolerably low order.

Differential settlement is not an issue where significant thicknesses (>20m) of opencast backfill are present.

The position of the highwall, which is understood to correlate with the Elsecar Fault, is broadly outlined by the investigation work and this is a constrain to building development.

The current layout has not been optimised to the tighter controlled location of the highwall, which has been made possible by this additional investigation. As a result, it is recommended that the location of Units 3 and 4 in Phase 2 are swapped to create a more consistent ground condition for both. A constraints drawing is provided as Figure 8 showing the interpreted surface representation of the feature.

11.7 Mining related settlement

Owing to the depth of extraction of the seams by opencast methods almost all of the site (except a small area to the east of Phase 2) is not at risk from potentially shallow worked coal seams. To east of the Elsecar fault in Phase 2 some shallow (<30m) seams are present, however in all drilled locations the seams are either too thin to be economically worked or are interpreted to have a sufficient thickness of intact Pennine Middle Coal Measures bedrock overlying them such that, if worked and subject to collapse, settlement of the ground surface would not be feasible. In addition, no evidence of shallow worked seams was identified during the site investigation works. Furthermore, the mine completion plans for the seams opencast to the east of the Elsecar fault do not indicate that any of the seams had evidence of old underground workings. On this basis, shallow worked coal seams are no longer thought to present a risk of ground settlement.

All of the surface and shallow features (mine entries, buildings etc) from the earlier deep mining beneath the site from Rockingham colliery have been excavated in full, however sections of two mine shafts remain beneath the opencast backfill in the Phase 3 area.

Of the two shafts in Phase 3 one has been located as part of this investigation. The current development proposals will reduce the loading from overlying soil on the shaft cap (as ground levels in this area are to be cut) however, dependant on the final layout, some remedial works are likely to be required as a void was discovered beneath the shaft cap. Appropriate treatment measures will need to be confirmed and agreed with the Coal Authority once a finalised development layout is available, however treatment is likely to include stowing the voided section possibly with stone with subsequent grouting consolidation or possibly by use of foam concrete or similar to fill the void and stabilise the shaft. The second shaft will need to be located and treatment may be required.

11.8 Comments on ground treatment

Based on the results of the large-scale loading test and the settlement modelling presented above significant settlements can be expected to be induced from future loading in areas both where ground levels are to be raised and from the structural loads of the new buildings. In order to permit development, the anticipated settlements will have to be induced in advance of construction by ground treatment. In most areas this can only be practically achieved by placement of surcharge materials to effectively pre-load the development areas.

Where levels are to be raised as a result of the earthworks to provide the development platform, the modelling suggests settlements ranging from 50mm up to 250mm can be expected. Once the final development levels are reached the platform in areas of deeper opencast backfill should be left at least 3 months prior to construction of roads and infrastructure. In areas of the site where soils are cut this will not be required.

The geotechnical letter report (Appendix O) provides detail on the proposed surcharge treatment with surcharge heights and durations determined from the predicted settlements of each Unit across Phase 2 and Phase 3.

Suggested surcharge heights range from 3.0m 5.0m with suggested durations ranging from 4 months to 8 months. This assumes the in situ dry density of the surcharging material to be 2.0 Mg/m³, where lower density soils are used, particularly organic rich materials (topsoil) greater surcharge heights will be required to achieve the required settlement. The duration of treatment is difficult to predict due to the variable conditions across the site and instrumentation will be required to be installed and monitored to measure the induced settlement and confirm that the treatment is effective.

11.9 Comments on building construction

11.9.1 Development platforms

The proposed development requires a series of level building platforms to be provided upon which building can take place. This will require significant earthworks across the site to include areas where up to several metres of material are cut and others where several metres of fill have to be placed.

Where these earthworks include areas of fill the materials to be used will be placed as an engineered fill under strict supervision and control. This should follow an engineering specification, should be fully supervised, include appropriate validation testing and a verification report should be provided on completion.

11.9.2 Foundation options

After ground treatment is completed building development can then proceed. The proposed building loads can be supported on pad foundations within the made ground and can be designed on an allowable net bearing pressure of 100 kN/m². Excavations for all pads should be inspected to make sure that any pockets of soft or loose made ground are removed and, if required, the excavations should be deepened until underlying competent materials are encountered. If standing water is encountered then this should be removed, which may require pumping from sumps.

11.9.3 Floor slabs

After all earthworks and necessary ground treatment the formation will be suitable to support ground bearing floor slabs designed to support a time averaged loading of 35kN/m².

During construction all formations should be carefully examined in order to make sure that the materials are competent and any pockets of soft or loose materials are removed and replaced with well compacted fill.

11.9.4 Foundation works risk assessment

It is anticipated that a foundation works risk assessment report will not be required for the development because:

- the type of foundation / ground improvement method proposed does not have the potential to create preferential pathways for migration of ground gas to surface or groundwater to depth.

However, if a piled foundation solution is adopted on any area this would require further assessment and may need a foundation works risk assessment. This should be undertaken in accordance with relevant EA guidance and Coal Authority Guidance on Managing the Risk of Hazardous Gases when Drilling or Piling Near Coal.

11.9.5 Roads and hardstanding

The investigations completed have indicated that the shallow made ground across the site is variable in nature generally becoming more competent with depth. In some areas bedrock was present at shallow depth (within a couple of metres of existing ground level). The investigations have not included any in situ California Bearing Ratio (CBR) tests for road pavement design, so the comments below are based on inspection of the soils present on site and the requirements for regrading operations and ground treatment works.

In pavement design terms, the groundwater conditions are anticipated to comprise a low water table, at least 1m below the final pavement formation level, once all new drainage systems are installed. Currently there is some surface flow of water during heavy rain across the sloping site.

Based on inspection the estimated minimum, equilibrium soil-suction, California bearing ratio (CBR) value for the soils and groundwater conditions described above under a completed pavement is 1.5%, based upon Table C1 in TRRL (1984) Report LR1132. However, the sub-grade soils will be suitable to improvement by rolling with conventional compaction plant provided suitable moisture contents are achieved and consequently a recommended sub-grade soil CBR value for road pavement design is therefore 3%. This value assumes that during construction the formation level will be carefully compacted, and any soft spots removed and replaced with well-compacted granular fill.

The sub-grade condition at the time of construction should be confirmed by testing at the final formation level by in situ CBR testing.

The sub-grade soils can be regarded as frost-susceptible, based upon the criteria given in Appendix 1 of TRRL (1970) Report Road Note 29. When the sub-grade is frost-susceptible the thickness of sub-base must be sufficient to give a total thickness of non-frost-susceptible pavement construction over the soil of not less than 450 mm.

11.9.6 Excavations for foundations and services

Some of the trial pits became unstable during excavation. It is therefore recommended that excavation support systems are made available during the groundwork stage of the development. This recommendation can be reassessed after the proposed ground treatment as this will improve stability.

Man-entry into any excavations should not be undertaken without provision of suitable shoring and support and dewatering or suitable regrading and battering of side slopes to safe angles. Confined spaces protocols for the Health and Safety of personnel should always be used where man entry into excavations is to be undertaken as low oxygen

conditions may be present. Given the site history high carbon dioxide and methane concentrations are also possible so gas testing should be undertaken prior to and during confined space entry.

Groundwater seepages were identified in some of the trial pits. Dewatering may therefore be required to facilitate foundation and other excavations.

The cohesive nature of the soils encountered suggests that pumping from open sumps should be sufficient to keep the excavations reasonably dry.

Excavation was difficult in parts, primarily due to the coarse to very coarse grading of the soil. Though conventional plant is likely to be suitable in most areas some allowance for increased time (and a breaker) should be allowed for in all areas to excavate cobbles and boulders within the opencast backfill layers and in limited areas possible weathered bedrock.

11.9.7 Chemical attack on buried concrete

This assessment of the potential for chemical attack on buried concrete at the site is based on BRE Special Digest 1: Concrete in aggressive ground, which represents the most up-to-date guidance on this topic currently available in the UK.

The desk study and site reconnaissance indicate that, for the purposes of assessing the aggressive chemical environment of the site, the site should be considered as comprising brownfield ground likely to contain pyrite.

Based on testing results, Table 17 gives the characteristic pH, water-soluble and total sulphate content values for soils from each of the geological units and groundwater encountered on-site.

Table 17 Characteristic pH, water soluble sulphate and total sulphate values

Stratum	pH	Water Soluble Sulphate (mg/l)	Total Potential Sulphate (%w/w)
Made ground	5.23	200	0.26
Groundwater	6.5	400	0.11

Based on the results above and following the steps outlined in the BRE guidance, the Design Sulphate Classes and Aggressive Chemical Environment for Concrete classifications are summarised in Table 18, on the basis of water soluble sulphate and total potential sulphate, respectively. Results from the water monitoring carried out at the site indicate that static ground water conditions can be assumed for the assessment.

Table 18 Concrete design class

Stratum	Ground water	Water Soluble Sulphate		Total Potential Sulphate	
		DS Class	AC Class	DS Class	AC Class
Made Ground	Static	DS1	AC-1s	DS2	AC-2s

Stratum	Ground water	Water Soluble Sulphate		Total Potential Sulphate	
		DS Class	AC Class	DS Class	AC Class
Groundwater	Static	DS2	AC-1s	DS1	AC-1s

The proposals include the reuse of potentially pyritic material derived from the Pennine Lower Coal Measures for earthworks, i.e. cutting and filling, or excavation and backfill, consequently the recommended ACEC Classification is AC-2s with a Design Sulphate Class of DS-2.

11.9.8 Infiltration drainage

The ground conditions are not suitable from a geotechnical viewpoint for the use of pit soakaways to discharge surface run-off water into the opencast backfill because of the risk of inundation settlement. Surface infiltration of water should be actively discouraged in the design process including placement of well compacted engineered fills where levels are to be raised or by use of surface compaction methods in areas of cut.

Where surface water overflow (or SUDS) ponds are proposed these would benefit from installation of an impermeable clay layer or membrane liner.

12 CONCLUSIONS AND RECOMMENDATIONS

12.1 Geo-environmental assessment

The results of the site investigation and GQRA indicate that all but one of the identified potentially complete pollutant linkages are absent based on the data available. The only exception to this is the risk posed by ground gas which is commented on further below.

From the six monitoring rounds completed a potential ground gas risk has been identified. Investigation of the identified ground gas sources has identified elevated CO₂ at a maximum concentration of 24.6% v/v. Maximum gas flow rates were recorded up to 2.4l/hr. Based on these results the site has been characterised as CS2.

A potentially complete pollutant linkage therefore exists and will need to be broken by the adoption of suitable gas protective measures in all structures at the site.

The risk posed by trace gases is understood to be low based upon levels recorded during the gas assessment.

Vigilance should be maintained during future works at the site to ensure that odour thresholds are not breached in open air and proper consideration of the potential gas risks should be given prior to any confined space entry.

Once the required protective measures have been confirmed with, submitted to and approved by Barnsley Council, and any required verification procedures are completed, the development will be suitable for use.

Boreholes should remain protected for ongoing monitoring until such a time as this becomes impracticable. Prior to construction borehole installations should be removed and grouted to prevent them acting as gas migration pathways.

Should unforeseen contamination be encountered during the development then specialist advice should be sought to determine the appropriate course of action.

Imported material (e.g. topsoil, subsoil) should be validated before use on-site to confirm its suitability.

12.2 Geotechnical assessment

The key findings of the geotechnical assessment are as follows:

- self-weight settlement of the made ground is indicated as being complete in the area to the east of the Elsecar fault (Phase 2 east). There is some uncertainty for the area to the west of the fault and further monitoring is required. If this indicates settlement is ongoing then additional surcharge treatment would be necessary
- the opencast backfill is susceptible to significant load induced settlement, particularly the shallowest soils. Ground treatment by surcharging will be required to induce a significant proportion of the anticipated long-term settlement before building construction works can begin
- there is no evidence of deep groundwater recovery and collapse compression settlement at the base of the opencast backfill is not considered feasible. Surface

inundation settlement, although considered unlikely, is a plausible mechanism and further testing will be required

- across most of the site differential settlement from construction over varying thicknesses of opencast backfill can be reduced to acceptable limits by the proposed surcharge treatment works. Buildings should not straddle the high walls, particularly over the Elsecar fault
- no shallow worked coal seams (other than those known from opencast mining records), nor any evidence of underground shallow workings have been identified by the investigation
- a mineshaft (Coal Authority Reference: 435401-003) has been located at its recorded position and proven to be capped, however a void has been discovered beneath the cap extending at least 25m. Mineshaft (Coal Authority Reference: 435401-002) has not been located but is understood to have been capped at the same time as 435401-002. Treatment and further investigation are likely to be required
- made ground soils used to backfill the former opencast workings are variable and there is potential for a significant number of boulders and cobbles to hinder excavation. These may be underrepresented in the site logging
- in respect of buried concrete, the recommended ACEC Classification is AC-2s with a Design Sulphate Class of DS-2.

12.3 Recommendations

The following recommendations are made for further assessment and remediation of the site to address the risks identified above and to address remaining uncertainties.

12.3.1 Environmental

Gauging of groundwater levels should continue on the current programme, comprising a two-monthly cycle for a further 2 months. At this point the groundwater assessment can be reviewed and a judgement made if further monitoring is required. Before development proceeds all monitoring boreholes should be grouted to prevent potential migration pathways.

12.3.2 Geotechnical

Monitoring of surface PGMs should continue for the next 2 months (as originally scheduled) in order to provide further information on the potential self-weight settlement in the area to the west of the Elsecar fault. Recommendations will then be provided based on the results of the monitoring.

Surcharge treatment will be required for all Units. Recommended surcharge heights range from 3.0m to 5.0m with durations ranging from 3 months to 8 months. Prior to the construction of any new surcharge treatment mounds instrumentation will need to be installed in order to allow for monitoring and assessment of the induced settlements which in turn will allow an informed decision on the timescale of completion of treatment.

When the existing large load test is removed further monitoring should be carried out to measure re-bound and this should be supported by surface plate load testing to confirm

the stiffness of the shallow soils underlying the test mound. This will provide validation of the modelling and generate unloading information that can be used to refine the predicted surcharge and building settlements.

It will be necessary to carry out surface inundation tests and it is recommended that these are carried out in areas where ground levels are to be cut once the final ground levels have been achieved. Monitoring of these will be required for approximately 3 months.

As there should be no construction over the highwall/ Elsecar fault it is recommended that the location of Unit 3 and Unit 4 in Phase 2 are switched in order to avoid the now better-defined constraint of the former opencast pits highwall/ fault.

Dependant on the development layout the Coal Authority mineshaft ref: 435401-003 will require treatment, the details of which will have to be agreed with the Coal Authority. At this stage it is expected to require stowing with stone and grout (PFA/cement grout mix) consolidation treatment or possibly infilling with foam concrete or similar in order to fill the void. The location of Coal Authority mineshaft ref: 435401-002 should be confirmed by additional rotary drilling work before any decision is made over the requirement or otherwise for treatment.

Plate load testing of the final road formation level is recommended to confirm the required CBR design values.

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FIGURES



Ordnance Survey © Crown copyright 2010 of the Ordnance Survey paper map.
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Spring Lodge
172 Chester Road
Helsby
Cheshire
WA6 0AR

Tel: +44 1928 726006
Fax: +44 1928 725633
Web: www.rsk.co.uk

Client

HARWORTH ESTATES
INVESTMENTS LTD

Project Title

ROCKINGHAM 2 AND 3

Drawing Title

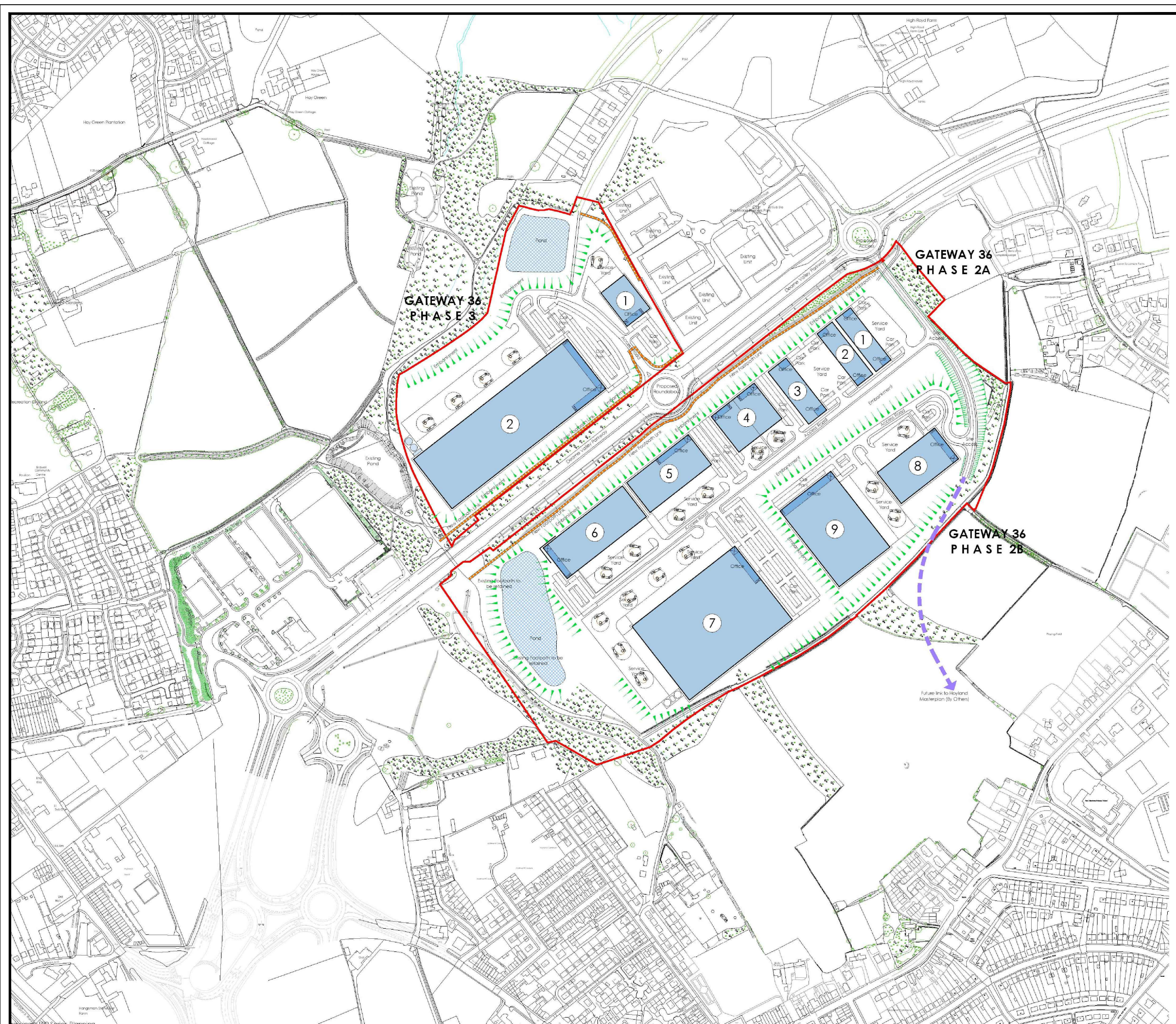
SITE LOCATION PLAN

Drawn	Date	Checked	Date	Approved	Date
HD	20.02.20	AC	20.02.20	GMG	20.02.20

Project No.
322638

Drawing File
322638-R02(00)D001A

Scale	Orig Size	Dimensions	Drawing No.	Rev.
NTS	A4	—	FIGURE 1	A



LEGEND:

Site boundary

N

A	20.02.20	FIRST ISSUE	HD	AC	GMG
REV	DATE	DESCRIPTION	BY	CHD	APR.
Dimensions		Projection	Scale	Orig Size	
m			NTS	A3	

RSK

Spring Lodge
172 Chester Road
Helsby
Cheshire
WA6 0AR

Tel: +44 1928 726006
Fax: +44 1928 725633
Web: www.rsk.co.uk

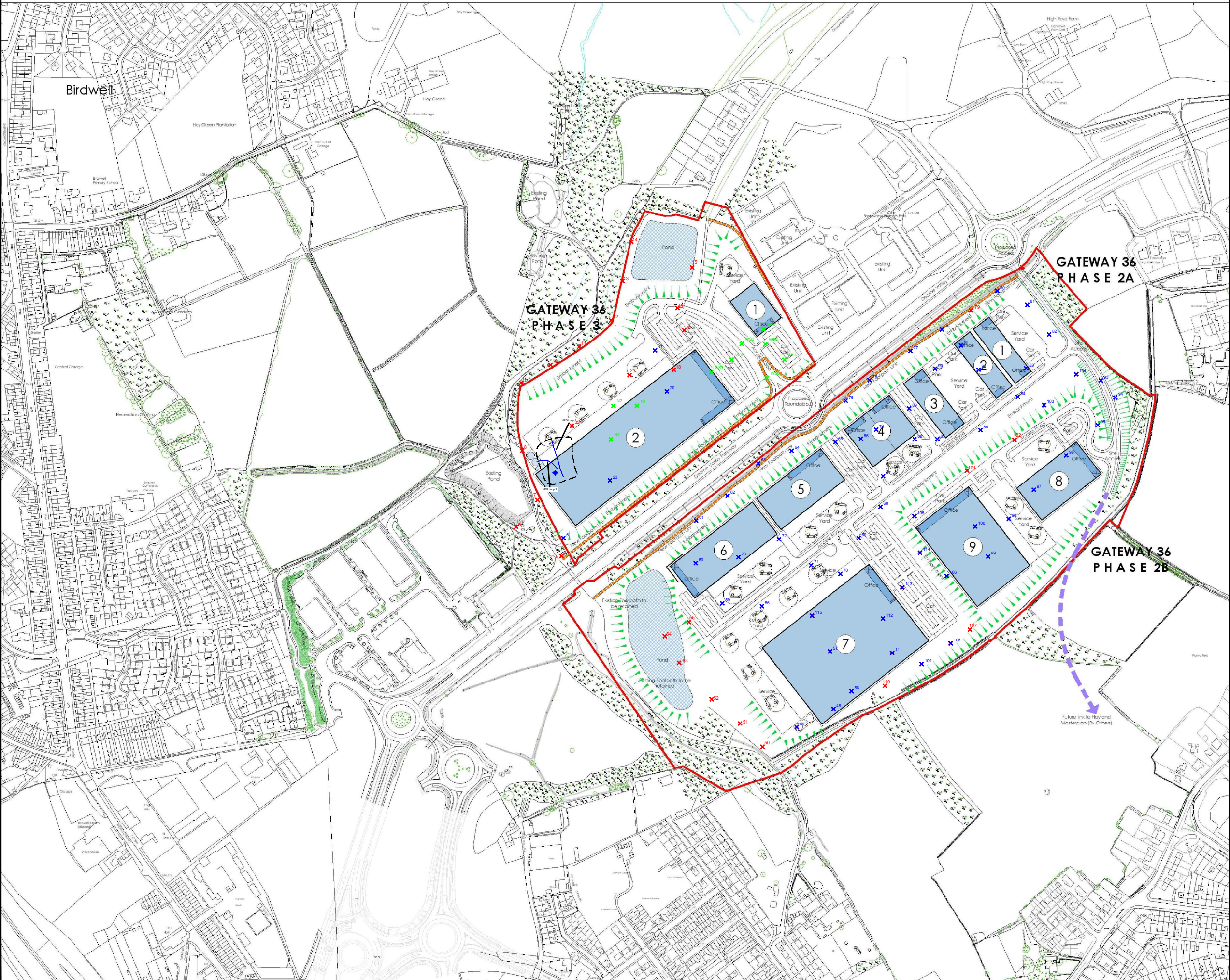
CLIENT	HARWORTH ESTATES INVESTMENTS LTD				
PROJECT	ROCKINGHAM 2 AND 3				
TITLE	SITE BOUNDARY PLAN				
JOB No.:		DRAWING FILE:			
322638		322638-R02(00)D002A			
BY:	DATE:	CONTRACT NO.	FIGURE 2		REV:
HD	20.02.20				A



- LEGEND:**
- Site boundary for Rockingham 4
 - RSK cable percussive borehole
 - RSK trial pit
 - RSK rotary borehole
 - Previous RSK Site investigation locations
 - Window sample location
 - Trial pit location
 - Borehole location
 - Rotary borehole location



A	20.02.20	FIRST ISSUE		HD	AC	GMG
REV	DATE	DESCRIPTION		BY	CHD.	APR.
Dimensions		Projection	Scale	Orig Size		
m			AS SHOWN	A3		
 Spring Lodge 172 Chester Road Helsby Cheshire WA6 0AR Tel: +44 1928 726006 Fax: +44 1928 725633 Web: www.rsk.co.uk						
CLIENT HARWORTH ESTATES INVESTMENTS LTD						
PROJECT ROCKINGHAM 2 AND 3						
TITLE EXPLORATORY HOLE LOCATION PLAN						
JOB No.:			DRAWING FILE:			
322638			322638-R02(00)D003A			
BY:	DATE:	CONTRACT NO.		FIGURE 3		REV:
HD	20.02.20					A
Scale bar 						



- LEGEND:**
- Site Boundary
 - HPG access pipes
 - Extensometer borehole
 - New PGMs
 - Existing PGMs
 - Lost PGMs
 - Approximate extent of load test mound



A	03.03.20	FIRST ISSUE	HD	AC	GMG
REV.	DATE	DESCRIPTION	BY	CHD	APR.
Dimensions		Projection	Scale	Orig Size	
m			1:5,000	A3	

RSK

Spring Lodge
172 Chester Road
Helsby
Cheshire
WA6 0AR

Tel: +44 1928 726006
Fax: +44 1928 725633
Web: www.rsk.co.uk

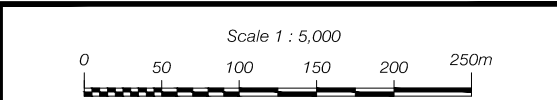
CLIENT HARWORTH ESTATES
INVESTMENTS LTD

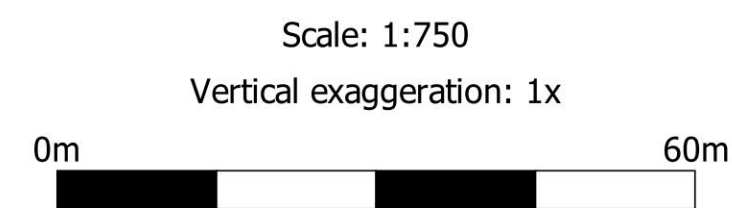
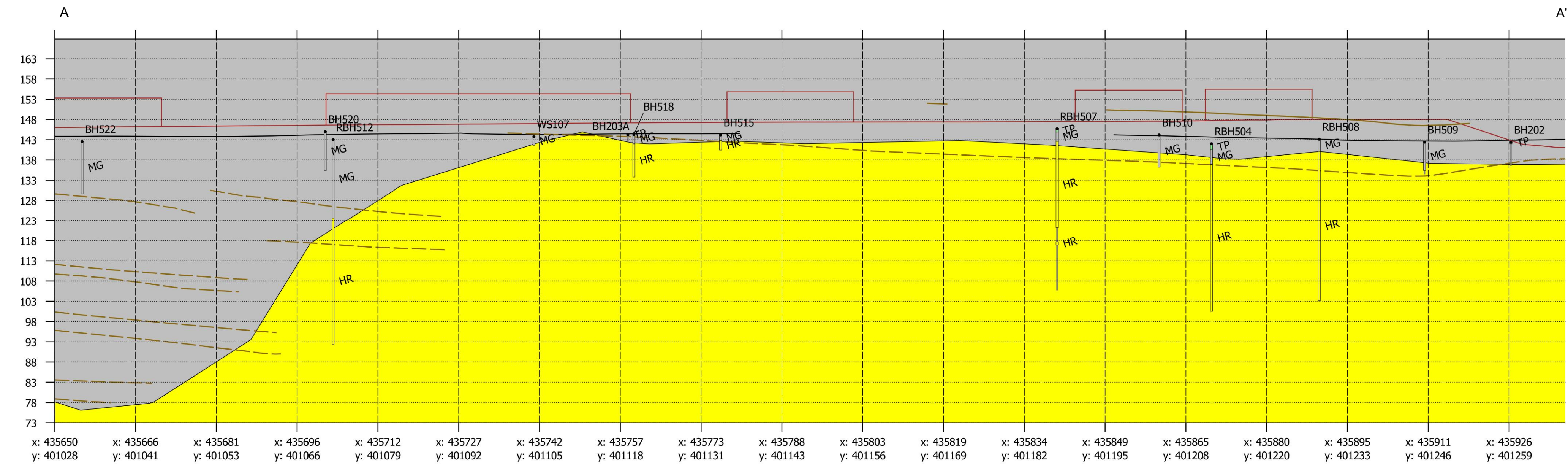
PROJECT ROCKINGHAM 2 AND 3

TITLE LOAD TEST AND SETTLEMENT
MONITORING PINS

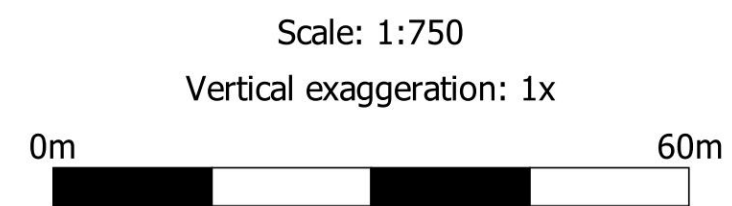
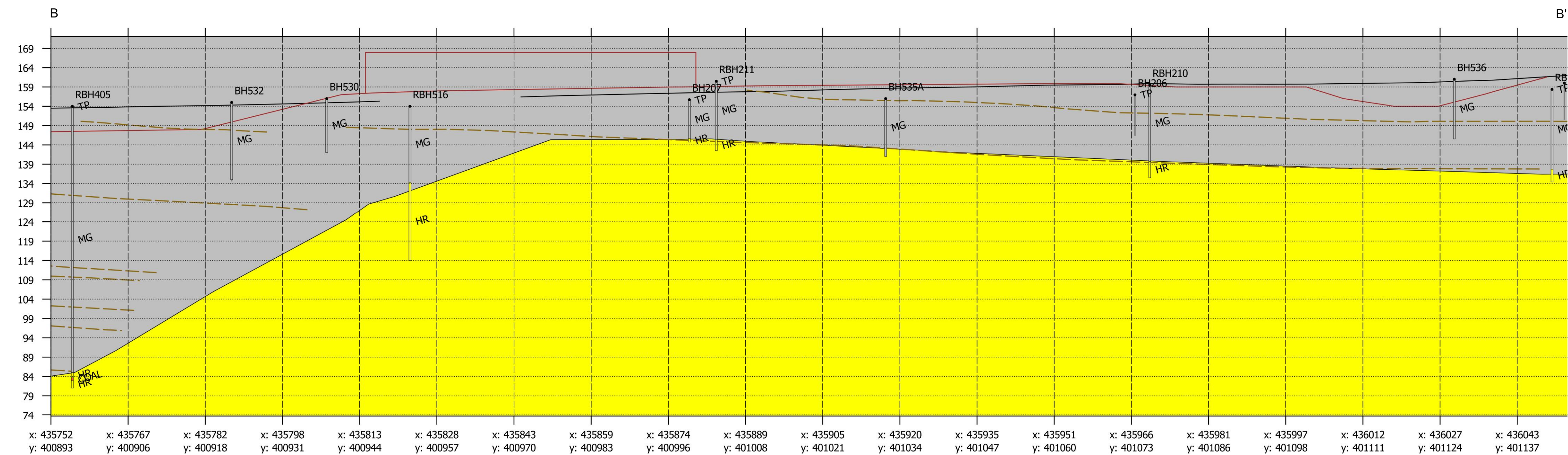
JOB No.:	DRAWING FILE:
322638	322638-R02(00)D04A

BY:	DATE:	CONTRACT NO.	REV:
HD	03.03.20		A

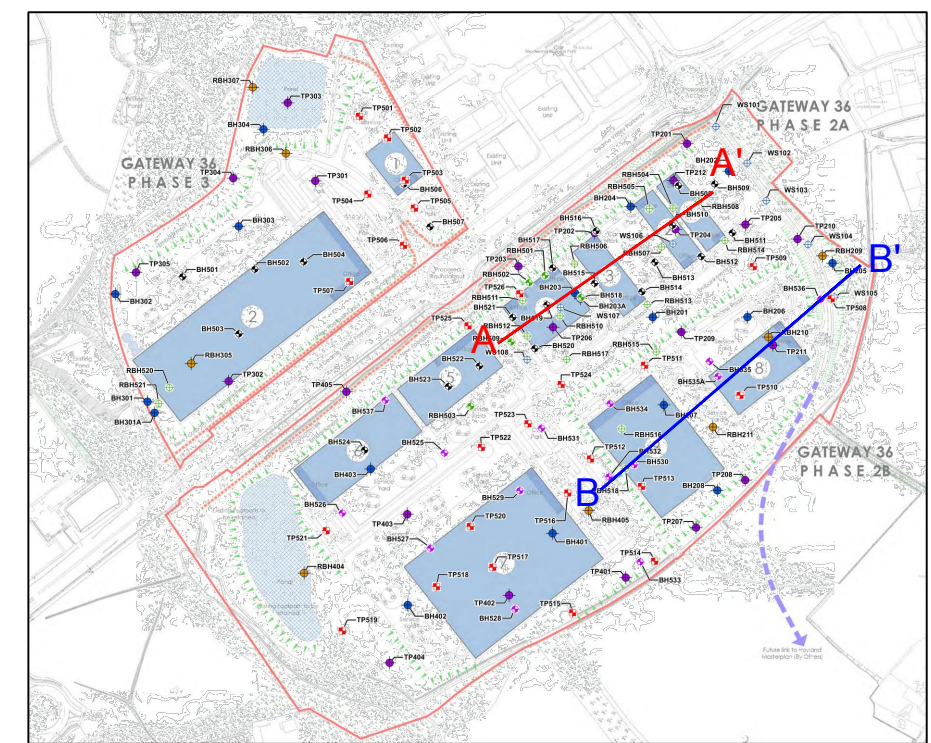




Location
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A': 435937, 401268



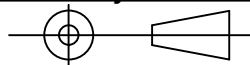
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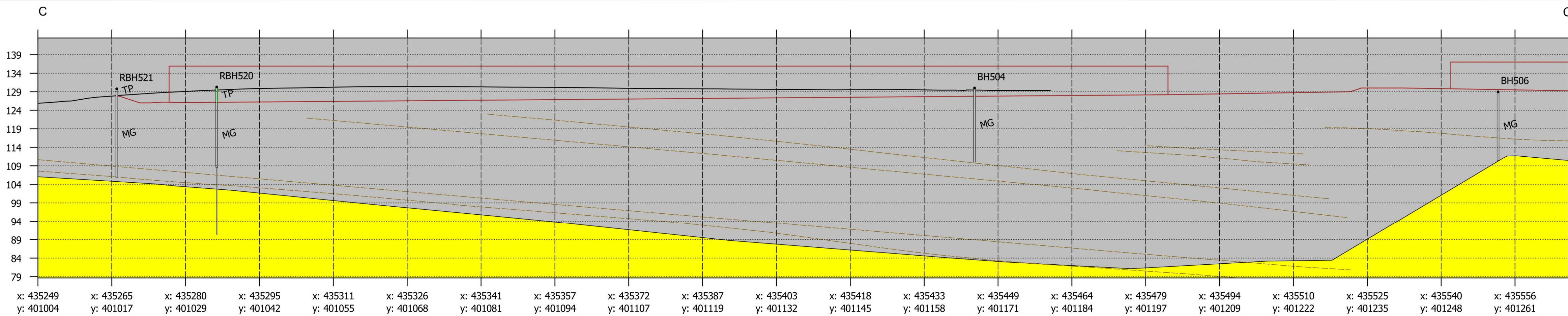


LEGEND:

- Existing topography
- Proposed levels and commercial units
- Extracted coal seams
- Bedrock (Pennine Middle Coal Measures)
- Made Ground (colliery backfill)

The cross section is presented based on the information from the intrusive investigation and predicted ground conditions as modelled from available information. Actual ground conditions may vary from those displayed

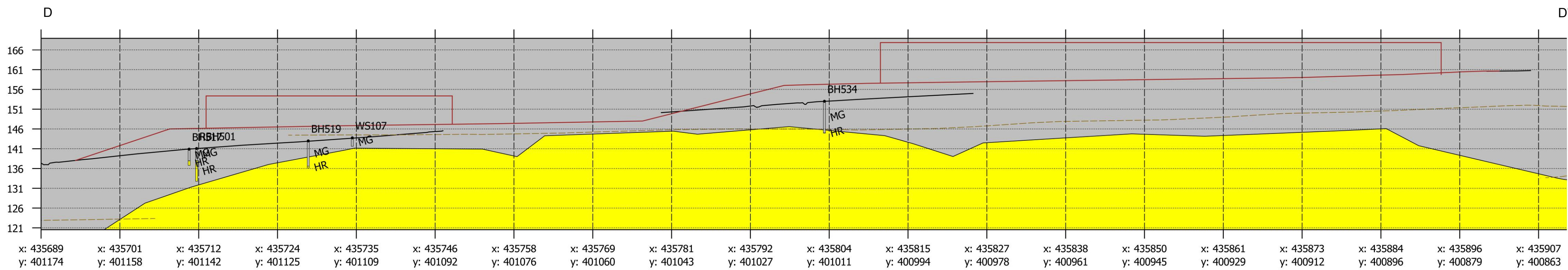
REV	DATE	DESCRIPTION	BY	CHD.	APR.
Dimensions		Projection	Scale	Orig Size	
m			AS SHOWN	A0	
 Spring Lodge 172 Chester Road Helsby Cheshire WA6 0AR Tel: +44 1928 726006 Fax: +44 1928 725633 Web: www.rsk.co.uk					
CLIENT					
HARWORTH ESTATES (INVESTMENTS) LTD					
PROJECT					
ROCKINGHAM 2 AND 3					
TITLE					
SECTION A-A' & SECTION B-B'					
JOB No.:			DRAWING FILE:		
322638			322638-R02(00)D005A		
BY:	DATE:	CONTRACT NO.	FIGURE 5		REV:
HD	20.02.20				A



Scale: 1:750
Vertical exaggeration: 1x

0m 60m

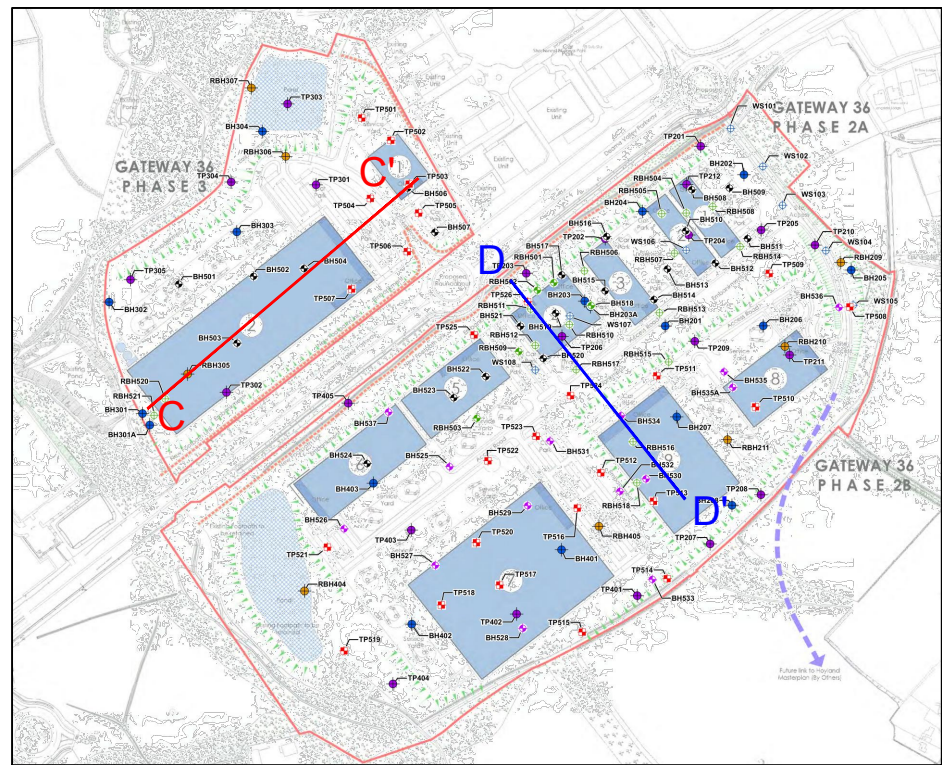
Location
C: 435249, 401004
C': 435576, 401278



Scale: 1:750
Vertical exaggeration: 1x

0m 60m

Location
D: 435689, 401174
D': 435911, 400857



- LEGEND:**
- Existing topography
 - Proposed levels and commercial units
 - Extracted coal seams
 - Bedrock (Pennine Middle Coal Measures)
 - Made Ground (colliery backfill)

The cross section is presented based on the information from the intrusive investigation and predicted ground conditions as modelled from available information. Actual ground conditions may vary from those displayed

REV	DATE	DESCRIPTION	BY	CHD	APR.
Dimensions		Projection	Scale	Orig Size	
m			AS SHOWN	A0	

RSK

Spring Lodge
172 Chester Road
Helsby
Cheshire
WA6 0AR

Tel: +44 1928 726006
Fax: +44 1928 725633
Web: www.rsk.co.uk

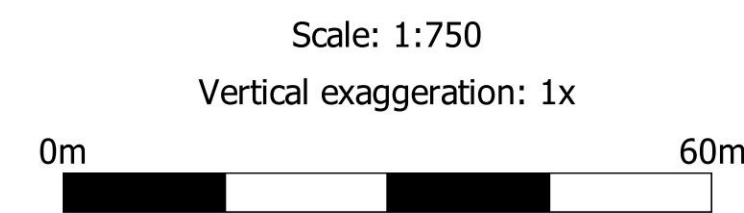
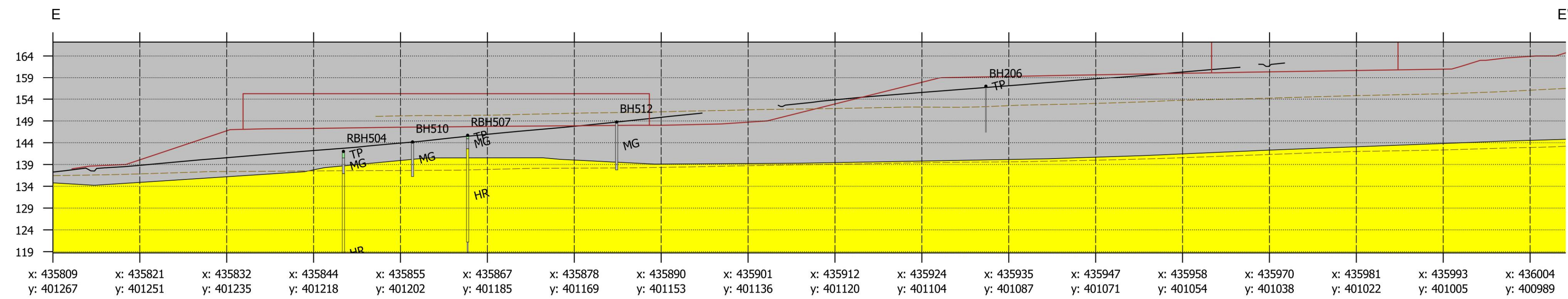
CLIENT
HARWORTH ESTATES (INVESTMENTS) LTD

PROJECT
ROCKINGHAM 2 AND 3

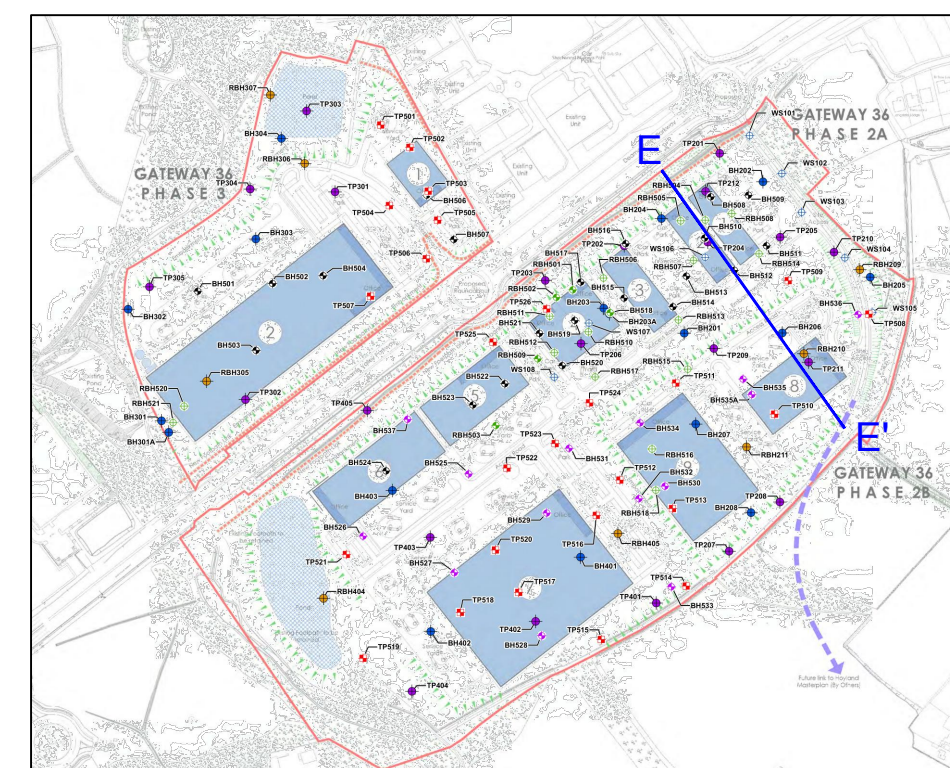
TITLE
SECTION C-C' &
SECTION D-D'

JOB No.:	DRAWING FILE:
322638	322638-R02(00)D006A

BY:	DATE:	CONTRACT NO.	FIGURE 6	REV:
HD	20.02.20			A



Location
E: 435809, 401267
E': 436009, 400982

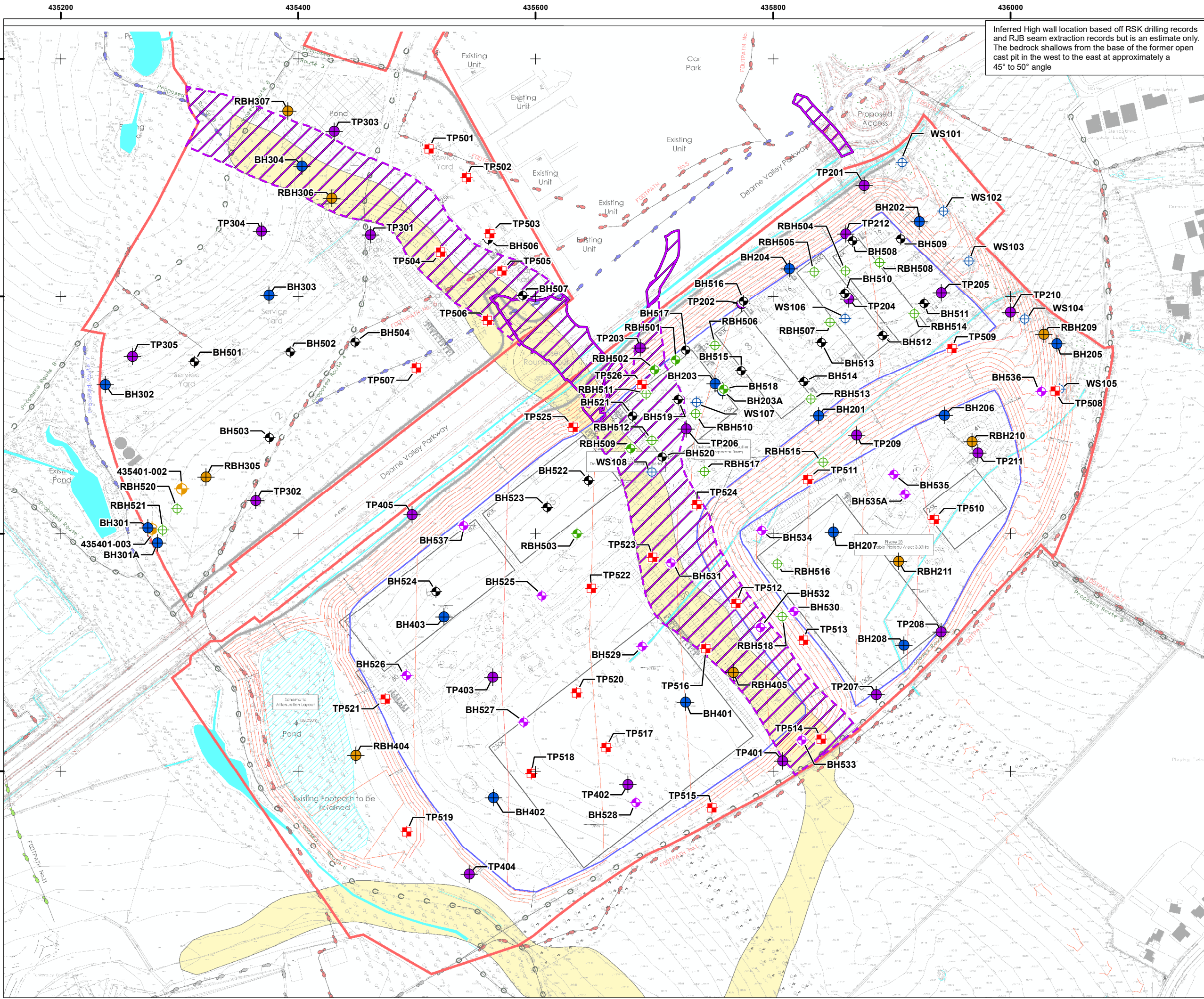


LEGEND:

- Existing topography
- Proposed levels and commercial units
- Extracted coal seams
- Bedrock (Pennine Middle Coal Measures)
- Made Ground (colliery backfill)

The cross section is presented based on the information from the intrusive investigation and predicted ground conditions as modelled from available information. Actual ground conditions may vary from those displayed

REV	DATE	DESCRIPTION		BY	CHD.	APR.
Dimensions		Projection		Scale		Orig Size
m				AS SHOWN		A0
 Spring Lodge 172 Chester Road Helsby Cheshire WA6 0AR Tel: +44 1928 726006 Fax: +44 1928 725633 Web: www.rsk.co.uk						
CLIENT						
HARWORTH ESTATES (INVESTMENTS) LTD						
PROJECT						
ROCKINGHAM 2 AND 3						
TITLE						
SECTION E-E'						
JOB No.:				DRAWING FILE:		
322638				322638-R02(00)D007A		
BY:	DATE:	CONTRACT NO.		FIGURE 7		REV:
HD	20.02.20					A



Inferred High wall location based off RSK drilling records and RJB seam extraction records but is an estimate only. The bedrock shallows from the base of the former open cast pit in the west to the east at approximately a 45° to 50° angle

- Legend:**
- Area of High Wall (Mott MacDonald certification report)
 - Inferred High Wall Location
 - Coal Authority Mineshaft Locations
- Previous SI Location:**
- Cable Percussive Borehole (RSK, February 2014)
 - Rotary Borehole With Limited Coring (RSK, June 2014)
 - Trial Pit (RSK)
- 2019 Boreholes:**
- Cable Percussive Borehole (RSK, 2019)
 - Rotary Boreholes (RSK, 2019)
 - Trial Pits (RSK, 2019)
 - Window Sampling Location (RSK, 2019)
- 2020 Boreholes:**
- Cable Percussive Borehole (RSK, 2020)
 - Rotary Borehole (RSK, 2020)

Coordinate System: British National Grid
Projection: Transverse Mercator
Datum: OSGB 1936
Units: Meter



Rev	Date	Description	Drn	Chk	App
00	31/03/2020	First Draft	DR	AC	AC

Rockingham Infrastructure

TITLE:
322638 R02 (00)
Figure 8:
Revised Constraints Plan

0 50 100
Meters
SCALE: 1:3,000 @ A3

REV 02

APPENDIX A

SERVICE CONSTRAINTS

1. This report and the site investigation carried out in connection with the report (together the "Services") were compiled and carried out by RSK Environment Limited (RSK) for Harworth Estates (Investments) Limited (the "Client") in accordance with the terms of a contract [RSK Environment Standard Terms and Conditions] between RSK and the Client, dated 19 September 2019. The Services were performed by RSK with the reasonable skill and care ordinarily exercised by an environmental consultant at the time the Services were performed. Further, and in particular, the Services were performed by RSK taking into account the limits of the scope of works required by the client, the time scale involved and the resources, including financial and manpower resources, agreed between RSK and the Client.
2. Other than that, expressly contained in paragraph 1 above, RSK provides no other representation or warranty whether express or implied, in relation to the Services.
3. Unless otherwise agreed in writing, the Services were performed by RSK exclusively for the purposes of the Client. RSK is not aware of any interest of or reliance by any party other than the Client in or on the Services. Unless expressly provided in writing, RSK does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and RSK disclaims any liability to such parties. **Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.**
4. It is RSK's understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without RSK's review and advice shall be at the client's sole and own risk. Should RSK be requested to review the report after the date of this report, RSK shall be entitled to additional payment at the then existing rates or such other terms as agreed between RSK and the client.
5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of RSK. In the absence of such written advice of RSK, reliance on the report in the future shall be at the Client's own and sole risk. Should RSK be requested to review the report in the future, RSK shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between RSK and the client.
6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the Client and RSK. RSK has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and RSK. RSK is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, RSK did not seek to evaluate the presence on or off the site of asbestos, invasive plants, electromagnetic fields, lead paint, heavy metals, radon gas or other radioactive or hazardous materials, unless specifically identified in the Services.
7. The Services are based upon RSK's observations of existing physical conditions at the Site gained from a visual inspection of the site together with RSK's interpretation of information, including documentation, obtained from third parties and from the Client on the history and usage of the site, unless specifically identified in the Services or accreditation system (such as UKAS ISO 17020:2012 clause 7.1.6):



- a. The Services were based on information and/or analysis provided by independent testing and information services or laboratories upon which RSK was reasonably entitled to rely.
- b. The Services were limited by the accuracy of the information, including documentation, reviewed by RSK and the observations possible at the time of the visual inspection.
- c. The Services did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services.

RSK is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to RSK and including the doing of any independent investigation of the information provided to RSK save as otherwise provided in the terms of the contract between the Client and RSK.

8. The intrusive environmental site investigation aspects of the Services are a limited sampling of the site at pre-determined locations based on the known historic / operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the properties of the materials adjacent and local conditions, together with the position of any current structures and underground utilities and facilities, and natural and other activities on site. In addition, chemical analysis was carried out for a limited number of parameters (as stipulated in the scope between the client and RSK, based on an understanding of the available operational and historical information) and it should not be inferred that other chemical species are not present.
9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan but is (are) used to present the general relative locations of features on, and surrounding, the site. Features (intrusive and sample locations etc) annotated on site plans are not drawn to scale but are centred over the approximate location. Such features should not be used for setting out and should be considered indicative only.
10. The comments given in this report and the opinions expressed are based on the ground conditions encountered during the site work and on the results of tests made in the field and in the laboratory. However, there may be conditions pertaining to the site that have not been disclosed by the investigation and therefore could not be taken into account. In particular, it should be noted that there may be areas of made ground not detected due to the limited nature of the investigation or the thickness and quality of made ground across the site may be variable. In addition, groundwater levels and ground gas concentrations and flows, may vary from those reported due to seasonal, or other, effects and the limitations stated in the data should be recognised.
11. Asbestos is often observed to be present in soils in discrete areas. Whilst asbestos-containing materials may have been locally encountered during the fieldworks or supporting laboratory analysis, the history of brownfield and demolition sites indicates that asbestos fibres may be present more widely in soils and aggregates, which could be encountered during more extensive ground works.
12. Unless stated otherwise, only preliminary geotechnical recommendations are presented in this report and these should be verified in a Geotechnical Design Report, once proposed construction and structural design proposals are confirmed.



APPENDIX B

DEVELOPMENT DRAWINGS

THE DRAWING IS THE PROPERTY OF JPG (LEEDS) LIMITED
REGISTERED IN ENGLAND NO. 070406. COPYRIGHT RESERVED.

DO NOT SCALE

NOTES

PROPOSED LEVELS

EXISTING WATERCOURSE

PROPOSED ATTENUATION - SCHEMATIC:
SUBJECT TO FURTHER DESIGN

Levels Have Been Produced To Assess Cut/Fill
Quantities. Drawing Should Be Read In Conjunction
With JPG Drawing No.:
4652-2-JPG-SW-00-DR-C-1201_S2_P05-CutFill_Analysis

POS	ARCHITECT LAYOUT ALTERATION.	25.11.19	OLT
P04	LAYOUT ALTERATION IN LINE WITH ARCHITECTS COMMENTS.	25.11.19	OLT
P03	PROPOSED LEVELS ALTERATION IN LINE WITH LINE ROAD ADJUSTMENTS.	07.11.19	OLT
P02	ALTERATIONS TO LEVELS IN LINE WITH ARCHITECTS COMMENTS.	26.09.19	OLT
P01	FIRST ISSUE.	09.09.19	OLT
REV	DESCRIPTION	DATE	BY

Project
ROCKINGHAM PHASE 2A & 2B,
ROCKINGHAM 2&3,
HOLYLAND

Drawing Title
PROPOSED EARTHWORK LEVELS

INFORMATION ISSUE

Architect
THE HARRIS PARTNERSHIP

JPG

www.jpg.group

Leeds London Birmingham 0113 263 1155

JPG Project Ref

Scale of A0

Date

Checked

Drawn

4652-2

1:1000

SEP19

OLT

4652-2 - JPG - SW - 00 - DR - C - 1200 S2 P05



DO NOT SCALE

NOTES

Cut/Fill Depth By Colour Banding			
Number	Minimum Elevation	Maximum Elevation	Colour
1	-12.00	-10.00	
2	-10.00	-8.00	
3	-8.00	-6.00	
4	-6.00	-4.00	
5	-4.00	-2.00	
6	-2.00	0.00	
7	0.00	2.00	
8	2.00	4.00	
9	4.00	6.00	
10	6.00	8.00	
11	8.00	10.00	
12	10.00	12.00	

Site Specific

Maximum Cut Depth: 7.63m

Maximum Fill Build-Up: 8.32m

PROPOSED LEVELS

Cut/Fill In Brief

Cut: 328371.11 Cu. M.

Fill: 337108.02 Cu. M.

Net Shortfall: 8736.91 Cu. M.

Site Perimeter Has Battered To Existing Levels At 1:3.

A 1:4 Batter Between Proposed Plateaus Has Been Shown To Account For A Break In Slope In A 1:3 Batter.

This Is A Site-Wide Cut/Fill Analysis And Should Not Be Relied Upon For Final Design. Further Detailed Design Is Required.

Levels Have Been Produced To Tie Into Proposed Link Road Alignment Option 2E.

Gradients And Spot Elevations Displayed Reflect The Proposed Finished Floor Levels.

A 300mm Site Strip Was Calculated And Removed Prior To The Cut/Fill Analysis.

A Site Strip Volume of 72008.98 Cu. M. Has Been Calculated.

Attenuation Volume Has Been Accounted For In The Cut/Fill Analysis.

A 5% Bulking Factor Has Been Accounted For In The Cut/Fill Analysis.

Areas Not Shaded With The Cut/Fill Colour Banding Have Not Been Included In The Cut/Fill Analysis.

The Topography Used In The Cut/Fill Analysis Has Been Generated From Combining 'Greenhatch Group, Topographical Survey, Drawing No. 20379_OGL_Rev_3, Date 05-06.14'

POS	ARCHITECT LAYOUT ALTERATION.	29.11.2019	OLT
POS	LAYOUT ALTERATION IN LINE WITH ARCHITECTS COMMENTS	25.11.19	OLT
POS	PROPOSED LEVELS ALTERATION IN LINE WITH LINK ROAD ADJUSTMENTS	07.11.2019	OLT
POS	ALTERATIONS TO LEVELS IN LINE WITH ARCHITECTS COMMENTS	26.09.2019	OLT
POS	FIRST ISSUE	09.09.2019	OLT
REV	DESCRIPTION	DATE	BY

Project
ROCKINGHAM PHASE 2A & 2B,
ROCKINGHAM 2&3,
HOCKLAND

Drawing Title
CUT/FILL ANALYSIS

INFORMATION ISSUE

Architect

THE HARRIS PARTNERSHIP

JPG

www.jpg.group

Leeds London Birmingham 0113 263 1155

JPG Project Ref

4652-2

Scale of A0

1:1000

Date

28/11/19

Checked

Drawn

OLT

4652-2 - JPG - SW - 00 - DR - C - 1201 S2 POS

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
Cut/Fill Analysis	1.000	1.000	240029.93sq.m	303210.58 Cu. M.	337108.02 Cu. M.	33897.44 Cu. M.<Fill>
Attenuation				10000.00 Cu. M.	0000.00 Cu. M.	10000.00 Cu. M.<Cut>
Bulking Factor (5%)				15160.53 Cu. M.	0000.00 Cu. M.	15160.53 Cu. M.<Cut>
Total				328371.11 Cu. M.	337108.02 Cu. M.	8736.91 Cu. M.<Fill>

Analysis has been performed using topographical surface generated from 'Greenhatch Group, Topographical Survey, Drawing No. 20379_OGL_Rev_3, Date 05-06.14'.

Analysis has incorporated a 300mm site strip, and so site strip volume is not included in the calculation above.

The total site strip volume calculated is 72008.98Cu. M.

Analysis has included attenuation volume.

Analysis has included a 5% bulking factor.

DO NOT SCALE

NOTES

PROPOSED LEVELS

EXISTING WATERCOURSE

PROPOSED ATTENUATION - SCHEMATIC.
SUBJECT TO FURTHER DESIGN

Levels Have Been Produced To Assess Cut/Fill
Quantities. Drawing Should Be Read In Conjunction
With JPG Drawing No.:
'4652-2-JPG-SW-00-DR-C-1203_S2_P05-Phase_3_
Cutoffill_Analysis'

P03	ARCHITECT LAYOUT ALTERATION.	29.11.19	OLT
P02	ALTERATION TO LAYOUT TO ASSIST IN CUT/FILL BALANCE.	10.10.19	OLT
P01	FIRST ISSUE.	24.09.19	OLT
REV	DESCRIPTION	DATE	BY

Project
ROCKINGHAM PHASE 3,
ROCKINGHAM 2&3,
HOYLAND

Drawing Title
PHASE 3 PROPOSED EARTHWORKS
LEVELS

INFORMATION ISSUE

Architect
THE HARRIS PARTNERSHIP



www.jpg.group
Leeds London Birmingham 0113 263 1155

JPG Project Ref 4652-2	Scale at A1 1:1000	Date SEPT'19	Checked	Drawn OLT
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REGISTERED IN ENGLAND AND WALES. COPYRIGHT RESERVED

DO NOT SCALE

NOTES

Cut/Fill Depth By Colour Banding			
Number	Minimum Elevation	Maximum Elevation	Colour
1	-12.00	-10.00	
2	-10.00	-8.00	
3	-8.00	-6.00	
4	-6.00	-4.00	
5	-4.00	-2.00	
6	-2.00	0.00	
7	0.00	2.00	
8	2.00	4.00	
9	4.00	6.00	
10	6.00	8.00	
11	8.00	10.00	
12	10.00	12.00	

Site Specific
Maximum Cut Depth: -4.93m
Maximum Fill Build-Up: 7.49m

PROPOSED LEVELS

Cut/Fill In Brief
Cut: 112546.29 Cu. M.
Fill: 109425.07 Cu. M.
Net Surplus: 3121.22 Cu. M.

Site Perimeter Has Been Bartered To Existing Levels At 1:3.

This Is A Site-Wide Cut/Fill Analysis And Should Not Be Relied Upon For Final Design. Further Detailed Design May Be Required.

Gradients And Spot Elevations Displayed Reflect The Proposed Finished Floor Levels.

A 300mm Site Strip Was Calculated And Removed Prior To The Cut/Fill Analysis.

A Site Strip Volume of 27261.47 Cu. M. Has Been Calculated.

Attenuation Volume Has Been Accounted For In The Cut/Fill Analysis.

A 5% Bulking Factor Has Been Accounted For In The Cut/Fill Analysis.

Areas Not Shaded With The Cut/Fill Colour Banding Have Not Been Included In The Cut/Fill Analysis.

The Topography Used In The Cut/Fill Analysis Has Been Generated From 'Greenhatch Group, Topographical Survey, Drawing No. 20379_OGL_Rev_3, Date 05-06.06.14'



Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
Cut/Fill Analysis	1.000	1.000	90871.57sq.m	97663.14 Cu. M.	109425.07 Cu. M.	11761.94 Cu. M.<Fill>
Attenuation				10000.00 Cu. M.	0000.00 Cu. M.	10000.00 Cu. M.<Cut>
Bulking Factor (5%)				4883.15 Cu. M.	0000.00 Cu. M.	4883.15 Cu. M.<Cut>
Total				112546.29 Cu. M.	109425.07 Cu. M.	3121.22 Cu. M.<Cut>

Analysis has been performed using topographical surface generated from 'Greenhatch Group, Topographical Survey, Drawing No. 20379_OGL_Rev_3, Date 05-06.06.14'.

Analysis has incorporated a 300mm site strip, and so site strip volume is not included in the calculation above.

The total site strip volume calculated is 27261.47 Cu. M.

Analysis has included attenuation volume.

Analysis has included a 5% bulking factor.

P02	ARCHITECT LAYOUT ALTERATION.	29.11.19	OLT
P01	FIRST ISSUE.	10.10.19	OLT

REV	DESCRIPTION	DATE	BY
-----	-------------	------	----

Project
ROCKINGHAM PHASE 3,
ROCKINGHAM 2&3,
HOLYLAND

Drawing Title
PHASE 3 CUT/FILL ANALYSIS

INFORMATION ISSUE

Architect
THE HARRIS PARTNERSHIP

JPG

www.jpg.group

Leeds London Birmingham 0113 263 1155

JPG Project Ref

4652-2

Scale of A0

1:1000

Date

06/11/19

Checked

Drawn

OLT

APPENDIX C

SUMMARY OF LEGISLATION AND POLICY RELATING TO CONTAMINATED LAND

Part IIA of the Environmental Protection Act 1990

Part IIA of the Environmental Protection Act 1990 (Part IIA) and its associated Contaminated Land Regulations 2000 (SI 2000/227), which came into force in England on 1 April 2000, formed the basis for the current regulatory framework and the statutory regime for the identification and remediation of contaminated land. Part IIA of the EPA 1990 defines contaminated land as 'any 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 that there is significant possibility of significant harm being caused, or that pollution of controlled waters is being or is likely to be caused'. Controlled waters are considered to include all groundwater, inland waters and estuaries.

In August 2006, the Contaminated Land (England) Regulations 2006 (SI 2006/1380) were implemented, which extended the statutory regime to include Part IIA of the EPA as originally introduced on 1 April 2000, together with changes intended chiefly to address land that is contaminated by virtue of radioactivity. These have been replaced subsequently by the Contaminated Land (England) (Amendment) Regulations 2012, which now exclude land that is contaminated by virtue of radioactivity.

The intention of Part IIA is to deal with contaminated land issues that are considered to cause significant harm on land that is not undergoing development (see Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance, April 2012). This document replaces Annex III of Defra Circular 01/2006, published in September 2006 (the remainder of this document is now obsolete).

Planning Policy

Contaminated land is often dealt with through planning because of land redevelopment. This approach was documented in Planning Policy Statement: Planning and Pollution Control PPS23, which states that it remains the responsibility of the landowner and developer to identify land affected by contamination and carry out sufficient remediation to render the land suitable for use. PPS23 was withdrawn early in 2012 and has been replaced by much reduced guidance within the National Planning Policy Framework (NPPF), reference ISBN: 978-1-5286-1033-9, February 2019.

The new framework has only limited guidance on contaminated land, as follows:

Chapter 11. Making effective use of land

117 Planning policies and decisions should promote an effective use of land in meeting the need for homes and other uses, while safeguarding and improving the environment and ensuring safe and healthy living conditions. Strategic policies should set out a clear strategy for accommodating objectively assessed needs, in a way that makes as much use as possible of previously-developed or 'brownfield' land.

118. Planning policies and decisions should:

c) give substantial weight to the value of using suitable brownfield land within settlements for homes and other identified needs, and support appropriate opportunities to remediate despoiled, degraded, derelict, contaminated or unstable land.

Chapter 15. Conserving and enhancing the natural environment

170. Planning policies and decisions should contribute to and enhance the natural and local environment by:

e) preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by, unacceptable levels of soil, air, water or noise pollution or land instability. Development should, wherever possible, help to improve local environmental conditions such as air and water quality, taking into account relevant information such as river basin management plans; and

f) remediating and mitigating despoiled, degraded, derelict, contaminated and unstable land, where appropriate.

Ground conditions and pollution

178. Planning policies and decisions should ensure that:

a) a site is suitable for its proposed use taking account of ground conditions and any risks arising from land instability and contamination. This includes risks arising from natural hazards or former activities such as mining, and any proposals for mitigation including land remediation (as well as potential impacts on the natural environment arising from that remediation);

b) after remediation, as a minimum, land should not be capable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990; and

c) adequate site investigation information, prepared by a competent person, is available to inform these assessments.

179. Where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner.

Water Resources Act (WRA)

The Water Resources Act 1991 (Amendment) (England and Wales) Regulations 2009 updated the Water Resources Act 1991, which introduced the offence of causing or knowingly permitting pollution of controlled waters. The Act provides the Environment Agency with powers to implement remediation necessary to protect controlled waters and recover all reasonable costs of doing so.

Water Framework Directive (WFD)

The Water Framework Directive 2000/60/EC is designed to:

- enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands that depend on the aquatic ecosystems
- promote the sustainable use of water
- reduce pollution of water, especially by 'priority' and 'priority hazardous' substances
- ensure progressive reduction of groundwater pollution.

The WFD requires a management plan for each river basin be developed every six years.

Groundwater Directive (GWD)

The 1980 Groundwater Directive 80/68/EEC and the 2006 Groundwater Daughter Directive 2006/118/EC of the WFD are the main European legislation in place to protect groundwater. The 1980 Directive is due to be repealed in December 2013. The European legislation has been transposed into national legislation by regulations and directions to the Environment Agency.

Priority Substances Directive (PSD)

The Priority Substances Directive 2008/105/EC is a 'Daughter' Directive of the WFD, which sets out a priority list of substances posing a threat to or via the aquatic environment. The PSD establishes environmental quality standards for priority substances, which have been set at concentrations that are safe for the aquatic environment and for human health. In addition, there is a further aim of reducing (or eliminating) pollution of surface water (rivers, lakes, estuaries and coastal waters) by pollutants on the list. The WFD requires that countries establish a list of dangerous substances that are being discharged and EQS for them. In England and Wales, this list is provided in the River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010. In order to achieve the objectives of the WFD, classification schemes are used to describe where the water environment is of good quality and where it may require improvement.

Environmental Permitting Regulations (EPR)

The Environmental Permitting (England and Wales) Regulations 2016 (as amended) provide a single regulatory framework that streamlines and integrates waste management licensing, pollution prevention and control, water discharge consenting, groundwater authorisations, and radioactive substances regulation. Schedule 22, paragraph 6 of EPR 2016 states: 'the regulator must, in exercising its relevant functions, take all necessary measures - (a) to prevent the input of any hazardous substance to groundwater; and (b) to limit the input of non-hazardous pollutants to groundwater so as to ensure that such inputs do not cause pollution of groundwater.'

Notes:

1. *The above information is provided for background but does not constitute site-specific advice*
2. *The above summary applies to England only. Variations exist within other countries of the United Kingdom*