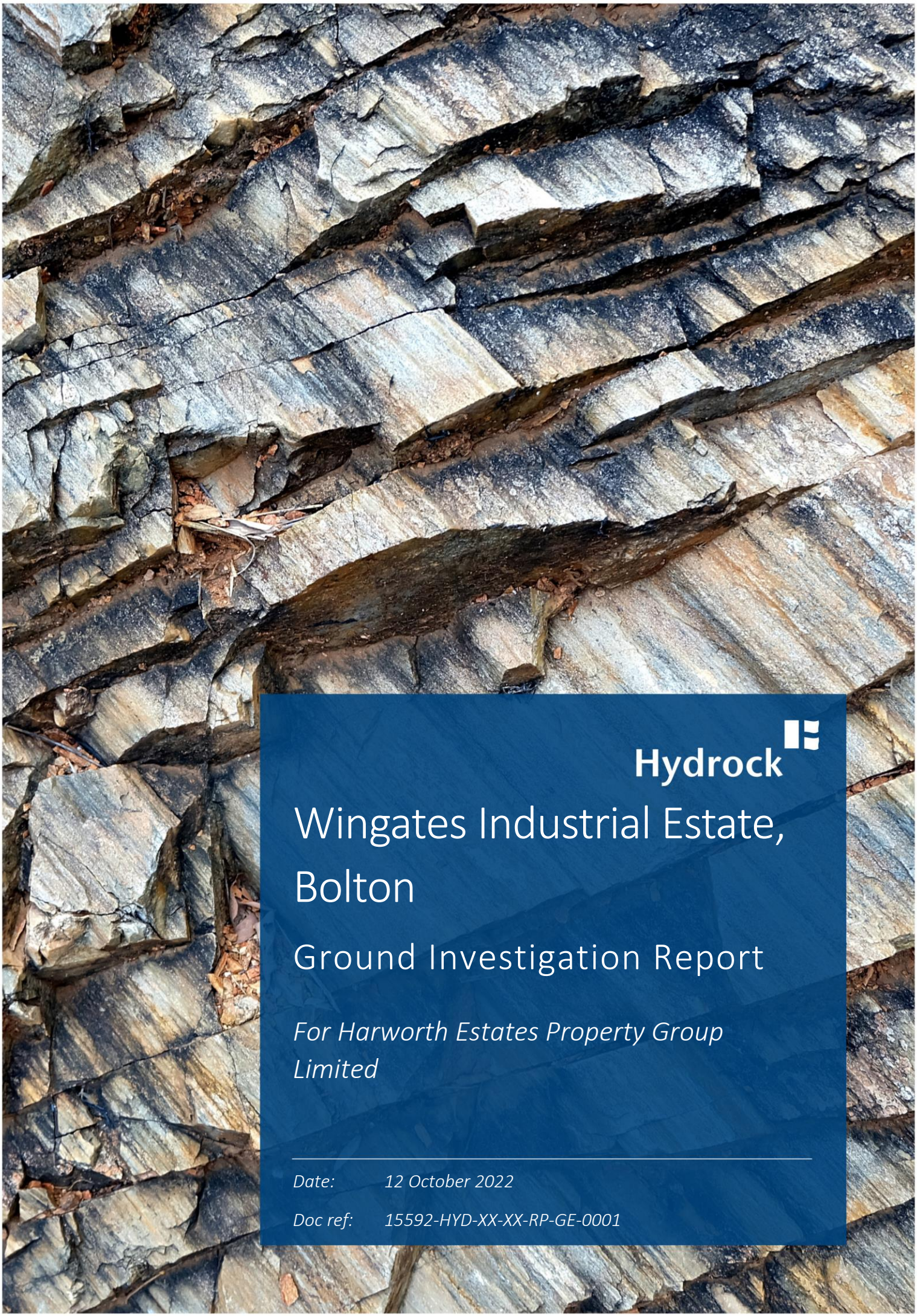

Hydrock

Wingates Industrial Estate, Bolton

Ground Investigation Report

For Harworth Estates Property Group Limited

Date: *12 October 2022*

Doc ref: *15592-HYD-XX-XX-RP-GE-0001*

DOCUMENT CONTROL SHEET

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S2	P03	15/02/2022	Updated monitoring data and ground gas risk assessment following completion of monitoring.
S2	P04	12/10/2022	Updated following ground investigation at proposed ecological mitigation area.

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SITE INFORMATION AND SETTING	
Objectives	To assist in clearing planning conditions and to assist with the design of the development.
Client	Harworth Estates Property Group Limited
Site name and location	Wingates, located south of Chorley Road and west of Wimberry Hill Road, 1km north west of Westhoughton Railway Station (National Grid Reference 364488E, 407608N).
Proposed development	The proposed development is to comprise nine commercial units varying in size with associated car parking and access roads. The development will include Three attenuation ponds in the south and acoustic bunds along the northern boundary, and in the west an area of habitat enhancement will take place. To form the development plateaus cut to fill will be undertaken.
GROUND MODEL	
Desk study summary	The site is predominantly undeveloped agricultural fields split by a gravel access. The gravel track transects from north east to south west. There are five ponds in the northern section of the site and two in the south. Mature trees are present across the northern boundary and are sporadically present on the southern boundary. An overhead electricity cable is present crossing the centre of the site from west to east and from the centre of the site orientating south an offshoot transects offsite. The eastern field rises from Chorley Road at 132m AOD to a topographical higher plateau at 137m AOD in the approximate centre of the site. The eastern field then slopes from the topographical high point towards the south and south east to 120m AOD. The field west of the gravel track slopes from north east to south west from 136m AOD to 127m AOD. Review of historical Ordnance Survey mapping indicates: • Throughout the historical maps the site is shown to remain predominantly undeveloped. The ponds currently present onsite are recorded on mapping from 1849. Between 1893 and 1929 a mine shaft is present close to the existing gravel track. • Three historic landfills are indicated to be present onsite, two in the eastern fields and one in the south of the western field. • Between 1849 and 1894 Albert Colliery and pit is shown 100m north of the site. Also recorded 750m to the north of the site between 1849 and 1929 is New Winnings Coal Pit. Between 1894 and 1929 various coal pits are labelled to the east and south of the site. In 1979 Wingates Industrial estate is shown adjacent to the south east. A non-specialist UXO assessment indicates a low bomb risk. Three historic landfills are recorded onsite, in the north, south and south west of the site and with localised deep Made Ground anticipated in these areas. The superficial geology comprises Glacial Till over the Pennine Lower Coal Measures Formation. Part of the Westphalian Coal Measures Group and the Cannel Rock (Sandstone) is likely to be overlying the Pennine Lower Coal Measures Formation in the north of the site. The site is in an area which could be affected by underground mining in six seams including shallow depth to 380m bgl. The Cannel Coal Seam outcrops across the north of the site from west to east. Beyond the Cannel Coal Seam, the older King Coal Seam sub crops offsite by approximately 50m north. One mine entry (364407-005) is present in the west of the site, adjacent to the existing gravel access track. Two further mine entries (364407-002 and 36407-001) are recorded up to 20m from the site boundary. Two faults are present in the area the first offsite 15m north and the second encroaches onto the north east corner of the site trending north west to south east with the downthrow also recorded onsite.

	The Glacial Till is classed as a Secondary Undifferentiated Aquifer. The Pennine Lower Coal Measures Formation and Cannel Rock are classified as Secondary A aquifers. There are no recorded groundwater abstractions wells within 900m of the site and the does not overlie a Groundwater Source Protection Zone. Several ponds and a series of drainage ditches are present across the site.
Ground and groundwater conditions encountered by investigation	The ground conditions as proven by the investigation(s) undertaken at the site comprise: • General Made Ground to depths ranging between 0.40 – 1.80m bgl. • Landfill material to depths ranging between 0.20 - >4.80m bgl. • Topsoil material to depths between 0.10 and 1.00m bgl. with an average thickness of 0.42m. • Peat was encountered in one location (RSK-TP52) during the RSK investigation at a depth of 2.00m extending to 2.70m bgl. • Glacial Till was encountered between ground level and 4.20m bgl. and extends to depths between 1.80m bgl and 11.20m bgl, with an average thickness of 6.27m. • The top of the Pennine Lower Coal Measures formation (PLCM) was encountered between 3.00m at its shallowest to 11.20m bgl. at its deepest. The average depth to the top of the PLCM is 6.84m bgl. Broken ground and a loss of flush was encountered in RO01 at 11.0 – 14.0m bgl, with no flush returns to the full depth of the borehole at 40.0m bgl. This indicates the presence of possible workings in the Cannel seam. In RO14 at 20.0 – 21.0m bgl soft ground was encountered which also suggests possible workings within the Cannel seam. A shallow groundwater body present at 0.18m – 3.80m bgl in the Glacial Till with another deeper groundwater body in the Glacial Till at 6.18 – 8.62m bgl. Groundwater is also present in the PLCM at 5.0m to 9.82m bgl. Visual and olfactory evidence of potential contamination was identified in two locations in the northern landfill consisting of black Hay/straw, ash, wood, large pieces of timber, metal, and a strong organic odour.
GEOTECHNICAL CONCLUSIONS	
Conclusions of geotechnical assessment	All Made Ground to be removed and processed where required to allow re-use. Significant settlement is anticipated where engineered fill is placed as part of the earthworks. Ground improvement by the installation of PVD and geotechnical monitoring recommended. Excavated materials likely to comply with general fill to external areas and roads. However, geotechnical improvement with hydraulic binders recommended below structures. Removal of low strength Glacial Till (upper 3m) within influencing distance of foundations. Alternative forms of ground improvement could include VSC in areas of cut or preload and surcharge. Following the earthworks (to a suitable specification) and ground improvement, shallow foundations with allowable foundation pressures up to 150kPa for pads possible. Floor slab loading should be limited to 50kPa without further ground improvement. Subgrade improvement will likely be required especially near cut / fill boundary. Following improvement, a design CBR of 2.5% should be used for preliminary design. Higher values of subgrade stiffness possible with additional improvement. Soakaway drainage is considered unsuitable for this site. Design Sulfate Class - DS-1 and ACEC Class AC-1. Equivalent to Design Chemical Class DC-1 for a 50 year design life.
GEO-ENVIRONMENTAL CONCLUSIONS	
Conclusions of contamination	Human health: • There are no chemicals of potential concern that exceed the GAC. Controlled Waters:

Generic risk assessment	• The risk of pollution to controlled waters at the site is very low on the basis that historically the majority of the site has remained undeveloped (with the exception of the known landfill areas, with no viable source of contamination (demonstrated by soil concentrations). The site is also not within a Source Protection Zone and there are no groundwater abstractions within 900m of the site. • The site is also underlain entirely by low permeability cohesive Glacial Till, which is expected to inhibit the downward migration of chemicals within soils. Ground gases: • Provisionally classification of the site commensurate with CS2 conditions, with this classification to be reassessed and subject to change following the supplementary monitoring once the cut to fill earthworks are completed. • On this basis CS2 conditions apply until the post-earthworks monitoring is completed and the risk assessment is updated. Ground gas mitigation measures will be recommended post-earthworks following the reassessment. Radon: • The site is not in a Radon Affected Area. Water supply pipes: • Standard pipework is envisaged. However, confirmation should be sought from the water supply company at the earliest opportunity.
Proposed mitigation measures	The mitigation measures proposed to remove unacceptable risks include: • The excavation of landfill material, removal of organic constituents, and reuse of suitable material on site in landscaping areas. Landfill material is not to be reused beneath buildings or infrastructure; • Mineshaft treatment; • Supplementary ground gas monitoring to be undertaken post-earthworks to confirm the Characteristic Situation and appropriate mitigation measures. The methodology for the remediation should be presented in a Remediation Strategy, which will need to be submitted to the warranty provider and the regulatory authorities for approval. In addition, the production of a Materials Management Plan and its approval by a Qualified Person will be required to allow reuse of suitable material at the site. Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works.
Waste management	Excavated soils to be disposed of as waste, are likely to be classed as non-hazardous.
FUTURE CONSIDERATIONS	
Further work	Following the ground investigation works undertaken to date, the following further works will be required: • discussion with the Coal Authority with regard to treatment of the on-site mine shaft; • discussion and agreement with utility providers regarding the materials suitable for pipework; • discussions with regulatory bodies and the warranty provider regarding the conclusions of this report; • assessment of tree influence on foundations and design of foundations; • discussions with Vibro-stone Column Contractors regarding the viability of, and potential improvement by, VSCs; • provision of geotechnical design for the Category 3 structures (earthworks, retaining, floor slabs, foundations etc.); • production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider); • production of a Materials Management Plan relating to reuse of soils at the site and import of soils to the site;

	• remediation and mitigation works; and • ground investigation following completion of the cut to fill earthworks to install boreholes with monitoring standpipes for supplementary ground gas monitoring; • completion and reporting of the supplementary gas monitoring following completion of the cut to fill earthworks, hence the conclusions in this report are provisional, subject to the completion of monitoring; • verification of the earthworks, remediation and mitigation works.

This Executive Summary forms part of Hydrock Consultants Limited report number 15592-HYD-XX-XX-RP-GE-0001 and should not be used as a separate document.

1. INTRODUCTION

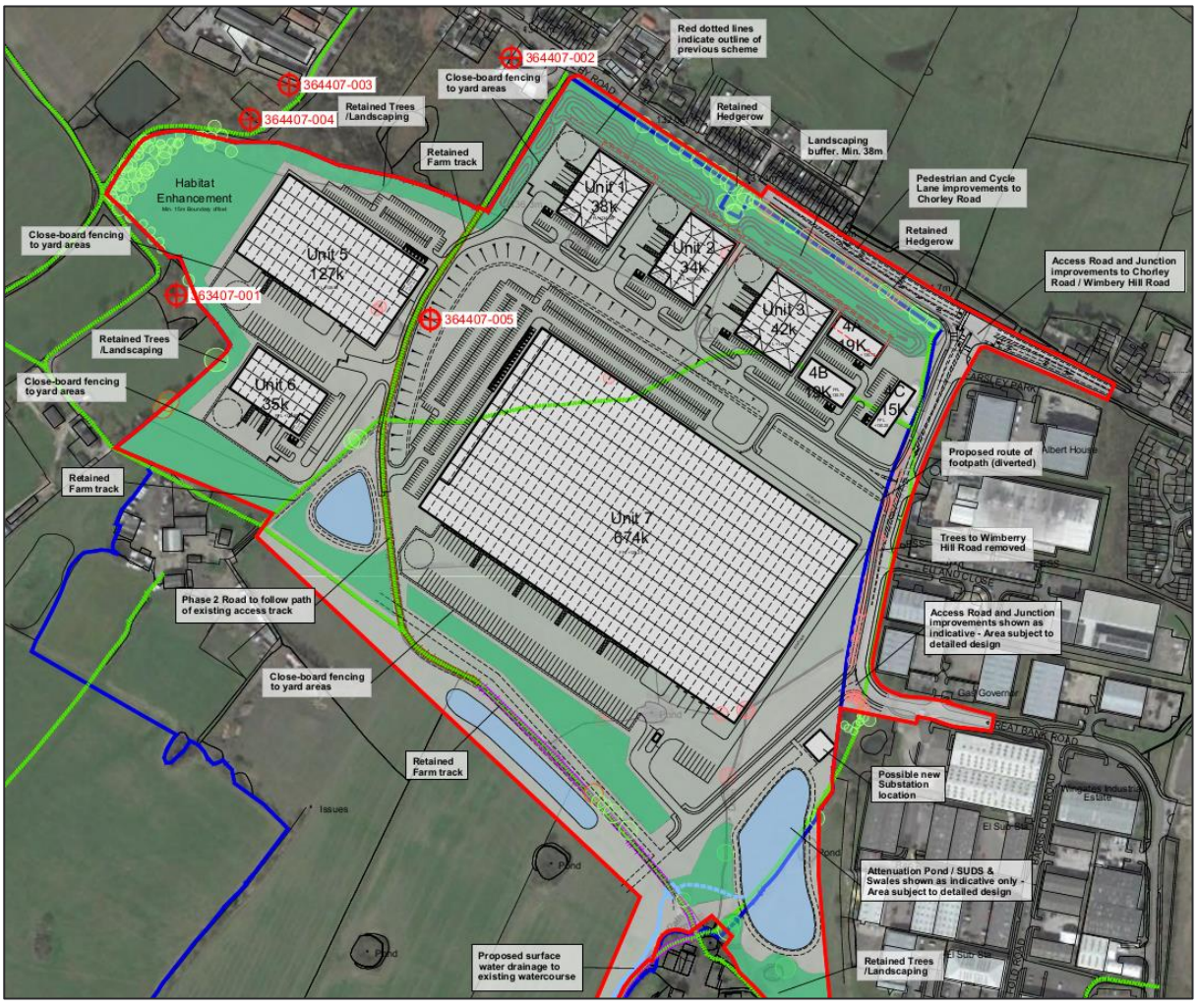
1.1 Terms of reference

In June 2021, Hydrock Consultants Limited (Hydrock) was commissioned by Harworth Estates Property Group Limited (the Client) to undertake site investigation, comprising a ground investigation at land south of Chorley Road, Westhoughton, Bolton, BL5 3LZ.

The site is currently undeveloped agricultural fields split by a gravel access track. Five ponds are present in the eastern field, with drainage ditches in the centre and also the south. A barn is present in the east of the site. The western field contains two ponds in the approximate centre with mature trees in between. An overhead electricity cable transects across the centre of the site from west to east and then from the centre of the site an offshoot transects south offsite. Mature trees are present along the northern boundary and sporadically in the south with localised hedgerows in the south of the site.

The proposed development is to comprise nine commercial units. In the north eastern fields there will be four units (Units 1, 2 ,3, 4A-C) varying in size from 15,777sq ft (square foot) to 42,421sq ft. In the centre and south of the site Unit 7 is the largest proposed unit at 673,523sq ft. In the west there will be two further units (Units 5 and 6) which are proposed to be 35,079sq ft and 127,180sq ft. An extract from the latest proposed masterplan RPS Drawing SK065 Rev F is shown in Figure 1-1.

Figure 1-1: Extract from the current RPS masterplan (ref SK65 Rev F)



As part of the proposed development acoustic bunds will be placed along the northern boundary adjacent to Chorley Road. Three attenuation ponds will be formed in the south of the site. Associated car parking and access roads will surround the units with the main access road from the eastern boundary off Wimberry Hill Road. Habitat enhancement will take place in the west of the site beyond Unit 5. To form the development plateaus for the nine Units, which range from 128.8AOD to 134.6AOD, a cut to fill earthworks operation will be undertaken. The proposed illustrative masterplan (RPS Drawing SK065 Revision F, dated 1st June 2018) is presented Appendix A.

The works have been undertaken in accordance with Hydrock's proposal referenced (C-15592-E-FP-001.P2_Rev A) and the Client's instructions to proceed (emailed dated 16th June 2021).

1.2 Objectives

A Phase 1 Desk Study and Phase 2 ground investigation has previously been completed at the site by RSK. The Hydrock works have been commissioned to provide additional data to assist in clearing planning conditions and to assist with the design of the development. The planning application reference for the development is 04766/18 with permission granted on 21st June 2021. This report relates to the following planning conditions:

Condition 30 (in part)

I. *A methodology for the assessment of the nature and extent of contamination affecting the site (if any) and the potential for off-site migration (if any);*

II. *A site investigation and risk assessment examining potential pollutant linkages identified in the Preliminary Risk Assessment;*

Condition 33 (in part)

Prior to the commencement of development, a scheme of intrusive site investigations to assess the ground conditions and the potential risks posed to the development by past mining activity shall be submitted to and approved in writing by the Local Planning Authority. The scheme shall include:

I. *The submission of a report of findings arising from the further intrusive site investigations, including details of any remedial works for approval for both mine entry and shallow mine workings, if necessary;*

The specific objective of the Hydrock Phase 2 Ground Investigation is:

- to resolve uncertainties identified in the previous Phase 1 Desk Study and Phase 2 ground investigation by refining and updating the current Ground Model, determining geo-environmental and geotechnical site conditions and identifying key contamination risks by updating and finalising the Conceptual Model in accordance with the principles of LCRM;
- to identify geo-environmental mitigation requirements to enable development;
- to assess the risk posed by past coal mining and provide mitigation recommendations;
- to aid in the design of the earthworks required to form the development plateaus; and
- to provide preliminary geotechnical recommendations for design.

1.3 Scope

The scope of the Phase 2 Ground Investigation comprises:

- a review of previous investigations carried out at the site;
- development of a preliminary Ground Model representing ground conditions at the site;
- development of an outline Conceptual Model (oCM), including identification of potential pollution linkages;
- a qualitative assessment of any geo-environmental risks identified; and
- identification of plausible geotechnical hazards.

The scope of the Phase 2 Ground Investigation comprises:

- a ground investigation including trial pitting, windowless sampling, cable percussive boring, rotary open hole drilling, cone penetration testing and light weight deflectometers to:

» obtain data on the ground and groundwater conditions of the site;

» allow collection of samples for geotechnical and chemical laboratory analysis;

» allow geotechnical field tests to be undertaken;

» install gas and groundwater wells;

- gas concentration and groundwater level monitoring;
- gas and groundwater sampling;
- geotechnical and chemical laboratory analysis;
- updating of the preliminary Ground Model;
- preparation of a geotechnical risk register;
- presentation of an initial geotechnical design recommendations;
- formulation of an updated Conceptual Site Model (CM), including identification of plausible pollution linkages;
- completion of a generic quantitative risk assessment of potential chemical contaminants to establish 'suitability for use' under the current planning regime;
- discussion of potential environmental liabilities associated with land contamination (soil, water and gas); and
- identification of outline mitigation requirements to ensure the site is 'suitable for use'.

1.4 Available information

The following documents, reports etc have been provided to Hydrock by Harworth Estates for use in the preparation of this report:

- RSK. August 2017. 'Wingates, Bolton: Preliminary Risk Assessment and Coal Risk Assessment', Ref: 322362-R1 (00);
- RSK. March 2018. 'Wingates, Bolton: Geo-environmental Assessment', Ref: 322362-R02 (01);
- RSK. September 2018. 'Wingates, Bolton: Supplementary Geo-environmental Site Assessment; Ref: 322362-R03 (00);
- RPS. June 2018. 'Wingates, Bolton: Illustrative Masterplan', Ref: SK065.

- The Environmental Partnership. August 2018. 'Land West of Wingates Industrial Estate, Westhoughton: Illustrative Landscape Masterplan, Ref: D6474.02.001B.
- BE Design. September 2018. 'Wingates, Bolton: Detailed Planning Proposed Earthworks Plateaus', Ref: NWK-180009-BED-EX-00-DR-C-0200; and
- BE Design. September 2018. 'Wingates, Bolton: Detailed Planning Proposed Earthworks Sections', Ref: NWK-180009-BED-EX-00-DR-C-0205 to 0209 sheets 1 to 5 to.

The Client has commissioned or obtained assignment of the above documents and Hydrock is entitled to full reliance upon their contents.

1.5 Regulatory context and guidance

The investigation work has been carried out in general compliance with recognised best practice, including (but not limited to) BS 5930:2015, BS 10175:2011+A2:2017 and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

The geo-environmental section of this report is written in broad accordance with BS 10175:2011+ A2:2017, 'Land Contamination: Risk Management' (LCRM, 2019) and the AGS (2006) 'Good Practice Guidelines for Site Investigations'.

The methods used follow a risk-based approach, the first stage of which is a Phase 1 desk study and field reconnaissance, with the potential geo-environmental risk assessed qualitatively using the 'source-pathway-receptor contaminant linkage' concept to assess risk as introduced in the Environmental Protection Act 1990 (EPA, 1990). Potential geotechnical risks are also assessed.

Phase 2 comprises intrusive ground investigation work and testing. The factual information from Phase 1 and Phase 2 are used to develop the Conceptual Model (CM). This CM is based on a ground model of the site physical conditions and an exposure model of the possible contaminant linkages. The CM forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines. This GQRA might lead to more Detailed Quantitative Risk Assessment (DQRA).

Professional judgement is then used to evaluate the findings of the risk assessments and to provide recommendations for the development.

The geotechnical section of this report is prepared in general accordance with BS EN 1997-1+A1: 2013, BS EN 1997-2:2007 and BS 8004:2015. This report constitutes a Ground Investigation Report (GIR) as described in Part 2 of Eurocode 7 (BS EN 1997-2) (EC7). However, it is not intended to fulfil the requirements of a Geotechnical Design Report (GDR) as specified in EC7.

The geo-environmental and geotechnical aspects are discussed in separate sections. Throughout the report the term 'geotechnical' is used to describe aspects relating to the physical nature of the site (such as foundation requirements) and the term 'geo-environmental' is used to describe aspects relating to ground-related environmental issues (such as potential contamination). However, it should be appreciated that this is an integrated investigation and these two main aspects are inter-related. Designers should take all aspects of the investigation into account.

Remaining uncertainties and recommendations for further work are listed in Section 9.0 and Section 10.

Reference to the details of the approach and the methodologies presented in Appendix I.

2. PHASE 1 STUDY (DESK STUDY REVIEW AND FIELD RECONNAISSANCE)

2.1 Introduction

Hydrock has been provided with a Desk Study which covers the subject site and a wider area prepared by others (as detailed in Section 1), RSK, Preliminary Risk Assessment and Coal Risk Assessment, Report Ref: 322362-R1 (00). Hydrock generally agree with the findings of the risk assessments and the following section is a summary of the pertinent information presented in the Desk Study, supplemented by additional information as required. Full reference should be made to the RSK report for detailed information and the full set of desk study information.

Hydrock have undertaken an updated field reconnaissance survey on 28th of April 2021 to visually assess potential geotechnical hazards, contaminant sources and receptors and ensure the site conditions as reported in the desk study are similar to current conditions. The weather during the updated field reconnaissance survey was overcast.

2.2 Site location

The site is located south of Chorley Road and west of Wimberry Hill Road, 1km north west of Westhoughton Railway Station. The National Grid Reference for the centre of the site is 364488E, 407608N.

2.3 Site description

The site is predominantly undeveloped agricultural fields split by a gravel access track with a small barn and associated unspecified tank present in the east. The gravel track transects from north east to south west and splits into two sperate tracks within the south west of the site. There are five ponds in the northern section of the site and two in the south. A drainage ditch transects east from a pond in the centre of the site. A further drainage ditch is present in the south of the site transecting from the eastern boundary towards the southern boundary.

Mature trees are present across the northern boundary and are sporadically present on the southern boundary. Hedgerows are present across the northern and eastern boundary and also locally in the north east and south of the site.

On the site walkover a small area of demolition rubble was noted in the eastern fields, the rubble mainly comprised bricks and concrete.

An overhead electricity cable is present crossing the centre of the site from west to east and from the centre of the site orientating south an offshoot transects offsite.

The eastern field rises from Chorley Road at 132m AOD to a topographical higher plateau at 137m AOD in the approximate centre of the site. The eastern field then slopes from the topographical high point towards the south and south east to 120m AOD. The field west of the gravel track slopes from north east to south west from 136m AOD to 127m AOD.

Offsite, a car maintenance garage is present adjacent to the north west of the site. Wingates industrial estate is adjacent to the east. Westhoughton Caravan Storage Yard is adjacent to the south west. To the south are further undeveloped agricultural fields.

2.4 Site history

Based on the historical maps provided in the RSK report the site is shown to remain predominantly undeveloped. The ponds currently present onsite are recorded on mapping from 1849. Between 1893 and 1929 a mine shaft is present close to the existing gravel track in the centre west of the site. Small unnamed buildings are recorded adjacent to the northern and eastern boundary, presumed to be barns associated with the nearby farm. In 1894 a small area of woodland is shown in the northern section of the site.

Between 1849 and 1894 Albert Colliery and pit is shown 100m north of the site. Also recorded 750m to the north of the site between 1849 and 1929 is New Winnings Coal Pit. Between 1894 and 1929 various coal pits are labelled to the east and south of the site. In 1979 Wingates Industrial estate is shown adjacent to the south east.

2.5 Geology

As shown in Figure 2-1 three historic landfills are recorded onsite, in the north, south and south west of the site and therefore it is likely that localised deep Made Ground will be present in these areas associated with former landfilling operations.

The superficial geology underlying the entire site comprises Glacial Till recorded as sandy gravelly clay. The solid geology comprises the Pennine Lower Coal Measures Formation (mudstone, siltstone and sandstone). Also, part of the Westphalian Coal Measures Group and as shown in Figure 2-2, the Cannel Rock (Sandstone) is likely to be overlying the mudstone of the Pennine Lower Coal Measures Formation in the north of the site.

As shown in Figure 2-2 the Cannel Coal Seam (Ca) outcrops across the north of the site from west to east and is dipping approximately 2° south west. Underlying the Cannel Coal Seam, the older King Coal Seam (Kg) sub crops offsite approximately 50m to the north, due to the dip direction of seams in the area the King Coal Seam will likely be present underlying the site. Two faults are present in the area, the first offsite 15m north and the second encroaches onto the north east corner of the site trending north west to south east with the downthrow on the northeast side. Given the presence of the King Seam between the two faults it may be absent underlying the site. The fault in the north east corner of the site has resulted in disturbance to the Cannel Coal Seam and it could therefore be present on the downthrow side of the fault in the north east corner of the site.

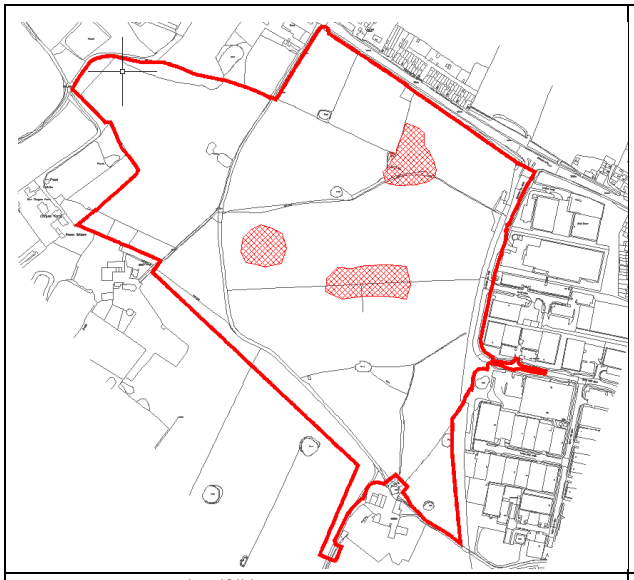


Figure 2-1: Historic landfill locations (Based on data from Landmark)

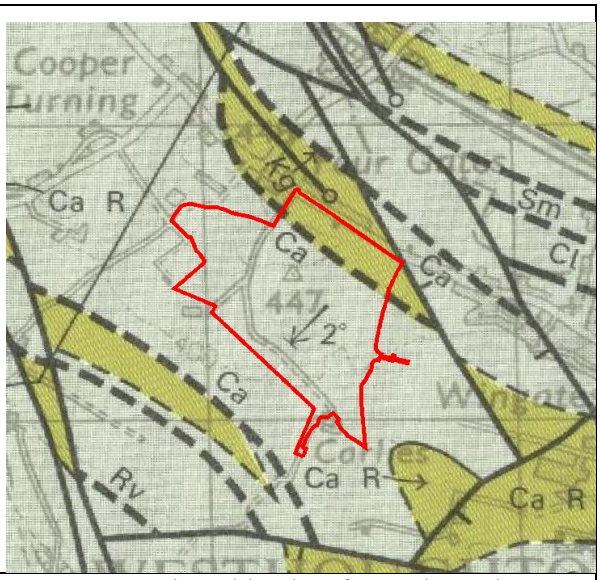


Figure 2-2: BGS Archive Solid Geology of Wigan Sheet 84 (1:50, 000)

Outcrop of the Cannel Seam and an unnamed seam, assumed to be the King seam, southwest of the site suggest that the underlying strata forms a synclinal structure with the axis adjacent to the southwest boundary.

2.6 Hydrogeology

The Glacial Till is classed by the Environment Agency as a Secondary Undifferentiated Aquifer. The Pennine Lower Coal Measures Formation and Cannel Rock are classified as Secondary A aquifers.

Shallow groundwater possibly at the Made Ground and Glacial Till interface will likely flow in a south and south east direction towards the unnamed drainage ditches. There could also be shallow perched groundwater within granular soils present in the landfilled Made Ground.

The presence of the low permeability Glacial Till will inhibit vertical connection between shallow groundwater at the Made Ground/Glacial Till interface and deeper groundwater within the Pennine Lower Coal Measures Formation and Cannel Rock.

It is likely that shallow groundwater onsite is in hydraulic continuity with the surface water within the ponds onsite. The ponds onsite will likely be directly underlain by the Glacial Till.

There is no recorded groundwater abstraction wells within 900m of the site and the site does not overlie a Groundwater Source Protection Zone.

2.7 Hydrology

There are seven ponds present onsite. A drainage ditch trends north east out of the pond in the approximate centre of the site and then is likely culverted in the north east of the site. A drainage ditch transects from the eastern boundary to the south of the site. This drainage ditch is likely flowing in a south eastern direction towards Marsh Brook located offsite. A drainage ditch appears to offshoot south west from a pond in the south of the site and then likely culverts offsite. Surface water within this ditch appears to be flowing south west and will discharge into Borsdane Brook offsite.

Reference to the Environment Agency web site shows the site is located within the catchment of the Glaze, with the specific river water body being the Hey/Borsdane Brook. The current (2016 cycle 2)

overall status under the Water Framework Directive is 'moderate'. The reasons for moderate status included dissolved oxygen concentrations and physio-chemical quality elements.

There are two surface water abstractions within 1500m of the site boundary and both are used for spray irrigation at a golf course.

2.8 Flood risk

The desk study information indicates the proposed development is in Flood Zone 1 (with a low probability of flooding from rivers or the sea).

No further consideration of flood risk is undertaken in this report. Specialist flood risk advice should be sought with regard to drainage and flooding.

2.9 Coal Mining

A review of the CON29M for the site and wider area referenced 128614289-2 provided in the RSK report states that the site is in an area which could be affected by underground mining in six seams including shallow depth to 380m bgl. The relevant seams likely include youngest to oldest (Cannel, King, Ravine, Yard, Half Yard and Cockloft).

The RSK report shows two available mine abandonment plans for site named the Yard Coal Workings and Arley Mine from Scot Lane Collieries, Westhoughton. Both show workings within the Yard Coal Seam at 112m bgl and the Arley Mine 232m bgl. However, given the depths to the Yard and Arley Coal Seams, workings within these seams are unlikely to pose a risk to future development. The two seams which are likely to be at shallow depth and therefore within influencing distance of the surface, include the Cannel and King Coal Seam.

There is one mine entry (364407-005) present in the centre west of the subject site adjacent to the existing gravel access track. The abandonment plans indicate that this shaft is associated with workings within the King coal seam at approximately 45m below ground level. Two further mine entries (364407-002 and 36407-001) are recorded up to 20m from the site boundary associated with the Arley mine and King mine respectively. There are no records for treatment undertaken on 364407-005, 364407-002 and 36407-001.

The site is not in an area where an opencast mine is present within 200m of the site boundary and there are no records of mine gas within the area. Seven damage claims offsite to the south are recorded within the area and all were investigated by the Coal Authority and subsequently rejected as the damage was not caused by subsidence from shallow coal workings.

The coal authority viewer shows a high risk development area across the centre off the site associated with potential workings in the Cannel Coal Seam. There is also a high-risk development area surrounding mine entry 364407-005 adjacent to the gravel access track. Probable shallow coal mine workings are also indicated within the Cannel Coal Seam. No probable shallow coal mine working is indicated in the north of the site therefore the presence of the faults offsite to the north could be resulting the absence of the King Coal Seam.

Given the presence of 364407-005 mine entry in the centre west of the site with no records of treatment undertaken and the outcropping and potentially shallow Cannel Seam across the north/centre of the site the risk posed to the site by past coal workings is considered high.

2.10 Natural ground instability

Trees and hedges are present around the site boundaries with sporadic trees across the site. Cohesive deposits of the Glacial Till may be affected by potential for shrink-swell ground movements in clays as a result of changes in moisture content from removal or growth of trees.

There are backfilled historical features that represent a geotechnical risk due to the presence of heterogenous Made Ground, including the mine entry and three landfills.

2.11 Waste management

There are three historic landfills present onsite shown in Figure 2-1, which are recorded as operated Mr J Langford and first accepted waste including inert, industrial, commercial and household from August 1994. There are no records of when the landfills last accepted waste, however the environmental report notes them as inactive. The EA waste reference for the former landfills is 53419.

The environmental report records fourteen areas to the west of the site presumed to be infilled water features (former ponds). There are four other additional areas offsite where ground has been infilled, these are located 35m and 52m east, 35m west and 41m south of the site.

2.12 Regulatory information

There are two discharge consent within 250m of the site boundary. They include the discharge of final treated effluent. One consent at 79m south east is at a domestic property with no receiving water noted. The second consent is 124m west of the site at a domestic property with receiving water recorded as Cunningham brook, a tributary of Borsdane Brook.

There are four pollution incidents recorded within 250m of the site boundary. At 15m west of the site other pollutants run off, 81m west agricultural run-off, 122m south sewage from a wrong connection and 165m west agricultural run off all to the receiving water of Cunningham Brook. All incidents are recorded as Category 3 minor incidents and are not considered to have significantly impacted the subject site.

2.13 Natural soil chemistry

The previous desk study did not identify any significantly elevated naturally occurring elements that may present a risk to future site users.

2.14 Radon

The previous desk study indicates that the site is in a Radon Affected Area where recorded radon levels in 1-3% of homes are above the action level but no radon protection measures are required for new buildings at this location in line with current guidance. However, consideration should be given to fitting basic protection measures on the ‘as low as reasonably practicable’ principle in view of advice given to householders and the legal responsibilities of rental landlords and employers with commercial properties.

2.15 Unexploded ordnance (UXO)

The previous desk study indicates a very low risk and no further assessment is required with regard to UXO in relation to ground investigation. Further assessment may be considered prudent for construction activities.

3. OUTLINE CONCEPTUAL MODEL

3.1 Introduction

The outline Conceptual Model (oCM) incorporates evidence from the site walkover, the Desk Study and previous investigations carried out at the site. The formulation of an outline Conceptual Model is a key component of the LCRM methodology. The oCM incorporates a ground model of the site physical conditions and an exposure model of the possible contaminant linkages; it forms the basis for Generic Quantitative Risk Assessment (GQRA) in accordance with current guidelines.

3.2 Ground model

The preliminary ground model provides an understanding of the ground conditions and is the basis for preparing the preliminary geotechnical hazard assessment (Section 3.3) and the preliminary geo-environmental exposure model (Section 3.4).

3.3 Geotechnical hazard identification

3.3.1 Context

The preliminary geotechnical hazard identification has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622.

The following section sets out the identified geotechnical hazards and the development elements potentially affected (see Table J.1 in Appendix G for further information).

3.3.2 Plausible geotechnical hazards

Plausible geotechnical hazards identified at the site are:

- Uncontrolled Made Ground (variable strength and compressibility).
- Soft / loose compressible ground (low strength and high settlement potential).
- Shrinkage / swelling of the clay fraction of soils under the influence of vegetation.
- Variable lateral and vertical changes in ground conditions.
- Attack of buried concrete by aggressive ground conditions.
- Obstructions.
- Shallow groundwater.
- Changing groundwater conditions.
- Loose Made Ground, leading to difficulty with excavation and collapse of side walls.
- Earthworks – poor bearing capacity of new fill.
- Earthworks – unsuitability of site won material to be reused as fill.
- Mining.

3.3.3 Potential development elements affected

Development elements potentially affected by geotechnical hazards are:

- Buildings – foundations.

- Buildings – floor Slabs
- Roads and pavements.
- Services.
- Landscape areas.
- Construction staff, vehicles and plant operators.
- Concrete below ground.
- Earthworks control, inability to place and compact fill.
- Insufficient fill to complete earthworks.

Health and safety risks to site Contractors and maintenance workers have not been assessed during these works and will need to be considered separately during design.

The above plausible geotechnical hazards and development elements affected have been carried forward for investigation and assessment. The investigation is presented in Section 4 and the assessment is presented in Section 6.

3.4 Geo-environmental exposure model

3.4.1 Context

The preliminary exposure model is used to identify geo-environmental hazards and to establish potential pollution linkages, based on the source-pathway-receptor (SPR) approach.

A viable pollution linkage requires all the components of an SPR to be present. If only one or two are present, there is no linkage and no further assessment is required.

3.4.2 Potential contaminants

For the purpose of this assessment the potential contaminants have been separated according to whether they are likely to have originated from an on-site or off-site source.

3.4.2.1 Potential on-site sources of contamination

- Landfilled waste including inert, household, commercial and industrial, possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons. (S01).
- Leachate from landfilled waste including inert, household, commercial and industrial possibly including elevated concentrations of metals, metalloids and PAHs. (S02).
- Ground gases (carbon dioxide and methane) from organic materials in the landfilled waste or backfill above the onsite mine shaft (S03).
- Made Ground associated with the backfilling above the mine shaft in the west of the site possibly including elevated concentrations of metals, metalloids, asbestos fibres, Asbestos Containing Materials, PAH and petroleum hydrocarbons. (S04)
- Hydrocarbon fuels from the general spillage, together with uncontrolled disposal and spillage from waste receptacles potentially stored within the barn in the east of the site. (S05)

- Hydrocarbon vapours from potential petroleum hydrocarbon spillages/leaks from uncontrolled disposal and spillage from waste receptacles at the barn in the east of the site. (S06)

3.4.2.2 Potential off-site sources of contamination

- Hydrocarbon fuels or VOCs from the general spillage, together with uncontrolled disposal and spillage from waste receptacles potentially stored at the car garage adjacent to the north west or caravan storage yard immediately to the south (S07)
- Hydrocarbon vapours from potential VOC and petroleum hydrocarbon spillages/leaks associated with the adjacent garage to the north west or caravan storage park to the south west (S08).
- Ground gases (carbon dioxide and methane) from organic materials in the backfilled ponds in vicinity of the site boundary (S09).

3.4.3 Potential receptors

The following potential receptors in relation to the proposed land use have been identified.

- People (neighbours, site end users) (R01).
- Development end use (buildings, utilities and landscaping) (R02).
- Groundwater: Secondary A aquifer status of the Pennine Lower Coal Measures Formation (PLCM) or Cannel Rock (R03).
- Surface water: on-site drainage ditch and ponds (R04).

3.4.4 Potential pathways

The following potential pathways have been identified.

- Ingestion, skin contact, inhalation of dust and outdoor air by people (P01).
- Methane or carbon dioxide ingress via permeable soils and/or construction gaps (P02).
- VOC and petroleum hydrocarbon vapour ingress via permeable soils and/or construction gaps (P03).
- Root uptake by plant (P04).
- Migration of contaminant via leachate migration through the unsaturated zone in Made Ground or Glacial Till (P04).
- Surface water, via drainage discharge (P05).
- Surface water via base flow from groundwater (P06).

Health and safety risks to site development contractors and maintenance workers have not been assessed as part of this study and will need to be considered separately.

The above sources, pathways and receptors have been considered as part of the Preliminary Risk Assessment in accordance with LCRM (2019), are considered to be plausible in the context of this site and have been carried forward for investigation and assessment. The investigation is presented in Section 5 and the assessment is presented in Section 7. An assessment of the Source – Pathway – Receptor linkages is undertaken following the assessment (Section 7) and is presented in Appendix H (Table K.1).

4. GROUND INVESTIGATIONS

4.1 Investigation rationale

The ground investigation rationale was based on the findings of the preliminary risk assessment and is summarised in Table 4-1. The ground investigation was designed to fill in data gaps identified in the previous RSK investigations to inform elements of the detailed design.

Table 4-1: Investigation rationale

Location	Purpose
General coverage	
HYDCP01 – HYDCP31	To assess deeper ground conditions and to allow SPTs/U100s to be undertaken. To allow collection of samples for geotechnical characterisation. Installation of gas and groundwater monitoring and sampling wells.
HYDCPT01 – HYDCPT54	To investigate the strength profile of the Glacial Till and the depth to rockhead.
HYDTP01 – HYDTP33	To assess shallow ground conditions. To allow collection of samples for geotechnical and contamination testing. To take in-situ hand shear vane tests to inform the strength profile of superficial deposits.
HYDTP34 – HYDTP39	Undertaken in the recently acquired southern portion of land for the purposes of due diligence. To assess shallow ground conditions. To allow collection of samples for contamination testing.
HYDWS01 – HYDWS11	To assess shallow ground conditions and to allow SPTs to be undertaken. To allow collection of samples for geotechnical characterisation. Installation of gas and groundwater monitoring and sampling wells.
LWD's	To determine subgrade stiffness values for road and pavement design.
Mining	
RO01 – RO20	To target coal seams and establish presence/absence of workings beneath the site.
RO101 – RO117	To target the Cannel seam and establish presence/absence of workings beneath the site.
Areas of suspected landfill	
HYDTT01 – HYDTT18	To investigate the presence/absence of tipped material, delineate the extent of suspected landfill areas, and to allow collection of samples for contamination testing.

4.2 Constraints

Several areas of ecological interest were identified by an ecologist prior to the ground investigation. Exploratory locations were moved accordingly to provide satisfactory clearance from these areas, and an ecological watching brief was present during the setting out of exploratory holes to confirm the positions were acceptable.

An archaeological watching brief was also present on site during the trial pitting.

Whilst Hydrock understood that the entire site could be investigated, upon mobilisation, access to 'field 6' was prevented by the tenant farmer. However, access was permitted the following week to field 6.

4.3 Site works

The main ground investigation fieldwork took place between 24th May and 18th June 2021 and an additional investigation took place between 1st and 9th November 2021, and is summarised in Table 4-2. The ground investigation locations were surveyed in using a topographic survey quality GPS and are shown on the Exploratory Hole Location Plan's (Hydrock Drawing 15592-HYD-XX-XX-DR-GE-0001-S2-P02; 15592-HYD-XX-XX-DR-GE-0006; and 15592-HYD-XX-XX-DR-GE-0009) in Appendix A.

The logs, including details of ground conditions, soil sampling, *in situ* testing and any installations, are also presented in Appendix B. .

Table 4-2: Summary of site works

Activity	Method	No.	Depth (m bgl)	In situ tests	Notes (e.g. installations)
June 2021					
Drilling, Pitting and Probing					
Boreholes	Cable percussive	31	5.00 – 11.65	SPT	63mm HDPE wells with gas taps in 17 holes.
	Rotary open hole	20	40.00	N/A	Water Flush drilling medium. 63mm HDPE wells with gas taps in two holes.
	Windowless sampler	11	3.45 – 4.45	SPT	63mm HDPE wells with gas taps in 11 holes.
Trial pits	Machine (13T excavator)	33	2.20 – 3.80	Hand shear vane (HSV)	Backfilled with arisings on completion.
Trial Trenches		18	0.80 – 4.80	N/A	Backfilled with arisings on completion.
Probes	Static Piezocone Penetration Tests (CPTu)	56	2.38 - 13.16	Cone Resistance, q_c, Sleeve Friction, f_s, Porewater Pressure in the shoulder position, u_2, Inclination in X and Y axes.	N/A
Other in situ testing					
Lightweight Deflectometer (LWD)	Hand Held	14	0.15 – 0.60	Subgrade stiffness and equivalent California Bearing Ratio (CBR)	N/A
November 2021					
Drilling and Pitting					
Boreholes	Rotary open hole	17	24.00 – 25.00	N/A	Water Flush drilling medium. Holes backfilled with cement on completion.
Trial pits	Machine (6T excavator)	6	1.80 – 2.00	N/A	Backfilled with arisings on completion.

Wells for monitoring groundwater levels and ground gas concentrations, were installed in 17 of the cable percussion boreholes, 11 of the windowless sampler holes and two of the rotary open holes. A

summary of the monitoring well installations is presented in Table 4-3 and the location is shown on drawing 15592-HYD-XX-XX-DR-GE-0002-S2-P1 Appendix A.

Table 4-3: Summary of monitoring installations

Location	Ground level (m OD)	Standpipe diameter	Screen top and base depth (m bgl)	Screen top and base elevation (m OD)	Strata targeted
HYDCP01	132.83	50	1.00 - 7.50	131.83 - 125.33	Glacial Till
HYDCP04	133.48	50	8.10 - 9.60	125.38 - 123.88	PLCM
HYDCP05	133.27	50	1.00 - 7.90	132.27 - 125.37	Glacial Till
HYDCP06	136.52	50	1.00 – 10.00	135.52 - 126.52	Glacial Till
HYDCP07	136.61	50	1.00 – 7.00	135.61 - 129.61	Glacial Till
HYDCP11	134.45	50	1.00 - 6.80	133.45 - 127.65	Glacial Till
HYDCP12	137.49	50	1.00 - 6.60	136.49 - 130.89	Glacial Till
HYDCP13	132.74	50	6.30 – 8.00	126.44 - 124.74	PLCM
HYDCP15	133.7	50	1.00 - 3.50	132.70 - 130.20	Glacial Till
HYDCP17	136.16	50	1.00 - 5.50	135.16 - 130.66	Glacial Till
HYDCP18	131.64	50	1.00 - 6.50	130.64 - 125.14	Glacial Till
HYDCP19	134.47	50	1.00 – 7.00	133.47 - 127.47	Glacial Till
HYDCP20	129.28	50	4.80 – 6.00	124.48 - 123.28	PLCM
HYDCP22	129.9	50	1.00 – 7.00	128.90 - 122.90	Glacial Till
HYDCP25	127.13	50	7.00 - 8.50	120.13 - 118.63	PLCM
HYDCP26	124.73	50	1.00 – 4.00	123.73 - 120.73	Glacial Till
HYDCP27	125.1	50	1.00 – 5.00	124.10 - 120.10	Glacial Till
HYDCP30	120.16	50	7.00 – 8.00	113.16 - 112.16	PLCM
HYDCP31	119.53	50	1.00 – 10.00	118.53 - 109.53	Glacial Till
HYDWS01	131.47	50	1.00 – 3.00	130.47 - 128.47	Glacial Till
HYDWS02	134.42	50	1.00 – 3.00	133.42 - 131.42	Glacial Till
HYDWS03	136.07	50	1.00 – 3.00	135.07 - 133.07	Glacial Till
HYDWS04	134.91	50	1.00 – 2.00	133.91 - 132.91	Glacial Till
HYDWS05	132.7	50	1.00 - 3.50	131.70 - 129.20	Glacial Till
HYDWS06	135.29	50	1.00 - 3.50	134.29 - 131.79	Glacial Till
HYDWS07	134.13	50	1.00 - 3.80	133.13 - 130.33	Glacial Till
HYDWS08	131.86	50	1.00 – 2.00	130.86 - 129.86	Glacial Till
HYDWS09	131.16	50	1.00 - 3.50	130.16 - 127.66	Glacial Till
HYDWS10	131.92	50	0.80 - 3.80	131.12 - 128.12	Glacial Till
HYDWS11	119.24	50	1.00 – 3.00	118.24 - 116.24	Glacial Till
RO11	136.68	50	10.00 - 22.50	126.68 - 114.18	PLCM
RO14	134.08	50	10.00 – 22.00	124.08 - 112.08	PLCM

4.4 Geo-environmental testing

4.4.1 Sampling strategy and protocols

Exploratory hole positions were determined by reference to the site conditions and uncertainties identified in the Initial Conceptual Model.

The three areas of suspected landfill were targeted for specific investigation, but a reasonably even spacing was used for the remainder of the site.

No specific sampling statistics or grid were utilised in this instance. Exploratory locations were positioned to infill data gaps in the previous investigation.

Samples were taken, stored and transported in general accordance with BS 10175:2011+A2:2017.

4.4.2 *Geo-environmental monitoring*

Gas monitoring boreholes have been monitored on six occasions. The results are presented in Appendix D Monitoring as part of this commission is now complete. However further monitoring will be required following completion of earthworks.

4.4.3 *Geo-environmental laboratory analyses*

The chemical test certificates for testing undertaken by Hydrock are provided in Appendix E. Wherever possible, UKAS and MCERTS accredited procedures have been used.

The geo-environmental analyses undertaken on soils in Hydrock investigation are summarised in Table 4-4.

Table 4-4: Geo-environmental analyses of soils or other solids

Determinand Suite	Topsoil	Made Ground	Glacial Till
Hydrock minimum suite of determinands for solids*	9	9	13
Speciated aliphatic and aromatic banding Total petroleum hydrocarbons by HS-GC/MS and GC/FID (Hydrock Tier 2 TPH Suite)	-	8	-
Volatile organic compounds (VOC target list plus TIC) by HS-GC/MS	-	4	-
Semi-volatile organic compounds (SVOC target list plus TIC) by GC-MS	-	4	-
*Hydrock minimum soil suite comprises: As, B (water soluble), Be, Cd, Cr (total), Cr (VI), Cu, Hg, Ni, Pb, S (elemental), Se, V, Zn, cyanide (total), sulfide, pH, asbestos fibres, speciated polynuclear aromatic hydrocarbons (PAH, by GC-FID), total phenols and fraction of organic carbon			

The soils chemical test data (Hydrock data) are interpreted and assessed in Sections 7.0 and Section 8.0.

4.5 Geotechnical testing

4.5.1 *Geotechnical laboratory testing*

The geotechnical tests undertaken by Hydrock are summarised in Table 4-5 and the test certificates are provided in Appendix C. Wherever possible, UKAS accredited procedures have been used.

Table 4-5: Summary of sample numbers for geotechnical tests

Test	Glacial Till
Natural moisture content	44
Atterberg limits	27
Particle size distribution (wet sieve)	8

Test	Glacial Till
Sulfate and aggressive chemical environment classification for buried concrete classification (full BRE SD1 suite)	24
Single stage undrained triaxial compressive strength	25
One dimensional oedometer consolidation	5
Optimum Moisture Content / Maximum Dry Density Relationship (2.5kg rammer), with hand shear vane at each compaction point	7
Remoulded California Bearing Ratio at natural moisture content	8
Remoulded undrained triaxial shear strength at natural moisture content	4
Particle density	8
Effective Stress - Consolidated Undrained Triaxial test & porewater pressure	2

The geotechnical test data are summarised in Section 5.5 and interpreted in Section 6.

5. GROUND INVESTIGATION RECORDS AND DATA

5.1 Physical ground conditions

5.1.1 Summary of strata encountered

The following presents a summary of the properties of the ground and groundwater conditions encountered, based on field observations, interpretation of the field data and laboratory test results, taking into account drilling, excavation and sampling methods, transport, handling and specimen preparation.

All relevant data from the Hydrock investigation discussed in Section 4 as well as any relevant data from the previous RSK investigations noted in Section 1.4 and discussed in Section 2 are used from this point forward. The exploratory holes completed by RSK are shown along with the Hydrock exploratory holes on drawing 15592-HYD-XX-XX-DR-GE-0006 in Appendix A.

Details of the Hydrock ground investigation works are provided in the logs in Appendix B, a summary of the ground model which includes the Hydrock investigation data and previous RSK investigation data, is presented in Table 5-1 and the individual strata are described in the sections below. Cross-sections (reference 15592-HYD-XX-XX-M2-GE-0004) and contour plots (reference 15592-HYD-XX-XX-DR-GE-0007) are presented in Appendix A.

Table 5-1: Strata encountered

Stratum	Depth to top (m bgl)	Depth to base (m bgl)	Thickness (m) (range)	Thickness (m) (average)
General Made Ground	0.00	0.40 – 1.80	0.40 – 1.80	0.52
Landfill material	0.00	0.20 - >4.80	0.20 - >4.80	2.00
Topsoil	0.00	0.10 - 1.00	0.10 - 1.00	0.42
Peat*	2.00	2.70	0.70	-
Glacial Till	0.00 – 4.20	1.80** – 11.20	1.20 – 10.30	6.27
Pennine Lower Coal Measures	1.80** – 11.20	Not proven	Not proven	Not proven

*Peat only encountered at one location (RSK-TP52)
**considered to be erroneously recorded. Shallowest depth is 3.00m bgl

5.1.2 General Made Ground

General Made Ground was encountered at a total of 14 locations to depths ranging between 0.40 – 1.80m bgl.

At 12 of these locations the General Made Ground is encountered to maximum depths of 0.40m bgl. sporadically across the site. This material is considered to be topsoil surface material with occasional inclusions of anthropogenic materials including brick, glass and concrete.

The Made Ground at these locations can generally be described as dark brown sandy gravelly silt with some fine rootlets and a low cobble content of brick. Gravel is angular to subrounded fine to coarse of sandstone, concrete, and brick fragments.

In HYD-CP18 located in the north east of the site, adjacent to the barn structure, the Made Ground was encountered to 1.80mbgl and is described as tarmac, brick, concrete fill (drillers description).

In RSK-R09 located in the west of the site the Made Ground was encountered to 1.30m bgl and is described as soft yellowish brown gravelly sandy clay with sandstone, limestone and brick.

5.1.3 *Landfill material*

Landfill material was encountered in a total of 26 targeted locations to depths ranging between 0.20 - >4.80m bgl. with an average thickness of 2.0m at the locations in which the base proven. A contour plot of the depth of Made Ground based on the investigation and the known location of the landfills is shown in Figure 5-1.

Northern Landfill

Hydrock investigated the northern landfill, specifically with trial trenches TT01 – TT06, in which landfill material was encountered in four of the six locations (TT02 – TT05), and was absent in both TT01 and TT06. The landfill material was encountered to depths between 0.30m and >4.80m bgl (TT03)

RSK investigated the northern landfill with TP26, TP27, TP57, CP06, WS02 and WS03, in which landfill material was encountered in three of six locations (TP57, WS02 and WAS03). The landfill material was encountered to depths between 0.70m and 4.20m bgl (WS02).

The material encountered in the northern landfill can generally be described as very soft dark grey and brown slightly clayey slightly sandy gravelly silt or clay with a low to medium cobble content of brick, with bundles of hay, ash, wood, metal, rebar, plastic bags and plastic fragments and glass. Gravel is angular to subrounded fine to coarse of sandstone, coal, concrete, and brick fragments. A strong organic odour from the material was noted.

Central west landfill

Hydrock investigated the central west landfill specifically with trial trenches TT15 – TT18, with landfill material encountered at each location to depths ranging between 0.60 – 1.60m bgl.

RSK investigated the central west landfill with TP17, TP18 and CP04 with landfill material encountered at each location to depths ranging between 0.90 – 2.60m bgl.

The material encountered in the central west landfill can generally be described as soft to firm brown sandy gravelly clay with a medium cobble content of sandstone, brick, and tarmacadam, with metal, plastic, timber, carpet fabric, glass and rare pieces of burnt wood. Gravel is angular to subrounded fine to coarse of siltstone, coal, and brick fragments

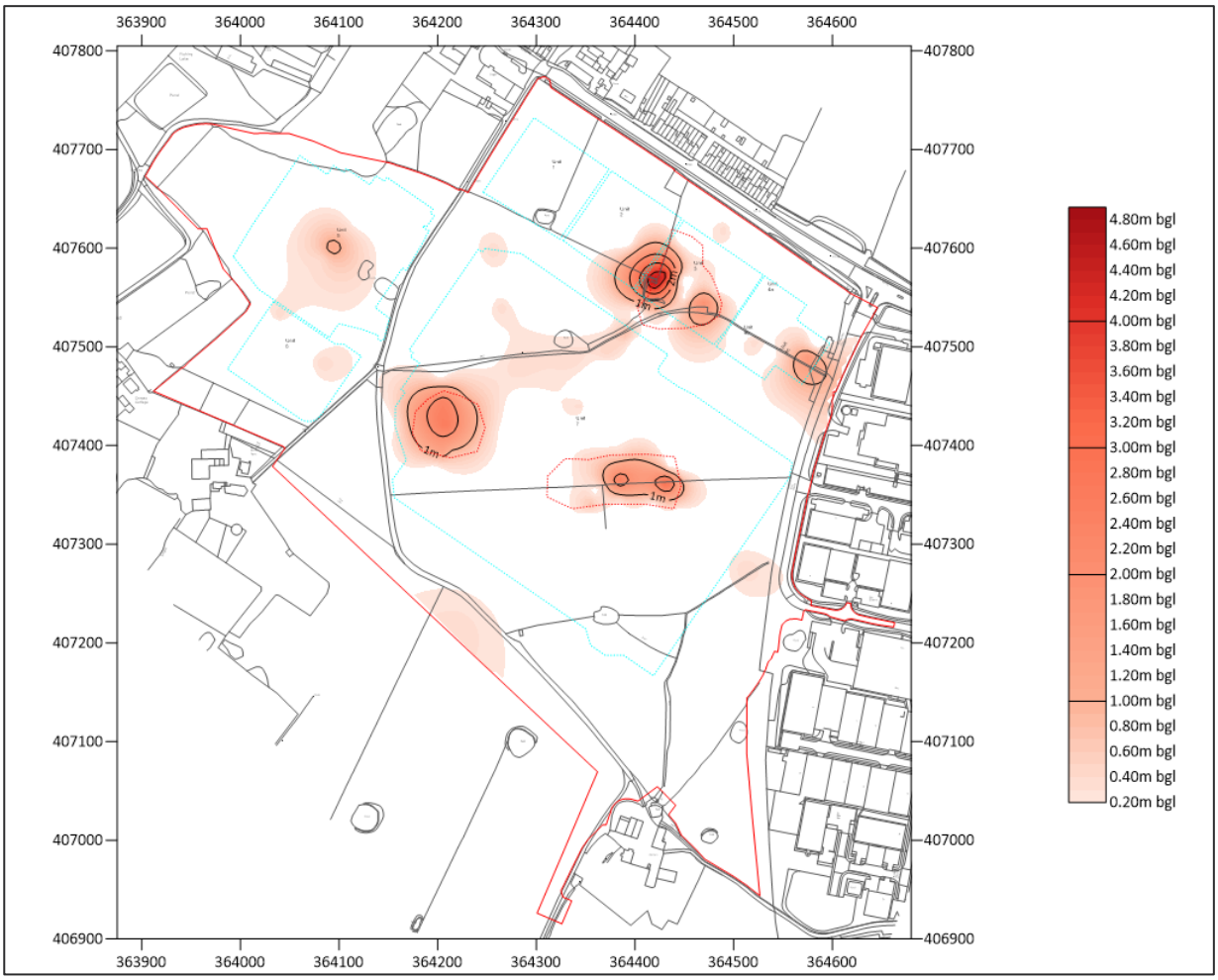
Central landfill

Hydrock investigated the central landfill specifically with trial trenches TT07 – TT14, with landfill material encountered in TT07, TT08, TT09, TT10, TT12 and TT13 (absent in TT11 and TT14). The landfill material was encountered to depths ranging between 0.20 – 0.80m bgl.

RSK investigated the central landfill with TP19, TP21, CP07, WS08 and WS09, with landfill material encountered in only TP21 and CP07 to depths ranging between 2.60 - 3.20m bgl.

The material encountered in the central landfill can generally be described as dark brown slightly sandy slightly gravelly silt or sandy gravelly clay with a low boulder content and some fine rootlets. Gravel is angular to subangular fine to coarse of sandstone, coal, brick and rare ceramic fragments.

Figure 5-1: Contour plot showing the base of Made Ground (m bgl) includes Hydrock and RSK data. Three landfill areas are also outlined in red.



5.1.4 Topsoil

Topsoil material was encountered at a total of 117 locations ranging to depths between 0.10 and 1.00m bgl. with an average thickness of 0.42m.

Topsoil thickness cannot be zoned to one area of the site, and appears to be thicker sporadically in some areas at the site perimeter or in the proximity to hedgerows.

The topsoil material can generally be described as dark brown slightly sandy slightly gravelly silt with rootlets or soft dark brown slightly sandy clay with occasional rootlets.

5.1.5 Peat

Peat was encountered in one location (RSK-TP52) in the north of the site during the RSK investigation at a depth of 2.00m extending to 2.70m bgl.

The peat is recorded as underlying soft yellow sandy clay, and is described as plastic very low strength blackish brown sandy peat, with strong organic odour and frequent plant matter.

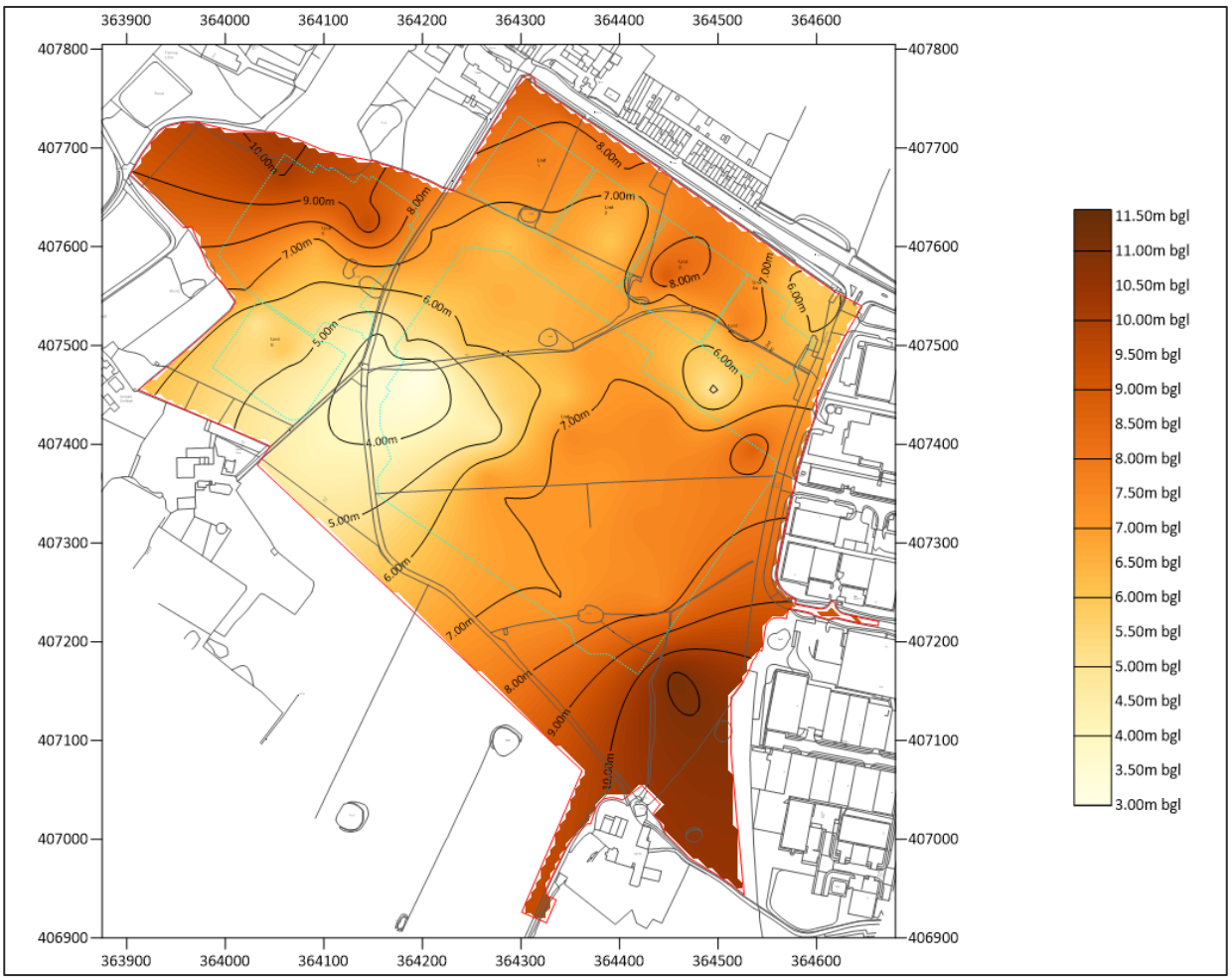
It is noted that RSK-TP52 is positioned adjacent to a hedgerow field boundary in the north field, as such considered possible that a drainage ditch may have once been located in this area, resulting in the accumulation of organic matter. Peat has not been encountered in any other locations on site.

5.1.6 Glacial Till

Glacial Till was encountered at 170 locations with the top of the strata encountered between ground level and 4.20m bgl. and is found to extend to depths between 1.80m bgl and 11.20m bgl, with an average thickness of 6.27m. However, where the base of the Glacial Till was recorded at 1.80m bg it is inconsistent with the surrounding boreholes, which record the Glacial Till at around 6.00 to 7.00m bgl. On this basis, the ground modelling has removed this anomaly.

Glacial Till is thickest in the northwestern portion of the site typically ranging between 6.0m to 10.0m thick. The Thickness of the Glacial Till is reduced in the centre west of the site (near Reeves Farm) ranging between 3.0m to 4.0m thick. The Glacial Till thickness then increases in the southeastern portion of the site, typically ranging between 7.0m to 10.0m thick. The variation in thickness of the Glacial Till is illustrated in Figure 5-2.

Figure 5-2: Depth to base of Glacial Till (m bgl) including RSK and Hydrock Data



The Glacial Till is typically defined by the following two layers:

- Upper 2.0 – 3.0m: Soft to firm light brown mottled orange and grey slightly sandy slightly gravelly clay. Gravel is angular to subangular, fine to medium of sandstone and coal fragments.

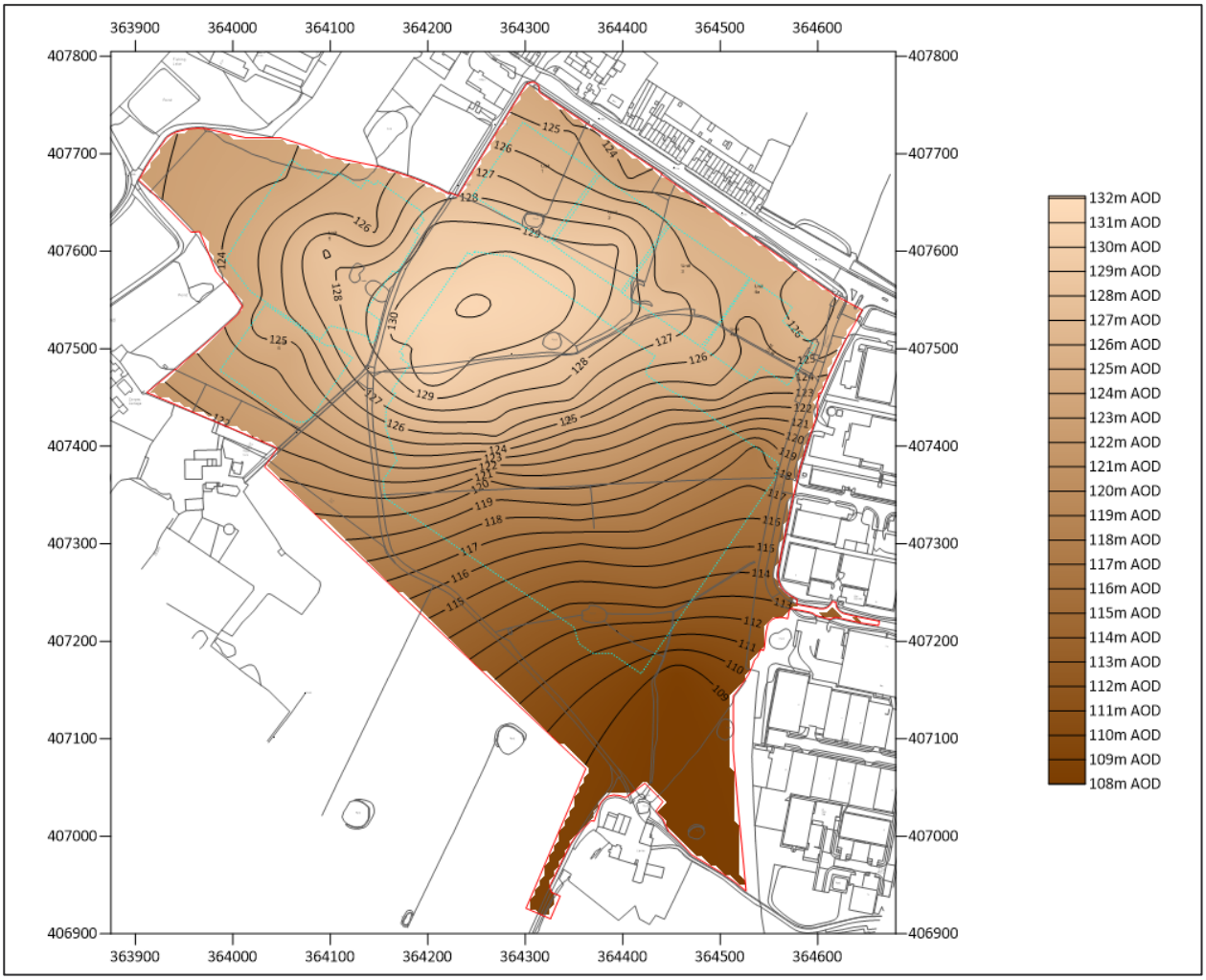
- Below 3.0m: Firm becoming stiff brown/grey mottled orange slightly sandy gravelly clay. Gravel is angular to subrounded, fine to coarse of mudstone, siltstone, sandstone and rare coal fragments. Typically becoming stiff at 4.0- 5.0m bgl.

5.1.7 *Pennine Lower Coal Measures*

The Pennine Lower Coal Measures formation (PLCM) was encountered in a total of 60 borehole locations, with the top of the strata encountered between 3.00m (HYD-RO17) at its shallowest to 11.20m bgl (HYD-CP31) at its deepest in the southeast of the site. The average depth to the top of the PLCM is 6.84m bgl.

The rockhead level (top of PLCM) ranges between a highpoint of around 131mAOD in the north of the site and reduces to a low point of 108mAOD in the southern corner of the site as shown in Figure 5-3. The rockhead level generally follows the site topography.

Figure 5-3: Level of Rockhead (mAOD) including RSK and Hydrock data



The PLCM was proven to a maximum depth of 40.0m bgl at the base of RO01 – RO20.

The top of the PLCM can generally be described as weak dark grey mudstone or carbonaceous mudstone, recovered as gravel or clayey gravel. Sandstone is recorded underlying the Glacial Till in 16 of the deeper Hydrock open holes, with Mudstone found underlying the Glacial Till in RO04, RO17, RO18, and RO19.

The PLCM is interbedded with coal seams at various depths ranging between 4.0m bgl and 33.8m bgl, details of the locations and depth at which coal was encountered is provided Table 5-2 below.

Table 5-2: Coal seams encountered

Location ID	Depth Top (m)	Depth Base (m)	Depth Top (AOD)	Depth Base (AOD)	Thickness (m)	Comment	Inferred Seam Name
RO17	4.00	5.00	129.75	128.75	1.00	Intact	Unnamed
HYDCP20	4.80	5.60	124.48	123.68	0.80	Intact	Unnamed
HYDCP14	5.00	5.30	125.65	125.35	0.30	Intact	Unnamed
RSK-R10	5.60	6.10	120.26	120.06	0.50	Intact	Unnamed
RO11	7.00	7.30	129.68	129.38	0.30	Intact	Unnamed
RO18	7.00	7.60	126.38	125.78	0.60	Intact	Unnamed
RO19	7.80	8.00	117.52	117.32	0.20	Intact	Unnamed
RSK-R14	7.90	8.50	115.36	114.76	0.60	'Coal gravel' – non-intact	Unnamed
RO04	8.20	8.40	126.92	126.72	0.20	Intact	Unnamed
RO09	8.70	9.00	123.51	123.21	0.30	Intact	Unnamed
RO19	9.00	10.20	116.32	115.12	1.20	Intact	Unnamed
RO108	9.50	10.50	125.64	124.64	1.00	Intact	Unnamed
RO08	10.00	10.80	122.06	121.26	0.80	Intact	Unnamed
RO17	10.00	11.00	123.75	122.75	1.00	Intact	Unnamed
RO06	10.00	11.00	122.22	121.22	1.00	Intact	Unnamed
RO113	10.00	11.00	126.88	125.88	1.00	Intact	Unnamed
RO105	10.20	11.10	125.65	124.75	0.90	Intact	Unnamed
RO107	10.20	11.60	125.51	124.11	1.40	Intact	Unnamed
RO106	10.50	11.50	126.05	125.05	1.00	Intact	Unnamed
HYDCP06	10.60	11.00	125.92	125.52	0.40	Intact	Unnamed
RSK-R11	10.90	11.10	119.88	119.68	0.20	Intact	Unnamed
RO19	11.00	11.50	114.32	113.82	0.50	Intact	Unnamed
RO01	11.00	14.00	122.94	119.94	3.00	Broken ground and Loss of flush	Cannel
RO18	11.50	12.00	121.88	121.38	0.50	Intact	Unnamed
RO12	11.50	11.80	125.89	125.59	0.30	Intact	Unnamed
RO17	12.00	12.30	121.75	121.45	0.30	Intact	Unnamed
RO20	12.50	13.20	112.43	111.73	0.70	Intact	Unnamed
RO11	13.00	13.80	123.68	122.88	0.80	Intact	Unnamed
RO18	13.00	14.00	120.38	119.38	1.00	Intact	Unnamed
RSK-R10	13.20	14.40	112.96	111.76	1.20	Intact	Unnamed
RO112	13.20	14.10	123.22	122.32	0.90	Intact	Unnamed
RO114	13.50	14.30	120.26	119.46	0.80	Intact	Unnamed
RO109	13.50	14.20	119.20	118.50	0.70	Intact	Unnamed
RSK-R07	13.90	14.10	115.62	115.42	0.20	Intact	Unnamed
RO101	14.50	15.00	120.41	119.91	0.50	Intact	Unnamed
RO102	14.50	15.50	120.45	119.45	1.00	Intact	Unnamed

Location ID	Depth Top (m)	Depth Base (m)	Depth Top (AOD)	Depth Base (AOD)	Thickness (m)	Comment	Inferred Seam Name
RO103	15.20	16.60	120.02	118.62	1.40	Intact	Cannel
RO04	15.50	16.80	119.62	118.32	1.30	Intact	Cannel
RSK-R07	15.60	15.90	113.92	113.62	0.30	Intact	Unnamed
RO10	16.00	17.00	110.31	109.31	1.00	Intact	Cannel
RO09	16.50	17.20	115.71	115.01	0.70	Intact	Cannel
RO07	17.00	17.50	117.07	116.57	0.50	Intact	Cannel
RO08	17.50	18.00	114.56	114.06	0.50	Intact	Cannel
RO14	17.80	19.00	116.28	115.08	1.20	Intact	Cannel
RO105	17.80	19.00	117.42	116.85	1.20	Intact	Cannel
RO107	17.80	18.70	117.92	117.02	0.90	Intact	Cannel
RO108	18.20	19.60	116.95	115.55	1.40	Intact	Cannel
RO116	18.20	19.70	115.76	114.26	1.50	Intact	Cannel
RO106	18.30	19.60	118.25	116.96	1.30	Intact	Cannel
RO110	18.50	19.10	115.96	115.36	0.60	Intact	Unnamed
RO16	19.00	20.00	111.25	110.25	1.00	Intact	Cannel
RO19	19.00	20.00	106.32	105.32	1.00	Intact	Cannel
RO112	19.20	20.40	117.20	116.02	1.20	Intact	Cannel
RO115	19.20	20.70	114.48	112.98	1.50	Intact	Cannel
RO06	19.50	20.00	112.72	112.22	0.50	Intact	Unnamed
RO15	19.50	20.50	112.09	111.09	1.00	Intact	Cannel
RO113	19.70	21.00	117.19	115.89	1.30	Intact	Cannel
RO17	20.00	20.80	113.75	112.95	0.80	Intact	Cannel
RO14	20.00	21.00	114.08	113.08	1.00	Soft ground	Cannel
RO114	20.00	20.80	113.76	112.96	0.80	Intact	Cannel
RO109	20.20	21.00	112.50	111.70	0.80	Intact	Cannel
RO111	20.50	21.60	115.52	114.42	1.10	Intact	Cannel
RO20	20.50	21.50	104.43	103.43	1.00	Intact	Cannel
RO18	21.00	23.00	112.38	110.38	2.00	Intact	Cannel
RO12	21.00	21.50	116.39	115.89	0.50	Intact	Unnamed
RO13	21.00	22.20	113.99	112.79	1.20	Intact	Cannel
RO11	21.00	22.00	115.68	114.68	1.00	Intact	Cannel
RO12	22.00	22.20	115.39	115.19	0.20	Intact	Unnamed
RSK-R07	23.10	23.80	106.42	105.72	0.70	Intact	Unnamed
RO01	29.00	29.50	104.94	104.44	0.50	Soft ground	King
RO10	30.00	30.40	96.31	95.91	0.40	Soft ground	King
RO02	30.00	31.00	102.41	101.41	1.00	Intact	King
RO03	32.00	33.00	99.85	98.85	1.00	Intact	King
RSK-R07	33.80	34.10	95.72	95.42	0.30	Intact	King

June 2021 Hydrock Ground Investigation

As detailed in Table 5-2, during the Hydrock investigation, broken ground and a loss of flush was encountered in RO01 at 11.0 – 14.0m bgl, with no flush returns to the full depth of the borehole at 40.0m bgl. This indicates the presence of possible workings in the Cannel seam. In RO14 at 20.0 – 21.0m bgl soft ground was encountered which also suggests possible workings within the Cannel seam.

There is evidence to suggest possible workings within the deeper King seam in RO01 at 29.0 – 29.5m bgl. and in RO10 at 30.0 – 30.4m bgl where soft ground was also encountered.

RSK report that non-intact coal gravel is present in R14 at 7.9 – 8.5m bgl. in an unnamed seam, and is noted to be non-intact due to disturbance from drilling. There was no further evidence of possible workings identified in the RSK report for the exploratory locations within the current site boundary.

A selection of borehole cross sections showing coal seams encountered during the Hydrock investigation are shown on drawing 15592-HYD-XX-XX-M2-GE-0004 in Appendix A.

November 2021 Hydrock Coal Mining Investigation

As detailed in Table 5-2, during the Hydrock investigation, no broken ground or loss of flush was encountered in any of the 17 rotary open holes drilled. In the majority of open holes both the upper unnamed seam and the Cannel seam were encountered, with both seams found to be intact which suggests that neither seam has been worked beneath the site.

5.2 Visual and olfactory evidence of contamination (soil)

Visual and olfactory evidence of potential contamination was noted in the Hydrock investigation of the landfill areas and is summarised in Table 5-3.

Table 5-3: Visual and olfactory evidence of contamination - soils

Stratum	Location	Depth (m bgl)	Description
Landfill material	TT03	0.70 – 4.80	Frequent mottled black hay/straw, some plastic bin liner, and rare wood fragments with organic odour.
	TT05	0.70 – 2.00	Hay/straw, ash, wood, large pieces of timber, metal, and a strong organic odour.

There was no visual or olfactory evidence of potential contamination identified in the RSK exploratory locations within the current site boundary.

5.3 Groundwater

5.3.1 Groundwater observations and levels

Groundwater encountered during the investigation is listed in

Table 5-4. A groundwater observation represents the depth at which groundwater was first observed and is likely to be deeper than the actual water table level at that location.

Table 5-4: Groundwater occurrence

Location	Fieldwork		Comment
	Groundwater observation (m bgl)	Rose to after 20 mins (m bgl)	
Glacial Till			
HYDTT05	0.9	-	Fast ingress
HYDCP21	1.2	0.7	Slow ingress
HYDTP03	1.2	-	Moderate seepage
HYDTP05	1.4	-	Slow seepage
HYDTP25	1.4	-	Slow seepage
HYDTP30	1.4	-	Slow seepage
HYDWS11	1.4	-	Slow ingress
HYDTP01	1.5	-	Slow seepage
HYDTP02	1.5	-	Slow seepage
HYDTP04	1.6	-	Fast ingress
HYDTP09	1.6	-	Slow seepage
HYDTP14	1.8	-	Slow seepage
HYDTP11	2.2	-	Fast ingress
HYDTP18	2.2	-	Slow seepage
HYDTP29	2.2	-	Slow seepage
HYDTP16	2.3	-	Moderate seepage
HYDTP02	2.9	-	Slow seepage
HYDTP23	3.0	-	Slow seepage
HYDTP32	3.0	-	Slow seepage
HYDTP28	3.1	-	Slow seepage
HYDTP25	3.2	-	Fast ingress
HYDWS06	3.5	-	Slow ingress
HYDTP05	3.6	-	Moderate seepage
HYDCP27	4.1	3.9	Slow ingress
HYDCP24	4.7	3.3	Moderate ingress
HYDCP29	5.0	0.0	Fast Ingress – possible artesian water strike
Pennine Lower Coal Measures			
HYDCP25	7.0	3.1	Fast Ingress
HYDCP30	7.0	5.6	Moderate ingress
HYDCP28	7.2.	5.4	Moderate ingress
HYDCP23	7.5	4.9	Moderate ingress
HYDCP27	7.6	7.2	Slow ingress
HYDCP31	11.1	9.7	Slow ingress

Groundwater levels recorded during post-fieldwork monitoring are summarised in Table 5-5.

Table 5-5: Groundwater level data summary

Stratum	Date range	Location	Post-fieldwork monitoring	
			Depth to groundwater (range) (m bgl)	Groundwater elevation (range) (m OD)
Glacial Till	22/06/21 - 08/09/21	CP01	0.91 1.38	131.92 131.45
		CP05	2.15 2.27	131.12 131.00
		CP06	2.52 8.62	134.00 127.90
		CP07	2.16 2.44	134.45 134.17
		CP11	6.18 6.65	128.27 127.80
		CP12	6.47 6.67	131.02 130.82
		CP15	3.69 3.80	130.01 129.90
		CP18	0.46 1.81	131.18 129.83
		CP19	7.13 7.14	127.34 127.33
		CP22	0.82 1.64	129.08 128.26
		CP26	0.27 0.89	124.46 123.84
		CP31	0.63 1.31	118.90 118.22
		WS01	0.87 2.19	130.60 129.28
		WS02	0.66 1.12	133.76 133.30
		WS03	0.85 1.44	135.22 134.63
		WS04	0.81 1.11	134.10 133.80
		WS05	0.50 1.39	132.20 131.31
		WS06	0.48 2.06	134.81 133.23
		WS07	0.70 1.58	133.43 132.55
		WS08	1.01 2.02	130.85 129.84
		WS09	0.40 1.37	130.76 129.79
		WS10	0.18 1.02	131.74 130.90
		WS11	0.67 1.17	118.57 118.07
Pennine Lower Coal Measures	22/06/21 - 08/09/21	CP04	6.67 8.26	126.27 125.22
		CP13	7.95 8.19	124.79 124.55
		CP20	4.85 5.19	124.43 124.09
		CP25	2.29 2.42	124.84 124.71
		CP30	5.54 5.67	114.62 114.49
		RO11	7.81 9.82	128.87 126.86
		RO14	1.03 1.03	133.05 133.05

5.3.2 *Infiltration tests*

The results of the infiltration testing undertaken are summarised in Table 5-6. The results sheets are presented in Appendix B.

Testing was carried out in accordance with Hydrock's 1-day assessment methodology (see reference in Appendix I). This is in general accordance with BRE Digest 365 (BRE DG 2016) where infiltration rates allow three test runs during a working day (or where there is no infiltration), but where low infiltration rates were encountered the available time may not have been sufficient to fully comply with the BRE test method (i.e. three runs of the test).

Table 5-6: Infiltration test results

Stratum	Location	Depth to base of pit (m bgl)	Infiltration rate (m/s) *		
			Run 1	Run 2	Run 3
Hydrock data					
Glacial Till	SOAK01	1.00	No infiltration	-	-
	SOAK02	1.30	No infiltration	-	-
	SOAK03	1.20	No infiltration	-	-
RSK data					
Glacial Till	RSK-TP34	1.5	7.90×10^{-7}	-	-
	RSK-TP35	1.5	1.34×10^{-6}	-	-
	RSK-TP38	1.4	1.12×10^{-7}	-	-
	RSK-TP41	1.5	9.93×10^{-8}	-	-
	RSK-TP44	1.5	3.35×10^{-7}	-	-
	RSK-TP47	1.5	1.34×10^{-7}	-	-

*None of the tests could be completed three times during the Hydrock or RSK investigations as a result of limited or no infiltration, and time constraints. The above values provided by RSK are extrapolated as the water level did not fall to the 25% or 75% of the effective depth for the duration of the tests.

The results of the soakaway tests undertaken by Hydrock in June 2021 and RSK in May 2018 indicate the Glacial Till exhibits infiltration values typical for low permeability cohesive superficial deposits. In the three Hydrock test locations, and in five of the six RSK test locations the water level did not fall below the 75% fill depth.

The results provided in Table 5-6 indicates the Glacial Till to have a low infiltration rate, and is therefore not considered a suitable stratum for standard soakaway drainage.

5.3.3 *Groundwater summary*

During the fieldworks, shallow groundwater was encountered at 12 locations within the Glacial Till at 0.90m to 1.80m bgl and was typically encountered as a slow seepage with the exception of TT05 and TP04 where fast groundwater ingress occurred. A possible artesian water strike was noted in CP29 characterised by fast ingress at 5.0m bgl. rising to ground level after 20 minutes.

The monitoring data indicates there is a shallow groundwater body present at 0.18m – 3.80m bgl in the Glacial Till with another deeper groundwater body in the Glacial Till at 6.18 – 8.62m bgl.

During the fieldworks, deeper groundwater was encountered in the underlying Pennine Lower Coal Measures at 7.00m to 11.10m bgl, and In HYDCP25 the groundwater had risen after 20 minutes from 7.00m to 3.10m bgl. During post-fieldwork monitoring, groundwater was encountered in this stratum at 2.29m bgl (CP25) to 9.82m bgl (RO11). The groundwater ingress is originating from within the granular bands within the Pennine Lower Coal Measures generally below 5.00m.

In CP25 the groundwater level in the PLCM had risen 4.71m to above the top of the response zone as a result of positive pore-water pressure in the cohesive clayey gravel mudstone, and is filling the standpipe due to the predominantly impermeable nature of the strata.

The shallow and deeper groundwater in the Glacial Till appears to be topographically controlled and is flowing toward the lowest areas of the site which in this instance is in the south, this is exhibited by the possible artesian water strike encountered in CP29.

5.4 Ground gases (carbon dioxide and methane)

Records from the gas monitoring boreholes are presented in Appendix D and summarised in Table 5-7.

Six monitoring visits have been undertaken and the scheduled monitoring as part of this commission is now complete. Further monitoring will be required following completion of earthworks. The data are assessed further in Section 7.5.

Table 5-7: Range of ground gas data

Stratum	Methane (%)	Carbon dioxide (%)	Oxygen (%)	Steady flow rate (l/hr)	Comment
Glacial Till	0.0 – 0.2	0.0 – 9.6	0.4 – 21.0	-4.3 – 11.9	Carbon dioxide detected between 5% and 10% regularly in five boreholes. Flow rate is elevated.
Pennine Lower Coal Measures	0.0 – 0.1	0.1 – 6.5	4.3 – 21.0	-1.7 – 3.0	Carbon dioxide detected between 5% and 10% sporadically in three boreholes. Flow rate is generally negligible.

5.5 Geotechnical data

5.5.1 Introduction

Laboratory test results are contained in Appendix C with *in situ* test results shown on the relevant exploratory hole log or datasheet in Appendix B. The following sections summarise the main findings and provide interpretation where appropriate.

5.5.2 Plasticity

The volume change potentials in terms of BRE Digest 240 with respect to building near trees have been determined from the results of plasticity index tests on samples of soil. These are summarised in Table 5-8.

Table 5-8: Volume change potential

Stratum	No. of tests	Plasticity Index			Modified Plasticity Index			Plasticity designation	Volume Change Potential
		Min.	Max.	Av.	Min.	Max.	Av.		
Hydrock data									
Glacial Till	27	10	24*	13	7.6	21.8	11.9	Low to intermediate	Low
RSK data									
Glacial Till	72	10	25	14	10	25	11.7	Low to intermediate	Low

*Out of 27 tests, one Atterberg Limits test was identified at the threshold of medium volume change potential (PI = 34). This outlier has been discounted due to weight of evidence.

5.5.3 *Particle size distribution*

Particle Size Distribution test (PSDs) results are summarised in Table 5-9 and summary descriptions and PSD plots of the material analysed are presented in Appendix C.

Table 5-9: PSD results summary

Stratum	No. of tests	Silt/Clay %	Sand %	Gravel %	General description
Hydrock data					
Glacial Till	8	35 - 59	32 - 47	9 - 18	Gravelly very sandy clay.
RSK data					
Glacial Till	7	37 - 51	30 - 45	6 - 29	Slightly sandy slightly gravelly clay.

5.5.4 *Soil strength*

Table 5-10 summarises information pertaining to the shear strength of the soils according to geological stratum. Factual results are summarised for laboratory tests, field tests (e.g. hand shear vane) and uncorrected Standard Penetration Tests (SPT). Where the SPT is used to infer shear strength by published correlation, this is also tabulated. A shear strength versus depth profile plotted from hand shear vane field testing and laboratory triaxial testing is presented in Figure 5-4. Shear strength versus depth profiles from selected CPT holes are also presented in Figure 5-5 to Figure 5-8, and plots are presented in Appendix C.

Table 5-10: Soil strength results and derived values

Stratum	No. of tests	SPT (N-value) (range)	c_u (kPa)	CBR (%)	MPa	Method
Hydrock data						
Glacial Till	130	1 - 31	-	-	-	SPT – cable percussion and windowless sampler boreholes
	130	-	5 - 155	-	-	Derived from SPT N values
	71	-	17 - 138	-	-	Hand shear vane
	19	-	26 - 265	-	-	Laboratory triaxial test
	-	-	25 - 150	-	-	CPT correlation
	5	-	-	0.5 – 1.7	-	Laboratory Remoulded CBR
	14	-	-	0.2 – 6.0	5.8 – 55.8	Lightweight Deflectometer field test.

Stratum	No. of tests	SPT (N-value) (range)	c_u (kPa)	CBR (%)	MPa	Method
Pennine Lower Coal Measures	46	12 - 50	-	-	-	SPT – cable percussion and windowless sampler boreholes
	1	-	74	-	-	Laboratory triaxial test
	-	-	125 - 200	-	-	CPT correlation
RSK data						
Glacial Till	-	5 – 40	-	-	-	SPT – cable percussion and windowless sampler boreholes
	-	-	25 - 200	-	-	Derived from SPT N values
	5	-	35 - 73	-	-	Laboratory triaxial test
	5	-	-	0.7 – 2.0	-	Laboratory Remoulded CBR
Pennine Lower Coal Measures	7	-	-	-	0.41 – 3.25	Laboratory Point Load test
	1	-	-	-	52.1	Laboratory Uniaxial Compressive Strength test

Figure 5-4: Glacial Till undrained shear strength (kN/m²) vs Depth (m bgl)

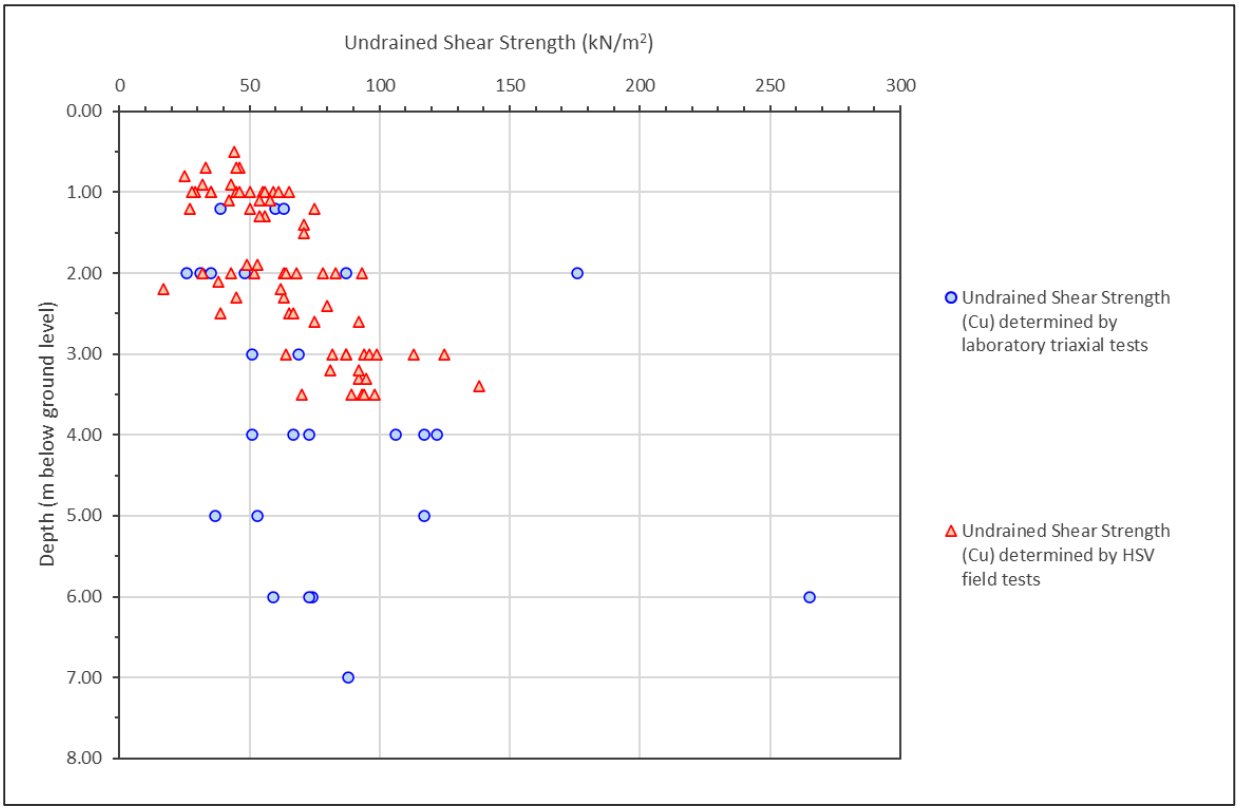


Figure 5-4 presents the variation in undrained shear strength of the Glacial Till with depth (m bgl) taken from hand vane field tests and laboratory triaxial testing.

Figure 5-4 shows the gradual increase in undrained shear strength with depth in the Glacial Till. Shear strength in the upper 2.0m is shown to range typically between 25 and 60kN/m², and below 3.0m shear strength is shown to range between approximately 50 and 125 kN/m².

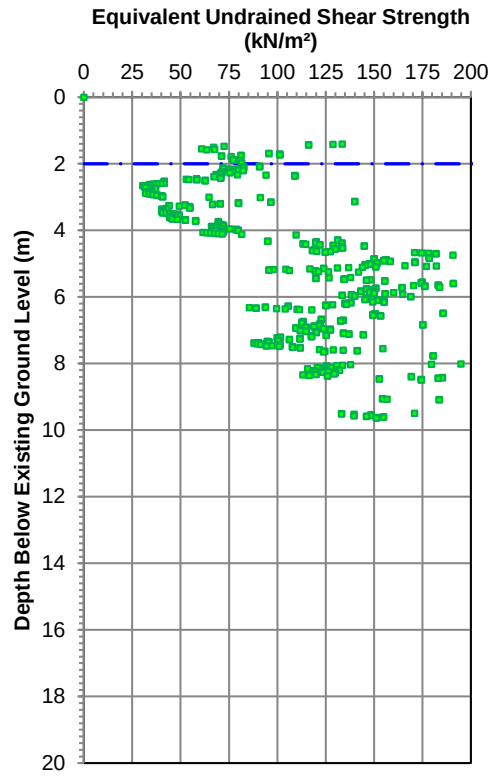


Figure 5-5: CPT03 Undrained shear strength Vs depth (m bgl.) plot

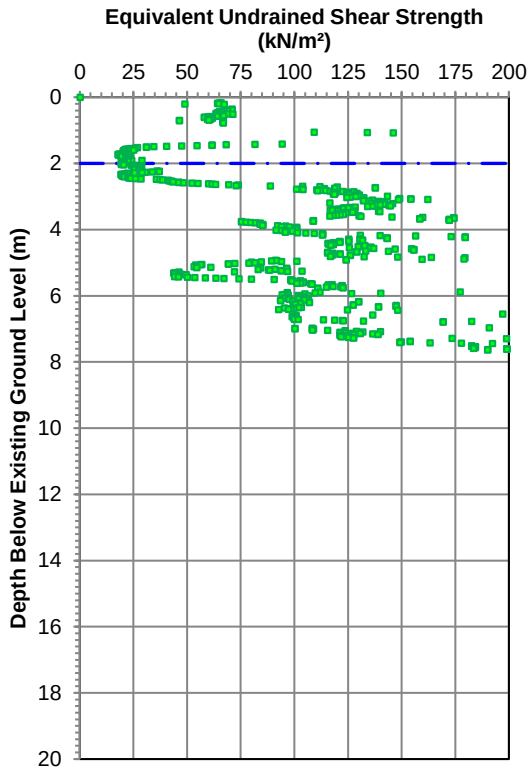


Figure 5-6: CPT06 Undrained shear strength Vs depth (m bgl.) plot

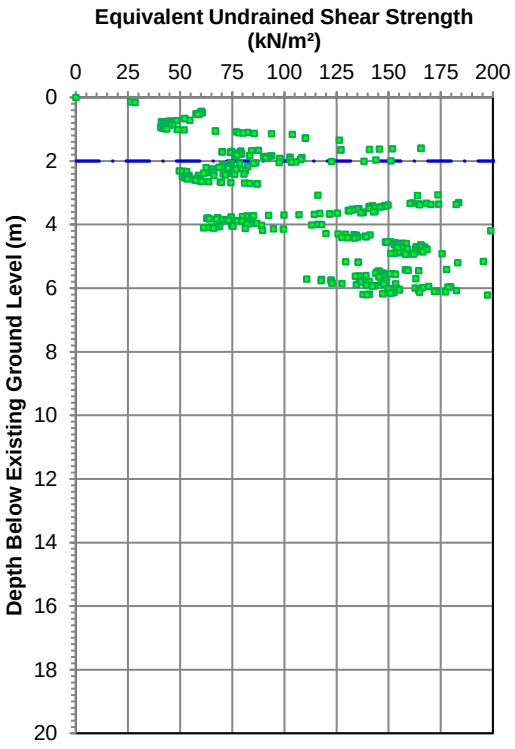


Figure 5-7: CPT20 Undrained shear strength Vs depth (m bgl.) plot

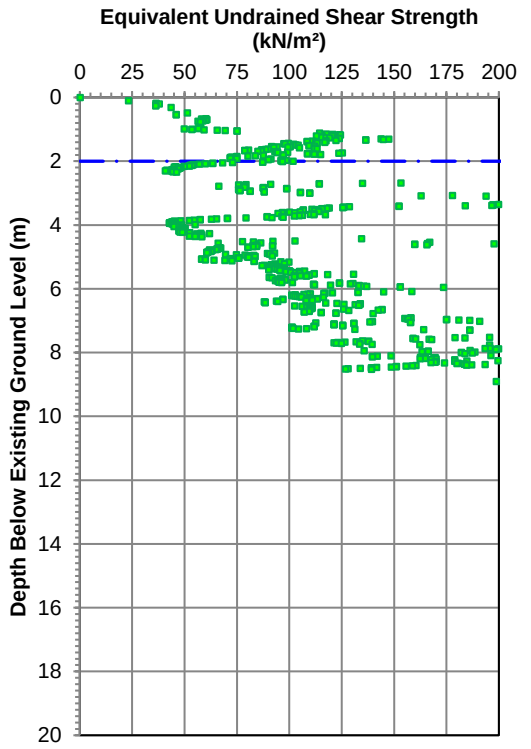


Figure 5-8: CPT28 Undrained shear strength Vs depth (m bgl.) plot

The data trends from the CPT tests, shown in Figure 5-5 to Figure 5-8, are similar to the laboratory test data in Figure 5-4. The strength profile of the Glacial Till indicates the upper 2.0 to 4.0m is generally low strength, typically with undrained shear strengths of 25 to 75 kN/m², over medium to high strength Glacial Till exhibited by undrained shear strengths of 50 to 150 kN/m² to the base of the strata.

With the exception of CPT06, below 4.00m, the strength generally increases linearly with depth, with the CPTs typically refusing at the top of the Pennine Lower Coal Measures bedrock. In CPT06 a soft layer is shown between 5.0 to 6.0m bgl indicated by a reduction in shear strength from around 100 kN/m^2 to 45 kN/m².

5.5.5 *Compressibility*

Table 5-11 presents a summary of the derived parameters for coefficient of consolidation and compressibility from one dimensional oedometer testing. The data indicates that the material is generally of medium to high compressibility over the pressure ranges tested.

Table 5-11: Summary of compressibility

Stratum	No. of tests / results	Method	Pressure range (kN/m²)	Coefficient of volume compressibility (m_v) (m²/MN)	Coefficient of consolidation (C_v) (m²/yr)
Hydrock data					
Glacial Till	4	One Dimensional Oedometer Testing	30 - 60 40 - 100 100 - 200 200 - 240 240 - 320 Unload	0.87 0.22 – 0.57 0.10 – 0.14 0.035 0.081 – 0.087 0.014 - 0.489	2.7 3.7 – 9.7 9.5 – 16.0 18.0 16.0 – 35.0 -

5.5.6 *Compaction and moisture content*

Table 5-12 presents a summary of the moisture content tests and compaction studies undertaken at the site.

Table 5-12: Compaction study results

Stratum	No. tests	Method	Natural moisture content (%) (range)	Optimum moisture content (%) (range)	Particle density (Mg/m³) (range)	Maximum dry density (Mg/m³) (range)
Glacial Till	7	2.5kg Rammer	11 - 16	11 - 12	2.62 - 2.68	1.92 - 2.03

5.5.7 *Subgrade stiffness*

The subgrade stiffness and CBR values results are summarised in Table 5-13.

Table 5-13: CBR results and derived values

Stratum	No. tests	Method	Subgrade Stiffness (MPa)	CBR (%) (Range)
Hydrock data				
Glacial Till	*14*	Lightweight Deflectometer field test	5.8 - 55.8	0.2 – 6.0
	7	Laboratory remoulded sample at Natural Moisture Content (NMC)	13.8 – 25.0	0.5 – 1.7

Stratum	No. tests	Method	Subgrade Stiffness (MPa)	CBR (%) (Range)
RSK data				
Glacial Till	5	Laboratory remoulded sample at Natural Moisture Content (NMC)	19.3 – 27.0	0.7 – 2.0

5.5.8 Sulfate content

The range of sulfate concentrations identified in the samples analysed are presented in Table 5-14 below.

Table 5-14: Sulfate content

Stratum	No. tests	Water soluble sulfate (mg/l) Range.	Total Sulfur (%)	Total potential sulfate	pH Range
Hydrock data					
Glacial Till	20	5.1 – 244	0.012 – 0.142	0.0 – 0.5	5.9 – 8.5
Pennine Lower Coal Measures	5	19.3 - 156	0.036 – 0.357	0.1 – 1.1	6.2 – 8.3
RSK data					
Glacial Till	14	11.0 – 81.0	-	-	6.36 – 8.79

In accordance with BRE (Special Digest 1), the Design Sulfate (DS) classification and the Aggressive Chemical Environment for Concrete (ACEC) classification are presented in Section 6.12. The assessment summary sheets are presented in Appendix C.

5.5.9 Drained Shear Strength Parameters

Two consolidated undrained triaxial compression tests with pore pressure measurement were undertaken to determine the effective stress parameters. The results of the testing are summarised in Table 5-15 below.

Table 5-15: Drained Shear Strength Parameters

Test Ref	Depth	Initial σ_3 range (kPa)	Effective cohesion c' (kPa)	Effective Angle of Friction φ' (°)
HYDCP31	2.00 - 2.45	20, 40, 80	3	29.4
HYDCP31	4.00 - 4.45	40, 80, 160	Unable to interpret Mohr circles	

6. GEOTECHNICAL ASSESSMENT

6.1 Geotechnical categorization of the proposed development

Eurocode 7, Section 2 advocates the use of geotechnical categorization of the proposed structures to establish the design requirements.

The proposed development is to comprise up to nine commercial units. In the eastern fields there will be five units (units 1, 2 ,3, 4A-C and 7) varying in size from 15,777sq ft (square foot) to 42,421sq ft. In the centre and south Unit 7 is the largest proposed unit at 673,523sq ft. In the west there will be two units (Units 5 and 6) which are proposed to be 35,079sq ft and 127,180sq ft.

As part of the proposed development acoustic bunds will be placed along northern boundary adjacent to Chorley Road. Three attenuation ponds will be formed in the south of the site. Associated car parking and access will surround the units with the main access road situated on the eastern boundary off Wimberry Hill Road. Habitat enhancement will take place in the west of the site beyond Unit 5. To form nine development plateaus ranging from 128.8mAOD to 134.6mAOD, a cut to fill exercise will be undertaken. The proposed illustrative masterplan (RPS Drawing SK065, dated 1st June 2018) is presented Appendix A.

A significant cut to fill operation is required to create a series of level development platforms for each of the units. Based on the above proposed development and the ground conditions encountered, including the possible presence of shallow underground mine workings and low strength superficial deposits in the upper 3.0m, the foundations and floor slab design for the proposed structures have been classed as Geotechnical Category 3.

For Category 3 structures specialist design input is required (i.e for any mine treatment). The Geotechnical Category should be re-assessed at the design stage and specific geotechnical design for individual elements (in addition to this investigation), is required. However, further investigation of the possible underground mine workings is proposed, which will allow re-assessment of the Geotechnical Design Category.

Assessment has been undertaken in accordance with the general requirements of ICE/DETR Document 'Managing Geotechnical Risk' and the HE documents HD 41/15 and CD 622. The preliminary Geotechnical Risk Register following investigation is provided in Appendix G and will need to be updated following any further investigation and during future design works.

6.2 Characteristic design values

In accordance with BS EN ISO 1997-1 (EC 7), Hydrock consider the proposed structures initially would be classified as Category 3 structures. As part of the separate geotechnical design, the designer should determine the appropriate geotechnical design values.

To assist outline design, Table 6-1 provides characteristic geotechnical values. These are based on laboratory testing, *in situ* testing and by professional judgement using published data together with knowledge and experience of the ground conditions. Care should be exercised in using these assumed soil parameters for any purpose beyond the scope of this report because it may be that additional sampling and testing are required for certain purposes. The reader should refer to the original test results summarised in Section 5 and provided in Appendix B and Appendix C.

Table 6-1: Characteristic geotechnical values

Parameter	Bulk unit weight kN/m³	Effective angle of internal friction °	Undrained shear strength kN/m²	Coefficient of compressibility m²/MN	Subgrade Stiffness (MPa)
Stratum	γ [a]	ϕ' [b c]	c_u [d]	m_v [e]	k [f]
Glacial Till (upper 3m)	21	28	30	0.20	18
Glacial Till (below 3m)	21	28	60	0.15	30
Pennine Lower Coal Measures Formation	The designer is to determine appropriate values for the PLCM or undertake further testing specific to the geotechnical element.				

a. Measured as part of the triaxial strength tests, and estimated based on the recommendations of BS 8004-2015.

b. Internal friction (φ') values for the granular in situ *material derived from SPT data following the recommendations of Peck et al., (1967).*

c. Internal friction (φ') values for the cohesive in-situ material derived from BS 8004-2015, where φcv' is derived from plasticity index. The use of φcv' in the analysis is considered to provide a conservative estimate of φ' and should be used with a c' = 0kPa

d. Site measurements and laboratory data.

e. Laboratory data.

f. Based upon the equilibrium long term CBR from laboratory testing and in situ field testing.

6.3 Groundwork

6.3.1 Site preparation

Whilst no buried obstructions were encountered by this investigation, the possibility of buried obstructions being encountered remains in the areas of landfilling. Therefore, it is recommended that an allowance be made for breaking out obstructions, for example provision of pneumatic breakers for site plant. If underground structures cannot be removed, they will need to be surveyed in three dimensions and the new structures will need to be designed to accommodate them.

Topsoil should be removed from beneath all building and hardstanding areas.

Trees, vegetation and root balls should be removed from the development areas and include over-excavation of roots and potentially desiccated soils in the vicinity of trees and hedgerows.

6.3.2 Groundworks

Excavation of shallow soils should be readily undertaken by conventional plant and equipment. However, excavation through the intact rock quality strata may require heavy-duty excavation plant/ the use of specialist breaking equipment.

Trial pit faces were noted to remain generally vertical without collapse. The faces of shallow, near vertically sided excavations put down at the site are likely to remain stable for short periods of time. However, it should be noted that the Glacial Till can become unstable where groundwater ingress is present especially in horizons with a higher granular content.

Random and sudden falls should be expected from the faces of near vertically sided excavations put down at the site. Temporary trench support, or battering of excavation sides, is recommended for all excavations that are to be left open for any length of time and will definitely be required where man entry is required. Particular attention should be paid to excavation at, or close to, site boundaries/adjoining existing roads/structures/buildings, where collapse of excavation faces could have a disproportionate effect.

A risk assessment of the stability of any open excavation should be undertaken by a competent person and appropriate measures adopted to ensure safe working practise in and around open excavations. Further guidance on responsibilities and requirements for working near, and in, excavations can be obtained from the Construction Design and Management Regulations (2015); Construction Information Sheet 47: Inspections and Reports (2005) and HSG47: Avoiding Danger from Underground Services.

To ensure no loads are imposed on the sides of the excavation, spoil should not be placed immediately adjacent to the excavation. Spoil should be placed a suitable distance from the side of the excavation (as assessed by a competent person).

Based on site observations, the rate of water ingress to the proposed excavations is likely to be slow to moderate with localised areas of fast ingress. The Contractor should allow for management of groundwater. In these circumstances, groundwater control by sump pumping is likely to be sufficient with suitable temporary surface drainage during the earthworks to prevent instability or reduced bearing capacity of the subgrade.

It should be recognised that groundwater levels may vary from those at the time of the investigation, for example in response to seasonal fluctuations and the timing of construction may dictate the extent of groundwater control required.

Any water pumped from excavations may need to be passed via settlement tanks (to reduce suspended solids) before being discharged to the sewer. Discharge consents may also be required.

6.3.3 Earthworks/reuse of site-won materials

The preliminary earthworks cut to fill is shown on RSK drawing 'Figure 8 Rev A' from the supplementary site assessment and indicates that generally up to 8m of cut is required in the north and up to 10m of fill is required in the southern section of the site.

The classification of materials depends on both the proposed end use and whether the material will meet the performance requirements of that end use. Based on Hydrock's understanding, the following assessment is based on the use of General Fill within external areas and Structural Fill for the building footprint.

The key performance criterion for an engineered fill designed to support structures and pavements is the remoulded strength/stiffness. Assuming a standard compactive effort, the material strength is dependent on the moisture content at the time of compaction.

It should also be recognised that at lower moisture contents a high compactive effort will be required to ensure air voids are sufficiently reduced. Therefore, any specification for engineered fill should also include a lower moisture content limit (upper shear strength and/or upper air void content).

An initial assessment of the classification data (provided in Appendix C) has been completed based on Hydrock's understanding of the development and the potential to reuse site-won materials as an engineered fill. The assessment is summarised in Table 6-2.

Table 6-2: Preliminary earthworks assessment

Stratum	Proposed end use	Preliminary classification (SHW Series 600)	Comment	Suitability for improvement by the inclusion of binders
Topsoil	Bunds and landscape areas	Class 4	Unsuitable for General and Selected Fill due to high organic content and compressible nature of material. Can only be used in areas which are not sensitive to settlement.	N/A
Made Ground	Bunds and landscape areas	Class 4	Likely unsuitable for General and Selected Fill due to high organic and deleterious content. Some of the Made Ground may be suitable for General or Selected Fill following segregation and processing to remove unsuitable material.	Potentially suitable subject to further testing following segregation and processing
Glacial Till	External Areas and roads	Class 2A (wet cohesive material)	Suitable for engineered fill. Material currently at the upper limit of moisture content for general fill. Some reduction in moisture content should be allowed for especially outside of summer months.	Likely to be suitable subject to further detailed design and testing.
	Internal Areas	Class 7A	Only suitable following reduction in moisture content (around 3-4% based on the testing to date). However, material from deeper excavations may be suitable in the as dug condition.	Likely to be suitable subject to further detailed design and testing.
Pennine Lower Coal Measures	TBC	TBC	Potential for PLCM to be excavated in northern section of the site. Likely constitute small volume of overall fill. Compaction trial required to confirm level of processing required to re-use material.	Unlikely due to the presence of pyrite

It should be noted that the samples were taken from within the upper 3m and were restricted by the maximum depth of the trial pits. It is likely that material excavated from deeper within the Glacial Till may be suitable with little or no modification due to the lower moisture content. Testing for suitability at all levels within the excavation should be undertaken as part of the main works and in accordance with a site specific earthworks specification.

The earthworks on site will need to be undertaken in accordance with the CL:AIRE Definition of Waste Code of Practise demonstrated by the preparation, and possible declaration, of a suitable Materials Management Plan.

Before the use of hydraulic binders is approved, comprehensive testing will need to be completed by a specialist Contractor to satisfy both themselves and the Engineer of the suitability of the soils for

treatment and to confirm that the requisite end-performance of the material is achievable. In all instances where improvement by the inclusion of binders is considered, a mix design is required and as part of this design, samples should be checked for swelling, even where very low sulfate values are recorded.

Where it is proposed to use materials as an engineered fill it will be necessary to develop an appropriate site specific Earthworks Specification as part of the geotechnical design. The basis for the earthworks design and specification should be BS EN 1997, BS EN 16907 and the latest version of the Specification for Highway Works (SHW), specifically Series 600.

6.3.4 *Consolidation settlement from land raising*

Based on the latest proposed site levels and the indicative cut to fill on the RSK drawing the final ground level will be raised by up to 10m in parts of the proposed building footprint (southern corner of Unit 7), which will lead to consolidation settlement of the underlying soils.

Based on a review of the Cone Penetration Test (CPT) test results and considering the maximum thickness of fill, consolidation due to land raising is likely to result in settlements in the order of 70 to 100mm, which would occur over the next 4 to 5 years following construction. A number of options are available to reduce post construction settlement to tolerable levels and are summarised in Table 6-3. Given the relatively high loading requirements of the floor slabs, the selected ground improvement technique should aim to remove as much of the consolidation as possible.

Table 6-3: Ground Improvement Options

Ground Improvement Method	Comment
Preload with installation of PVD	Straightforward technique which allows for a given degree of consolidation to occur prior to construction. Would need the installation of vertical drains to reduce consolidation time, which could be in the order of 3-6 months depending on spacing. Accurate monitoring required. Degree of consolidation of at least 90% would be required.
Preload and temporary surcharge with installation of PVD	As above but with the addition of a surcharge of temporary fill. This reduces the hold period allowing construction prior to 90% consolidation. Additional temporary fill can also be designed to replicate the design load of the floor slab reducing the need for additional ground improvement. Requires significant additional fill, potential to re-use topsoil prior to placement in landscape bunds.
Vibro Stone Columns (VSC) and load transfer platform prior to the placement of fill	Additional cost with little additional benefit over the above techniques. VSC more effective immediately below structural foundations and slabs.
Over-excavation and replacement of the low strength fill	Over-excavation of the upper 2m of low strength material. Whilst this would not remove the settlement completely it would reduce the total settlement and potentially reduce the need for ground improvement below pad foundations. However, excavated fill likely need treating prior to re-use to reduce the moisture content.

A separate geotechnical design will be required to fully assess the impact of settlement and to design the ground improvement works. Site monitoring during the earthwork construction will be required to confirm the required settlements has been achieved.

The ground improvement strategy should be considered in conjunction with any ground improvement required for the ground bearing floor slabs and pad foundations. Further detail is provided in Section 6.7.

6.4 Slopes and retaining walls

6.4.1 Slope stability

The redevelopment of the site will require both the cutting of temporary and permanent slopes and the construction of slopes from engineered fill. The stability of permanent slopes should be confirmed following a separate geotechnical analysis. For the purposes of this report, only general comments are made based on the encountered ground conditions. The cutting of temporary slopes should be undertaken in accordance with a suitable temporary works design and is outside the scope of this report.

The key slopes proposed for the site include a cutting up to 6m high in the central north of the site that carries the main access road and a 9m high embankment constructed from engineered fill. It is understood that the slopes are currently set at a face angle of 1:3 (18°).

Based on experience of similar soils it should be possible to design fill suitable to support permanent slopes at angles up to 1:3 or shallower. However, it is recommended that the design of the site levels considers reducing the face angle of the 9m high embankment supporting the Unit 7 plateau by as much as possible to help with long term stability. In addition, the minimum effective stress parameters (c' and φ') should be confirmed as part of source suitability and acceptability testing and additional measures such as drainage (typically a toe drain as a minimum) may need to be incorporated into the design.

Based on the ground model the cutting in the north of the site is likely to intercept the entire profile of Glacial Till and possibly encounter the PLCM at the base. In addition, groundwater seepages are likely to be encountered at a number of levels with more prominent seepages from sandy horizons. Temporary groundwater control will likely be required at the toe of the slope prior to installation of permanent drainage. Furthermore, consideration should be given to slope face drainage to prevent the development of erosional features and undercutting.

6.4.2 Retaining walls

With reference to the latest earthworks and proposed ground level drawings it is understood that a retaining structure is required in the east of the site where the corner of Unit 7 comes in close proximity to Wimberry Hill road.

Based on preliminary sketches the maximum retained height is around 3.0m over a length of around 10m and retaining and engineered fill embankment. As part of the drainage works in the verge of Wimberry Hill road it is understood that a 1350mm diameter surface water drain is required to be installed near the base of the wall at an invert depth of approximately 3.6m below the verge level. Further assessment will be required with regards to the temporary works and sequencing. However, at this stage installing the drainage in a temporary cutting prior to completion of the earthworks fill and retaining wall is likely to be the effective approach. Any maintenance to the pipe during the service life should be undertaken following a suitable temporary works design potentially including limiting the excavation length or installing temporary sheet piles or trench supports.

A number of wall types are considered suitable for this part of the site and are summarised in Table 6-4.

Table 6-4: Retaining Wall Options

Wall Type	Comment
Precast cantilever wall	Precast L-shaped sections bolted to concrete strip foundation. Requires granular backfill and drainage through wall. Structural design of wall stem can accommodate additional surcharge from HA loading area and possibly warehouse structure.
Timber/concrete crib lock gravity wall	Cost effective solution. Flexible structure potentially unsuitable to support additional surcharge loading or settlement sensitive structures. Vehicle restraint barrier likely require support slab.
Embedded retaining wall (sheet piles)	Unlikely to be suitable as it requires overfilling to install for an embankment. Furthermore, driving may damage newly installed services. Difficulty with driving sheet piles where PLCM encountered at shallow depth.
Mechanically Stabilise Earthworks (MSE)	Can be constructed at the same time as the fill. Steep face angles possible with proprietary facing system. Potentially more aesthetically pleasing once vegetation established. Can be difficult to incorporate service trenches near the crest due to the presence of the geogrid as well as vehicle restraint system.

Additional retaining structures are likely to be required at the southern end of the site where the Unit 7 access road runs adjacent to the proposed attenuation pond. Minor retaining structures may also be required between plots in order to accommodate the level changes and maximise development area.

Additional design and assessment should be undertaken to check for sliding, overturning and deep-seated shear failure taking into consideration any surcharge load at the top of the wall and the groundwater conditions.

Allowance should be made in the design of the retaining walls for adequate drainage behind the structure, or for water seepage through the face of the wall. The stability of the retaining wall is not considered in this report and should be considered by the designer.

Care will need to be taken to ensure that any works close to the site boundary will not destabilise or cause damage to the existing highway or infrastructure.

6.5 Mineworkings

6.5.1 Abandoned mineworkings

June 2021 Hydrock Coal Mining Investigation

The June 2021 investigation concluded that potential abandoned mineworkings had been identified to underlie the site at shallow depth recorded at one location in RO01 between 11.0 – 14.0m bgl. At this location broken ground and loss of flush was noted. At 20.0 – 21.0m bgl in RO14, soft ground was encountered and this is also potentially indicative of a worked seam. It was interpreted that these possible workings are in the Cannel seam. There is evidence to suggest further possible workings within the deeper King seam at 29.0 – 29.5m bgl in RO01 and at 30.0 – 30.4m bgl in RO10 where soft ground was encountered.

Where underground mineworkings at shallow depth are present this poses an unacceptable risk to the proposed development due to the potential for collapse and upward migration of voids. A thickness of around 3.0m of broken ground was encountered in RO01 and 1.0m of soft ground in RO14, which suggests partial collapse may have occurred.

At this stage, based on the available evidence, it is recommended that a series of rotary open holes are drilled in the proximity of RO01 and RO14 to determine the extent of workings in the Cannel seam prior to recommending treatment options. Hydrock drawing 15592-HYD-XX-XX-DR-GE-0005 in Appendix A

shows a zone of higher risk from underground workings, which is located down dip of the Cannel seam outcrop. It is considered that further investigation will allow the areas of possible mine workings beneath the site to be further defined so that the risk can be more accurately determined. The proposed scope of investigation is also shown on the drawing.

Where workings are positively identified it will be necessary to stabilise abandoned mineworkings where there is insufficient intact rock cover above the workings to prevent the upward migration of voids. The local premise for suitable rock cover typically being ten times the thickness of the worked seam, although this is dependent on the type and condition of the rock cover. Further information can be obtained from CIRIA Report C758D 'Abandoned Mine Workings Manual '(Parry and Chiverrell, 2019).

Based on the above principle of sufficient rock cover, the King seam interpreted in RO01 and RO10 is considered to pose a low risk and is unlikely to require treatment.

This assessment has been updated following the initial ground investigation, and is detailed in the section below..

November 2021 Hydrock Coal Mining Investigation

During the Hydrock investigation, no broken ground or loss of flush was encountered in any of the 17 rotary open holes drilled. In the majority of open holes both the upper unnamed seam and the Cannel seam were encountered, with both seams found to be intact which suggests that neither seam has been worked beneath the site.

Summary

No evidence of mine workings was encountered in the November investigation which specifically targeted the Cannel seam. It was in this seam where broken ground and a loss of flush was encountered in RO01 in the June Investigation. It would be expected that if the Cannel seam had been subject to working then this would have been picked up in the 17 open holes drilled in the November investigation. As this was not the case the information to date suggests the Cannel seam has not been mined beneath the site.

Potential evidence of workings in the Cannel seam have been identified at only one location, as such this suggests that the broken ground and loss of flush encountered in RO01 in June 2021 is considered to be indicative of rock and coal that is highly fractured and/or broken as a result of geological processes. If the Cannel seam had been subject to coal working beneath the site this would have been exhibited by broken ground, voids and losses in flushing medium within the cannel seam, none of which were encountered during the November investigation.

Based on the information from the rotary open hole drilling collected to date there does not appear to be substantial evidence to suggest that the upper unnamed seam or the cannel seam have been subject to mine working beneath the site. On this basis the risk to the future development is considered to be low.

No treatment or further mitigation measures are considered necessary to the shallow seams beneath the site.

6.5.2 *Mine shafts or entries*

There is known to be one recorded mine shaft within the site boundary (CA reference 364407-005) and a further four lying off-site to the north and west within influencing distance. The locations are shown on Hydrock drawing 15592-HYD-XX-XX-DR-GE-0005 in Appendix A.

RSK investigated shaft 364407-005 as part of the 2018 supplementary investigation. This confirmed the location of the mine entry through the excavation of trial pits finding the shaft to be centred at National Grid Reference 364180.57, 407565.04. Review of the abandonment plans indicates that the shaft served the King Mine at approximately 46m bgl. There is no record of any historical treatment having been undertaken on any of the shafts.

In relation to the current redevelopment proposals the shaft is located between Unit 5 and Unit 7 within the cutting for the access road. No new structures are proposed to overly the mine shaft.

Based on the location of the off-site mine shafts, the recommended departure from the Coal Authority guidance and the anticipated depth to rockhead, it is considered that these shafts do not pose a risk to the development.

Prior to any earthworks taking place (or as part of the enabling works) the mineshaft (364407-005) located on site will require treatment and capping in accordance with a specification agreed by the Coal Authority.

Guidance on the potential zone of influence from a theoretical collapse of a mine shaft can be found in CIRIA Report C758D 'Abandoned Mine Workings Manual '(Parry and Chiverrell, 2019). It is recommended that all shafts within influencing distance of proposed structures are stabilised prior to development.

It is envisaged that this stabilisation can be undertaken as part of the enabling phase of the development and in conjunction with any bulk infilling of underground workings where this is required. Where mineshafts lie off-site there may be significant practical difficulties associated with gaining access to undertake stabilisation works. It must be cautioned that recorded shaft locations can vary significantly from the true positions and there is a risk of unrecorded mineshafts being present.

Should the position change of any proposed buildings, which may interact with where mine shafts lie directly beneath or very close to a proposed structure, it will be necessary to install a cap to a structural specification. The design will require agreement with the ground improvement Contractor, building control, the Coal Authority and the warranty provider. It is recommended that where possible the siting of structures over shafts is avoided.

6.6 Foundation recommendations

In accordance with EC7, BS EN 1997-1+A1 (2013), the proposed commercial distribution buildings are considered to be Geotechnical Category 3 primarily on account of the potential underground workings. As such, foundation recommendations are presented to aid development proposals only and separate geotechnical design will be required.

6.6.1 *Foundation Types*

There is up to 8.0m of cut and 10.0m of fill required across the site area to create the development platform with the cut/fill line falling across the building footprint of Unit 7.

The Made Ground is considered unsuitable in its present condition for use as founding soils on the basis of it containing a high quantity of deleterious material including wood, plastic and metal and should be fully penetrated by all new foundations or excavated, screened, processed and re-engineered to create the development platform. The Made Ground found in the northern landfill is geotechnically unsuitable to remain in situ, and will require excavation. Material from this landfill is unlikely to be suitable for re-use on the development platform.

Based on the results of the ground investigation the upper 2-3m of Glacial Till is also considered unsuitable in its present condition for use as founding soils on the basis of its low strength and high compressibility and should be fully penetrated by all new foundations. Alternatively, the Glacial Till can be improved by the use of ground improvement or be completely removed and re-engineered. Options are discussed further in Sections 6.7 and 6.13.

It is recommended that the earthworks and ground improvement are designed to facilitate the structures supported from shallow pad foundations. Whilst a fully piled solution is an option it is unlikely to be economically feasible.

In accordance with EC7, for Category 2 and 3 structures, geotechnical verification of the overall stability and serviceability of foundations will need to be undertaken likely in conjunction with the earthworks and ground improvement design.

6.6.2 Spread foundations

Pad foundations are considered suitable for the buildings to support the columns for the proposed structures. Following the cut to fill earthworks, foundations will either be supported within the natural Glacial Till in areas of cut or within suitable engineered fill.

Based on the low volume change potential of the clay soils, the minimum founding depth for pad foundations is 0.9m below ground level. However, this assumes at least stiff Glacial Till is encountered or the founding material is suitably designed engineered fill. At this level a maximum permissible foundation pressure of 150kN/m² is likely to be feasible and can be used for preliminary foundation design. However, where specialist ground improvement is implemented such as VSC, the maximum foundation pressure may need to be reduced. Any engineered fill will need to be suitably designed to ensure that settlements are limited to tolerable levels.

Where the low strength Glacial Till is within influencing distance of the foundations, i.e. within a given distance of the cut / fill line, ground improvement will be required. This could either take the form of excavation and replacement or vibro ground improvement at pad locations.

Where trees and vegetation are to be removed, the roots and desiccated soils (if present) should be excavated and replaced with suitable engineered fill prior to undertaking the land raise or construction of foundations.

Deepening of foundations in accordance with BRE 240 and BRE 298 will be required where pad foundations are within the zone of influence of existing, removed or proposed trees and proposed shrub planting. A tree survey should be undertaken by an arboriculturist in accordance with BS 5837:2012 to identify the type, and height of existing trees on the site and including any off site trees, that could have an effect on foundation design. Ensuring that the foundations are suitably deepened to avoid the negative effects of trees is the responsibility of the foundation designer.

Where trees are removed and where it is not practical to deepen individual pads beyond the influencing distance of the desiccated soils, it is recommended that bulk excavation of the affected area be undertaken and, following moisture conditioning, the soils are replaced to an Engineered Specification.

Where foundations are within the zone of potential desiccation from trees and are deeper than 1.5m bgl, a suitable compressible material or void former will be required on the inside faces of foundations to external walls,.

Foundation formations should be inspected by a geotechnical engineer or other suitably competent person to ensure the founding conditions are suitable and as indicated in this report. Any formation materials deemed as unsuitable should be excavated and replaced with lean mix concrete or deepened to suitable strata.

Foundation excavations should be protected from rain and snow and inflow of surface water, frost and freezing conditions. They should also be protected from excessive drying out and cracking in hot dry weather.

Any water that collects at the base of the foundation excavations should be removed by pumping from a sump in the base. However, groundwater records from the investigation indicate localised zones of fast ingress and alternative methods of groundwater control may be required.

6.7 Ground improvement

Based on review of the ground investigation ground improvement will be required in the following circumstances:

- In areas of fill where the additional load causes excessive consolidation of the underlying soils;
- Where the low strength Glacial Till (upper 2-3m) is within influencing distance of structures and foundations. This will occur a distance either side of the cut fill line; and
- Where the moisture content of the engineered fill cannot be reduced sufficiently to support foundation or floor slab loads.

The ground improvement recommendations assume that the Made Ground and peat/organic soils are removed.

A number of ground improvement options are presented in Table 6-3 and discussed in further detail below. As the number of options and potentially combination options are complex, an additional section of the report is added in Section 6.13 discussing the overall enabling works strategy.

6.7.1 Vibro Stone Columns (VSC)

Treatment by VSC at suitable spacing should lead to significant improvement of the soils by the creation of stone columns. The depth and spacing of the VSC treatment should be determined by a specialist Contractor. The technique could be used prior to the placement of fill to both reduce the total settlement and increase the rate of consolidation. Alternatively, it could be used immediately below foundations and floor slabs where the existing soils or engineered fill is of insufficient strength to support the loads.

Typically, VSC are used to treat relatively shallow soils up to in the order of 10m and, as such, the potential for full depth treatment in the thickest areas of fill would need to be discussed with a specialist.

Following treatment below pad foundations, allowable foundation pressures of around 125kN/m^2 are normally possible subject to confirmation from a specialist contractor. Treatment is also possible below floor slabs, however where loading above 50kPa is required other forms of ground improvement such as Vibro Concrete Columns (VCC) or Controlled Modulus Columns (CMC) will likely be more appropriate.

6.7.2 Prefabricated Vertical Drains (PVD)

PVD work by reducing the drainage pathway within a material undergoing consolidation such that the total consolidation occurs over a shorter time period. The PVD is installed by a mandril to depths of up to 20m in suitable ground conditions with spacing selected based on the required consolidation period.

Target consolidation is usually around 90% and at close spacing consolidation can be expected to occur within a period of 2 to 3 months.

PVD would be effective at the Wingates site where significant thicknesses of fill are required to ensure that all of the consolidation (or as much as possible) is complete prior to commencing construction. The PVD are connected at the surface via a granular drainage blanket, which can also function as the working platform.

6.7.3 Preload and Surcharge

The stiffness and load carry capability of the shallow Glacial Till and engineered fill could be improved by preloading with a temporary surcharge of fill. This fill could be won from site following the site strip using topsoil.

There are potentially two applications for preload and surcharge on site:

1. An additional surcharge of fill could be used on top of the fill embankments in order to decrease the consolidation time prior to construction. This works by removing the surcharge at a degree of consolidation equivalent to 90% consolidation under the design load i.e. at a degree of consolidation of less than 90% under the surcharge load;
2. Additional fill could be used to increase the stiffness of the natural soils and engineered fill in areas of structural foundations and floor slabs. A ‘preload’ of fill for example is placed equivalent to the anticipated design load of the floor slab in order to induce consolidation prior to construction. Normally, additional surcharge is placed over and above the preload to result in a greater level of improvement. In this case, the minimum height of fill is a function of the design load and so for a floor slab with a design load of 50kPa and a surcharge of 30% the minimum design height would be in the order of 3.6m.

Based on the cohesive nature of the Glacial Till to be improved it is likely that the installation of vertical drains (PVD) will be required to reduce the consolidation period. Based on a relatively close spacing of between 1.0-1.5m the improvement period can typically be reduced to between two to four months.

In the same way as the other foundation solutions and ground improvement methods their appropriateness will be based on the levels of permissible total and differential settlement. Given that the thick fill will be susceptible to ongoing secondary compression and self-weight settlement, total settlements may be locally very high even after ground improvement.

6.7.4 *Dynamic Compaction*

Dynamic Compaction and other proprietary compactive techniques such as High Energy Impact Compaction (HEIC) and Rolling Dynamic Compaction (RDC) are not considered suitable due to the cohesive nature of the fill and the likely serviceability requirements for the structures.

6.8 Working Platforms

For the installation of VSC and PVD, a working platform will be required prior to the arrival on site of tracked plant. This should be designed and installed in accordance with BR470 (BRE 2004) based on data provided on the FPS certificate appropriate to the proposed plant and equipment.

6.9 Ground Floor Slabs

Subject to geotechnical design and on the basis that improvement of the Glacial Till will be undertaken and all structural fill will be placed strictly in accordance with an appropriate Earthworks Specification, then ground bearing floor slabs may be adopted. Where the ground bearing floor slab is founded on engineered fill or the natural Glacial Till (in areas of >3m of cut) a modulus of sub-grade reaction (k) of 37MN/m³ can be used for slab design. This value could be increased during the geotechnical design by the inclusion of an appropriate sub-grade improvement capping layer and geogrids.

An appropriate form of ground improvement should be designed to support the floor slab. For ground bearing floor slabs with a design UDL of up to 50kPa a fill stiffness (E') of around 20MPa would be required in the areas of greatest fill thickness. Alternatively, ground improvement using VSC or surcharging could be implemented. Confirmation of the subgrade design parameters should be established at the design stage.

The floor slab should be designed by a structural engineer and a limit state assessment undertaken as part of the geotechnical design.

Prior to the placement of the founding materials and the construction of the ground bearing floor slab, the sub-formation and formation will need to be inspected and checked by a competent person to ensure the ground conditions at time of construction are consistent with the Specification and the design parameters derived from this ground investigation. Testing should be undertaken in accordance with The Concrete Society Technical Report 34 (The Concrete Society 2013). It is recommended that the verification of the sub-formation and formation include, as a minimum, the measurement of modulus of sub-grade reaction (k) determined by static plate load testing.

6.10 Roads and Pavement

Based on the test results and subject to ***in situ*** testing during construction, a design CBR of <2.5% (equivalent to a subgrade stiffness of <30MPa) should be assumed. However, following subgrade improvement and the placement of fill in accordance with a suitable specification, a design CBR of 2.5% could be used for preliminary design.

Subgrade improvement could include one or a combination of the following:

- Over-excavation and replacement of the low strength material;
- Treatment and stabilisation with hydraulic binder. This process could be combined with replacement of the capping with stabilised material; and
- The inclusion of geogrid at the base of the capping.

Depending on the method chosen, proof rolling of the formation level will be required and any loose or soft spots should be removed and replaced with an engineered fill, in accordance with a suitable Specification. In either case the Made Ground should be completely removed and replaced prior to installation of the pavement foundations. The formation level will also need to be protected during inclement weather from deterioration; all slopes should be trimmed to falls to shed rain water and the surface sealed to limit infiltration.

Prior to the placement of the founding materials and the construction of the road pavement, the subformation and formation will need to be inspected and checked in accordance with a suitable specification to ensure the ground conditions are as expected. All testing should be carried out in accordance with DMRB CD622 to confirm that the ground conditions at time of construction are consistent with the previous design parameters.

6.11 Drainage

Indicative infiltration rates for the ground investigation are presented in Appendix C and are summarised in Table 5-6.

Soakaways are considered unsuitable for the site based on the low infiltration rates obtained from testing. However, the infiltration rates recorded may assist with attenuation as part of a Sustainable Urban Drainage System (SUDS).

6.12 Buried concrete

Based on guidelines provided in BRE Special Digest 1 (BRE 2005) and the information presented in Section 5.5.8 (Table 5-14):

- The Glacial Till can be classified as Design Sulfate Class DS-1 and ACEC Class AC-1.
- The Pennine Lower Coal Measures can be classified as Design Sulfate Class DS-1 and ACEC Class AC-1.

This equates to a Design Chemical Class[1] of DC-1 for the Glacial Till and the Coal Measures.

The designer should check and confirm the classification of concrete using the information presented in Appendix B and Appendix C during the design. Furthermore, any imported material shall be tested for sulphate content in accordance with Clause 601 of the SHW to ensure they comply with the concrete design.

6.13 Enabling Works Recommendations

Further to the geotechnical assessment undertaken in the preceding sections, a number of foundation and ground improvement options are available and to some extent will be based on the Client's and Contractor's preferences.

The following is Hydrock's recommended enabling works strategy.

[1] The calculated ACEC class can be used in accordance with BS 8500-1+A2 (2019), Table A.9 to select the Designated Concrete (DC) class for an intended working life of 50 years. However, the designer is referred to BS 8500-1+A2 (2019), for full details and notes to Table A.9, including any Additional Protective Measures (APMs).

1. Topsoil strip and stockpile for future use in landscape bunds. Care should be taken to avoid stripping large areas in inclement weather where the subgrade could be damaged by standing water;
2. Over-excavation and replacement of the Made Ground. Unsuitable material to be removed from site, processing and treatment of remainder to allow re-use on site;
3. Over-excavation and replacement of peat and organic soils;
4. Over-excavation and removal of trees, vegetation, root balls and potentially desiccated soils in the vicinity of trees and hedgerows to be removed;
5. Over-excavation of 2-3m of low strength Glacial Till below structures across the cut/fill line. Alternatively separate ground improvement, such as VSC, could be used below foundations and floor slabs in these areas;
6. Installation of a granular basal drainage layer in areas of fill where excessive consolidation is predicted;
7. Installation of PVD in areas of fill where excessive consolidation is predicted;
8. Installation of geotechnical monitoring equipment including vibrating wire piezometers and rod settlement gauges to assess the settlement due to land raising;
9. Cut and fill to form the development platform with the inclusion of horizontal drainage in areas of fill to increase the rate of self-weight settlement;
10. Treatment of selected fill with hydraulic binder in order to meet the minimum stiffness requirements below structures. Alternatively, preload and surcharge could be used reducing the treatment requirements of the fill;
11. Geotechnical and geo-environmental testing of all fill in accordance with the design documents;
12. On-going assessment of consolidation with construction in areas of fill permitted only when sufficient consolidation has taken place.

It may be that different techniques may be appropriate for different plots depending on the local ground conditions, whether the finished levels are in cut or fill and whether the plots are programme critical.

7. GEO-ENVIRONMENTAL ASSESSMENT

7.1 Updated conceptual model

7.1.1 Updated ground model

The preliminary ground model developed from the RSK desk study (Section 2) has been updated using the findings of the ground investigation and is presented in Section 5. This ground model is the basis for the geo-environmental assessment presented in this section.

7.1.2 Updated exposure model

Following the ground investigation, the plausible contaminant sources, receptors and pathways identified in the preliminary geo-environmental exposure model (Section 3), have been updated or confirmed as follows.

7.1.3 Sources

The following potential sources have been removed from the exposure model.

On site potential sources

- Hydrocarbon fuels from the general spillage, together with uncontrolled disposal and spillage from waste receptacles potentially stored within the barn in the east of the site.
- Hydrocarbon vapours from potential petroleum hydrocarbon spillages/leaks from uncontrolled disposal and spillage from waste receptacles at the barn in the east of the site.

Following inspection this area of the site is covered by concrete hardstanding which appears to be in good condition, with no evidence of apparent fuel storage or spillage at this location. No odours or visual evidence of contamination were encountered during investigation works.

Off site potential sources

- Hydrocarbon fuels or VOCs from the general spillage, together with uncontrolled disposal and spillage from waste receptacles potentially stored at the car garage adjacent to the north west or caravan storage yard immediately to the south.
- Hydrocarbon vapours from potential VOC and petroleum hydrocarbon spillages/leaks associated with the adjacent garage to the north west or caravan storage park to the south west.

Following inspection of this off site property, it was confirmed that the garage is covered by concrete hardstanding at surface level which appears to be in good condition, with no evidence of apparent fuel spillage. No odours or visual evidence of contamination were encountered on site during investigation works.

7.1.4 Receptors

No potential receptors have been removed from, or added to the exposure model.

7.1.5 Pathways

No pathways have been removed from, or added to the exposure model.

7.2 Risk assessment approach

Generic risk assessments have been undertaken in accordance with the principles of LCRM (Environment Agency, 2019) using the CM that has been updated following the ground investigation.

Firstly, the risks associated with the identified potential contaminant linkages have been estimated using standardised methods (typically involving comparison of site data with published 'screening values'). Secondly, where screening values are exceeded, the result has been evaluated in an authoritative review of the findings with other pertinent information to determine whether or not the exceedance is, or is not acceptable in the site-specific circumstances. Further explanation is presented in the sections below.

The data sets used in the assessment comprise the analytical results obtained by Hydrock as listed in Section 4 together with any reliable data from previous investigations.

In cases where unacceptable risks are indicated, actions such as more advanced stages of risk assessment or remediation are proposed in Section 7.8.

7.3 Human health risk assessment

This is a Tier 2 assessment using soil screening values applicable to the commercial / Industrial CLEA land use scenario.

The soil screening values used are generic assessment criteria (GAC). It should be noted that Category 4 Screening Levels (C4SL) for lead have been used as there is no recognised GAC for lead and the use of the term 'GAC' in this report includes the C4SL for lead.

Statistical testing is used where data sets are suitable. The critical issue is sample numbers. For data sets with low sample numbers and where sampling is targeted at specific areas, individual sample test results are compared directly with the screening values. Larger and non-targeted data sets are subject to statistical testing.

The phrase 'further assessment required' is used to denote soil concentrations that are equal to, or exceed, a GAC. This does not necessarily mean that the soil is 'contaminated' or not otherwise suitable for use. The assessment and any mitigation required are to ensure the site does not pose an 'unacceptable risk'.

The results of the assessment are presented in Appendix E.

7.3.1 Averaging areas

The 'averaging areas' used in this report are based on the conceptual model and the proposed development, and are summarised as:

- Landfill material;
- Topsoil;
- natural soils of the Glacial Till.

7.3.2 Risk estimation (including statistical testing)

7.3.3 Outliers

The data set for each chemical determinand has been assessed for potential outliers (based on the conceptual model). No outliers have been removed.

7.3.4 Statistical assessment

In accordance with the guidance provided by the CIEH (May 2008) the 95th upper confidence level on the true mean (US_{95}) has been calculated from the sample data. Reference to the methodology for statistical assessment is given in Appendix I.

Landfill material

Laboratory results from samples taken within the landfill materials have been assessed against GAC for human health with a commercial end use.

Samples of the landfill material were obtained in HYDTT10, HYDTT16, HYDTT15, HYDTT17, HYDTT03, HYDTT03, HYDTT05 at depths ranging between 0.3 – 4.8m bgl.

Based on no US_{95} exceedances of the GAC, there are no chemicals of potential concern that require further assessment.

Topsoil

Laboratory results from samples taken of the topsoil material at six locations across the site have been assessed against GAC for human health with a commercial end use.

Based on no US_{95} exceedances of the GAC, there are no chemicals of potential concern that require further assessment.

Glacial Till

Laboratory results from samples taken of the Glacial Till at 11 locations across the site have been assessed against GAC for human health with a commercial end use.

Based on no US_{95} exceedances of the GAC, there are no chemicals of potential concern that require further assessment.

7.3.5 RSK Risk Assessment (soils)

Landfill material

Samples of the landfill material were obtained in WS02 (at depths 0.8 – 1.0m bgl and 2.5 – 2.8m bgl.) and WS03 (at depths 0.3 – 0.6m bgl. and 1.1 – 1.3m bgl.).

Laboratory results from samples taken within landfill material were assessed against GAC for human health with a commercial end use.

A review of the RSK screening exercise has confirmed that there are no exceedances of the GAC for chemicals of potential concern.

Natural soils

Laboratory results from samples taken of natural soils were assessed against GAC for human health with a commercial end use.

A review of the RSK screening exercise has confirmed that there are no exceedances of the GAC for chemicals of potential concern.

Visual evidence of potential contamination

Visual evidence of potential hydrocarbon impacted Made Ground was identified in TP49 during the RSK investigation, located in an area of hardstanding of the farm in the north west of the site. Subsequent laboratory analysis of the Made Ground sampled did not exceed the GAC for commercial end use.

7.3.6 Risk evaluation

The screening exercise has identified that there are no chemicals of potential concern in natural soils at concentrations above the GAC, for the samples collected in the Hydrock and RSK investigations. No further consideration is required.

7.4 Pollution of controlled waters risk assessment

7.4.1 Risk estimation

Hydrock believes the risk of pollution to controlled waters at the site is very low on the following basis:

- Historically the majority of the site has remained undeveloped (with the exception of the known landfill area in the north);
- the ground investigation has not identified a viable source of contamination, with Made Ground generally limited to the northern landfill area;
- the tier 2 human health risk assessment for soils has identified that there are no chemicals of potential concern in the landfill material, topsoil or Glacial Till at concentrations above the GAC;
- the site is underlain by low permeability cohesive Glacial Till, which is expected to inhibit the downward migration of chemicals within soils;
- the proposed commercial development will see the introduction of hardstanding across the majority of the site, reducing the infiltration of surface water;
- There are no recorded groundwater abstractions wells within 900m of the site and the does not overlie a Groundwater Source Protection Zone.

On this basis Hydrock believe that in this instance chemical analysis of groundwater was not warranted.

Hydrock believes the risk to groundwater and surface water at the site is very low and no further consideration is required.

7.5 Ground gases risk assessment

7.5.1 Data

It is judged from the available evidence that the gas generation potential at the site is low to moderate (due to the presence of three localised areas of landfilling and the potential for mine gas) and that the sensitivity of the development is low (due to the proposed commercial development). Consequently,

and in accordance with CIRIA C665 (Table 5.5a and 5.5b), an appropriate minimum monitoring regime is six readings over two to three months, provided other monitoring requirements are also met, such as prevailing atmospheric pressure conditions (for example, BS 8485:2015 +A1:2019 suggests monitoring should include a period of falling atmospheric pressure).

Hydrock has completed all monitoring rounds, including periods of falling and low atmospheric pressure, with the conclusions presented below.

On a small number of occasions, high gas flow rates have been measured which is found to correspond with a rise in the groundwater level between monitoring rounds and are likely to be caused by this change. The rise in the water level in the standpipe will compress the gas in the standpipe head-space, resulting in a short, high-pressure release on opening the monitoring tap. It was generally noted that the high initial flow rates only occurred when the water level rose above the response zone of the pipe, presumably because the gas would otherwise be able to disperse via the slotted pipe. As such, the temporary initial high gas flow rates are discounted as not being typical of emission rates to a built development.

7.5.2 *Assessment*

The risks associated with the ground gases methane (CH_4) and carbon dioxide (CO_2) have been assessed using BS 8485:2015 +A1:2019, which cites the guidelines published by CIRIA (Wilson et al 2007) (known as Situation A).

There is an alternative assessment method described by the NHBC (Boyle and Witherington 2007) (known as Situation B). Whilst 'Situation B' may also be suitable for the assessment, it is Hydrock's opinion that the NHBC Guidelines are not at the current time fully aligned with current ground gas risk assessment principles (as described in BS 8485:2015 +A1:2019). As such, 'Situation A' has been chosen as the means by the gas risk will be assessed.

The assessment guidelines published by CIRIA are based on interpretation of the gas concentrations and the gas flow rates, amongst other variables, and are compliant with the model procedures of LCRM. The modified Wilson and Card assessment has been used by comparing the maximum gas concentrations and gas screening values (GSV[2]) in Appendix D with the published table (CIRIA Table 8.5) and the assessment is summarised in Table 7-1. The assessment is presented in Appendix D.

Table 7-1: Ground gas risk assessment

	Min	Max	Typical [(i)]	Comment
Hydrock data				
Steady Flow Rate (l/hr)	-4.3	11.9	<0.1*	Flow rate is elevated above the limit of detection on 37 occasions. On 15 of these occasions the groundwater level was encountered above the screen depth in the monitoring well and can therefore be discounted. The maximum flow rate was recorded during the second visit within the Glacial Till on one occasion.
Methane (%)	0.0	0.2	<1	Methane is negligible in the Glacial Till with a maximum concentration of 0.2%.
Carbon Dioxide (%)	0.0	9.6	<5	Carbon dioxide was detected at concentrations between 5% and 10% on two or more occasions in CP05 (Glacial

[2] Note: GSV is synonymous with 'site characteristic hazardous gas flow rate' (Q_{hgs}) of BS 8485:2015 +A1:2019 Table.

	Min	Max	Typical [i]	Comment
				Till), CP06 (Glacial Till/PLCM), CP11 (Glacial Till), CP19 (Glacial Till), and WS03 (Glacial Till). During the monitoring period carbon dioxide was typically detected at concentrations <5% in the remaining boreholes.
Carbon Monoxide (ppm)	0	58	<10	Carbon monoxide detected at 58ppm on one occasion in CP13. During the monitoring period Carbon Monoxide was typically detected at <10ppm with the exception of WS01 which typically recorded Carbon Monoxide at between 8.0ppm and 21.0ppm.
Hydrogen Sulphide (ppm)	0	14	<1	Hydrogen Sulphide detected at 14ppm on one occasion in CP13. During the monitoring period Hydrogen Sulphide was typically detected at <1ppm.
Oxygen (%)	0.4	21.0	19.0	Depleted Oxygen is typically detected in the boreholes where elevated Carbon Dioxide is detected (CP06, CP19 and RO13).
Carbon Dioxide GSV (l/hr)	0.00	0.36	<0.7	CS2**
Methane GSV (l/hr)	0.00	0.00	<0.07	CS1
RSK data				
Steady Flow Rate (l/hr)	-14.6	28.5	-	Elevated flow rate detected in vicinity of the central and southern landfill areas (WS07 and WS09). Sporadic slightly elevated flow rate detected in the Glacial Till.
Methane (%)	<0.1	59.4	<1	Methane detected above 1% in two boreholes at 59.4% in WS02 (located in the northern landfill), and at 3.6% in CP04 (located in the central west landfill). Methane is typically below the limit of detection.
Carbon Dioxide (%)	<0.1	23.4	<5	Carbon Dioxide detected between 5% and 10% in five boreholes (located in the vicinity of landfill areas). Carbon Dioxide detected above 10% in one borehole at 23.4% in WS04 (located in the vicinity of the northern landfill). Carbon Dioxide concentrations are typically below 5% in the Glacial Till.
Oxygen (%)	<0.1	21.8	18.0	Depleted Oxygen is detected sporadically in the Glacial Till and landfill material where flow rate is elevated.
Carbon Dioxide and Methane GSV	-	-	<0.7 <3.5	CS2 CS3***(central and southern landfill)

[i] Hydrock assume that values are considered to be atypical if 95% or more of the remaining data are less than the value under consideration

For the purposes of the calculation, where the recorded gas flow rate is below the manufacturer's limit of detection for the instrument used, the detection limit has been adopted for the gas flow rate.

* High gas flows discounted as anomalous data due the groundwater level which was encountered above the screen depth in the monitoring well.

** The Hydrock GSV for Carbon dioxide equates to CS2 conditions, however this classification will be reassessed and is subject to change following supplementary monitoring once the cut to fill earthworks are completed.

*** The RSK calculated GSV equates to CS3 conditions, however this is for two monitoring locations only (WS07 and WS09) targeted in the vicinity of the central and central west landfill.

As indicated above The RSK computed GSV for both carbon dioxide and Methane indicates CS2 conditions with carbon dioxide and methane at concentrations 'typically' below 5% and 1% respectively. On the basis of two boreholes installed in the central and southern landfill areas RSK classify the landfill areas as CS3.

The elevated concentrations of carbon dioxide and methane identified in the RSK data relate to boreholes targeting specific sources, which are located in the vicinity of landfill areas and the mineshaft.

The Hydrock computed GSV for carbon dioxide is CS2 and methane is CS1 conditions, with methane and carbon dioxide at concentrations are 'typically' below 5% and 1% respectively. Although the computed GSV for carbon dioxide indicates CS2 conditions, the data suggests this is borderline CS1 due to consistently elevated carbon dioxide (5-10%) detected in only six boreholes.

It is envisaged that as part of the site reprofiling that the areas of landfill material are to be excavated with materials containing higher organic matter will be removed, and reused elsewhere on site away from buildings. This would eliminate the requirement for protection measures commensurate with CS3 conditions. It is also anticipated that treatment of the mineshaft and the site wide reprofiling of ground levels will likely result in a change to the ground gas regime. As such further monitoring will be required following the cut to fill.

In conclusion Hydrock believes at this stage it would be prudent to provisionally classify the site commensurate with CS2 conditions, with this classification to be reassessed and subject to change following the supplementary monitoring once the cut to fill earthworks are completed.

On this basis CS2 conditions apply until the post-earthworks monitoring is completed and the risk assessment is updated. Ground gas mitigation measures will be recommended post-earthworks following the reassessment.

7.5.3 Off-site risks from carbon dioxide and methane

The National Planning Policy Framework requires that a developed site should be incapable of being determined as contaminated land under Part 2A of the Environmental Protection Act 1990. This position includes a consideration of the potential for off-site migration of ground gases that may impact on adjacent properties.

Consequently, it may be necessary to consider the imposition of measures to protect adjacent, off-site receptors. In this case due to the typical low flow rate, low level concentrations of Carbon Dioxide and inconsistent concentrations of Methane from the landfill areas, the subject site is not considered to present a risk to adjacent properties.

7.6 Construction materials risk assessment

7.6.1 Water pipelines

A formal water pipe investigation and risk assessment is beyond the scope of this report. However, the findings of this investigation have been compared to the threshold values in Water UK HBF (2014), Table 1 as far as is practicable, to give an indication of the possible restrictions to the use of plastic pipes for water supply to the site (see the reference in Section 11 for further information).

The site is predominantly previously undeveloped, with three localised areas of brownfield (former landfill's). However, the investigation has not detected organic contamination in exceedance of the threshold values and Hydrock believes standard pipework may be suitable for the site. However, confirmation should be sought from the water supply company at the earliest opportunity.

7.6.2 Other construction materials

Plastic pipes for drains and sewers are manufactured from unplasticized poly (vinyl chloride) (PVC-U), polypropylene (PP) or polyethylene (PE). These materials may be affected by the presence of organic compounds in the soil.

In accordance with the British Plastics Federation Guidance (August, 2018), as the concentrations of PAH, and BTEX are below 100mg/kg and the concentrations of petroleum hydrocarbons (TPH) are below 200 mg/kg, PVC-U, PP or PE pipework is considered suitable.

The implications for buried concrete are discussed in Section 6.12.

7.7 Contamination risks to ground workers

7.7.1 Introduction

Whilst risks to construction workers are not discussed in detail, the following section discusses potential risks that should be considered.

Information presented in this document is provided to assist in managing the risk associated with contamination in soil and groundwater at the site but is not definitive. The Contractors are responsible for undertaking their own assessments and assessing what risks are present and what control measures are required.

Task specific risk assessments and method statements should be in place, and risks and required mitigation measures communicated to all relevant personnel prior to the works commencing. Appropriate PPE and, if required, RPE should be provided and utilised.

7.7.2 Metals, PAH and petroleum hydrocarbons

There are no exceedances of contaminants within the Made Ground, Topsoil or Glacial Till in relation to the GACs for a commercial development. However, the presence of high concentrations of metals, PAH and petroleum hydrocarbons cannot be discounted within the landfill materials and construction workers should wear appropriate PPE specific to the task they are undertaking.

7.7.3 Ground Gas

It is noted that concentrations of carbon dioxide (an asphyxiant) in the soil exceed HSE Workplace Exposure Limits for personnel in the working environment of 1.5% for short term (15 minutes) exposure and 0.5% for long term exposure. Furthermore, soil concentrations of oxygen are below the HSE recommendations of 18%.

Soil gas concentrations are not necessarily reflected by those in the breathing zone, as such, all Contractors and maintenance workers should be made aware of the possible presence of carbon dioxide and should take all necessary health and safety precautions when working in trenches or confined spaces.

7.7.4 Asbestos

As no clearly identifiable ACM has been seen during the site walkover or during the ground investigation and no fibres have been detected in soil samples analysed by laboratory testing, CAR2012 does not apply. However, there is always the possibility of unexpected contamination, specifically in the landfill areas and the Contractors should undertake a watching brief during the works. If any

suspect material is encountered, works in that area of the site should stop, the area fenced off and Hydrock should be notified.

7.8 Findings of the generic contamination risk assessments

The potential sources, pathways and receptors identified in the desk study (Section 2) have been investigated (Sections 4 and 5) and assessed (Sections 7.3 to 7.7). A Source-Pathway-Receptor linkage assessment has been undertaken and is presented in Appendix H (Table K.2).

A summary of the Source-Pathway-Receptor (SPR) contaminant linkages for which the risks may be unacceptable and require mitigation (those that are moderate or higher) are discussed in Table 7-2.

Table 7-2 assumes the following SPR linkages which have been discounted (subject to agreement) at the risk evaluation stage are confirmed by the regulators and the warranty provider as not requiring further consideration (mitigation). If these assumptions are not agreed during regulatory discussions, the conclusions as noted in Table 7-2 will need to be updated:

- Elevated concentrations of carbon dioxide and Methane in the vicinity of landfill areas, and slightly elevated concentrations of carbon dioxide in the Glacial Till.

Table 7-2: Residual risks following risk evaluation

Contaminant Linkage				Comments	
Pollutant Linkage	Sources	Pathways	Receptors	General	Mitigation
PL 1.	Methane and Carbon Dioxide from biodegradable matter in the Landfill material.	Migration through soils or groundwater to indoor air.	End users of new buildings (asphyxiation).	Monitoring has indicated elevated concentrations of Methane and Carbon Dioxide in the vicinity of landfill areas. The landfill areas are provisionally classed as Characteristic Situation 3.	As part of the sites reprofiling to create the required development platform the landfill material is to be excavated, sorted to remove organic constituents with suitable material reused on site away from buildings and infrastructure. Supplementary monitoring is required post-earthworks to confirm the Characteristic Situation and appropriate mitigation measures.
			New buildings (damage by explosion).		
PL 2.	Methane and Carbon Dioxide from the mineshaft.	Migration through soils or	End users of new buildings (asphyxiation).	Monitoring data has indicated elevated concentrations of	It is anticipated the mineshaft will be treated, which is expected to change the

Contaminant Linkage				Comments	
Pollutant Linkage	Sources	Pathways	Receptors	General	Mitigation
		groundwater to indoor air.	New buildings (damage by explosion).	Methane and Carbon Dioxide in the vicinity of the Mineshaft.	ground gas regime in this area of the site. Supplementary monitoring in this area of the site is required post-earthworks to confirm the Characteristic Situation and appropriate mitigation measures.
PL 3.	Carbon dioxide from the Glacial Till and PLCM.	Migration through soils or groundwater to indoor air.	End users of new buildings (asphyxiation).	Monitoring has indicated elevated concentrations of Carbon Dioxide. The Glacial Till and PLCM are provisionally classed as Characteristic Situation 2.	Supplementary monitoring is required post-earthworks to confirm the Characteristic Situation and appropriate mitigation measures.

7.9 Mitigation measures

As shown in Table 7-2 (and subject to regulatory agreement), Hydrock consider the following mitigation is required to ensure the site is suitable for use for the proposed end use. The mitigation measures include:

- The excavation of landfill material, removal of organic constituents, and reuse of suitable material on site in landscaping areas. Landfill material is not to be reused beneath buildings or infrastructure (PL1).
- Mineshaft treatment (PL2).
- Supplementary ground gas monitoring to be undertaken post-earthworks to confirm the Characteristic Situation and appropriate mitigation measures (PL1, PL2 and PL3).

The methodology for the remediation should be set out in a Remediation Strategy (which will include the 'Implementation Plan', the 'Verification Plan' and the 'Long Term Monitoring and Maintenance Plan'), which will need to be submitted to the warranty provider and the regulatory authorities for approval.

In addition, the production of a Materials Management Plan and its approval by a Qualified Person will be required to allow reuse of suitable material at the site in accordance with waste regulations.

Verification reports by a competent independent geo-environmental specialist will be required following completion of any remedial works (including ground gas membrane installation).

7.9.1 Gas protection measures

The requirement for gas protection measures is to be confirmed following the supplementary monitoring once the cut to fill is completed. The ground gas risk assessment is to be updated and mitigation measures recommended accordingly.

8. WASTE AND MATERIALS MANAGEMENT

8.1 Introduction

The Waste Framework Directive (WFD) (2009/98/EC) defines waste as '*any substance which the holder discards or intends to discard.*' In a geo-environmental context, the waste is most often 'soil' and the two main scenarios are offsite disposal of the material as a waste and/or reuse of the material on site. For cost and sustainability reasons, reuse is preferred to off-site disposal.

The section below describes the key issues relating to off-site disposal to landfill and Section 8.3 considers requirements relating to reuse of soils and materials management.

8.2 Waste disposal

8.2.1 Principles

Based on the WFD, any material excavated on site may be classified as waste and it is the responsibility of the producer of a material to determine whether or not it is waste. Where off-site disposal is undertaken, the following guidance applies.

Classification is a staged process:

- A hazardous waste is defined under the WFD as one which possesses one or more of fifteen defined hazardous properties. If a waste is not defined as hazardous, then it is non-hazardous.
- Where the materials are soil, it is then be assigned using the 'List of Waste Codes', which classifies the material as either:

» hazardous (17-05-03), which is defined as "*soil and stones containing hazardous substances*"; or

» non-hazardous (17-05-04), which is defined as "*soil and stones other than those mentioned in 17-05-03*".

» Hydrock utilise the proprietary assessment tool, HazWasteOnline™ to undertake this assessment.

- Waste Acceptance Criteria (WAC) testing is then undertaken if required, and are only applicable following classification of the waste, and only where the waste is destined for disposal to landfill. The WAC are both qualitative and quantitative. The WAC and the associated laboratory analyses (leaching tests) are not suitable for use in the determination of whether a waste is hazardous or non-hazardous.

It should be noted that some non-hazardous wastes may be suitable for disposal at an inert landfill as non-hazardous waste, subject to meeting the appropriate waste acceptance criteria.

It should be noted that classification must be undertaken on the waste produced, by the waste producer. Necessary sampling frequency to adequately characterise a soil population is defined within WM3.

Further discussion with regards to the characterisation process for different scenarios and waste types is provided below.

Topsoil and Peat

Topsoil and peat are biodegradable, therefore if they are surplus to requirements and cannot be re-used in accordance with a Materials Management Plan, they cannot be classified as inert. As such, topsoil and peat need to be classified by a staged assessment and sampling process and would either be classified as hazardous or non-hazardous, depending upon the results of the assessment.

Greenfield Sites

Waste from completely greenfield sites may be accepted at a landfill as inert waste if it meets the requirements of paragraph 10 (wastes acceptable without testing at landfills for inert waste) of the Landfill (England and Wales) (Amendment) Regulations (2005) ('the Regulations') can be met. Paragraph 10 of the Regulations states, "*soils may be able to be classified as inert waste without testing, if:*

- *they are single stream waste of a single waste type;*
- *there is no suspicion of contamination and they do not contain other material or substances such as metals, asbestos, plastics, chemicals, etc."*

As such, where the site is greenfield and the waste producer is confident about the quality of a soil (i.e. naturally occurring and uncontaminated), further sampling and laboratory testing is not necessary for the Basic Characterisation and this can be undertaken on qualitative Waste Acceptance Criteria testing.

In this instance the waste producer can characterise the waste based on visual assessment and written description of the waste in addition to supporting evidence such as a desk study assessment of the greenfield status. However, it should be noted this characterisation is subject to agreement by the landfill operator who may require testing to be undertaken to confirm classification.

Contaminated or potentially contaminated sites

If the site is brownfield, contaminated or potentially contaminated, the waste must undergo an initial waste classification exercise using background information on the source and origin of the waste and assessment of chemical test data in accordance with Environment Agency Technical Guidance WM3.

If following the initial waste classification exercise, the soils are acceptable for disposal to a non-hazardous landfill, further qualitative Waste Acceptance Criteria (WAC) testing is not required.

However, if soils are potentially able to be disposed to an inert landfill as non-hazardous waste, or require testing to determine if they can be disposed of to a stable non-reactive hazardous or hazardous class of landfill, the next stage of assessment is to undertake qualitative WAC testing. This will determine the Basic Characterisation and the landfill category at which the soils can be accepted.

Hazardous material must be subjected to WAC testing to determine whether it requires treatment before it can be accepted at the hazardous landfill, while non-hazardous material can be tested to determine whether it may be suitable for placement in an inert landfill.

8.2.2 HazWasteOnline™ assessment

The site theoretically is undeveloped greenfield land, but with known areas of tipped waste in order to inform the preliminary waste characterisation process, Hydrock has undertaken an exercise using the proprietary web-based tool HazWasteOnline™. The output of the HazWasteOnline™ assessment is provided in Appendix F and a summary of the preliminary waste classification is provided below in Section 8.2.5.

8.2.3 WAC Testing

WAC testing has not been undertaken to date but will be required on the excavated soils that are to be disposed of, to assist with waste disposal options prior to disposal. A summary of the preliminary waste disposal options is provided below in Section 8.2.4.

8.2.4 Preliminary waste disposal options

A HazWasteOnline™ assessment have been undertaken for the soil samples collected during the Hydrock 2021 investigation. As long as no unexpected contamination is encountered and if suitable segregation of different types of natural waste streams is put in place, for soils to be disposed of, it is considered that:

- The landfill material is likely to be classified as non-hazardous waste for disposal at a non-hazardous landfill.
- The topsoil material is likely to be classified as non-hazardous waste for disposal at a non-hazardous landfill.
- The Glacial Till is likely to be classified as non-hazardous waste for disposal at a non-hazardous landfill.

Any soils containing > 0.1% asbestos or visible asbestos containing materials would be considered as hazardous.

8.2.5 General waste comments

It should be noted that:

- It is the waste producer's responsibility to segregate the waste at source and waste producers must not mix waste materials/streams or dilute hazardous components, for example by mixing with less or non-hazardous waste on site to meet WAC limit values.
- The above preliminary assessment has been made on the basis of the soils tested as part of the ground investigation, using the HazWasteOnline™ assessment. However, the formal classification of waste can only be undertaken on the material to be disposed of, and by the waste producer and the receiving landfill as license conditions vary from landfill to landfill.
- Basic Characterisation should be undertaken in accordance with Environment Agency guidance by the waste producer. Hydrock can assist if required and this report will assist the characterisation. However, Basic Characterisation does not form part of the current commission and would require further assessment and testing on the wastes actually to be disposed.
- Once the waste producer has undertaken an initial Basic Characterisation on each waste stream, they can manage the soils as part of the on-site processing programme (for example, stockpiling, treatment, screening and separation). The waste producer and landfill operator

will then need to agree the suite of compliance testing for regularly generated waste to demonstrate compliance with the initial Basic Characterisation prior to disposal.

- At the time of disposal, additional testing on the excavated soils to be disposed of, will likely be necessary.
- Non-hazardous and hazardous soils require pre-treatment (separation, sorting and screening) prior to disposal.
- The costs for disposal of non-hazardous and hazardous soils are significant compared to disposal of inert material.
- In addition to disposal costs, landfill tax will be applicable. Non-hazardous and hazardous waste will generally be subject to the Standard Rate Landfill Tax. Inert or inactive waste will generally be subject to the Lower Rate Landfill Tax. The landfill tax value changes each April and can be found at https://www.gov.uk/government/publications/rates-and-allowances-landfill-tax/landfill-tax-rates-from-1-april-2013.
- Before a waste producer can move waste to a landfill site for disposal, they need to check the landfill site has the appropriate permit and must have completed the following[3]:

» Duty of care transfer note / Hazardous Waste consignment note, including comment as to if pre-treatment has been undertaken; and

» Basic Characterisation of the waste, to include: description of the waste; waste code (using list of wastes); composition of the waste (by testing, if necessary) and; WAC testing (if required).

8.3 Materials management

8.3.1 Introduction

Soils that are to remain on site, should be managed and reused in accordance with a Materials Management Plan (MMP), prepared in accordance with 'The Definition of Waste: Development Industry Code of Practice', Version 2 (CL:AIRE), known as the DoWCoP. Where all aspects of the DoWCoP are followed the soils are considered not to be waste, because they were never discarded in the first place.

Version 2 of the DoWCoP clearly sets out the principles and an outline of the requirements of a MMP. The following compliance criteria must be seen to apply to the MMP for the site:

- Factor 1: Protection of human health and protection of the environment.
- Factor 2: Suitability for use, without further treatment.
- Factor 3: Certainty of Use.
- Factor 4: Fixed Quantity of Material.

The reuse of soils at sites should be considered during the planning and development design process so that compliance with issues such as fixed quantity and certainty of use clearly relate to agreed site levels. Suitability of Use is normally evident from the remediation strategy or the design statement, which form an integral part of a MMP. However, some soils may need to be tested post-excavation to prove they are suitable for use.

[3] ENVIRONMENT AGENCY. November 2010. Guidance on waste acceptance procedures and criteria. Waste acceptance at landfills. The Environment Agency.

Once the MMP is finalised, it must be declared by a Qualified Person (QP). The Declaration is an on-line submission as part of which the QP is required to confirm that the declaration is being made before the relevant works have commenced (i.e. it is not a retrospective application).

Once all material movements have been completed in accordance with the MMP a verification report must be produced, kept for 2 years and provided to the EA on request.

It should be noted that failure to comply with the requirements of the DoWCoP when re-using materials has potentially significant consequences for the waste holder. The risk is that the reused materials are still regarded as a waste that has been illegally deposited. From 1 April 2018, the scope of Landfill Tax has been extended to sites operating without the appropriate environmental disposal permit, and operators of illegal waste sites will now be liable for Landfill Tax. Further information is available at: https://www.gov.uk/government/publications/landfill-tax-disposals-not-made-at-landfill-sites/landfill-tax-disposals-not-made-at-landfill-sites.

If soils are excavated and reused on sites (or moved to another site) without a MMP, exemption, or appropriate Permit in place, anyone who knowingly facilitates the disposal may be '*jointly and severally liable*' to any assessment of tax, fines or prosecution.

8.3.2 Materials management scenarios

The materials management scenarios present on site are discussed below.

It should be noted that more than one scenario may apply, dependent upon where the soils are proposed for reuse.

8.3.2.1 Clean, naturally occurring materials – reused on the site of origin

Where soils are naturally occurring, uncontaminated and are reused on the site they are excavated (i.e. greenfield site with documented site history, with no Made Ground), they will fall outside the Waste Framework Directive (WFD) (i.e. they will not be a waste when reused on the site of origin).

However, there needs to be certainty of that reuse, and evidence is necessary to support this strategy, for example through information provided during the planning process. The onus is on the developer to demonstrate that the materials are not a waste and will never become a waste. As such, a Materials Re-use Strategy is recommended to show certainty. Alternatively, if the volume of material is under 1,000 tonnes, then a U1 waste exemption may be applied for from the Environment Agency.

It may be noted that some 'clean naturally occurring materials' may still fail the 'suitable for use' test, for example, soils with a naturally high organic content may not be suitable for use because of their propensity to produce ground gases such as methane. Rules regarding other more unusual circumstances such as where natural soils contain an unacceptably high mineral content are described in the DoWCoP.

8.3.2.2 Clean, naturally occurring materials – transferred to other sites

Where soils are naturally occurring, uncontaminated and are transferred to other sites (i.e. direct transfer), they will not become waste as long as the transfer is undertaken in accordance with the DoWCoP. A MMP must be prepared for the receiving site and the materials movement must be noted in the MMP of the Donor site. This movement must have been declared to CL:AIRE prior to the works commencing.

8.3.2.3 Made Ground and other contaminated soils

On sites where Made Ground or contaminated soils are present, any soils excavated will be a waste as soon as they are excavated (even if they are clean, naturally occurring materials), unless they are subject to reuse in accordance with the DoWCoP. As such, for any brownfield site or a site where Made Ground is present and soils are being moved and reused, the materials could be deemed a waste, subject to either:

- a Materials Management Plan (MMP), to prevent the material being classified as a waste following reuse; or
- an exemption (for limited volumes); or
- an environmental permit, dependant on its status.

Other commonly occurring circumstances are:

If Made Ground is being moved between sites, it must be ensured that appropriate permits are in place to ensure the soils are not classified as a waste. Made Ground cannot be moved between sites under DoWCoP alone and would require relevant permits as part of the MMP documentation for the Hub site the material is being treated at.

8.3.2.4 Made Ground and other contaminated soils

All recycled materials (6F2 etc.) must be produced under the 2013 WRAP 'Quality Protocol: Aggregates from inert waste', whether on site or off-site. If they are not, they will be deemed a waste and can only be used on site under a permit. More information can be found at https://www.gov.uk/government/publications/quality-protocol-production-of-aggregates-frm-inert-waste.

8.3.2.5 Geotechnical improvement requirements

Construction activities carried out on uncontaminated soils solely for the purpose of improving geotechnical properties e.g. lime / cement modification, are not generally regarded as waste treatment operations and do not require a permit.

However, should processing be needed (such as screening, treatment or improvement), that would constitute a waste activity and require a mobile treatment permit. This may be as simple as removing oversize material with an excavator bucket, to using a riddle bucket to remove hardcore to full mechanical screening.

9. ADDITIONAL SOUTHERN PARCEL OF LAND

Background

An additional parcel of land has been recently acquired by Harworth Estates Ltd. (the client) which is to be included within the proposed development layout. The size of the area is approximately 0.83ha and proposed to include an extension to the landscaped areas and a section of the attenuation basin as shown on RPS Drawing SK065 Rev F.

Hydrock were instructed by Harworth Estates Ltd. (the client) to undertake a ground investigation on this parcel of land. On the basis the there are no structures proposed in this area of the site and limited filling, the scope of the ground investigation is based on general due diligence with regards to the shallow soils and any possible contamination.

The investigation comprised the excavation of six trial pits and collection of shallow soil samples for chemical analysis (5 Hydrock suites allowed). The exploratory hole locations are shown on Hydrock drawing 15592-HYD-XX-XX-DR-GE-0009.

Ground Conditions

Topsoil

Topsoil was encountered at all trial pit locations varying in thickness between 0.2m and 0.4m, and was found to generally comprise grass over very soft dark grey slightly sandy slightly gravelly silt with a low cobble content.

Glacial Till

Glacial Till was encountered underlying the topsoil in all trial pit locations. The Glacial Till was encountered to the full depth of the trial pits ranging between 1.8 and 2.0m bgl. The base of the Glacial Till was not proven. The Glacial Till generally comprised an upper layer (to depths between 0.8m to 1.2m) of soft to firm orangish brown mottled grey and yellow sandy slightly gravelly clay. Underlying this the Glacial Till is generally described as firm to stiff brown mottled orange slightly sandy gravelly clay with a low to medium cobble content.

In two trial pits a band of granular material was encountered. In TP37 light brown slightly gravelly fine to medium sand was encountered between 0.9m and 1.5m bgl, and in TP38 brown silty fine to medium sand was encountered between 0.85m and 1.60m bgl.

The trial pit logs are provided in Appendix B.

Chemical Analysis

A total of five samples were tested, the laboratory testing includes a combination of the Hydrock default suite of contaminants comprising: Asbestos Screen & ID, As, Be, B, Cd, Cr(vi), Cr(III), Cu, Pb, Hg, Ni, Se, V, Zn, free cyanide, total phenols (monohydric), pH, PAH - Speciated (EPA 16), and FOC.

Human Health Risk Assessment

The laboratory results indicate there are no exceedances of the GAC when compared against the screening values for the commercial (2.5% SOM) end use scenario.

A copy of laboratory results is provided in Appendix E.

10. ECOLOGICAL ENHANCEMENT / MITIGATION AREA

Background

A parcel of land in the north west of the site, which is proposed to be developed as an Ecological Mitigation Area (EMA) was previously un-investigated due to the presence of invasive species. The invasive species in his area have recently undergone a programme of treatment to minimise the risk posed by the species. Following the treatment access to this area of the site was possible enabling a ground investigation to be undertaken providing an update the generic qualitative risk assessment (GQRA), and subsequently assist in discharging associated planning conditions.

The size of the EMA is approximately 1 hectare and proposed to include an area of soft landscaping with vegetation including planted trees and the formation of 10no. ponds. The proposed EMA layout is shown on Landscape Architect (TEP) drawing D9645.001 dated September 2022 (provided in Appendix A).

Hydrock were instructed by Harworth Estates Ltd. (the client) to undertake a ground investigation on this parcel of land. On the basis the there are no structures proposed in this area of the site and limited filling, the scope of the ground investigation is based on general due diligence with regards to the shallow soils and any possible contamination.

The investigation was carried out on 20 September 2022 and comprised the excavation of eight hand dug trial pits, and collection of shallow soil samples for chemical analysis (8no. Hydrock suite and 5no. TPH allowed). The exploratory hole locations are shown on Hydrock drawing 15592-HYD-XX-XX-DR-GE-0011. In addition, at the request of the landscape architect the following additional analysis was undertaken to inform the Soil Management Plan:

- 3no. Topsoil Suite to BS3882:2015; and
- 2no. Subsoil Suite to B38601:2013.

The results of the topsoil BS3882 and subsoil B3860 suite testing are excluded from this report and are discussed in the Soil Management Plan (ref. 15592-HYD-XX-XX-RP-GE-0006).

Ground Conditions

Topsoil

Topsoil was encountered at all trial pit locations varying in thickness between 0.2m and 0.5m, and was found to generally comprise grass over dark brown slightly gravelly very sandy clay or very clayey sand with rootlets and rare cobbles of subrounded sandstone. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and rare/tile brick inclusions.

Rare anthropogenic inclusions were noted in the topsoil including brick and tile fragments, however the material can still be categorised as naturally deposited topsoil. The rare anthropogenic inclusions are considered to have been introduced sporadically at surface as a result of agricultural activities undertaken in this area of the site.

No visual or olfactory evidence of contamination was noted in the topsoil.

Groundwater was not encountered in the topsoil.

Glacial Till

Glacial Till was encountered underlying the topsoil in all locations. The Glacial Till was encountered to the full depth of the hand pits ranging between 0.5 and 1.0m bgl. The base of the Glacial Till was not proven. The Glacial Till generally comprised light orangish brown mottled grey sandy, slightly gravelly clay with fine to coarse sand lenses. Gravel is subangular to subrounded, fine to coarse of sandstone, siltstone, mudstone and coal.

No visual or olfactory evidence of contamination was noted in the Glacial Till.

Groundwater was not encountered in the Glacial Till.

The trial pit logs are provided in Appendix B.

Chemical Analysis

A total of eight samples were tested, the laboratory analysis includes a combination of the Hydrock default suite of contaminants comprising: Asbestos Screen & ID, As, Be, B, Cd, Cr(vi), Cr(III), Cu, Pb, Hg, Ni, Se, V, Zn, free cyanide, total phenols (monohydric), pH, PAH - Speciated (EPA 16), and FOC.

A total of five samples were scheduled for Hydrock TPH Level 2 suite comprising carbon banding with aliphatic/aromatic split plus BTEX and MTBE.

Human Health Risk Assessment

The laboratory analysis results indicate there are no exceedances of the GAC when compared against the screening values for the Public Open Space (POS) 1% SOM CLEA end use scenario. As such, in relation to human health no mitigation measures are required for the proposed Ecological Mitigation Area end use.

A copy of the laboratory results is provided in Appendix E.

11. UNCERTAINTIES AND LIMITATIONS

11.1 Site-specific comments

The monitoring to date is insufficient at this stage to fully characterise the sites ground gas regime in relation to the proposed development due to the significant site-wide reprofiling required. Whilst the monitoring completed to date provides a preliminary indication of the gas regime of the site in its current condition, additional monitoring following completion of the cut to fill earthworks is required and the conclusions of this report will need to be updated following completion of the additional monitoring.

11.2 General comments

Hydrock Consultants Limited (Hydrock) has prepared this report in accordance with the instructions of Harworth Estates Property Group Limited (the Client), by e-mail dated April 2021 under the terms of appointment for Hydrock, for the sole and specific use of the Client and parties commissioned by them to undertake work where reliance is placed on this report. Any third parties who use the information contained herein do so at their own risk. Hydrock shall not be responsible for any use of the report or its contents for any purpose other than that for which it was prepared or for use of the report by any parties not defined in Hydrock's appointment.

This report details the findings of work carried out in May and June 2021. The report has been prepared by Hydrock on the basis of available information obtained during the study period. Although every reasonable effort has been made to gather all relevant information, not all potential environmental constraints or liabilities associated with the site may have been revealed.

Hydrock has used reasonable skill, care and diligence in the design of the investigation of the site and in its interpretation of the information obtained. The inherent variation of ground conditions allows only definition of the actual conditions at the locations and depths of trial pits and boreholes at the time of the investigation. At intermediate locations, conditions can only be inferred.

Groundwater data are only representative of the dates on which they were obtained and both levels and quality may vary.

Plans that provide assessment of foundation types and depths are indicative and subject to further design. This design should incorporate a detailed assessment of the influence of trees, influence of cut to fill proposals and geological conditions.

Unless otherwise stated, the recommendations in this report assume that ground levels will remain as existing. If there is to be any re-profiling (e.g. to create development platforms or for flood alleviation) then the recommendations may not apply.

Information provided by third parties has been used in good faith and is taken at face value; however, Hydrock cannot guarantee its accuracy or completeness.

Where the existing report(s) prepared by others have been provided by the Client, it is assumed that these have been either commissioned by the Client, or can be assigned to the Client, and can be relied upon by Hydrock. Should this not be the case Hydrock should be informed immediately as additional work may be required. Hydrock is not responsible for any factual errors or omissions in the supplied data, or for the opinions and recommendations of others. It is possible that the conditions described may have since changed through natural processes or later activities.

The work has been carried out in general accordance with recognised best practice. The various methodologies used are referenced in Appendix I. Unless otherwise stated, no assessment has been made for the presence of radioactive substances or unexploded ordnance. Where the phrase 'suitable for use' is used in this report, it is in keeping with the terminology used in planning control and does not imply any specific warranty or guarantee offered by Hydrock.

The chemical analyses reported were scheduled for the purposes of risk assessment with respect to human health, plant life and controlled waters as discussed in the report. Whilst the results may be useful in applying the Hazardous Waste Assessment Methodology given in Environment Agency Technical Guidance WM3, they are not primarily intended for that purpose and additional analysis will be required at the time of disposal to fully classify waste. Discussion and comment with regards to waste classification are preliminary and do not form the requirements of 'Basic Characterisation' as required.

Assessment and testing for the presence of coal tar has only been completed at the locations of exploratory holes undertaken for risk assessment purposes. This investigation is not designed to provide a definitive assessment of the risk from coal tar, nor the waste classification for bituminous bound pavement arisings at the site.

Unless otherwise stated, at the time of this investigation the future routes of water supply pipes had not been established. This investigation and sampling strategy may not be fully compliant with UKWIR recommendations. Consequently, a targeted investigation and specific sampling and chemical testing may be required at a later date once the routes 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.

Whilst the preliminary risk assessment process has identified potential risks to construction workers, consideration of occupational health and safety issues is beyond the scope of this report.

Please note that notwithstanding any site observations concerning the presence or otherwise of archaeological sites, asbestos-containing materials or invasive weeds, this report does not constitute a formal survey of these potential constraints and specialist advice should be sought.

Any site boundary line depicted on plans does not imply legal ownership of land.

12. RECOMMENDATIONS FOR FURTHER WORK

Following the ground investigation works undertaken to date, the following further works will be required:

- discussion with the Coal Authority with regard to treatment of the on-site mine shaft;
- discussion and agreement with utility providers regarding the materials suitable for pipework;
- discussions with regulatory bodies and the warranty provider regarding the conclusions of this report;
- assessment of tree influence on foundations and design of foundations;
- discussions with Vibro-stone Column Contractors regarding the viability of, and potential improvement by, VSCs;
- provision of geotechnical design for the Category 3 structures (earthworks, ground improvement, retaining walls, floor slabs, foundations over voided mineworkings etc.);
- production of a Remediation Strategy and Verification Plan (and agreement with the regulatory bodies and the warranty provider);
- production of a Materials Management Plan relating to reuse of soils at the site and import of soils to the site;
- remediation and mitigation works;
- ground investigation following completion of the cut to fill earthworks to install boreholes with monitoring standpipes for supplementary ground gas monitoring;
- completion and reporting of the supplementary gas monitoring following completion of the cut to fill earthworks, hence the conclusions in this report are provisional, subject to the completion of monitoring; and
- verification of the earthworks, remediation and mitigation works.

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Appendix A Drawings

BUILT ENVIRONMENT DESIGN PARTNERSHIP
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NOTES:

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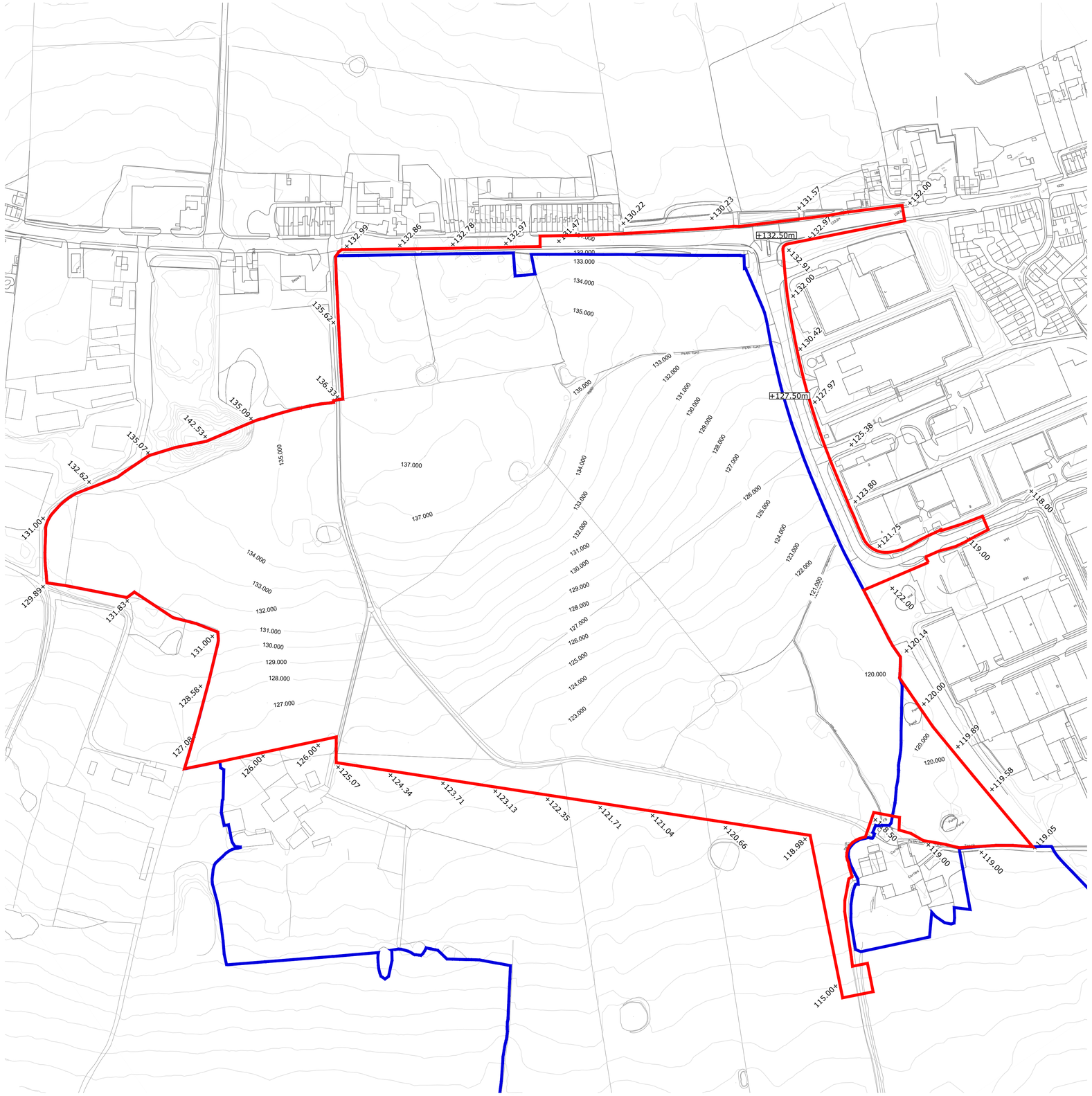

Existing Site Topography
Scale 1:2000

Rev	Amendments	By	Chk	Date
P03	Detailed planning application boundary updated.	CG	DC	11/10/18
P02	Planning Issue	AA	DC	28/09/18

Project:
Wingates
Bolton

Title:
Detailed Planning
Existing Site Topography

Drawing Number:
NWK 180009-BED-EX-00-DR-C-0201

Status:	Suitability Code:	Model Ref:	Rev:
Preliminary	S2	ACAD	P03

Scale:	Sheet:	By:	Check By:	Date Created:
1:2000	A1	TS	DC	27/09/18

Client:
Harworth

Notes

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KEY

- Site Boundary (33.14 Ha / 81.90 acres)
- Ownership Boundary
- Public Right of Way Footpath
- Right of access - Carlies Farm
- Right of access - Adjoining Land
- Existing Hedgerow (Retained)
- Existing Trees (Retained - Bat roosting potential)
- Existing Trees (Removed)
- New/Retained Trees & Landscaping

SCHEDULE OF ACCOMMODATION

		sq m	sq ft
Unit 1	:	3,550	38,215
Unit 2	:	3,133	33,719
Unit 3	:	3,941	42,421
Unit 4A	:	1,800	19,378
Unit 4B	:	1,800	19,378
Unit 4C	:	1,410	15,177
Unit 5	:	11,815	127,180
Unit 6	:	3,259	35,079
Unit 7	:	62,572	673,523
TOTAL (GIA)	:	93,280	1,004,070

Proposed planting and landscape scheme is shown indicatively, refer to Landscape Architects Proposals (TEP) for further detail.

Rev	Description	By	Ckd	Date
F	Unit 1 FFL reduced	AE	DEC	04.12.19
E	Redline Amended	AE	MJH	11.10.18
D	Route of Surface Water outfall amended	AE	MJH	25.09.18
C	Plot levels on Units 4a, 4b, 5 & 6 amended in line with latest cut & fill analysis. Acoustic fence added	AE	MJH	12.09.18
B	Amendments in line with design development	AE	MJH	16.08.18
A	Amendments in line with design development	AE	MJH	15.06.18

MAKING COMPLEX EASY

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Client: Harworth

Project: Wingates, Bolton

Title: Illustrative Masterplan

Status	Scale	Date Created
Preliminary	1:2000 @A1	01.06.18

Task Team Manager	Information Author	Task Information Manager
MJH	AE	MJH

Document Number: SK065

Project Code - Originator - Zone - Level - Type - Role - Drawing Number

RPS Project Number	Suitability	Revision
NK018161	S0	F

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