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APPLiED GEOLOGY

GROUND INVESTIGATION REPORT FOR HOYLAND COMMON, BARNSLEY, M1 JUNCTION 36

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1.0 INTRODUCTION

1.1 Scope and Objective of the Report

An area of land between the M1 motorway and Sheffield Road and to the west of Hoyland Common, near Barnsley, (the site) is to be developed by Newlands Developments (the Client). The proposals comprise the reprofiling of the site to create level development plateaus and enable the construction of a single large distribution warehouse together with other industrial units, a new link road and associated infrastructure, parking and landscaping.

Applied Geology Limited has been appointed by Newlands Developments to undertake a Ground Investigation to provide information to assist in the effective and economical design of the proposed development. This report covers Plots 1 to 3 inclusive of the development area known as 'Hoyland West', as shown on the Masterplan. A separate ground investigation is being carried out for a proposed balancing pond to the south of the site and this will be reported under separate cover.

This Ground Investigation Report (GIR) has been prepared in general accordance with guidance set out in British Standard EN 1997-2:2007 Eurocode 7 – Geotechnical Design (BS EN 1997-2, 2007). The report provides full details of the fieldwork and laboratory testing undertaken, presents the factual findings and provides an interpretation of the ground conditions and characteristic material properties of the various strata encountered for use in a Geotechnical Design Report (GDR), which is to be issued under separate cover. The report also includes an assessment of ground contamination and an updated coal mining risk assessment. This report should be read in conjunction with the General Notes presented at the end of the report text.

1.2 Description of Project

The site can be divided into three areas based on the proposed development. The main central area (Plot 1) comprising 18.35 hectares and is to comprise a large distribution warehouse measuring 375m by 75m and orientated NNW-SSE. There are associated lorry parking areas, a lorry wash, a lorry refuelling area, a staff car park surrounding the proposed building. The finished floor level is currently proposed at 144.5mOD (subject to change) and significant earthworks will be required to create a level site area at this elevation.

The south-eastern 9.02 hectare part of the site (Plot 2) is to be prepared for future light industrial development with a level development platform being created at 134.55mOD. This will involve significant areas of fill, increasing in thickness to the south and southeast, such that high engineered fill embankment slopes will need to be created at these site boundaries.

The 5.09 hectare part of the site to the north of Tankersley Lane (Plot 3) is also to be prepared to create a level development platform for future light industrial use. It is understood that several small units are proposed in this area, however, development plans have not been finalised. The plateau level in this part of the site is currently proposed at 145.6mOD and will also involve some element of cut and fill.

A new (adoptable) road is to be created linking Sheffield Road at the extreme southeast corner of the site to the existing roundabout immediately north of the site running along the eastern edges of the site. This will link the three parts of the

proposed development and keep site traffic, particularly HGVs, out of Hoyland Common centre.

As stated above, significant earthworks will be required to create the proposed plateau levels and it is currently understood that there will be up to 7m of cut and up to 13m of fill required. However, proposed site levels and therefore the extents of the cut and fill works are subject to change as the detailed design is undertaken. It is intended that the finished levels will be designed to achieve a cut-fill balance and, at the time of the investigation, no retaining structures were proposed.

The proposed site drainage scheme will include a large attenuation pond located in an area of existing agricultural fields c. 400m to the south of the main development areas. A deep excavation is required to form the pond with maximum cut depth of c. 10m to the north of the pond reducing to c. 4m in the south of the pond. Some limited engineered filling is needed on the southern end of the pond where a c. 1m high bund will be added to a limited area in order to maintain the required perimeter levee level. An adoptable drainage route with associated easements will link the main development area to the pond.

1.3 Geotechnical Category

The proposed development has been categorised as both Geotechnical Category 2 and Category 3 as defined by British Standard EN 1997-1:2007 Eurocode 7 – Geotechnical Design. This is because it involves conventional types of geotechnical structures, earthworks and activities but will also involve unusual and difficult ground conditions coupled with loading conditions associated with the placement of engineered fill. Furthermore, there will be construction of buildings above significant thicknesses of uncontrolled fill associated with the previous opencast coal mines.

2.0 EXISTING INFORMATION – DESK STUDY REVIEW

A Phase 1 Desk Study and Preliminary/Phase 1 Coal Mining Risk Assessment (CMRA) were carried out for the site by Applied Geology (Report Ref. AG3080-19-AJ70, Validated Issue 1 and Report Ref. AG3080-19-AJ77, Validated Issue 1), both dated January 2020. For full details of the coal mining issues and geo-environmental setting of the site, reference should be made to the reports detailed above. However, a summary of the key findings is provided below

2.1 Location & Topography

The site is located immediately southeast of Junction 36 of the M1 motorway just west of the village of Hoyland Common, approximately 6km south of Barnsley in South Yorkshire. The Ordnance Survey grid reference for the centre of the site is approximately 435491, 399728 as shown on the Site Location Plan in Appendix A.

The site is irregular in plan shape with maximum extents of 1.3km (NW-SE) and 750m (SW-NE) covering an area of approximately 46 hectares (114 acres). Site levels vary between approximately 150.5mOD towards the centre of the site with ground levels sloping down towards the southeast at around 117mOD. The northern half of the site is gently sloping/undulating and levels vary between approximately 140mOD and 150mOD.

2.2 Published Geological Information

Significant areas of the site are anticipated to be underlain by Made Ground comprising overburden used to backfill various separate historic opencast coal mines. The Pennine Middle Coal Measures Formation is anticipated to be present from shallow depth outside of the areas of opencast and also directly below the opencast backfill materials. Mine highwalls are expected on the down dip perimeter of the former opencast areas and these would be formed of the Pennine Middle Coal Measures Formation. The opencast mines appear to have extracted the Swallow Wood Coal seam to the north and immediately south of Tankersley Lane (the northern portions of the site) and the Harley/Dunsil Coal seam in the centre and south of the site, with coal seams below worked by deep underground mining. The possibility of unrecorded workings exists. Old coal/ironstone shafts are marked on the south-eastern edge of the site whilst other old ironstone and coal shafts, together with historic ironstone bell pits, are present adjacent to the southeast.

The GroundSure Report has classified the risk of various natural ground stability hazards depending on the anticipated ground conditions on site. These tend to have a range of risk given that part of the site is underlain by backfilled opencast pits and some by natural ground. The risk from ground dissolution of soluble rocks is negligible, the risks from shrink-swell of clays and running sand are both negligible to very low, the risk from collapsible deposits is very low, the risk from landslides is low to very low and the risk from compressible rocks is negligible to moderate.

The GroundSure Report, which sources information on radon affected areas from the BGS/Public Health England indicates that the site is within an area where between 1% and 3% of properties are above the Action Level.

2.3 History and Former Land Use

Historical Ordnance Survey maps were obtained in order to determine any significant past activity or land usage.

The site comprised fields since at least 1855 with Tankersley Lane crossing the northern part of the site and a small stream present in the southeast from that time. Significant parts of the site were mined for coal via opencast methods in the late 1940s and were backfilled with overburden (assumed uncontrolled) and restored back to agricultural use by the early 1950s. An aerial ropeway formerly crossed the north and west of the site associated with the opencast mining activities.

The immediate surrounding area has been subject to ironstone and coal extraction, with ironstone bell pits and opencast mining adjacent to the southeast of the site and close to the southwest of the site whilst collieries were formerly present to the north and southeast. A fuel filling station and haulage yard first appeared in the 1950s and are still present 50m east of the site. A former gas works, an engineering works, railway lines linking the pits and quarries, depots, garages, refuse tips, a builder's yard, a nursery, allotment gardens, electricity substations and former ponds were also present in the surrounding area. During the early 1970s the M1 motorway was constructed in a cutting adjacent to the west of the site.

2.4 Mining and Minerals

The site is within a Coal Mining Reporting Area, with much of the site within a Development High Risk Area. A Consultant's Coal Mining Report has been obtained, summarised below and a copy is included in Appendix B of the Phase 1 Desk Study report.

The Coal Mining Report identifies eleven ironstone mine shafts and four coal mine shafts on or in the immediate vicinity of the site. The shafts tie in with the bell pits and shafts marked on the historical maps adjacent to the southeast of the site. Land north of Tankersley Lane and the central, southern and south-eastern parts of the site are shown as having been subject to opencast mining. There is one coal mining subsidence claim close to the east of the site, along Sheffield Road. There are no records of mine gas issues within 500m of the site. There are no licences for current coal mining or future underground coal mining within 200m of the site.

There are numerous records of past underground mining on and near the site, mostly relating to coal seams, but two relating to ironstone seams, between 23m and 346m below ground level (bgl). These were last worked between 1857 and 1972. The GroundSure Report identifies one hundred and forty-four historic ground workings within 1km of the site, predominantly for ironstone and coal but also for sandstone and clay/shale. The closest was Swallow Wood Mine, adjacent to the southeast of the site. It should be noted that there is also the potential for unrecorded past workings to be present on site.

Abandonment plans for the site indicate shallow (opencast workings) up to c.12m deep in the east and shallowing to the west towards the mapped positions of the seam outcrops. The opencast mining on site occurred in the late 1940s with restoration completed very soon after by the early 1950s. The abandonment plans indicate that the opencast pits were infilled with overburden comprising clay, mudstone, sandstone and shale. Further details of the abandonment plans are included in the separate Phase 1 Coal Mining Risk Assessment report.

The Groundsure Report also notes the site is not located in an area of recorded natural cavity formation, nor is it within area of known brine or gypsum extraction.

2.5 Previous Ground Investigation and Other Reports

There has been a previous Ground Investigation undertaken on the site in 1989 and there have been previous investigations and reports undertaken by others relating to the immediately surrounding area, predominantly associated with the redevelopment occurring to the north of the site. Many of these reports and records were found to be available on the Planning Portal, as well as on the online British Geological Survey website. The relevant information from these investigations, where publicly available has been summarised in the Phase 1 Desk Study report.

2.6 Hydrology and Flooding

The nearest surface watercourse is a stream, which issues in the southeast of the site and flows to the southeast. There are no recorded surface water abstractions within 2km of the site. The site is not shown to be within Fluvial Flood Zones 2 or 3.

According to the GroundSure Report, there are three licensed discharge consents within 500m of the site, the nearest being 140m to the northeast for sewage discharges into the River Wiske.

2.7 Hydrogeology

The Pennine Middle Coal Measures Formation is classified by the Environment Agency as a Secondary A Aquifer. There are no groundwater abstractions within 500m of the site, the nearest being 580m southwest of the site for spray irrigation at Tankersley Park Golf Club. The site is not located within a groundwater Source Protection Zone.

2.8 Conceptual Site Model

A conceptual model of the site considering potential contamination sources, pathways and receptors for the site above was included in the desk study and is summarised below, together with the qualitatively assessed levels of risk:

Source	Pathway	Receptor	Risk*
Backfill material to historic opencast pits (on and off site) and possible spoil from any historic unrecorded workings (on site).	Dermal contact, ingestion and inhalation of dust	End users	Low
	Migration and leaching	Neighbours	Low
		Aquifer	Low-medium
		Stream	Low
	Downward migration via old shafts/wells	Aquifer	Low-medium
	Direct contact	Water Supply Pipes	Low
	Plant uptake	Landscaping	Low
Ground gas from spoil from any historic unrecorded workings and backfill material to historic opencast pits (on and off site)	Inhalation	End users	Medium
	Upward migration via old shafts/wells	End users	Low-medium
	Migration and inhalation	Neighbours	Low
Mine gas from the Pennine Middle Coal Measures strata (on and off site)	Inhalation	End users	Low-medium
	Upward migration via old shafts/wells	End users	Low-medium
	Migration and inhalation	Neighbours	Low
Potential hydrocarbons from current and former land uses (off site)	Migration and leaching	End users	Low
		Aquifer	Low -medium
		Stream	Low-medium
		Water supply pipes	Low
		Landscaping	Low
Potential metals and other inorganic contaminants from former land uses (off site)	Migration and leaching	End users	Low
		Aquifer	Low
		Stream	Low

Source	Pathway	Receptor	Risk*
		Water supply pipes	Low
		Landscaping	Low
Elevated sulphates in backfill material/natural soils (on site)	Direct contact	Buried concrete	High

*** Definition of Risk Categories**
Negligible - Contaminants that might have unacceptable impact on key receptors, are unlikely to be present, or, no pathway is envisaged.
Low Risk: Contaminants may be present but are unlikely to be at levels to have unacceptable impact on key receptors, or pathways are likely to be minimal.
Medium Risk: Contaminants are probably present and might have an unacceptable impact on key receptors. Pathways may also be present therefore remedial measures may be necessary to reduce the risks.
High Risk – Contaminants probably or certainly present and pathways are probably also present. Therefore, contaminants are likely to have an unacceptable impact on key receptors and remedial measures are likely to be necessary to reduce the risks to acceptable levels.

2.9 Unexploded Ordnance (UXO) Risk

The Zetica on-line bomb risk map identifies the site to be within a low risk area of unexploded bombs from WWII.

3.0 FIELD AND LABORATORY STUDIES

3.1 Site Description

The main site comprised predominantly open fields including arable, pasture and ploughed fields. Apart from a few stables for horses, no buildings were present on site. An additional adjoining small area to the northeast included a running track (surfaced but covered in moss/vegetation), small grandstand, grass sports pitch and small area of woodland. Tankersley Lane crossed the site running ENE-WSW in the northern part of the site. Towards the south of the site, high voltage ENE-WSW aligned electricity cables supported on large pylons crossed the site. A further smaller overhead electricity cable crossed the extreme northwest corner of the site.

The site was bounded to the west by the M1 motorway (largely in cutting), to the south by woods and arable fields, to the north by the M1 Junction 36 roundabout and adjoining roads and to the east by Sheffield Road itself or, allotments, grassed fields/pasture, small industrial properties and a small number (<5) residential properties located off Sheffield Road, Green Lane or Tankersley Lane. A petrol filling station was located on Sheffield Road approximately 50m east of the site. There was a small haulage firm located adjacent to the filling station.

Temporary offices and core stores for the fieldwork were located at the rear of the small haulage firm. The majority of fields were accessed from Sheffield Road through a field gateway next to the petrol filling station. The running track was also accessed from Sheffield Road, via an access track associated with the sports centre further to the north.

3.2 Intrusive Ground Investigation

Fieldwork was generally carried out, in accordance with BS5930 “Code of Practice for Site Investigations”, BS10175 Investigation of Potentially Contaminated Sites, the

Association of Geotechnical and Geoenvironmental Specialist Guidelines for Good Practice in Site Investigations and supervised by an experienced Engineering Geologist.

The locations of the exploratory holes were selected by Applied Geology and set out on site by Applied Geology Limited. The various exploratory hole location methods were chosen for specific purposes and positioned to target specific on-site features, and sampling/testing requirements, more details of these are included in 3.2.1 to 3.2.6.

The statutory utility plans indicated the site had a very low density of utilities, however, two overhead powerlines crossed the site. The site walkover inspection indicated the presence of several c.300mm diameter surface water drains with associated cast iron covers crossing the site in the north-eastern fields south of Tankersley Lane. A specialist utility surveyor traced and marked out the route of these, were possible, and not blocked. A 20mm metal private water supply pipe, assumed to source water troughs in the fields alongside Sheffield Road was identified following hand trenching and shallow excavation. Therefore, with the exception of where the presence of services was considered more likely, in proximity to existing development (housing), hand dug inspection pits were not undertaken.

Where encountered during trial pitting/trenching, land drains were repaired with a similar diameter length of plastic drainage pipe to ensure they remained functional following backfill of the excavation. Records of all repairs are noted on logs and photographs were taken.

The positions of the exploratory holes were levelled and located on site by specialist contractor (Benchmark Engineering). The locations are presented on the Exploratory Hole Location Plan, Drawing N^{o} AG3080-19-06 in Appendix A.

Descriptions and depths of the various strata recovered are presented on the exploratory hole records, reproduced in Appendix B, together with sample depths, the results of in-situ testing, comments on groundwater inflows, pit stability and any other pertinent information. The soils and rocks encountered have been described in accordance with BS5930:1999 + A2:2010 and BS EN ISO 14688-1:2002 and BS EN ISO 14689-1:2003.

The following scope of fieldwork was undertaken:

- 118 No. machine excavated trial pits (TP1001 to TP1114, TP1107A and TP1201 to TP1203);
- 35 No machine excavated trial trench locations (TT2001 to TT2036), many of these include more than one log or excavation at each location (TT2001-A suffix indicates more than one excavation, and excavation with more than one log with have the suffix of the direction of that end of the pit e.g. TT2001-South). TT2026 was not completed due to the presence of underground services (water main and land drains) coinciding with fences and walls;
- 21 No. Rotary Sonic Boreholes (RS3002 to RS3015, RS3017 to RS3020 and RS3022 to RS3024;
- 13 No. driven continuous sampling with rotary cored follow-on boreholes (RC4001 to RC4013);

- 22 No. cone penetration tests (CPT5001 to CPT5018, and CPT5012A, CPT5014A, CPT5015A and CPT5018A;
- 12 No. driven continuous sampling boreholes (DCS6001 to DCS6005, RS3001 and RS3025 to RS3030).

Copies of all exploratory hole records, SPT certificates and SPT summary sheets referenced above are presented within Appendix B. Trial Trench sketches and photos are also located in Appendix B, with photographs of rotary core and trial pits located in Appendix C.

3.2.1 Trial Pits

Machine dug trial pits were undertaken on a nominal 50m grid basis throughout areas of cut and within areas of suspected opencast backfilling (in the main area of development). These were excavated using a 20 tonne 360 tracked excavator. These provided information on the nature of the backfill material and allow samples to be taken for both laboratory contamination and geotechnical (earthworks) testing.

Additional machine dug trial pits were also located along the proposed access road routes and in the areas of opencast backfill where the greatest thicknesses of engineered fill were proposed.

3.2.2 Trial trenches

Machine dug trial pits were also undertaken to accurately locate opencast high walls, many of these taking the form of extended trenches or multiple shorter excavations to locate the high walls. These were excavated using a 20 tonne 360 tracked excavator.

3.2.3 Rotary Sonic Boreholes

Rotary sonic boreholes were undertaken using a Sonic Drill Corporation SDC390-14 drill rig, providing information on the nature of the backfill material, prove the depth of the opencast backfill and allow samples to be taken for both laboratory contamination and geotechnical (classification) testing, with a focus on depths below those achieved by trial pitting. In the majority of rotary sonic boreholes, where confirmation the base of the opencast backfill was required, a nominal two to three metres of bedrock was cored at the base of each borehole.

In addition, a limited number of boreholes, ‘Undisturbed’ samples (UT) and standard penetration tests (SPTs) were undertaken in locations beneath proposed buildings and in the areas where the greatest thicknesses of engineered fill were proposed.

In selected boreholes, groundwater and gas monitoring and sampling standpipes were installed to determine the groundwater profile, to allow the sampling/testing of groundwater and to monitor for the presence of ground/mine gas.

3.2.4 Driven Continuous Sampling with Rotary Core Follow-on

Rotary cored boreholes were undertaken, using a Beretta T41, in the area where the main distribution warehouse is proposed and in areas where the greatest thicknesses of engineered fill was proposed. Some of these boreholes were located outside the

area of opencast and were used to better understand the coal measures sequence, seam spacing and to check for deeper mining disturbance/voids. Further rotary boreholes, with driven continuous samples of soil strength soils above rockhead, were located in areas where the highest slopes are being proposed in engineered fill.

Samples from these rotary cored boreholes were taken to allow rock strength testing to be undertaken, along with geotechnical and contamination testing on soil strength materials.

In addition, a limited number of boreholes standard penetration tests (SPTs) were undertaken in locations beneath proposed buildings and in the areas where the greatest thicknesses of engineered fill were proposed.

In selected boreholes, groundwater and gas monitoring and sampling standpipes were installed to supplement those installed in the shallower boreholes.

3.2.5 Cone Penetration Testing

A series of eighteen cone penetration tests (CPT's) were undertaken to ascertain soil property information for use in settlement analysis and geotechnical modelling, particularly in the south-eastern part of the site. Additionally, they provided more information on the depth of Opencast Backfill. The testing also included four repeat tests (CPT5012A, CPT5014A, CPT5015A and CPT5018A), which were carried out due to premature / shallow termination at the original test location. This was undertaken in the final phases of the investigation once it was confirmed that surface and ground conditions were suitable for the method of testing. The testing was carried out generally in accordance with BS ISO 22476-1:2012 using an 18.5 ton tracked rig with a 15 ton capacity hydraulic ram and utilising a piezocone and the full report is included within Appendix B.

3.2.6 Driven Continuous Sampling Boreholes

Five driven continuous sampling (DCS) boreholes (with SPTs) were undertaken along the route of the proposed road in the area of the running track in the northeast of the site (DCS6001-DCS6005). This method was selected to minimise disturbance of the sports field and because the underlying strata was anticipated to be weathered bedrock and not in an area of significant cut, hence the boreholes were not required to be deep.

A further two DCS boreholes were undertaken on the main site area in place of originally proposed rotary sonic boreholes RS3001 and RS3025, also to minimise surface damage/disturbance and also in areas of minimal cut and outside the areas of opencast backfill.

Five supplementary DCS boreholes (DCS3026-DCS3030) were also undertaken on the main site area (Plot 2), also to provide further geotechnical information of the shallow opencast backfill materials.

3.2.7 Instrumentation

A summary of the standpipe and piezometer installations is as follows:

Borehole Nº	Depth To Base (m)	Nominal Pipe Diameter (mm)	Response Zone (m bgl)	Response Zone Strata
DCS6002	3.0	50	1.0-3.0	Pennine Middle Coal Measures Formation
DCS6004	2.0	50	1.0-2.0	Pennine Middle Coal Measures Formation
RC4001	11.5	50	8.0-11.5	Pennine Middle Coal Measures Formation
RC4004	20.0	19	19.5-20.5	Pennine Middle Coal Measures Formation
RC4007	3.0	50	1.0-3.0	Made Ground - Open Cast Backfill
RC4009	14.5	19	13.5-14.5	Pennine Middle Coal Measures Formation
RC4010	10.8	19	10-11	Made Ground - Open Cast Backfill
RS3002	5.0	50	2.0-5.0	Made Ground - Open Cast Backfill
RS3003	5.0	50	2.0-5.0	Made Ground - Open Cast Backfill
RS3004	4.0	50	1.0-4.0	Made Ground - Open Cast Backfill
RS3005	4.0	50	1.0-4.0	Pennine Middle Coal Measures Formation
RS3008	3.0	50	1.0-3.0	Pennine Middle Coal Measures Formation
RS3010	5.0	50	4.0-5.0	Pennine Middle Coal Measures Formation
RS3013	4.0	50	1.0-4.0	Made Ground - Open Cast Backfill
RS3015	7.0	50	1.0-7.0	Made Ground - Open Cast Backfill
RS3017	5.0	50	2.0-5.0	Made Ground - Open Cast Backfill
RS3019	5.0	50	2.0-5.0	Made Ground - Open Cast Backfill
RS3022	6.0	50	2.0-6.0	Made Ground - Open Cast Backfill / Pennine Middle Coal Measures Formation
RS3025	3.0	50	1.0-3.0	Pennine Middle Coal Measures Formation
RS3026	5.0	50	1.0-5.0	Made Ground - Open Cast Backfill
RS3027	3.7	50	1.0-3.7	Made Ground - Open Cast Backfill
RS3028	5.0	50	1.0-5.0	Made Ground - Open Cast Backfill
RS3029	5.0	50	1.0-5.0	Made Ground - Open Cast Backfill
RS3030	4.0	50	1.0-4.0	Made Ground - Open Cast Backfill

3.2.8 Monitoring and Groundwater Sampling

Ground gas and groundwater monitoring visits were undertaken on 4 (two of these occasions were split over multiple days due to access constraints at the running track area) occasions from 3rd March to 22nd April 2020 including during 2 periods of low atmospheric pressure with all of these noted to also be falling. Each monitoring well was monitored for concentrations of carbon dioxide, methane, oxygen, carbon monoxide, hydrogen sulphide, flow rates, differential pressures and water level.

Two further monitoring visits were carried out to record groundwater levels in the standpipes installed on Plot 2 (RC4009, RC4010 and RS3026 to RS3030) these were carried out on the 22nd and 29th of July 2020.

Groundwater samples were collected from ten of the boreholes during the second monitoring visit on the 16th March 2020 via modified volume purge methods (recharge was not quick enough to facilitate three wells volumes of purge in all of the standpipes) and using dedicated bailers. Insufficient water was present in all other standpipes to allow samples to be collected. On the previous visit the standpipes were developed using a submersible pump. The monitoring results are included in Appendix D.

3.2.9 Variable Head Testing

Following completion of the monitoring, falling head permeability tests were undertaken in standpipes installed within RS3002, RS3003, RS3004, RS3013, RS3015, RS3017, RS3019 and RC4007 in general accordance with BE EN ISO

2282-2. The results and calculated permeabilities are discussed in Section 5 and the results are presented in Appendix D.

3.3 Geotechnical Laboratory Testing

A programme of geotechnical laboratory testing was scheduled on samples selected of soil and rock core by Applied Geology.

The geotechnical testing was carried out generally in accordance with BS 1377:1990 Method of Tests for Soils for Civil Engineering Purposes and ISRM Suggested Methods and was undertaken by specialist laboratories (Professional Soils Ltd, Geolabs and i2), comprising:

- 108 No Natural Moisture content tests (soil)
- 18 No Natural Moisture content tests (rock);
- 100 No Atterberg Limit tests;
- 46 No Particle Size Distribution tests;
- 6 No Quick Undrained Triaxial tests;
- 41 No Compaction tests (comprising mainly 4.5kg tests with some 2.5kg tests)
- 35 No Particle density tests;
- 41 No remoulded CBR tests;
- 3 No triaxial permeability tests;
- 26 No Franklin Point Load tests;
- 38 No Laboratory Hand Vane tests;
- 25 No Unconfined Compressive Strength (UCS) tests;
- 28 No BRE “Special Digest 1” suites;
- 15 No Calorific Value tests;
- 15 No Loss on Ignition tests;
- 4 No coal content tests;
- 7 No coal quality tests;
- 3 No one dimensional consolidation test by oedometer;
- 3 No 60mm shear box tests (peak and residual).

In addition, 93 No point load tests were undertaken by Applied Geology on samples of rock core as part of the logging process during the site works.

The geotechnical laboratory test results and ‘field’ point load test results are presented in Appendix E.

3.4 Chemical Laboratory Testing

A programme of chemical laboratory testing was scheduled on samples selected of soil and groundwater by Applied Geology. The tests were carried out by specialist laboratory i2 and comprised:

- 74 No soil suites comprising heavy metals, PAHs, water soluble sulphate, pH and SOM on a combination of topsoil, soil, weathered rock and Made Ground samples;
- 9 No pesticide screening tests on topsoil samples;
- 3 No speciated petroleum hydrocarbon tests on black stained soils;
- 3 No asbestos screen tests on Made Ground samples;

- 26 No BRE SD1 sulphate suite tests on soil and weathered rock samples (in addition to those mentioned above);
- 10 No site-specific groundwater suites, comprising heavy metals, PAHs, pH, sulphate, hardness and various water quality parameters.

The test results are presented in Appendix F.

3.5 Specialist Topsoil Testing

Twelve soil samples were sent to Tim O'Hare Associates to determine the suitability for general landscape purposes (trees, shrubs and amenity grass). In addition, these samples were assessed to determine compliance with the requirements for the British Standard for Topsoil (BS3882:2015 - Specification for Topsoil - Table 1, Multipurpose Topsoil).

The specialist report is presented in Appendix G.

3.6 Coal Quality Testing

Seven coal samples from the Pennine Middle Coal Measure Formation were sent to Socotec UK Ltd. to determine the quality of the coal. The analysis comprised the following suite of testing:

- Moisture content;
- Ash content;
- Volatile matter;
- Sulphur;
- Chlorine;
- Phosphorous;
- Gross calorific value;
- Net calorific value;
- Fixed carbon;
- Loss on ignition;
- Metal oxide analysis together with Base Acid Ratio, Fouling Factor and Slagging Index.

The results are presented in Appendix F.

4.0 GROUND CONDITIONS

The levels and depths of Made Ground were highly variable across the site due to the site's mining heritage. The various assigned strata were however relatively similar across the site.

A layer of Topsoil and Topsoil/Made Ground less than 0.50m thick was encountered at surface. The Made Ground typically consisted of Opencast Backfill - reworked natural materials of the Pennine Middle Coal Measures Formation. Natural soils consisted of the Pennine Middle Coal Measures Formation - a weathered clay horizon was encountered where natural materials were present at shallow depths, increasing to rock strength with depth, and below the Opencast Backfill. A contour plot of depth

to the base of the Opencast Backfill (in m bgl) is included in Appendix A as drawing AG3080-19-16.

Groundwater was recorded at variable levels across the site.

4.1 Topsoil & Topsoil/Made Ground

The term 'Topsoil' was used where the surface soils did not contain any man-made artefacts (e.g. brick fragments) and where it was underlain by natural soils.

The term 'Topsoil/Made Ground' was used to denote where it appeared to have been placed or at least disturbed by man. This was either where the topsoil contained such as brick, pottery or concrete fragments or where it was underlain by opencast backfill materials and therefore clearly must have been placed by man as part of the opencast restoration works.

The average thickness of Topsoil and Topsoil/Made Ground in combination was 0.3m. The average soil organic matter (SOM) content was 4% although it is worth noting that the running track area (located north of Tankersley Lane) returned an average SOM value of 9%.

Information on Topsoil classification, particle size and nutrient content etc. is included in the specialist report included within Appendix G.

4.2 Made Ground

Made Ground interpreted to not be related to the backfilling of the former opencast mines was only encountered locally as follows:

- Running track area (TP1202 and TP1023) – Made Ground encountered to a depth of between 1.30m and 1.45m bgl, comprising a slightly gravelly clay containing coal and rare brick fragments, likely associated with the construction of the running track;
- In close proximity to (c. 2m south) of TP1023 an area of burning/bonfire was observed on the ground surface including ash, glass and metal fragments;
- Extreme SE corner of site (RS3025) Made Ground encountered to a depth of 1.0m bgl, comprising slightly gravelly clay containing clinker and brick fragments, no known / obvious source suspected to be somehow linked to the former coal mining.

4.3 Made Ground – Opencast Backfill

The Made Ground – Opencast Backfill typically comprised reworked natural materials of the Pennine Middle Coal Measures Formation. There was minimal anthropogenic detritus, bricks, metal fragments etc. present within this material. The depth to the base of this stratum is contoured on drawing AG3080-19-16 in Appendix A.

Across the areas of opencast backfill there generally was an initial 'capping' layer below the Topsoil/Made Ground and above the either granular or cohesive fill. This layer was typically comprised light grey mottled light orangish brown slightly gravelly silty clay. This stratum was present to depths of between 0.70m and 1.20m bgl. This material was likely derived from the weathered upper horizons of the Pennine Middle Coal Measures, previously overlying the site.

The Opencast Backfill materials were mostly cohesive, with approximately a third to a quarter of all materials encountered being more granular but still with a cohesive component or matrix. Individual exploratory holes often encountered either cohesive or granular material below the 'capping' layer, however, there was no obvious pattern to where predominantly cohesive soils and predominantly granular soils were present.

Below the cohesive capping layer, where present, cohesive materials typically comprised brownish grey, grey and dark grey slightly gravelly to gravelly silty clay with occasional to frequent cobbles. The strength of this material was highly variable, as discussed in other sections of this report. Granular strata typically comprised brownish grey, grey and dark grey slightly sandy clayey to very clayey gravel with occasional to frequent cobbles. Gravel was typically comprised of mudstone, siltstone and sandstone, locally including coal and ironstone. Cobbles typically comprised siltstone, occasionally mudstone and sandstone. From an overview of all of the Made Ground – Opencast Backfill materials encountered in this investigation, it is estimated that approximately one third of the stratum was noted to contain a proportion of cobble sized fragments and that, where noted, they typically constitute 10-20% of the soil volume.

The presence of siltstone and sandstone boulders within both cohesive and granular strata were rare and generally only encountered in the east of St Peter's (W) + Ext and Bell Ground opencast mines. In these areas typically one or two boulders, with typical dimensions of 0.30m x 0.40m x 0.60m, were present within trial trenches/pits.

The presence and depth of the opencast strata was extremely variable across the site but was broadly in line with the abandonment plans summarised in the Phase 1 Coal Mining Risk Assessment Report. Trial trenches along with trial pits and rotary sonic boreholes were used to investigate the opencast extents. Trial trenches focussed on locating the highwalls identified by the abandonment plans, with rotary sonic boreholes proving the base where trial pits could not.

A slight disparity between the opencast abandonment plans and the conditions encountered on site were the two sections of St Peter's opencast present on site, which were identified to be c. 10-15m further south, albeit the same shape and size indicated by the plans. In addition, the western highwall boundary of the Bell Ground opencast was further to the west than indicated on the abandonment plans. This is likely due to the initial shallow gradient of the base of the opencast in this area with the true highwall recorded further into the opencast and thus defining the extents is somewhat subjective.

CPTs were also undertaken to provide more information on the strength and composition of the Made Ground - Opencast Backfill, particularly in the area where the greatest thickness of fill is to be placed. Three of the 22 locations refused at depths significantly shallower than the predicted opencast base depth, likely as a result of a cobble or boulder within the backfill material. These tests were repeated c.1m away from the original location, all progressing deeper on the second attempt indicating a localised obstruction, not shallow bedrock. The remaining locations typically terminated with a refusal at a depth more in line with that predicted for the natural competent bedrock and in line with that identified by the other exploratory hole location types.

The Made Ground – Opencast Backfill was generally dry on excavation with just localised seepages, except for the materials encountered within Tankersley Common Ground Opencast, north of Tankersley Lane and the opencast backfill in close proximity to the motorway within the north eastern section of St Peter's opencast, where soils were saturated and groundwater inflow rapid.

4.4 Pennine Middle Coal Measures Formation

Strata considered to represent the Pennine Middle Coal Measures Formation were present directly below the Topsoil, locally shallow Made Ground and below the Made Ground – Opencast Backfill.

Where natural soils were encountered near surface, typically at depths of less than 3m bgl, there was a weathered horizon typically comprising firm to stiff light grey mottled orangish brown silty clay overlying stiff to very stiff very closely to closely fissured friable grey silty clay with frequent fine to medium gravel sized mudstone lithorelicts. Locally at depths of less than 1m bgl within this weathered horizon thin bands of weak to medium strong (field assigned strength) siltstone and sandstone were encountered, typically recovered as tabular cobbles and boulders. This was most notable in the far northeast of the ploughed fields northeast of Tankersley Lane and in the grass fields in the far southeast of the site.

Below the weathered horizon, typically at depths below 3m bgl and below the Made Ground – Opencast Backfill, the Pennine Middle Coal Measures Formation comprised extremely to very weak, locally weak, very thinly to medium interbedded light grey, grey and dark grey mudstone, siltstone and occasionally sandstone. Coal seams were encountered within this Formation and are detailed in the table below stratigraphically in order from youngest (shallowest) to oldest (deepest):

Name of Coal Seam		Locations Encountered in	Thickness of Coal Seam (m)	Comments
Un-named Seam (Shallow)		RS3025, TP1093, TP1100, TP1109, TT2027B	0.3- 0.6	Encountered in far southeast of site.
Dunsil	Upper Leaf	RC4004, RC4005, RC4011, TP2026, TP1062, TP1072, TT2012	0.4- 0.5	
	Lower Leaf	RC4004, RC4005, RC4011, TP1026, TP1061, TP1062, TP1072, TP1105, TT2012	0.19- 0.45	Generally 0.3m thick.
	Undifferentiated	RC4007, RS3013, RS3023, TP1033, TP1034, TP1060, TP1075, TP1088, TP1091, TP1095, TT2014, TT2025, TT2029, TT2030	0.1- 0.6	Generally 0.3m thick, where 0.6m thick possibly both leaves encountered but not distinguishable due to excavation method.
Dunsil Marker		RC4002, RC4003, RC4004, RC4005, RC4007, RC4009, RC4010, RC4011, RC4012, RS3006, RS3008, RS3010, TP1019, TP2025	0.07-0.5	Generally 0.3m thick. On average recorded c. 6m below Dunsil Seam and c. 12m above Swallow Wood Seam.
Swallow Wood	Upper Leaf	RC4007, RC4009	0.90-0.97	Two common seams identified, the thicker of
	Lower Leaf	RC4007, RC4009	0.13-0.21	

Name of Coal Seam		Locations Encountered in	Thickness of Coal Seam (m)	Comments
	Undifferentiated	RC4001, RC4003, RC4004, RS3003, TT2001 (NORTH), TT2006 (WEST), TT2008 (EAST)	0.1-0.3 & 0.5-0.95	two is generally assumed to be the upper leaf.
Un-named Seam (Deep)		RC4004	0.14	Recorded at depth below Swallow Wood Seam

5.0 GROUND GAS & GROUNDWATER

5.1 Ground Gas

Owing to the presence of underground coal seams being encountered during drilling, personal gas monitors were used to record mine gas concentrations. There were no elevated concentrations of gas recorded during site works by these monitors. However, in trial pit TT2001 - NORTH a sulphurous odour and in RC4001 gas bubbles were noted within the return drilling flush whilst progressing through certain strata.

Four phases of ground gas monitoring of the installations have been undertaken as part of this investigation, the results of which are included in Appendix D. Installations were installed in the Made Ground Opencast Backfill and in the Pennine Middle Coal Measures, both being potential sources of ground/mine gas.

All installations recorded negligible methane concentrations, all below the level of detection (0.1%).

Most installations were measuring some carbon dioxide concentrations with five measuring >5% on one or more occasions, four of which were from the opencast backfill materials. Carbon dioxide concentrations from installations within natural Pennine Middle Coal Measures Formation ranged between less than the level of detection (0.1%) and 5.8%. Installations within the opencast backfill materials recorded carbon dioxide concentration between 0.1% and 22.1%, with approximately half recording concentrations of greater than 5%.

Oxygen concentrations were recorded as between 1.2% (depleted) and 21.3% (atmospheric).

Most installations monitored have negligible carbon monoxide concentrations, below the level of detection (less than 1ppm), except two both of which were installed in natural coal measures strata and in the later monitoring visits these had also fallen to negligible concentrations. The maximum recorded concentration was in RC4004 of 37ppm.

All hydrogen sulphide concentrations can be considered negligible.

The installation RC4001 targeting the stratum in which gas bubbles were noted within drilling flush returns did not record any notably elevated concentrations of ground gas, although flow rates in this borehole were marginally elevated on several occasions.

Flow rates were generally negligible with a maximum rate of 0.3l/hr recorded.

5.2 Groundwater

Groundwater across the site was locally encountered within the Opencast Backfill, particularly towards the base, and within more permeable horizons within the Pennine Middle Coal Measures Formation.

Of note, are the fast inflows encountered in excavations TP1002, TT2001, TT2003 in areas of opencast backfill north of Tankersley Lane, as well as in TP1034, TP1046 located in the centre west of the site, near the motorway, also in an area of opencast backfill. This fast inflow lead to instability within the excavations, to a greater extent than in other areas of site. The groundwater observations are detailed in the table below.

Location Nº	Depth of Strike (m bgl)	Remarks	Strata
RC4004	20.00	Medium seepage	Pennine Middle Coal Measures Formation
RC4007	8.80	Medium seepage	Pennine Middle Coal Measures Formation
RC4009	14.50	-	Pennine Middle Coal Measures Formation
RS3026	1.00	Slight seepage	Made Ground – Opencast Backfill
RS3028	1.30	Slight seepage	Made Ground – Opencast Backfill
RS3030	1.00	Seepage	Made Ground – Opencast Backfill
	4.00	Seepage	Made Ground – Opencast Backfill
TP1002	1.50	Fast inflow	Made Ground – Opencast Backfill
TP1003	0.90	Seepage	Base of Made Ground – Opencast Backfill
TP1003	2.00	Seepage	Pennine Middle Coal Measures Formation
TP1006	2.00	Seepage	Made Ground – Opencast Backfill
TP1007	0.60	Slight seepage	Made Ground – Opencast Backfill
TP1007	3.50	Moderate seepage	Made Ground – Opencast Backfill
TP1014	0.30	Seepage	Pennine Middle Coal Measures Formation
TP1019	0.10	Seepage	Base of Topsoil
TP1022	2.80	Slight seepage	Pennine Middle Coal Measures Formation
TP1027	2.80	Seepage	Made Ground – Opencast Backfill
TP1029	4.00	Seepage	Made Ground – Opencast Backfill
TP1033	0.90	Slight seepage	Made Ground – Opencast Backfill
TP1034	3.50	Fast inflow	Made Ground – Opencast Backfill
TP1039	2.70	-	Made Ground – Opencast Backfill
TP1042	0.10	Seepage	Base of Topsoil
TP1046	2.00	Fast inflow	Made Ground – Opencast Backfill
TP1047	3.00	Moderate seepage	Made Ground – Opencast Backfill
TP1047	4.40	Moderate seepage	Made Ground – Opencast Backfill
TP1051	1.20	Seepage	Made Ground – Opencast Backfill
TP1052	0.50	Slight seepage	Made Ground – Opencast Backfill
TP1055	0.20	Seepage	Base of Topsoil
TP1058	2.00	Slight seepage	Pennine Middle Coal Measures Formation
TP1061	2.00	Slight seepage	Made Ground – Opencast Backfill
TP1067	0.10	Slight seepage	Base of Topsoil
TP1070	0.50	Slight seepage	Made Ground – Opencast Backfill
TP1071	0.25	Slight seepage	Base of Topsoil
TP1074	3.30	Seepage	Pennine Middle Coal Measures Formation
TP1076	2.40	Slight seepage	Pennine Middle Coal Measures Formation
TP1077	4.20	Seepage	Made Ground – Opencast Backfill
TP1089	2.80	Seepage	Pennine Middle Coal Measures Formation
TP1093	2.50	Seepage	Pennine Middle Coal Measures Formation
TP1097	1.55	Slight seepage	Made Ground – Opencast Backfill
TP1098	0.40	Slight seepage	Base of Topsoil
TP1100	3.00	Seepage	Pennine Middle Coal Measures Formation

Location Nº	Depth of Strike (m bgl)	Remarks	Strata
TP1105	2.91	Slight seepage	Pennine Middle Coal Measures Formation
TP1107	0.60	-	Made Ground – Opencast Backfill
TP1110	3.80	-	Made Ground – Opencast Backfill
TP1202	2.00	Slight seepage	Pennine Middle Coal Measures Formation
TP1203	1.00	Seepage	Pennine Middle Coal Measures Formation
TT2001 - NORTH	1.30	Fast inflow	Pennine Middle Coal Measures Formation
TT2001 - MID	2.60	Slight seepage	Made Ground – Opencast Backfill
TT2003 - EAST	1.30	Fast inflow	Made Ground – Opencast Backfill
TT2003 -WEST	0.40	Seepage	Base of Topsoil
TT2004 - EAST	3.00	Slight seepage	Pennine Middle Coal Measures Formation
TT2006 - WEST	1.80	-	Pennine Middle Coal Measures Formation
TT2006 - EAST	2.30	Seepage	Made Ground – Opencast Backfill
TT2008 - EAST	3.00	Seepage	Pennine Middle Coal Measures Formation
TT2027A	3.80	Fast inflow	Made Ground – Opencast Backfill
TT2031	2.80	Slight seepage	Made Ground – Opencast Backfill
TT2035	0.20	Seepage	Base of Topsoil

Subsequent monitoring of the standpipes installed within selected boreholes was undertaken to record standing groundwater level. The fieldwork was undertaken during a period of very heavy rainfall, with saturated ground conditions but since the fieldwork, there has been an extended period of dry weather during which the groundwater monitoring has been undertaken. Therefore, over the several months of monitoring typically groundwater levels have reduced across the site.

A summary of the recorded standing groundwater levels in standpipes is given in the table below:

Stratum	Range of Recorded Groundwater depths (m bgl)	Range of Recorded Groundwater depths (m AOD)	Associated Borehole Installations and base of installation (m)
Made Ground-Opencast Backfill North of Tankersley Lane (Plot 3)	1.85 - 4.50	144.92 - 143.32	RS3002 (5.0), RS3003 (5.0), RS3004 (4.0)
Made Ground-Opencast Backfill South of Tankersley Lane (Plot 1)	2.80 - Dry (7.00)	149.64 - Dry (144.5)	RS3013 (4.0), RS3015 (7.0), RS3017 (5.0), RS3019 (5.0), RC4007 (3.0)
Made Ground-Opencast Backfill South of Tankersley Lane (Plot 2)	4.90 - Dry (5.00)	122.50 - Dry (118.26)	RS3026 (5.0), RS3027 (3.7), RS3028 (5.0), RS3029 (5.0), RS3030 (4.0)
Shallow Pennine Middle Coal Measures Formation (<8m bgl)	0.86 – 4.39	146.91 – 125.51	RS3005 (4.0), RS3008 (3.0), RS3010 (5.0), RS3022 (5.0), RS3025 (3.0)
Deep Pennine Middle Coal Measures Formation (>8m bgl)	2.30 - 9.88	139.94 - 116.82	RC4001 (11.5), RC4004 (20.0), RC4009 (14.5), RC4010 (10.8)

Groundwater levels within the opencast materials were highly variable and likely responsive to weather conditions. In the opencast to the north of Tankersley Lane the backfill materials were largely saturated with water encountered at shallow depths (c. 1.0m to 3.4m bgl) both during excavation and during subsequent monitoring of standpipes. There was little to no land drainage noted in the fields north of Tankersley Lane, which may be a factor in the greater degree of saturation in this area. To the south of Tankersley Lane groundwater in the opencast materials was more localised with seepage in the central area encountered at depths of between 1.0m and 4.0m bgl whilst other trial pits and boreholes within the area remained dry. In the southeast water was also encountered within the opencast at depths of between 1.5m and 3.8m bgl, however, again this was localised with an absence of water recorded in other excavations and installations. This suggests that water in the opencast backfill materials is localised and potentially perched in areas where the mixed backfill material comprises a greater proportion of fines.

Some limited groundwater seepage was encountered within the upper weathered horizons of the Pennine Middle Coal Measures Formation north of Tankersley Lane at depths of between 1.0m and 3.0m bgl and locally this was associated with the presence of coal seams. Localised perched groundwater was also encountered within the shallow Pennine Middle Coal Measures to the south of Tankersley Lane at between 1.75m and 3.0m bgl in the north of the area, between 2.0m and 2.8m in the centre and between 1.50m and 3.00m bgl to the far southeast. These seepages are considered to represent discrete interlaminar and fissure born groundwater flow of limited extent.

During formation of the boreholes, deeper groundwater strikes were recorded in the Pennine Middle Coal Measures Formation in RC4004 at 20m (126.1m AOD), in RC4007 at 8.8m (136.33m AOD) and in RC4009 at 14.5m (103.72m AOD). Subsequent monitoring of standpipes in these holes recorded standing water levels had risen to 6.10m (RC4004), 2.82m to 1.40m (RC4007) and c. 6.0m (RC4009). The strikes in RC4007 and RC4009 coincide with more permeable strata (siltstone) whilst RC4001 was also installed at depth within the Pennine Middle Coal Measures Formation (response zone 8.0m to 11.50m bgl). This indicates the groundwater encountered deeper within more permeable layers of the Pennine Middle Coal Measures Formation to be sub-artesian.

5.3 Variable Head Testing

Variable head tests were undertaken within RC4007, RS3002, RS3003, RS3004, RS3013, RS3015, RS3017and RS3019 within the Made Ground - Opencast Backfill, to give an indication of the permeability of this stratum, the results of which are included in Appendix D and summarised below:

Borehole No	Strata	Permeability (m/s)
RC4007	Made Ground – Opencast Backfill	1.6×10^{-8}
RS3002	Made Ground – Opencast Backfill	1.8×10^{-8}
RS3003	Made Ground – Opencast Backfill	4.4×10^{-8}
RS3004	Made Ground – Opencast Backfill	6.4×10^{-9}
RS3013	Made Ground – Opencast Backfill	1.5×10^{-5}
RS3015	Made Ground – Opencast Backfill	1.0×10^{-5}
RS3017	Made Ground – Opencast Backfill	1.9×10^{-7}
RS3019	Made Ground – Opencast Backfill	9.3×10^{-8}

Up to fifty litres of clean water was used in each test, and permeabilities of between 1.9 x 10^{-7} and 6.4 x 10^{-9}m/s were recorded, except in two locations, RS3013 and RS3015. Both these standpipes were dry and water was flowing away as it was being added such that a reliable head of water could not be maintained. This suggests a relatively high permeability and the analysis of the little data obtained from these tests (which only ran for 2 mins) suggests permeabilities in the region of 1 x 10^{-5}m/s.

6.0 GEOTECHNICAL PROPERTIES

A range of geotechnical properties have been derived for the various strata encountered. These have been drawn from various methods / sources including from direct measurements from in-situ testing (SPT, CPTu), laboratory analyses (classification, rock strength, sulphates) and published correlations (Coefficient of Compressibility - m_v). Only a limited number of 'undisturbed' UT100 samples could be obtained during the investigation due to the soft/loose and mixed nature of the opencast backfill materials, which could not easily be retained within sample tubes on extraction. Greater success at UT100 recovery was achieved at shallow depth in DCS boreholes in the Opencast Backfill in the southeast of Plot 2, hence the samples obtained are skewed toward this location and depths. The small number of UT100 samples has limited the scale of undrained shear strength and one-dimensional consolidation testing.

6.1 Classification/Index Properties

6.1.1 Moisture Contents

Moisture Content tests were undertaken on 55 no. samples from the Made Ground - Opencast material and 53 no samples from the soil strength Pennine Middle Coal Measures Formation. A summary of the results of this testing is presented in the table below:

Stratum	Moisture Content (%)		
	Min	Max	Average
Made Ground - Opencast	8.2	28	15.8
Pennine Middle Coal Measures Formation	6.2	44	20.1

A graph showing moisture content versus depth for soil strength materials is located in Appendix A. Whilst there is significant scatter to the results there is a general decrease in soil moisture content with depth for both strata.

18 no. Moisture Content tests were undertaken on samples from the rock strength Pennine Middle Coal Measures Formation. These have been divided into the material types and results presented in the table below:

Stratum	Moisture Content (%)		
	Min	Max	Average
Mudstone	2.8	3.9	3.4
Siltstone/Mudstone	3.0	4.6	3.5
Siltstone	1.3	7.6	3.9
Sandstone	3.0 (Only one sample)		

6.1.2 Atterberg Limits

100 no. Atterberg limit tests were undertaken on soil samples from across the site at a range of depths. The minimum, maximum and average values for Made Ground – Opencast Backfill and Pennine Middle Coal Measures Formation soils are presented below. The results are also presented on a plasticity chart in Appendix A.

Stratum		**w%**	**% passing 425um**	**wL**	**wP**	**PI**	
				uncorrected	*uncorrected*	*uncorrected*	*corrected*
Made Ground - Opencast Backfill	Min	8.2	25.0	36.0	18.0	18.0	5.0
	Avg	16.2	57.2	45.4	21.5	24.9	14.4
	Max	28.0	100.0	64.0	26.0	38.0	38.0
Pennine Middle Coal Measures	Min	6.2	28.0	36.0	19.0	16.0	5.6
	Avg	20.0	82.3	51.3	23.4	27.9	23.9
	Max	44.0	100.0	75.0	32.0	44.0	44.0

Made Ground - Opencast Backfill

48 no. Atterberg tests were carried out on samples of cohesive materials of Made Ground - Opencast Backfill. Of these 39 indicated intermediate/medium plasticity and 9 indicated high plasticity. The results also indicated the material to be of low to high shrinkability in the samples tested.

Pennine Middle Coal Measures Formation

52 no. Atterberg tests were carried out on samples of cohesive materials of Pennine Middle Coal Measures Formation. Of these 26 indicated intermediate/medium plasticity, 21 indicated high plasticity and 4 indicated very high plasticity, and 1 was recorded as being non-plastic. The results also indicated the material to be of low to medium shrinkability in the samples tested.

6.1.3 Organic Content/Loss on Ignition

Soil organic matter testing was carried out as part of the chemical laboratory testing. The results of 3no. tests on the Pennine Middle Coal Measures returned results of 0.8-1.6%, 37no. tests on the Made Ground-Opencast Backfill recorded results of 0.3-5.9% (average of 1.73%) and three tests on Made Ground from the existing running track / football pitch area returned results of 5.2-6.5%.

Loss on Ignition tests were undertaken on 14no. samples from the opencast backfill materials and 1no. sample of the coal measures with the results ranging from 2.8% to 7.9% for the opencast backfill (average value of 4.6%) and a value of 4.0% for the Coal Measures sample.

6.1.4 Calorific Value

Calorific Value tests were undertaken on 14no. samples from the Opencast Backfill materials and 1no. sample of the Coal Measures with all recorded values for both strata being reported at less than the level of determination (<1 MJ/kg).

6.2 **Particle Size Distribution**

34 no. Particle Size Distribution tests were undertaken on samples from the Made Ground - Opencast. The results of this testing and the resultant classification are given in the table below:

Location	Depth (m bgl)	Sample Proportion (%)					Classification
		Clay	Silt	Sand	Gravel	Cobbles	
RC4010	2.0	16	17	16	51	0	Very clayey/silty sandy GRAVEL
RC4010	6.0	21	23	18	38	0	Slightly sandy slightly gravelly clayey SILT
TP1002	3.0	24		12	64	0	Very clayey/silty sandy GRAVEL
TP1004	3.0	32		12	56	0	Very clayey/silty sandy GRAVEL
TP1007	0.6	46		17	37	0	Slightly sandy gravelly silty CLAY
TP1009	2.0	57		11	32	0	Slightly sandy gravelly silty CLAY
TP1012	1.6	39		22	39	0	Slightly sandy gravelly silty CLAY
TP1027	2.5	33		13	54	0	Slightly sandy gravelly silty CLAY
TP1029	3.0	40		11	49	0	Slightly sandy gravelly silty CLAY
TP1033	2.0	72		10	18	0	Slightly sandy slightly gravelly silty CLAY
TP1033	3.5	65		27	8	0	Slightly gravelly sandy silty CLAY
TP1036	3.0	22		12	66	0	Very silty/clayey sandy GRAVEL
TP1040	1.0	22		10	68	0	Very silty/clayey sandy GRAVEL
TP1042	3.0	55		12	33	0	Slightly sandy gravelly silty CLAY
TP1043	4.0	30		13	41	16	Slightly sandy gravelly silty CLAY with occasional cobbles.
TP1045	2.5	71		10	19	0	Slightly sandy slightly gravelly silty CLAY

Location	Depth (m bgl)	Sample Proportion (%)					Classification
		Clay	Silt	Sand	Gravel	Cobbles	
TP1047	2.5	77		12	11	0	Slightly sandy slightly gravelly silty CLAY
TP1048	1.5	28		10	62	0	Very silty/clayey sandy GRAVEL
TP1054	2.5	42		17	41	0	Slightly sandy gravelly silty CLAY
TP1055	3.0	57		18	25	0	Slightly sandy slightly gravelly silty CLAY
TP1056	0.5	88		9	3	0	Slightly sandy slightly gravelly silty CLAY
TP1063	2.0	31		11	58	0	Slightly sandy very clayey/silty GRAVEL
TP1064	3.0	22		9	60	9	Slightly sandy very clayey/silty GRAVEL
TP1069	2.5	23		8	51	18	Slightly sandy very clayey/silty GRAVEL with occasional cobbles.
TP1086	1.5	25		10	65	0	Slightly sandy very clayey/silty GRAVEL
TP1095	1.5	79		8	13	0	Slightly sandy slightly gravelly silty CLAY
TP1097	1.0	33	38	8	21	0	Slightly sandy slightly gravelly CLAY/SILT
TP1101	3.0	10	13	12	55	10	Slightly sandy very clayey/silty GRAVEL with occasional cobbles.
TP1103	2.5	10	16	6	63	5	Slightly sandy very clayey/silty GRAVEL with rare cobbles.
TP1111	2.0	13	18	16	53	0	Slightly sandy very clayey/silty GRAVEL
TP1113	2.5	13	18	18	51	0	Slightly sandy very clayey/silty GRAVEL
TT2009	2.5	13	16	17	54	0	Slightly sandy very clayey/silty GRAVEL
TT2031	2.0	17	21	13	49	0	Slightly sandy very clayey/silty GRAVEL

12 no. Particle Size Distribution tests were undertaken on samples from the Pennine Middle Coal Measures Formation. The results of this testing and the resultant classification are given in the table below:

Location	Depth (m bgl)	Sample Proportion (%)					Classification
		Clay	Silt	Sand	Gravel	Cobbles	
TP1003	2.5	24		12	64	0	Slightly sandy very clayey/silty GRAVEL.
TP1015	1.2	57		12	31	0	Slightly sandy gravelly CLAY/SILT
TP1017	2.0	58		7	35	0	Slightly sandy very gravelly silty CLAY
TP1018	1.0	92		3	5	0	Slightly sandy slightly gravelly silty CLAY
TP1022	0.9	67		11	22	0	Slightly sandy slightly gravelly silty CLAY
TP1024	1.0	47		11	42	0	Slightly sandy very gravelly silty CLAY
TP1030	2.5	28		11	61	0	Slightly sandy very clayey/silty GRAVEL
TP1032	0.5	92		6	2	0	Slightly sandy slightly gravelly silty CLAY
TP1032	2.0	26		11	63	0	Slightly sandy very clayey/silty GRAVEL
TP1049	1.5	91		8	1	0	Slightly sandy slightly gravelly silty CLAY
TP1049	3.0	24		12	54	10	Sandy very clayey/silty GRAVEL
TP1201	0.5	87		7	6	0	Slightly sandy slightly gravelly silty CLAY
TP1202	0.5	78		13	9	0	Slightly sandy slightly gravelly silty CLAY

6.3 Undrained Shear Strength

Four unconsolidated 'quick' undrained triaxial tests were undertaken on samples of the Made Ground Opencast Backfill from RS3027, RS3029 (2no.) and RS3030 at depths of between 0.3m and 1.0m. The test from 0.3m bgl recorded an undrained shear strength of 25kN/m^2 (low strength). The tests from 1.0m bgl recorded undrained shear strengths of between 51kN/m^2 and 76kN/m^2 (medium to high strength).

Two unconsolidated 'quick' undrained triaxial tests were undertaken on samples of the Pennine Middle Coal Measures Formation from RS3005 and RS3009 at depths of 1.5m and 1.0m bgl respectively. The tests recorded undrained shear strengths of 52kN/m^2 and 45kN/m^2 (medium strength) respectively.

Approximate undrained shear strengths derived from SPT N values and f_1 (after Stroud *et al*) assessed from average plasticity index are detailed in the table below. For the coal measures clay strata it has been possible to subdivide this into an upper and lower unit based on field description / consistency and the SPT Vs Depth profile. When calculating the approximate mass shear strengths the mean plasticity indices

were used being 24% for Opencast Backfill, 25% for the upper coal measures clay and 22% for lower coal measures clay.

Stratum		Approx. Undrained Shear Strength (kN/m^2) from SPT N and plasticity index		
		Min	Max	Average
Made Ground - Opencast Backfill		20	140*[1]	65*[1]
Pennine Middle Coal Measures Formation	Upper 1.5-2.0m bgl	25	130	60
	>1.5-2.0m bgl	65	260*[2]	135*[2]

*[1]: Excludes potentially erroneous SPT 'N' values of >30 in Opencast Backfill that are considered likely to represent coarse gravel and cobble content, which is not considered representative of the mass soil behaviour.
*[2]: Excludes values derived from extrapolated SPT 'N' values of >50.

6.4 Shear Box Tests

Three small shear box tests were undertaken on samples of Made Ground Opencast Backfill (clay) sub-sampled from undisturbed UT100 tubes obtained from the shallow DCS boreholes in Plot 2. The shearing stage for the three sub-samples lasted between 4 and 9 days each. Once the sample had been sheared and peak conditions recorded the apparatus was racked back allowing approximate residual conditions to be estimated. The results of the tests are tabulated below.

Location and depth	Peak Condition		Residual Condition	
	Apparent Cohesion (kPa)	Angle of Shearing Resistance (degrees)	Apparent Cohesion (kPa)	Angle of Shearing Resistance (degrees)
RS3026 (1.00-1.45m bgl)	17	32	9	19.5
RS3028 (1.00-1.45m bgl)	13	30	12	23
RS3030 (0.30-0.75m bgl)	5	28.5	0	26.5

All three of the above samples, whilst predominantly cohesive, contained a high proportion of coal and mudstone gravel that has clearly had a significant effect on the angle of shearing resistance. The laboratory also noted that all of the specimens required some gravel to be removed followed by patching with clay in order to form the 60mm subsamples required for the tests.

6.5 Bulk Density

Several UT100 samples of the Made Ground Opencast Backfill and upper weathered (clay strength) coal measures strata were obtained and these were submitted for bulk density determination as part of the quick undrained triaxial testing.

In addition, as part of the seven UCS tests on coal measures rock core bulk density was also determined. The results of which are summarised below:

Stratum	Bulk Density (Mg/m^3)
Made Ground Opencast Backfill	Min 2.04, Max 2.20, Ave 2.11
Pennine Middle Coal Measures Formation (Soil Strength)	1.89 and 1.98
Pennine Middle Coal Measures Formation (Rock Strength)	Min 2.47, Max 2.87, Ave 2.63

6.6 Float Yield and Ash Content

Four samples of Made Ground – Opencast Backfill were submitted for float yield and ash content analysis, three being from the main development area to the north and the fourth from the pond area. The results of which are summarised below:

Sample	Float Yield at specific gravity of 1.6		Ash content of floating fraction (%)	Analysis moisture of floating fraction (%)
	Float	Sink		
TP 1035 - 3.5-4.0m	0.5	99.5	15.8	4.8
TP1052 - 2m	3.4	96.6	20.3	4.3
RC4006 - 3-5m	2.9	97.1	10.5	6.6
TP1312 - 1-2m	2.9	97.1	12.7	8.8

6.7 Consolidation Properties

One dimensional consolidation tests were undertaken on three 'undisturbed' samples of the Made Ground Opencast Backfill. The oedometer m_v values were calculated for various pressure ranges from field curves reconstructed from the laboratory data. The results are presented in the table below.

Borehole	Depth	Pressure Range	m_v
		kPa	m^2/MN
RS3026	1.00 - 1.45	125-225	0.19*1
		225-325	0.13*2
RS3028	1.00 - 1.45	125-225	0.11*1
RS3030	0.30 - 0.75	120-220	0.20*1

*1 Based on pressure range equivalent to approximate current overburden pressure +100kN/m^2 to approximate current overburden pressure +200 kN/m^2

*2 Based on pressure range equivalent to approximate current overburden pressure +200kN/m^2 to approximate current overburden pressure +300 kN/m^2

The above values of m_v for the pressure range equivalent to existing overburden pressure are relatively consistent in the range 0.11-0.20 m^2/MN. However, it is important to note that these three samples have all been taken from a similar shallow depth and compressibility parameters at different depths in the Opencast Backfill are anticipated to be different and possibly more variable.

Approximate Coefficient of Compressibility (m_v) values have also been calculated for soils strength materials, derived from reference to the SPT N values and plasticity from each material and using the Stroud correlation.

Made Ground – Opencast Backfill

Plasticity in the opencast materials is very variable with values of between 18% and 38% and a mean average of 24% and a mode average of 20%. SPT N is also variable, however, excluding potentially erroneous higher values (>30-40), a reasonably consistent range of between 4 and 26 is apparent with a mean average of c. 10-12 with no obvious trend with depth. This correlates to approximate estimates of m_v of c. 0.10-0.50 m^2/MN with a tentative average value in the order of 0.25 m^2/MN (medium to high compressibility).

Pennine Middle Coal Measures

Plasticity in the coal measures clays is variable in the upper 1.5m with values of between 20% and 32% and a mean average of 25%. Below 1.5m plasticity is slightly more consistent at between 19% and 29% with both mean and mode average being 22%. SPT N is generally in the range 5 to 26 up to 1.5-2.0m with an average in the order of c. 12. SPT N below 1.5-2.0m increases with values in the order of 13 to 43 (excluding values of >50) with an average in the order of c. 26. These correlate to approximate estimates of m_v of c. 0.15-0.18 m^2/MN (medium compressibility) in the upper 1.5-2.0m decreasing to c. 0.05-0.10 m^2/MN (low compressibility) below 1.5-2.0m.

6.8 Maximum Dry Density/Optimum Moisture Content

The maximum dry density results from the 4.5kg rammer tests are as follows:

Stratum	Optimum moisture content (%)			Maximum dry density (Mg/m³)		
	Min	Max	Ave	Min	Max	Ave
Made Ground – Opencast Backfill	6.9	18	10.7	1.76	2.13	2.00
Pennine Middle Coal Measures Formation	8.8	18	13.1	1.64	2.04	1.88

The maximum dry density results from the 2.5kg rammer tests are as follows:

Stratum	Optimum moisture content (%)			Maximum dry density (Mg/m³)		
	Min	Max	Ave	Min	Max	Ave
Made Ground – Opencast Backfill	12	19	15.7	1.67	1.92	1.78
Pennine Middle Coal Measures Formation	13	20	15.7	1.64	1.85	1.78

For the Made Ground - Opencast material of the 27 comparisons undertaken of natural moisture content and optimum moisture content; 21 were wet of optimum (> +2%), 4 were within optimum +/- 2% and 1 was dry of optimum (< -2%).

For the Pennine Middle Coal Measures Formation material of the 14 comparisons undertaken of natural moisture content and optimum moisture content; 10 were wet of optimum (> +2%), 4 were classified as within optimum +/- 2% and none were dry of optimum (< -2%).

6.9 Particle Density

Particle Density tests were undertaken on the samples subjected to compaction testing. A summary of the results of this testing is presented in the table below:

Stratum	Particle Density (Mg/m^3)		
	Min	Max	Average
Made Ground – Opencast Backfill	2.48 (2.21*)	2.68	2.62
Pennine Middle Coal Measures Formation	2.60	2.66	2.63

*low value of particle density of OC believed to be as a result of high coal content.

6.10 CBR

CBR tests were undertaken on remoulded materials at optimum moisture content/maximum dry density alongside the compaction tests. The results from the 2.5kg compactive effort tests are summarised below:

Stratum	CBR Value (%)					
	Min		Max		Average	
	Top	Base	Top	Base	Top	Base
Made Ground – Opencast Backfill	8.3	9.3	10	11	9.3	9.9
Pennine Middle Coal Measures Formation	10	8.8	13	10	11.3	9.3

The results from the 4.5kg compactive effort tests are summarised below:

Stratum	CBR Value (%)					
	Min		Max		Average	
	Top	Base	Top	Base	Top	Base
Made Ground – Opencast Backfill	22	21	69	71	41.3	37.2
Pennine Middle Coal Measures Formation	29	28	65	56	43.8	38.5

Using the results of the plasticity index results for the materials inferred by the correlation outlined in Table 5.1 in the Interim Advice Note 73/06 Rev 1(2009), CBR values are indicated to range between 2.5% and 6% dependant on thick or thin pavement construction.

6.11 Triaxial Permeability

Three laboratory triaxial permeability tests were undertaken on samples of Made Ground Opencast Backfill from depths of between 2m and 4m bgl; the samples were remoulded in the laboratory using the 2.5kg rammer. The table below provides a summary of the results.

Sample	Depth (m bgl)	Coefficient of Permeability (m/s)
TP1094	3.00-4.00	4.2×10^{-10}
TP1102	2.00	3.8×10^{-10}
TP1112	4.00	7.9×10^{-10}

6.12 SPTs

Stratum		Uncorrected SPT N Value		
		Min	Max	Average
Made Ground – Opencast Backfill		4	29*[1] (176)	14*[1] (23)
Pennine Middle Coal Measures Formation	Upper Clay	5	26	12
	Lower Clay	13	50*[2]	26*[2]
	Rock	55	>250	>100
	Coal	16	73	37

*[1]: Excludes potentially erroneous SPT 'N' values of >30 in Opencast Backfill that are considered likely to represent coarse gravel and cobble content, which is not considered representative of the mass soil behaviour. Extrapolated maximum value included in brackets.
*[2]: Excludes values derived from extrapolated SPT 'N' values of >50.

Plots of SPT N value against depth (m bgl) and elevation (m AOD) are presented in Appendix A.

6.13 Rock Quality

A summary of the rock core quality data for the Pennine Middle Coal Measures Formation is presented below:

BH	Range of TCR (%)	Range of SCR (%)	Range of RQD (%)	Range of average If (mm)	Comments
RC4001	33-100	0-100	0-74	60-105	Notable drop in rock core quality between 9.10 and 12.10m.
RC4002	97-100	61-100	34-70	90-120	Lowest RQD between 3.50 and 6.50m.
RC4003	97-100	65-99	9-80	60-85	Typical RQD of less than 30%.
RC4004	75-100	10-100	0-75	35-215	Lowest rock core quality between 4.20 and 7.30m. Low RQDs also recorded between 18.00 and 19.50m and between 27.00 and 28.50m. Average If typically increases with depth with the exception of between 17.00 and 20.50m and between 26.70 and 30.00m.
RC4005	91-100	12-93	0-68	70-90	Lowest rock core quality between 5.50 and 7.00m. Typical RQD of less than 50%. Average If is non-intact between 5.11 and 6.82m
RC4006	17-100	17-100	0-55	90	Lowest rock core quality between 7.00 and 7.40m. Typical RQD of less than 10%.

BH	Range of TCR (%)	Range of SCR (%)	Range of RQD (%)	Range of average If (mm)	Comments
RC4007	83-100	43-100	0-77	75-150	Lowest rock core quality between 4.65 and 5.80m. Lowest SCR between 23.80 and 25.80m. Typical RQD of between 20% and 40%.
RC4008	95-100	76-86	21-71	128	Lowest rock core quality between 10.40 and 13.20m.
RC4009	57-100	33-100	0-61	55-100	Notable drop in rock core quality between 4.50 and 6.00m and also between 16.50 and 18.00m. Also, RQD of 0% between 3.00 and 4.50m.
RC4010	43-100	20-100	7-81	110-140	Notable drop in rock core quality between 13.90 and 14.50m. RQD of less than 30% between 12.40 and 15.40m.
RC4011	73-100	43-88	0-74	140-290	Lowest rock quality between 5.00 and 9.50m. Typical RQD of less than 30%.
RC4012	60-100	31-71	0-23	80	TCR generally improves with depth. Typical SCR of less than 35%.
RC4013	85-100	60-90	20-41	100	Lowest rock quality between 15.50 and 16.50m.

Key
TCR – total core recovery
SCR – solid core recovery
RQD - Rock Quality Designation
If – Fracture Spacing

6.14 Unconfined Compressive Strength

Unconfined compressive strength (UCS) testing of 18 samples of the rock core was undertaken in accordance with ISRM Suggested Methods - Rock Characterization Testing and Monitoring 1974 - 2006. Due to the nature of the test, only the more competent sections of core could be subsampled and tested, therefore, the results tend to represent the relatively higher strength strata over the range of field assessed strengths. However, the results broadly correlate with the field assessed strengths on similar strata. The results are presented in Appendix F and summarised below.

Rock type	UCS Range (min/average/max) (MPa)	Strength
Mudstone	2.3 / 12.1 / 25.2	Very weak to medium strong
Siltstone	4.6 / 17.3 / 58.6	Very weak to strong
Mudstone/Siltstone	7.6 / 14.5 / 26.5	Weak to medium strong
Sandstone	8.3	Weak

Moisture contents were measured on each UCS sample but there was not found to be any apparent correlation between UCS and moisture content or between moisture content and depth.

6.15 Franklin Point Load Test Index

Franklin point load tests were undertaken on samples of the rock core in general accordance with ISRM Suggested Methods - Rock Characterization Testing and Monitoring 1974 - 2006. A summary of the results is presented below.

Rock type	Axial/Diametral	Range of $Is_{(50)}$ Results (MPa)	Average $Is_{(50)}$ (MPa)
Mudstone	Axial	0.07-3.3	0.47
	Diametral	0.01-1.82	0.40
Siltstone	Axial	0.30-5.22	1.70
	Diametral	0.20-1.41	0.40
Sandstone	Axial	0.97-3.4	2.20
	Diametral	0.07	0.07
Siltstone/Mudstone	Axial	0.11-4.3	1.00
	Diametral	0.01-3.34	0.38
Coal	Axial	0.1-0.39	0.25
	Diametral	0.1-0.56	0.33

$Is_{(50)}$ results for the axial tests have also been plotted against elevation (m AOD) by material type and by depth (m bgl). In a number of cases it was possible to carry out Point Load tests on remnant samples which were still suitable following previous UCS testing. Copies of all these plots are included in Appendix A.

A comparison of these results provides highly variable 'k' values (the relationship between $Is_{(50)}$ and UCS) ranging between 5 and 30 for mudstone and siltstone materials. There were too few results of the sandstone to infer a value for 'k'. Literature values generally range between 10 and 25 for varying rock types, with values of 25 (Cavagnaro, 1980) suggested for Coal Measures strata and 14 (Agustawijaya 2007) suggested for 'soft' argillaceous rocks.

Using a 'k' value of 10 the results would indicate rock strengths of between 0.7MPa (extremely weak) and 52MPa (strong). Using a 'k' value of 14 the results would indicate rock strengths of between 1.0MPa (extremely weak) and 73MPa (strong). Using a 'k' value of 25 the results would indicate rock strengths of between 1.75MPa (very weak) and 130MPa (very strong). However, due to the significant scatter in point load test results and ranges of values for 'k', extrapolated UCS values derived from point load tests should not be used for design purposes.

6.16 CPT Derived Soil Parameters

As can be seen by reference to the appended CPT report, a series of soil properties have been derived from the end cone resistance and sleeve friction results using empirical relationships and published data. These include equivalent SPT N_{60}, modulus of volume change potential (m_v), Young's Modulus, Relative Density, peak friction angle and Over-Consolidation Ratio. The correlations used to derive many of these properties are based on research and data conducted in clean sands or relatively homogenous clays whilst the Made Ground-Opencast Backfill materials comprised a mixture of sand, silt and clay with gravel and cobbles sized fragments of

coal measures rocks (sandstone, ironstone and mudstone). However, the correlation for m_v makes use of the constrained modulus, which is intended for all soil types whilst the correlation for N_{60} is intended for sand, silt and clay. Therefore, the ranges of m_v and N_{60} as obtained from the CPT's are summarised in the table below.

The strata penetrated by the CPT's was predominantly Made Ground-Opencast Backfill materials with the tests terminating at the base of the opencast upon hard coal measures strata. In-situ natural coal measures strata were penetrated in CPT5013 and CPT5016 as noted below.

CPT Location	Depth to Refusal (m bgl)	Range of typical N_{60} values	Range of representative m_v values from predominantly cohesive horizons (m^2/MN)
CPT5001	8.56	0m-6m – 5-10 6m-8.5m – 5-15	Between c. 2m - 6m – 0.10-0.16
CPT5002	10.28	0m - 10m – 5-10	Between c. 3.5m - 10m – 0.12-0.18
CPT5003	7.80	0m - 4m – 5 4m - 7.5m – 5-10	Between c. 1.5m - 6m – 0.15-0.23 Between c. 6m - 7.5m – 0.08-0.10
CPT5004	10.68	0m - 5m – 5-10 5m - 10m – 3-15	Between c. 8m - 10.5m – 0.14-0.24+
CPT5005	7.02	0m - 7m – 5-10	Between c.1.5m - 2.0m – 0.20-0.24 Between c. 5.5m - 7.0m – 0.10-0.21
CPT5006	7.26	0m - 7m – 5-15	Between c. 5.5m - 7.0m – 0.13-0.21
CPT5007	6.90	Generally, 10-15, exception of 1.7m - 3.3m – 3-7	Between c. 1.7m - 3.3m – 0.20-0.24+ Between c. 6.3m - 6.9m – 0.11-0.14
CPT5008	5.08	0m - 5m – 5-10	Between c. 3.5m - 5.0m – 0.17-0.20
CPT5009	10.46	0m - 7.5m – 5-10 7.5m - 10.4m – 7-15	Between c. 0.0m - 3.5m – 0.16-0.24+ Between c. 5.2m - 10.4m – 0.09-0.16
CPT5010	11.68	0m - 5m – 3-7 5m - 11.5m – 7-15	Between c. 4.5m - 11.5m – 0.10-0.19
CPT5011	3.16	0m - 3m – 3-5	Between c. 1.0m - 3.0m – 0.23-0.24+
CPT5012	2.42	0m - 2.4m – 5	Between c. 1.0m - 2.0m – 0.16-0.24+
CPT5012A	3.00	0m - 1.5m – 5 1.5m - 3.0m – 15-40	No suitable cohesive strata.
CPT5013	2.74	0.8m - 2.0m – 10 *1 2.0m - 2.7m – 25-35 *1	Between c. 0.8m – 2.0m – 0.12 *1 >2.0m No suitable cohesive strata.
CPT5014	1.32	0.0m - 1.3m – 0-10	No suitable cohesive strata.
CPT5014A	10.14	0m - 2m – 5-10 2m - 6.5m – 2-6 6.5m - 10m – 5-12	Between c. 2m - 5m – 0.20-0.24+ Between c. 5m - 10m – 0.08-0.15
CPT5015	4.90	0m - 4.9m – 5-10	No suitable cohesive strata.
CPT5015A	10.12	0m - 10m – 5-10	Between c. 5m - 10m – 0.08-0.23
CPT5016	4.24	Linear increase from surface to base 0-50 *1	No suitable cohesive strata.
CPT5017	7.88	0m- 7.8m – 5-10	Between c. 4.0m - 7.5m – 0.12-0.24
CPT5018	2.10	0m - 2m – 5-10	No suitable cohesive strata.
CPT5018A	9.54	0m -5m – 5-10 5m - 9.5m – 7-15	Between c. 4.2m - 9.5m – 0.07-0.18

Notes:
*1: Strata interpreted to comprise in-situ natural coal measures comprising firm to stiff clays grading to extremely weak mudstone.

As discussed above the materials penetrated by the CPTs were varied and hence, derivation of undrained shear strength for the full depth of the CPT profiles is not

considered appropriate given the frequency and extent of sandy and silty strata. However, where relatively consistent horizons of clay were identified undrained shear strength in the Made Ground-Opencast Backfill materials typically ranged between 25kN/m^2 and 65kN/m^2.

6.17 Sulphates

Selected samples of soils were submitted for assessment of sulphate, sulphur and pH concentrations in order to assess classifications for the design of buried concrete. The table below provides a summary of the results.

Stratum	Characteristic Water-Soluble Sulphate (mg/l)*1	Characteristic Total Potential Sulphate (TPS) SO_4 % *2	Characteristic pH	Design Class based on w/s sulphate	Design Class based on TPS
TS	100	0.3	5.9	DS-1	DS-2
MG	200	0.1	5.5	DS-1	DS-1
OCBF	300	0.4	5.6	DS-1	DS-2
PMCMF	100	0.4	5.9	DS-1	DS-2
GW	800	n/a	6.1	DS-2	n/a

TS – Topsoil or Topsoil/Made Ground
MG - Made Ground
OCBF – Opencast Backfill
PMCMF – Pennine Middle Coal Measures Formation
GW – Groundwater
*1: Rounded to nearest 100mg/l (where a significant value i.e. >50mg/l)
*2: Rounded to nearest 0.1%.

Of the samples tested for acid soluble sulphate and total sulphur, 3 out of 30 samples of opencast backfill were potentially pyritic and 3 out of 33 Coal Measures samples were potentially pyritic. None of the limited number of topsoil or made ground samples tested were potentially pyritic. It could therefore be concluded that there is not a sufficient number of potentially pyritic samples to base the Design Sulphate Class on Total Potential Sulphate characteristic values. However, a design class of DS-2 is still recommended due to the soluble sulphate content of the groundwater.

Under BRE SD1, it could be argued that the site can be deemed greenfield as it essentially comprised natural soils or fill derived from natural soils and is unlikely to contain chemical residues produced by or associated with industrial production. Should this be the case, an ACEC Class of AC-2 would generally be appropriate, however, a pH value of 5.5 (which was measured in the Made Ground and very close this was recorded in the Opencast backfill) would indicate AC-3z conditions, assuming mobile groundwater. If a brownfield site is conservatively assumed, the ACEC Class would also be AC-3z conditions, based on mobile groundwater. Where static groundwater conditions can be assumed, the ACEC Class would be AC-1s.

The sulphate results have also been assessed for consideration of suitability of moisture modification by the addition of lime. In respect of Total Potential Sulphate (TPS) a total of 69no. determinations were made with results ranging between 0.02% and 0.9% with 9no. values (13% of results) at greater than 0.25%. The total (acid soluble) sulphate concentrations for all materials (except topsoil) tested ranged from 0.01 to 0.48%, with an average of 0.04% and only one sample being > 0.25%. Water soluble sulphate in soils and sulphates in groundwater all fall well below the limits set

by SHW600 (3000mg/l and 1400mg/l respectively). Two of the total 69no. tests recorded oxidizable sulphides of >0.6% whilst the remaining tests were in the range 0-0.535%. These results generally indicate that the sulphate concentrations of the materials beneath the site would not restrict the use of lime modification and/or stabilisation, if required.

6.18 Coal Quality Tests

Seven coal samples from the Pennine Middle Coal Measure Formation in areas of proposed cut were sent to Socotec UK Ltd. to determine the quality of the coal, should onward sale of excavated coal be considered instead of disposal. Of the seven tests, five were undertaken on samples from the Dunsil Seam from Plot 1 and two on samples from the Swallow Wood Seam from Plot 3.

Sample Location	Depth (m bgl)	Coal Seam
RC4004	0.80 and 1.75	Dunsil Seam
RC4007	4.45	Dunsil Seam
TP1026	1.00 and 1.90	Dunsil Seam
TP1061	4.30	Dunsil Seam
TP1062	2.20	Dunsil Seam
TT2006	1.50	Swallow Wood Seam
TT2008	2.50	Swallow Wood Seam

7.0 GEOTECHNICAL RISK REGISTER

The proposed development has been categorised as both Geotechnical Category 2 and Category 3 as defined by British Standard EN 1997-1:2007 Eurocode 7 – Geotechnical Design. This is because it generally involves conventional types of geotechnical structures, earthworks and activities but will involve unusual or difficult ground conditions or loading conditions associated with the placement of engineered fill and/or construction of buildings above significant thicknesses of uncontrolled fill associated with the previous backfilling of opencast mine workings.

A Geotechnical Risk Register has been derived for the proposed development and is presented in Appendix I. The aim of the risk register is to identify the geotechnical hazards and risks associated with the proposed development at the time of reporting. Later, as the project progresses with more detailed information in terms of design and mitigation measures, this should be revised and updated.

8.0 CONTAMINATION ASSESSMENT

One purpose of the ground investigation was to investigate the potential sources identified in the preliminary conceptual site model (principally the opencast backfill materials) and also to prove potential pathways and determine any impact on groundwater quality. The results of the chemical analysis of the soil and groundwater results and the implications on the source-pathway-receptor linkage and assessed risk are discussed below.

8.1 Human Health Risk Assessment

The results of the chemical testing on soils have been assessed as follows:

- Proposed end-use – commercial warehouses with lorry/car parking and minimal perimeter landscaping;
- Screening criteria – commercial/industrial, assuming 6.0% SOM for Topsoil and Topsoil/Made Ground and 2.5% SOM for other soils;
- Based on the soils encountered on the site and proposed redevelopment plans, the testing has been split into two data sets:
    - samples from Topsoil and Topsoil/Made Ground;
    - samples from all other soils beneath site (Made Ground, Made Ground Opencast Backfill and Pennine Middle Coal Measures).

As the development will create a significant surplus of topsoil it is possible that this will eventually be sent for use on other sites. Therefore, the results of the tests undertaken on Topsoil and Topsoil/Made Ground were also compared to residential with plant update screening criteria. Additionally, twelve samples were also sent to Tim O'Hare for specialist analysis and this also included a suite of chemical tests, the results of which have also been assessed below.

Spreadsheets summarising the laboratory results for each data set and relevant screening values are presented in Appendix F. From these summary spreadsheets, it can be seen that the majority of the determinants have been found not to exceed their relevant screening values.

One shallow sample taken from a possible contamination source (localised area of historic burning, TP1023) recorded an elevated concentration of Arsenic (160 mg/kg) exceeding the screening criteria for residential end use with plant uptake (37 mg/kg), this concentration however did not exceed the screening value for commercial and industrial end use (640 mg/kg). In addition, there were two marginal exceedances of the residential with plant update screening value (1.7 mg/kg) for Beryllium (TP1024 and TP1063, 1.8 mg/kg and 1.9 mg/kg).

Due to the current agricultural land use, a selection of Topsoil//Topsoil Made Ground samples were analysed for a suite of pesticides (SVOC suite with TICs). All of these recorded concentrations below the level of detection.

PAHs were widely tested for across all soil types and all recorded concentrations below relevant screening criteria, many below levels of detection.

TPH concentrations were recorded in one sample, from TT2001, of material with a high coal content and in close proximity to a road (where visible surface run-off was evident) with a concentration of TPH 140mg/kg, but none of the concentrations of each carbon band exceeded relevant screening values.

Asbestos screening tests did not typically detect the presence of any fibres in any of the Made Ground soils tested.

Based on the currently proposed commercial/industrial end use it is considered that the site presents a negligible risk to identified human health receptors.

8.2 Controlled Waters Risk Assessment

All concentrations in groundwater samples tested were below the conservative screening criteria adopted with the exception of nickel. The concentration so of nickel

ranged from 5.3 to 73 ug/l with an average of 27.4ug/l, compared to the WFD Environmental Standard of 20ug/l. There was no discernible difference between the results of samples of the opencast backfill and those from the natural strata and, therefore, it is concluded that the nickel in the groundwater is not as a result of contamination but is reflective of background concentrations in the groundwater within the natural Coal Measures strata.

It is therefore considered that the site presents a negligible risk to identified controlled water receptors.

8.3 Conclusions and Recommendations

The above risk assessments have established a negligible risk to human health and Controlled Water receptors. It is therefore considered that further assessment or remedial actions are not warranted for this development.

The results of the chemical testing confirm that the Topsoil and Topsoil/Made Ground is suitable, chemically, for re-use on site and potentially for re-use off-site on the development sites, including for housing. However, topsoil suitability depends on other factors including the nature of the proposed planting and the requirements of a Landscape Architect. Attention is drawn to the specialist Topsoil report included in Appendix H.

When stripping off Topsoil and Topsoil/Made Ground, care must be taken to separate and dispose of the localised (c. 5m x 5m x 0.50m) area of burnt waste/bonfire materials identified in proximity to TP1023. These extents can be visually identified at surface. This material should be disposed off-site and is anticipated to be classified as non-hazardous waste.

As part of the redevelopment, a large proportion of the natural and Made Ground Opencast Backfill materials will be excavated, especially from the north and centre of the site, to be re-used as engineered fill, and placed predominantly in the south of the site. The chemical testing undertaken on these soils has indicated that they are chemically suitable for re-use as engineered fill.

Issues regarding the potential impact on buried concrete, water supply pipes and possible lime modification of wet soils, is discussed in the Geotechnical design Report (GDR).

The development is being designed to achieve a cut-fill balance; hence the aim is to re-use all excavated materials on site as engineered fill to create the required development platforms. Should any excavated opencast backfill or natural soils require disposal off site, they should be appropriately tested and classified. On the basis of the test results undertaken as part of the current investigation, it is anticipated that the soils would be classified as inert. However, if the soils could not be recycled, the organic/coal content may preclude disposal at landfill as inert waste.

It is understood that measures will be included in the Earthworks Specification on how to deal with any suspected contamination, should it be uncovered as part of the redevelopment works.

Anecdotal evidence supplied by one of the land users (tenant shepherd) provided information of possible buried animal remains (sheep), in the grass field in the far southeast of the site, in several localised areas. This was not investigated during the fieldwork, however, specialist advice (Department of Environment, Farming and Rural Affairs) should be consulted if encountered during groundworks and appropriate precautions taken to minimise ground worker's exposure to any animal remains.

9.0 UPDATED COAL MINING RISK ASSESSMENT

The findings of the ground investigation, the coal seams and sequence of strata encountered in particular, have been used to update the previously issued Phase 1 Coal Mining Risk Assessment report. A specialist consultant, Phil Shelton of PS Geotech has reviewed the Applied Geology interpreted geological sections, assigned coal seam names, interpreted sequence of strata and assessed risks of coal mining related issues in relation to the proposed development and his report is included in Appendix H.

In summary, it is concluded that there is a low to negligible risk of coal mining related issues affecting the development with the exception of the subsidence risk from the opencast backfill materials. However, sufficient information on ground conditions and materials properties has been gathered by the ground investigation to enable these risks to be mitigated by appropriate design.

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GENERAL NOTES

A) The assessment made in this report is based on the site terrain and ground conditions revealed by the various field investigations undertaken and also any other relevant data for the site including previous site investigation reports (if available) and desk study data. There may be special conditions appertaining to the site, however, which have not been revealed by the investigation and which have not, therefore, been taken into account in the report. The assessment may be subject to amendment in the light of additional information becoming available. It must be recognised that many of the Environmental Searches obtained during the course of the desk study are often lengthy. Applied Geology have, where appropriate and in the interests of simplicity, only reproduced the summary of the searches within the report. A full copy of all the search data is held at the Applied Geology office and is available for inspection if required.

B) The services provided are defined within our proposal and are carried out in line with the terms of appointment between Applied Geology and the Client.

C) Where any data supplied by the Client or other external source, including that from previous site investigations, has been used it has been assumed that the information is correct. No responsibility can be accepted by Applied Geology for inaccuracies within this data.

D) Whilst the report may express an opinion on possible configurations of strata between or beyond the exploratory locations, or on the possible presence of features based on either visual, verbal or published evidence this is for guidance only and no liability can be accepted for the accuracy.

E) Comments on groundwater (and landfill gas) conditions are based on observations made during the course of the present and past investigations or with reference to published data unless otherwise stated. It should be noted, however, that groundwater (and landfill gas) levels vary due to seasonal (or atmospheric conditions) or other effects.

F) The copyright of this report and other plans (and documents prepared by Applied Geology) is owned by Applied Geology and no such report, plan or document may be reproduced, published or adapted without the written consent of Applied Geology. Complete copies of the report may, however, be made and distributed by the Client as an expedient in dealing with matters related to its submission.

G) This report is prepared and written in the context of the proposals stated in the introduction to the report and should not be used in a differing context. Furthermore, new information, improved practices and legislation may necessitate an alteration to the report in whole or in part after its submission. Therefore with any change in circumstances or after the expiry of one year from the date of the report, the report should be referred to Applied Geology for re-assessment and if necessary, re-appraisal.

H) The survey was conducted and this report was prepared for the sole internal use and reliance of the Client. This report shall not be relied upon or transferred to any other parties without the express written authorisation of Applied Geology. If an unauthorised third party comes into possession of this report they rely on it at their peril and Applied Geology owes them no duty of care and skill.

I) Ground conditions should be monitored during the construction of the works and the recommendations of the report re-evaluated in the light of this data by the supervising geotechnical or geo-environmental engineers.

J) Unless specifically stated, the investigation has not taken into account the possible effects of mineral extraction.

K) The works performed are not a comprehensive site characterisation and should not be construed as being such.

L) The findings of the geo-environmental risk assessment are based on information obtained from a variety of sources which Applied Geology believe to be correct. Applied Geology cannot and does not guarantee the authenticity or reliability of the information it has relied upon.

M) The report represents the findings and opinions of experienced geo-environmental consultants. Applied Geology does not provide legal advice and the advice of lawyers may be required.

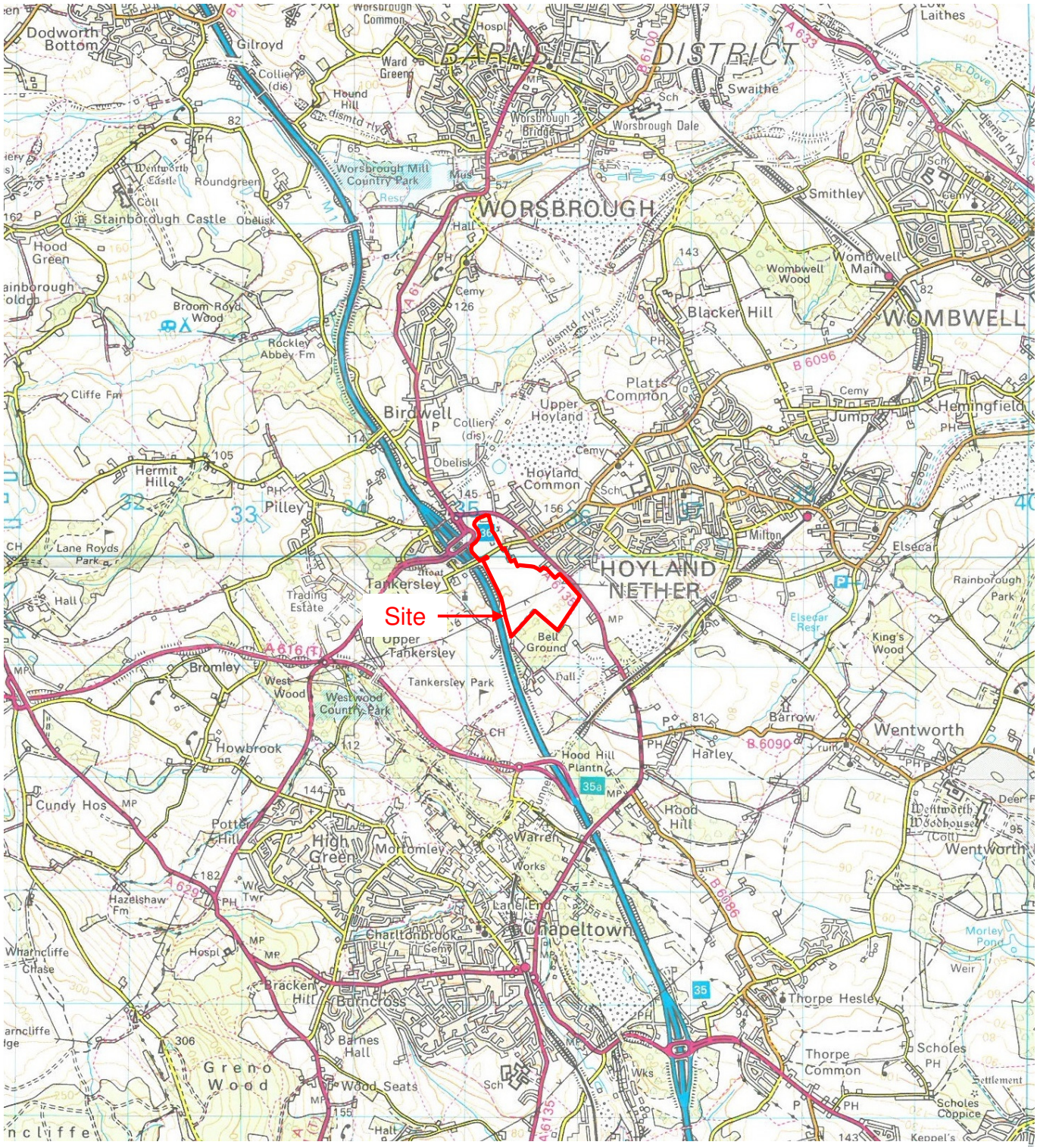
N) Conditions at the site are subject to change from the time of the site inspection.

O) It is possible that researches carried out by Applied Geology, whilst fully appropriate for a phase 1 desk study, failed to indicate the existence of important information sources. Assuming such indicators actually exist, their information could not have been considered in the formulation of Applied Geology findings and opinions.

P) The economic viability of the proposals referred to in the report, or of the solutions put forward to any problems encountered, depends on very many factors in addition to geotechnical considerations and hence its evaluation is outside the scope of this report.

Q) Applied Geology operates as a Consultancy and does not operate it's own laboratory for soil testing, this work being sub contracted to known and respected, generally UKAS accredited, laboratories. Applied Geology can therefore not be held responsible for the testing carried out.

APPENDIX A



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Project: HOYLAND COMMON, BARNSLEY
M1 JUNCTION 36

Drawn By:	Checked By:	Paper Size:
JS	SD	A4

Scale:	Date:	NGR:
NTS	08.01.2020	435491 399728

Drawing No:	Revision:
AG3080-19-01	0

Title: SITE LOCATION PLAN

KEY:

- TP1001 — Trial Pit
- TT2001 — Trial Trench
- RC4001 — Dynamic / Sample and Rotary Cored Borehole
- CPT5001 — Cone Penetration Test
- DCS6001 — Driven Continuous Sampling Borehole

Drawing based on stafsurv, drawing No:10663-T dated 06/11/2019 and Greenhatch, drawing 30326_T Revision 0 dated 23/05/18.

Rev	Notes	Date	By
1	RS3026, RS3027, RS3028, RS3029 & RS3030 added and symbol for RS3001 to RS3025 amended.	26.10.2020	FC

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Project:

HOYLAND COMMON, BARNSLEY
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Title:

EXPLORATORY HOLE LOCATION PLAN ON EXISTING TOPOGRAPHIC SURVEY

Drawn By:	Checked By:	Paper Size:
FD	SD	A1

Scale:	Date:
1:2000	04.05.2020

Drawing No:	Revision:
AG3080-19-06	1

KEY:

- Extent of Open Cast Site as shown on Coal Authority Abandonment Plans
- Interpreted Extent of Open Cast Site Based on Trial Trench Findings and Coal Authority Abandonment Plans
- TP1001 — Trial Pit
- TT2001 — Trial Trench
- RS3001 — Rotary (sonic) Borehole
- RC4001 — Dynamic / Sample and Rotary Cored Borehole
- CPT5001 — Cone Penetration Test
- DCS6001 — Driven Continuous Sampling Borehole
- A — A — Section Line (Geological Cross Section and GEO5 Analysis) - refer to drawing AG3080-19-08
- C — C — Section Line (Geological Cross Section only) - refer to drawing AG3080-19-08
- R — R — Section Line (GEO5 Analysis only)

Drawing based on statsurv, drawing No:10663-T dated 06/11/2019 and pHp Architects, drawing 029 Revision P4 dated 19th December 2019.

Rev	Notes	Date	By
3	RS3026, RS3027, RS3028, RS3029 & RS3030 added and symbol for RS3001 to RS3025 amended.	09.11.2020	FC
2	Section lines 'R', 'S' and 'T' added	30.07.2020	AP
1	Section line 'L' extended	07.07.2020	FD

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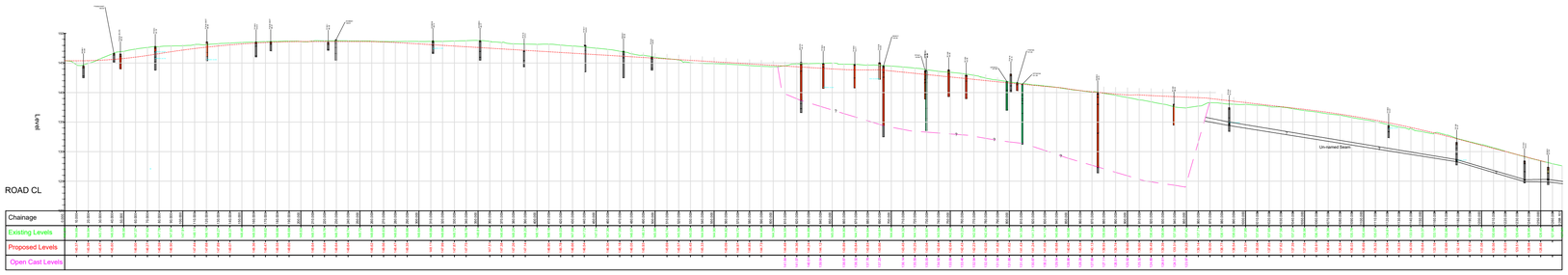
Project:
HOYLAND COMMON, BARNSLEY
M1 JUNCTION 36

Title:
EXPLORATORY HOLE LOCATION PLAN
WITH OPENCAST MINE EXTENTS &
GEOLOGICAL SECTION LINES

Drawn By:	Checked By:	Paper Size:
FD	SD	A1

Scale:	Date:
1:2500	19.05.2020

Drawing No:	Revision:
AG3080-19-07	3



Key:

- Topsoil
- Topsoil/ Made Ground
- Made Ground
- Made Ground- Opencast Backfill
- Coal Seams
- Pennine Middle Coal Measures Formation
- CPT Locations
- HIGHEST MONITORED WATER LEVEL
- WATER STRIKE
- EXISTING GROUND PROFILE
- PROPOSED DESIGN 4400-001-P12-3d
- BASE OF INFERRED OPEN CAST PROFILE
- PLAN OUTLINE OF INFERRED OPEN CAST

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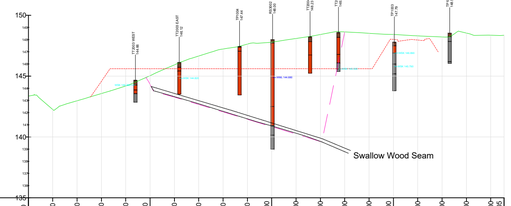
Title:
GEOLOGICAL CROSS SECTIONS-
SHEET 1 OF 4

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SB	FC	A1

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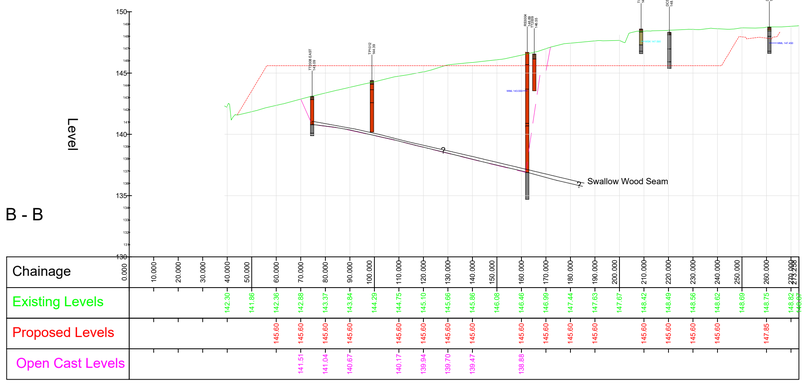
Drawing No:	Revision:
AG3080-19-08 Sheet 1 of 4	A

A - A



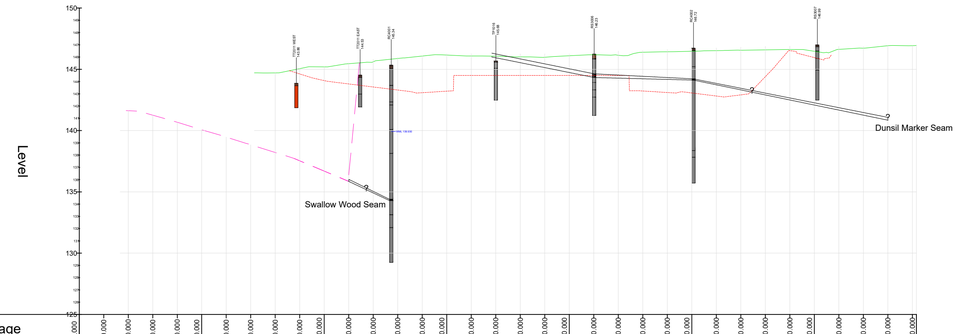
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Existing Levels	143.69	142.25	142.07	143.05	144.15	145.01	145.05	146.05	147.23	147.64	147.79	148.03	148.42	148.63	148.51	148.42	148.32	148.22	148.04	148.36	148.69
Proposed Levels				144.99	145.00		145.00	145.00	145.00	145.00		145.00	145.00	145.00	145.00		147.96				
Open Cast Levels							145.91	145.85	144.69	144.39		143.21	142.69								

B - B



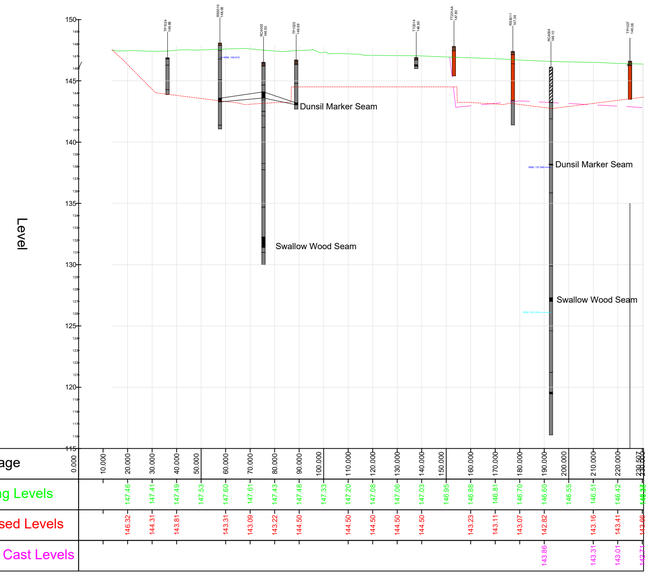
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Existing Levels					142.29	141.86	142.39	142.89	143.37	143.94	144.29	144.71	145.10	145.58	145.86	146.08	146.46	146.99	147.44	147.63	147.82	148.43	148.49	148.54	148.62	148.68	148.75	148.82
Proposed Levels							145.60	145.60	145.60	145.60		145.60	145.60	145.60	145.60		145.60	145.60	145.60	145.60		145.60	145.60	145.60	145.60		147.85	
Open Cast Levels							141.51	141.04	140.87			140.17	139.84	139.70	139.47		138.88											

C - C



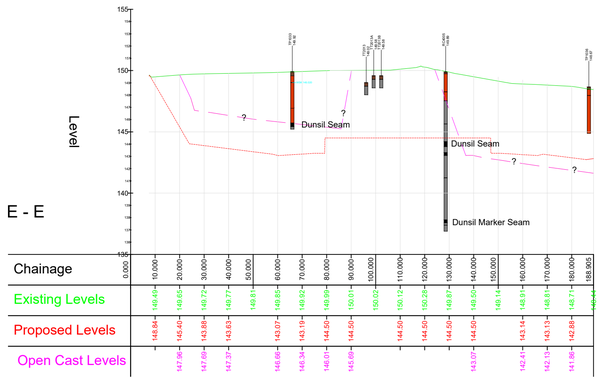
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Existing Levels										144.77	145.06	145.20	145.40	145.62	145.59	145.38	146.08	146.16		146.09	146.07	146.01	145.98	146.10	146.20	146.14	146.39	146.43	146.47	146.53	146.56	146.59	146.63	146.72	146.80	146.92
Proposed Levels											144.62			143.85	143.58	143.33	143.08			144.50	144.50	144.50		144.50		144.50	144.50	143.23	143.11			142.82	142.91	144.40	146.52	
Open Cast Levels		141.60	141.26	140.68			139.47	138.84	139.21																										

D - D



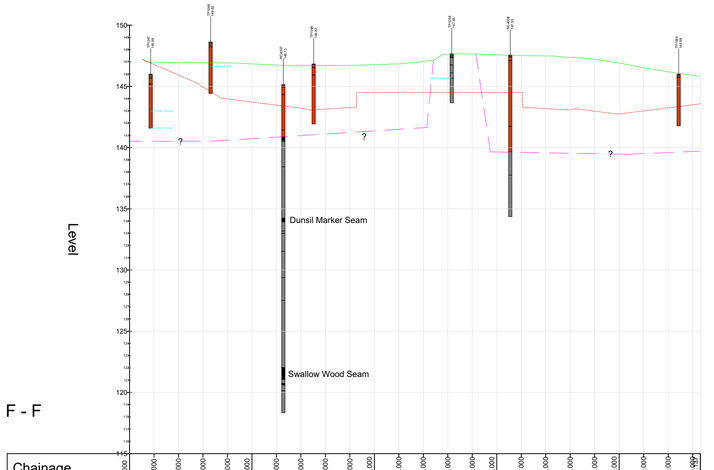
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Existing Levels		147.46	147.41	147.49	147.53		147.60	147.61	147.45	147.49	147.33	147.20	147.08	147.09	147.03	146.95	146.88	146.91	146.70	146.66	146.55	146.51	146.42	146.32	146.33
Proposed Levels		146.32	144.31	143.81			143.31	143.09	143.22	144.50		144.50	144.50	144.50	144.50		143.23	143.11	143.07	142.82		143.18	143.41	143.66	
Open Cast Levels																				143.86		143.31	143.01	142.77	

E - E



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000	188.905
Existing Levels		149.49	149.65	149.72	149.77	149.81	149.85	149.92	149.92	149.99	150.01	150.02	150.17	150.29	149.97	149.90	149.14	148.91	148.81	148.77	148.90
Proposed Levels		148.94	145.40	143.88	143.63		143.07	143.19	144.50	144.50		144.50	144.50	144.50	144.50		143.07		143.14	143.13	142.88	
Open Cast Levels			147.99	147.89	147.31		146.69	146.34	146.01	145.69								142.41	143.14	141.99			

F - F



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	238.000
Existing Levels		146.98	146.84	146.93	146.91	146.84	146.74	146.89	146.70	146.72	146.78	146.84	147.03	147.60	147.64	147.57	147.50	147.45	147.30	147.21	146.90	146.53	146.19	145.89	145.90
Proposed Levels		146.79	145.92	144.95	143.97		143.46	143.21	143.14	143.25		144.50	144.50	144.50	144.50		144.50	143.18	143.09	142.97		142.99	143.24	143.46	
Open Cast Levels		143.00	142.71	142.42	142.29		142.03	141.95	141.77	141.84		141.48	141.62				141.09	140.89	140.86	140.48		139.97	139.84	139.71	

Key:

- Topsoil
- Topsoil/ Made Ground
- Made Ground
- Made Ground- Opcast Backfill
- Coal Seams
- Pennine Middle Coal Measures Formation
- CPT Locations

- HIGHEST MONITORED WATER LEVEL
- WATER STRIKE
- EXISTING GROUND PROFILE
- PROPOSED DESIGN 4400-001-P12-3d
- BASE OF INFERRED OPEN CAST PROFILE

APPLiED GEOLOGY

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Client: newlands developments

Project: HOYLAND COMMON, BARNSLEY
M1 JUNCTION 36

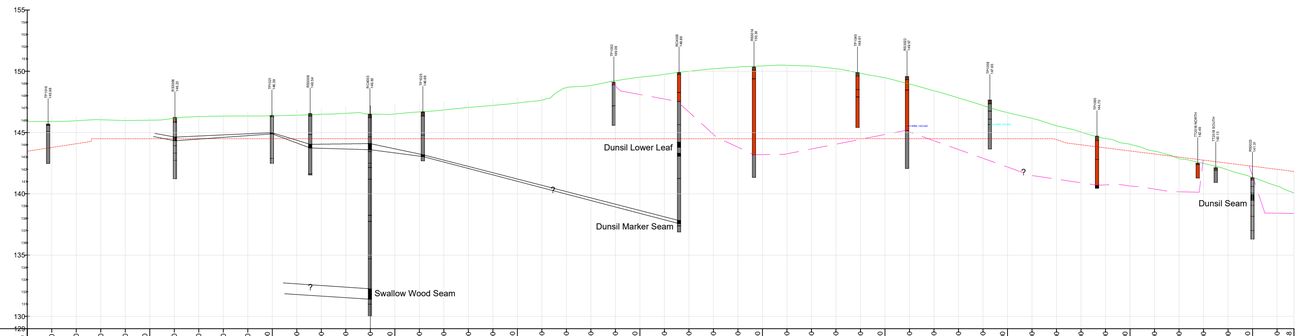
Title: GEOLOGICAL CROSS SECTIONS-
SHEET 2 OF 4

Drawn By:	Checked By:	Paper Size:
SB	FC	A1

Scale:	Date:
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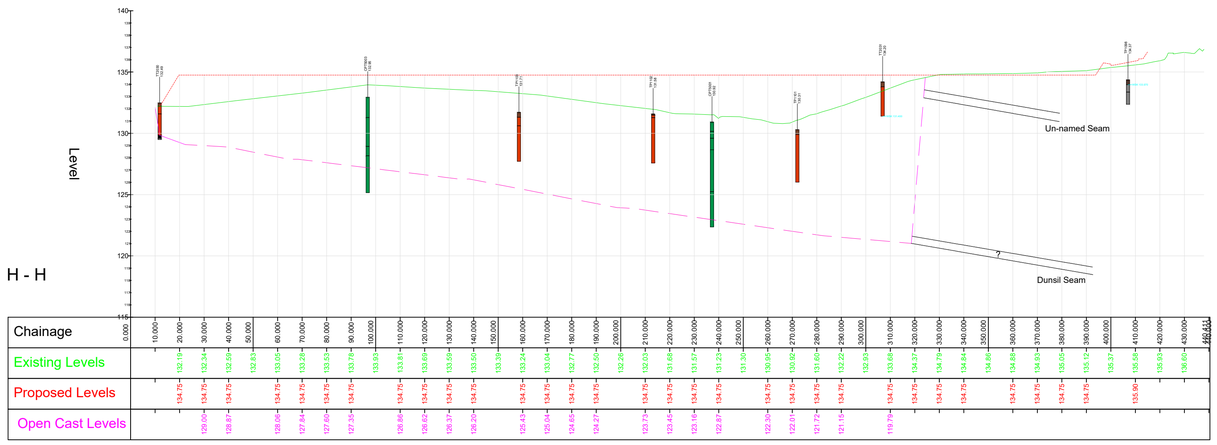
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AG3080-19-08 Sheet 2 of 4	A

G - G



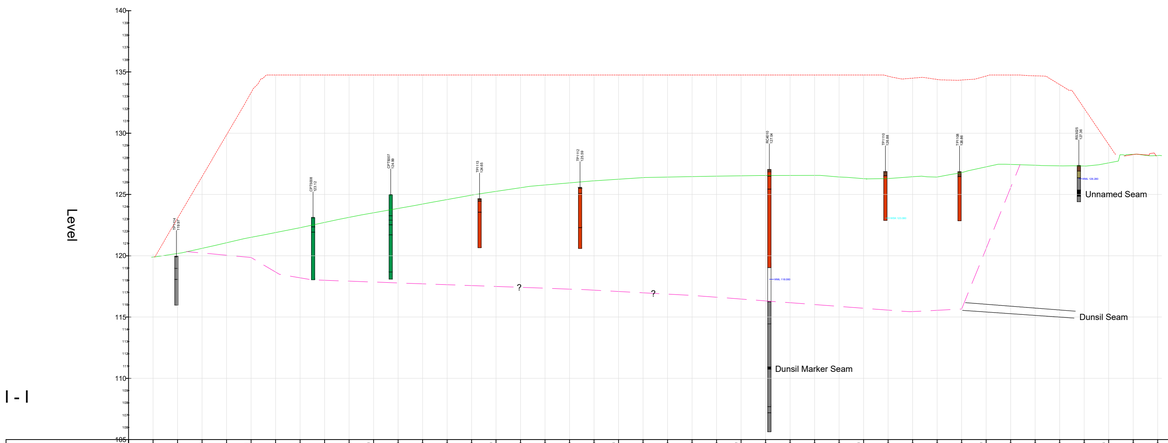
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Existing Levels	145.60	145.91	145.97	146.04	145.98	146.01	146.15	146.31	146.34	146.35	146.36	146.42	146.49	146.57	146.51	146.52	146.69	146.85	147.05	147.22	147.41	147.65	148.68	148.85	149.22	149.52	149.75	150.09	150.20	150.35	150.44	150.69	150.90	151.42	151.24	151.84	152.19	151.93	151.65	151.96	152.47	151.95	141.34	140.64	140.23
Proposed Levels		143.78	144.09	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	145.87	145.34	144.69	144.04	143.49	143.24	142.98	142.75	142.97	142.19	141.93	141.69	142.71	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	144.50	143.25	143.00	142.75	142.50	143.00
Open Cast Levels																												145.87	145.34	144.69	144.04	143.49	143.24	142.98	142.75																						138.42	138.42	

H - H



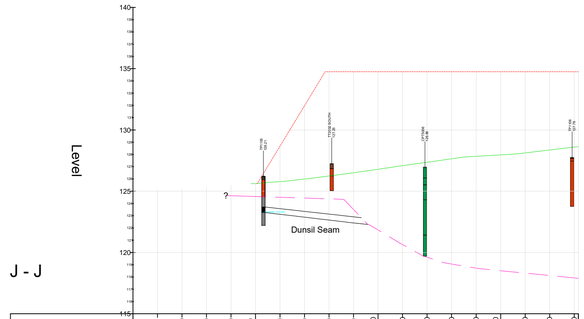
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Existing Levels		132.19	132.34	132.59	132.83	133.04	133.20	133.53	133.77	133.93	133.97	133.81	133.83	133.95	133.93	133.95	133.35	133.24	133.04	132.77	132.56	132.28	132.03	131.84	131.57	131.23	131.30	130.95	130.92	131.69	132.22	132.93	133.65	134.37	134.73	134.84	134.86	134.85	134.93	135.05	135.12	135.37	135.58	135.97	136.05	136.11	136.16	136.21	136.26	136.31	136.36	136.41	136.46	136.51	136.56	136.61
Proposed Levels		134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	135.90	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75
Open Cast Levels			125.05	128.87			128.06	127.84	127.69	127.35		126.86	126.62	126.37	126.20			125.43	125.04	124.65	124.27		123.73	123.45	123.18	122.87		122.30	122.01	121.72	121.15		119.79																													

I - I



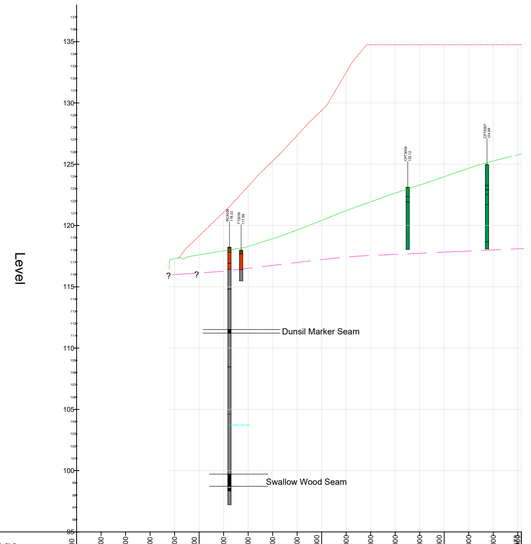
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Existing Levels		119.89	120.18	120.00	121.06	121.50	121.89	122.29	122.72	123.13	123.50	123.86	124.22	124.58	124.95	125.29	125.56	125.78	125.95	126.12	125.25	126.38	126.42	126.46	126.50	126.52	126.55	126.56	126.55	126.56	126.42	126.29	126.31	126.45	126.42	126.78	127.26	127.45	127.39	127.33	127.32	127.58	128.27	128.18	128.27	128.36	128.45	128.54	128.63	128.72	128.81	128.90	128.99	129.08	129.17	129.26
Proposed Levels		123.05	126.46	129.86	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	128.25	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75	134.75
Open Cast Levels										119.16	119.14	118.69	118.85	118.69	118.62			118.34	118.22	118.11	117.96		117.09	117.42	117.23	117.06		116.76	116.69	116.46	116.31		116.69	115.86	115.66	115.69																												

J - J



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000
Existing Levels						125.62	125.77	125.99	126.24	126.50	126.78	127.09	127.34	127.64	127.84	127.97	128.16	128.36	128.63
Proposed Levels							128.69	131.98	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75
Open Cast Levels												122.16	121.98	121.89	121.72		121.16	120.89	120.99

K - K



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	181.868
Existing Levels					117.29	117.60	117.89	118.26	118.62	119.64	120.41	121.21	121.93	122.65	123.30	123.98	124.67	125.30	125.77
Proposed Levels							121.07	123.20	125.26	127.35		132.48	134.75	134.75	134.75		134.75	134.75	134.75
Open Cast Levels															119.42		119.53	119.60	119.70

Key:

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- WATER STRIKE
- EXISTING GROUND PROFILE
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Project:
HOYLAND COMMON, BARNSLEY
M1 JUNCTION 36

Title:
GEOLOGICAL CROSS SECTIONS-
SHEET 3 OF 4

Drawn By:	Checked By:	Paper Size:
SB	FC	A1

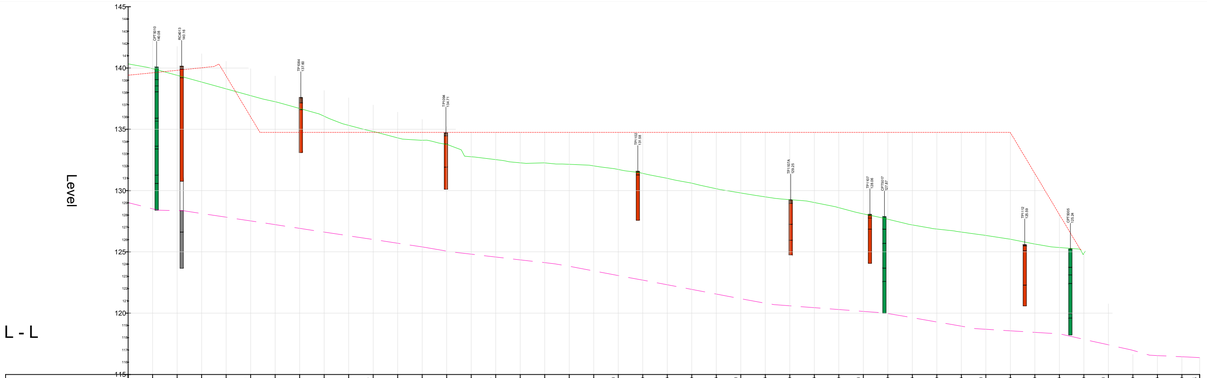
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Date: 29.05.2020

Drawing No: AG3080-19-08 Sheet 3 of 4

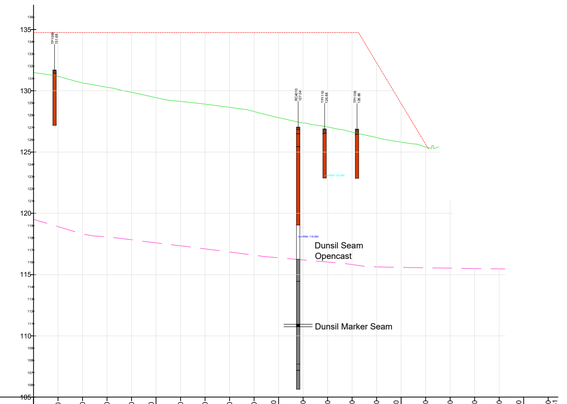
Revision: A

L - L



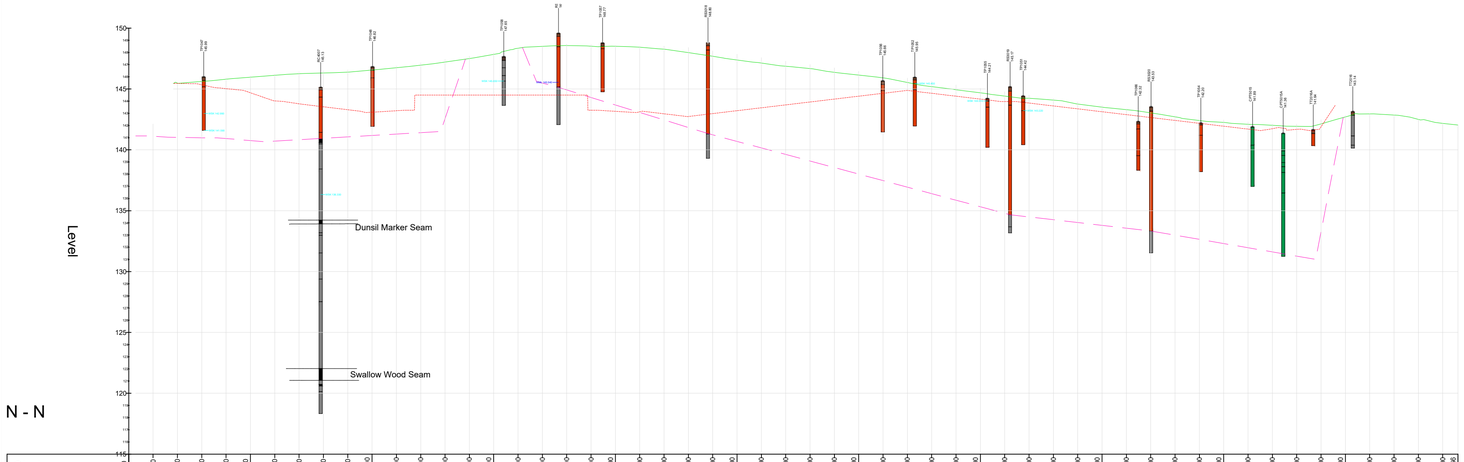
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Existing Levels	144.00	139.95	139.40	138.85	138.30	137.75	137.25	136.70	136.07	135.32	134.82	134.30	134.11	133.77	132.75	132.52	132.27	132.26	132.15	132.01	131.72	131.41	131.00	130.61	130.15	129.81	129.49	129.35	129.03	128.61	128.10	127.66	127.20	126.89	126.62	126.34	126.04	125.64	125.36	124.88					
Proposed Levels		139.61	139.82	140.02	139.36		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.74	131.40	128.05						
Open Cast Levels		130.65	130.04	129.44	128.86		127.66	127.07	126.47	125.85		124.37	127.86	127.26	126.65		125.06	124.45	123.84	123.25		122.13	121.57	121.01	120.44		119.34	119.04	118.74	118.66		118.31	118.17	118.02	117.85		117.36	117.20	117.05	116.90		116.60	116.54	116.44		

M - M



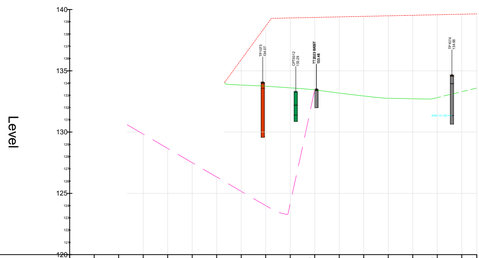
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Existing Levels	139.48	131.10	130.64	130.29	129.87	129.43	129.11	128.91	128.65	128.30	127.80	127.39	127.04	126.82	126.10	125.81	125.40						
Proposed Levels		134.75	134.75	134.75	134.75		134.75	134.75	134.75	134.75		134.75	134.75	134.75	132.29		125.63						
Open Cast Levels		118.91	118.31	118.07	117.84		117.34	117.10	116.86	116.56		116.29	116.05	115.82	115.60		115.56	115.52	115.40	115.47			

N - N



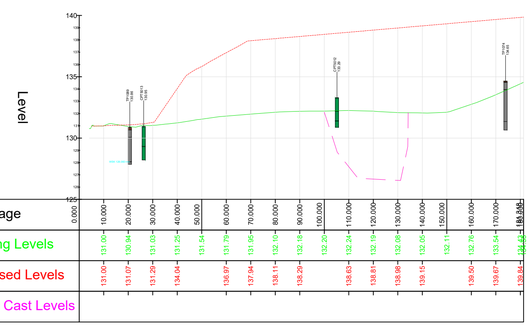
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Existing Levels			145.49	145.60	145.34	145.00	145.06		146.12	146.25	146.03	146.38	146.69		146.75	146.96	147.22	147.50	147.65	147.85		148.35	148.50	148.57	148.01	148.03		148.44	148.27	147.99	147.69	147.39		147.13	146.67	146.69	146.37	146.14		145.91	145.54	145.20	145.00	144.94	144.69		144.44	144.22	144.05	143.91	143.76		143.53	142.89	143.04	142.89	142.72	142.42		142.14	142.25		142.10	142.02	141.93	142.13	142.71	142.95	142.88	142.05	142.18	142.18
Proposed Levels																																																														
Open Cast Levels		142.10	142.09	142.05	141.97		141.71	141.71	141.71	141.72		141.72	141.71	141.71	141.71		144.00	144.00	144.00	143.29		141.29	140.69	143.13	142.96	142.74	142.88		140.39	143.46	143.89	143.93	144.17		146.14	144.65	144.88	144.65	144.41		138.91	138.46	138.09	137.63	144.44	144.69		138.78	143.97	143.84	143.91	143.97		135.50	134.66	134.23	133.89	142.42	142.18		133.39	142.25		132.53	141.70	141.74	141.65	141.89	141.47																																															

O - O



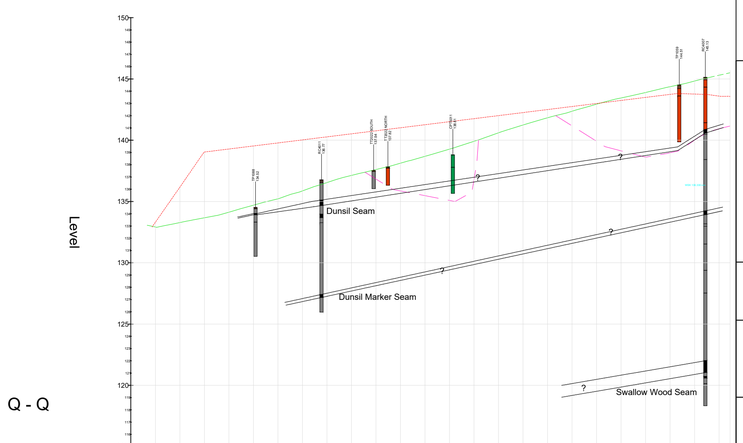
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Existing Levels								132.64	133.74	133.61	133.44	133.18	132.94	132.79	132.72	132.61	133.30	139.62
Proposed Levels								135.62	138.65	139.31		139.40	139.44	139.49	139.53		139.62	
Open Cast Levels			129.85	128.89		126.33	125.16	124.09	123.66		131.37							

P - P



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	184.346
Existing Levels		131.00	130.94	131.00	131.23	131.56	131.79	131.95	132.10	132.10	132.29	132.24	132.19	132.09	132.05	132.11	132.70	133.54	134.42
Proposed Levels		131.00	131.07	131.29	134.04		136.97	137.94	138.11	138.29		138.63	138.81	138.86	139.15		139.50	139.67	139.84
Open Cast Levels																			

Q - Q



Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	240.000	244.208
Existing Levels		133.30	132.95	134.17	133.03	134.13	134.69	135.22	135.86	136.54	137.10	137.60	138.12	138.68	139.27	139.91	141.00	141.25	141.85	142.39	142.85	143.42	143.88	144.13	143.76	143.59
Proposed Levels		133.30	134.17	139.03	139.28		139.78	140.02	140.27	140.52		141.02	141.26	141.51	141.76		142.25	142.50	142.75	143.00		143.49	143.74	143.76	143.59	
Open Cast Levels												137.24	137.28	137.32												

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M1 JUNCTION 36

Title: GEOLOGICAL CROSS SECTIONS-
SHEET 4 OF 4

Drawn By:	Checked By:	Paper Size:
SB	FC	A1

Scale: Horizontal 1:1250 Vertical 1:250

Date: 29.05.2020

Drawing No: AG3080-19-08 Sheet 4 of 4

Revision: A