Discovery CE

Geotechnical & Environmental Engineers

GROUND INVESTIGATION REPORT (GIR) VOLUME 2 INTERPRETATIVE REPORT AND PRELIMINARY GEOTECHNICAL DESIGN REPORT PHASE 1 PEEL LOGISTICS, SHEFFIELD

Carried Out For: **PEEL LOGISTICS PROPERTY**

September 2018 **Report Reference: 18012J-03**

GROUND INVESTIGATION REPORT (GIR) VOLUME 2 INTERPRETATIVE REPORT AND PRELIMINARY GEOTECHNICAL DESIGN REPORT PHASE 1 PEEL LOGISTICS, SHEFFIELD

Carried Out For: **PEEL LOGISTICS PROPERTY**

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GROUND INVESTIGATION REPORT (GIR) VOLUME 2
INTERPRETATIVE REPORT AND PRELIMINARY GEOTECHNICAL DESIGN REPORT PHASE 1 PEEL LOGISTICS, SHEFFIELD

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GROUND INVESTIGATION REPORT (GIR) VOLUME 2
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1 INTRODUCTION

1.1 Engagement of Discovery CE Limited

Discovery CE Limited (DCE) was instructed by BE Design Ltd (BED) on behalf of Peel Logistics Property (Peel) to carry out a ground investigation at a site known as Peel Logistics, Sheffield.

The offer to carry out the works is contained in DCE proposal reference 18012J-QLO01 dated 19th January 2018 and email dated 15th February 2018, and the instruction to proceed with the work was contained in an e-mail from BED to DCE dated 05th June 2018.

1.2 Objectives and Limitations

This report follows on from a Phase 1 Geotechnical desk study (DCE report ref. 18012J, Geotechnical Desk Study, Peel Logistics, Sheffield, dated August 2018) and Factual Report (DCE Report ref 18012J-02 “Ground Investigation Report (GIR) Volume 1 Factual Report Phase 1 Peel Logistics” dated September 2018) which along with the scope of works specified by BED has been used to facilitate the planning and execution of the ground investigation.

The overall objectives of the work presented in this report were to interpret the data presented in the factual report and assess the underlying ground conditions at the site with respect to geotechnical issues relating to future site development. Specifically, the objectives were to:

1. Provide an interpretation of the geotechnical data recovered and discuss geotechnical design issues and outline design solutions for foundation, floor slab and pavement design, and;

2. Provide conclusions and recommendations for further work if considered necessary.

All chemical laboratory testing undertaken during the current works was scheduled by DCE in agreement with Nova Consulting. It is understood that assessment of the chemical test results will undertaken and reported by Nova as a separate exercise.

The conclusions and recommendations provided in this report are based on the conditions encountered at the exploratory hole locations and intrusive work has been restricted to the level of detail considered necessary to achieve the stated objectives. The possibility of significant variations occurring between exploratory holes cannot be discounted and additional assessment may be necessary should such variation be revealed subsequent to preparation of this report. Design of the development is ongoing and additional investigation, assessment and design may be required for specific construction elements (particularly boundary retaining walls and slopes) as part of normal design development procedures or in response to conditions encountered during construction works.

Where stated loadings and soil parameter values have been presented in this report as Characteristic Values (as defined in BSEN 1997-1 and BS EN 1997-2). The design information presented in this report has been developed in consultation with BED and is suitable for preliminary (tender) design purposes. It does not substitute for a full and complete geotechnical design and should be validated, updated and expanded upon as appropriate by the responsible designer as part of the detailed design work for the project

1.3 Sources of Information

The following sources of information have been used in the preparation of this report.

1. DCE report ref 18012J-01 titled “Geotechnical Desk Study, Peel Logistics, Sheffield” dated August 2018;
2. DCE Report ref 18012J-02 “Ground Investigation Report (GIR) Volume 1 Factual Report Phase 1 Peel Logistics” dated September 2018 “
3. Discovery CE Site Walkover carried out on June 19th 2018;
4. British Geological Survey Sheet No. 100, Sheffield, 1:50 000 scale Bedrock and Superficial edition 2011;
5. BE Design document No. 150096 revision P3, titled “Peel Park, Sheffield, Site Investigation Report Specification” dated 11th January 2018;
6. Michael Sparks Associates drawing No. 30847-PL-201, titled “Peel Logistics Park, Sheffield, Site Layout Plan” dated August 2017;
7. BE Design drawing No. NWK 150096-00(00)-0615, titled “Earthworks Cut & Fill Analysis” dated 27th August 2017; and
8. Ordnance Survey Explorer Sheet No. 278, Sheffield & Barnsley, 1:25 000 scale.
9. BE Design Drawing NWK 150096-00(00)0600 “Design Levels Plan and Retaining Wall Layout”

1.4 Project description and geotechnical category

Full details of the proposed development at the site are not available at the time of writing of this report. A proposed development layout is on Figure 1 (understood to be subject to change) and building outlines on the exploratory hole plan is shown on Drawing 18012J-03-02. The proposals include two new industrial units with associated office areas, mezzanine flooring provision of car parking, access roads and hardstanding. Structural loadings will be derived as design develops however it is understood that Characteristic foundation loadings will not exceed 150 kN/m^2 and that foundation total and differential settlement limits of 25 mm and 15 mm respectively are required. Ground floor slabs will be designed to carry a Characteristic UDL of 50 kN/m^2 with a floor slab differential settlement tolerance of 1:500.

Figure 1 Proposed Development Layout

Made Ground of varying thickness has been encountered during the current and previous ground investigations carried out at the site.

Based on the available information the Geotechnical Categorisation for the development is **<u>CATEGORY 2 – CONVENTIONAL STRUCTURES WITH NO EXCEPTIONAL RISK</u>** in accordance with BS EN 1997-1

2 SITE DESCRIPTION

2.1 On site

The site is located at the northern end of the Peel Logistics/former Outokumpu property off Shepcote Lane, Sheffield, as shown in Figure A1 in Appendix A. The site is a roughly rectangular area occupying approximately 4 ha centred on approximate National Grid coordinates 439877, 390559, and at the time of the investigation works was a predominantly flat area of concrete locally broken and roughly vegetated.

The north eastern corner of the site is approximately 2 m higher than the main site area and is covered with rough undergrowth and mature trees. The northern edge of the site slopes up from west to east to meet the elevated area. The only notable surface features are remnant roadways allowing access and a brick wall extending from west to east across approximately half the width of the site. Plates 1 to 6 give general views of the site at the time of the site walkover.

Plate 1 View from north eastern raised area looking roughly south east

Plate 2 View from north eastern raised area looking roughly south

Plate 3 View from north eastern raised area looking roughly south west

Plate 4 View from raised north eastern area looking roughly west

Plate 5 View from raised north eastern area looking roughly north west

Plate 6 View of north eastern area looking roughly north east

2.2 Site surroundings

The site is bound to the north by a line of trees and fence, beyond which is a row of terraced houses along Greasbro Road. Beyond the terraced houses is Junction 34 of the M1. The River Don is located approximately 200 m north of the site, with Meadowhall shopping centre next to it approximately 600m north west of the site and an industrial area north of the site on the other side of the M1 to Meadowhall.

The eastern side boundary comprises mature trees and a fence in the north east and an approximately 4 m high retaining wall along the majority of the eastern boundary. Greasbro Road turns to run south past the site boundary with a gas substation located just off the north eastern corner of the site and a small warehouse unit off the south eastern corner of the site. Beyond Greasbro Road and the warehouse units the M1 motorway runs roughly north west – south east approximately 50 m from the site. Beyond the M1, residential properties extend for approximately 300 m before giving way to steel works and industrial buildings including the Magna Science Centre, beyond which is the town of Rotherham.

To the south the site has an open boundary with the larger Peel Logistics site (Phase 2). Phase 2 extends south approximately 500 m before giving way to the Outokumpu steel works. This is bordered to the south by the former Sheffield City Airport and commercial/industrial areas of Tinsley.

To the west, the site boundary is formed by the former Outokumpu boundary fence and wall alongside Shepcote Lane which runs north – south past the site. The western side of Shepcote lane is occupied by small warehouse units, with a canal and railway line running roughly north – south approximately 50 and 80 m from the site respectively. The canal joins the River Don approximately 500 m north of the site. The railway line spurs off approximately 100 m south west of the site to run through the Outokumpu works to the south of the site. Beyond the railway line to the west are the southern portion of the Meadowhall car park and industrial units extending towards Sheffield town centre

3 GEOLOGY, MINING, HYDROLOGY & HYDROGEOLOGY

3.1 Geology

British Geological Survey (BGS) sheet No. 100, Sheffield (1:50 000 scale Bedrock and Superficial Edition) indicates that the site is underlain by Pennine Middle Coal Measures Formation mudstone, sandstone and siltstone with occasional coal bands. No superficial deposits are indicated to be present, although alluvium deposits are indicated to be present along the line of the River Don and extending to the other side of Shepcote Lane to the site.

Based on the known site history and the findings of the desk study, Made Ground increasing in thickness towards the west and variable in composition is expected to be present across the whole site.

3.2 Mining

A Coal Authority Non-Residential Mining Report for the site is presented in the Desk Study report. The report indicated the site is in the likely zone of influence from workings in 5 No. seams at between 140 and 610 m bgl, last worked in 1942. Any ground movements from these coal workings should have stopped by now. There are no known coal mine entries for on site or within 20 m of the site boundary, nor is the site within 200 m of current opencast workings.

The site is not in the likely zone of influence of current workings, nor is it an area for which the Coal Authority is determining whether to grant a licence to remove coal.

Based on the mining data and the depth of rock cover to worked seams (in excess of 130 m) the risk of underground mining affecting the site is considered low.

3.3 Hydrology

The nearest surface water course identified is the canal which runs roughly north – south approximately 50 m west of the site and joins the River Don approximately 500 m north of the site. Other than this canal and the River Don, the only nearby water body appears to be a holding reservoir within the Outokumpu steel works approximately 500 m south of the site. Given its location and shape, it is considered likely that this reservoir is hydraulically isolated from the surrounding groundwater.

3.4 Hydrogeology

The Environment Agency (EA) classifies the Pennine Middle Coal Measures Formation as a Secondary A aquifer, defined as *"permeable layers capable of supporting water supplies at a local* *rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers."*

Previous investigations, as detailed in the desk study report, have identified groundwater as being present within the Made Ground and Pennine Middle Coal Measures Formation, however have also indicated that this data represents a single groundwater horizon across the site.

During fieldworks, groundwater was encountered at between 1.7 and 7.6 m bgl. Subsequent monitoring has identified groundwater at between 0.93 and 3.71 m bgl.

4 FIELDWORK & LABORATORY TESTING

4.1 Fieldwork

The fieldwork was carried out in general accordance with BS 5930 (2015) and comprised the works summarised in Table 1. Fieldwork positions are given in DCE drawing No. 18012J-03-01 in Appendix B. Details of the fieldworks are presented in the Ground Investigation Report (GIR) Volume 1.

Table 1 Fieldwork Undertaken

Works	Objectives
1 No. cable percussion borehole to rockhead with rotary follow on, designated BH101A.	To allow confirmation of near surface ground conditions including composition of Made Ground and depth to rockhead. To allow recovery of representative samples for chemical and geotechnical laboratory testing. Follow on rotary drilling to prove composition of bedrock including investigating the presence of coal bands. To allow installation of a deep groundwater monitoring well within the rock.
4 No. cable percussion boreholes to rockhead, designated BH201 to BH204.	To allow confirmation of near surface ground conditions including composition of Made Ground and depth to rockhead. To allow recovery of representative samples for chemical and geotechnical laboratory testing. To allow installation of monitoring wells.
Excavation of 16 No. trial pits, designated TP438 to TP450 including TP438A, TP444A and TP449A.	To investigate composition of Made Ground across the site, including recovery of large representative bulk samples for geotechnical and chemical laboratory testing. To allow determination of underlying material where Made Ground fully penetrated. To allow soakaway testing in 3 No. locations.
Completion of 3 No. soakaway tests in selected trial pits.	To allow determination of near surface infiltration properties across the site.
Completion of 10 No. cores through existing concrete.	To allow determination of variation in thickness of concrete across the site.
Completion of 11 No. SCPT tests.	To assess the underlying ground strength and indicate ground composition, particularly identifying Made Ground thickness and variation and depth to competent strata.
12 No. in-situ plate CBR tests in selected trial pit locations.	To allow determination of in-situ California Bearing Ratio values for Made Ground materials across the site.
Installation of 1 No. deep and 5 No. shallow monitoring wells.	To allow return monitoring visits to be undertaken over a 3 No. month period, including recovery of groundwater samples.
Gas and Groundwater monitoring and sampling.	Monitoring of boreholes including groundwater sampling over a 3 No. month period to provide data to characterise contaminant status and its variation over time and spatially and allow gas conditions to be characterized.
Surveying investigation positions to National Grid coordinates.	To allow accurate determination of investigation positions to national grid coordinates including elevation to Ordnance Datum.

4.2 Geotechnical Laboratory Testing

A programme of geotechnical laboratory testing has been carried out in accordance with BS1377 (1990) "Methods of Tests for Soils for Civil Engineering Purposes" at a UKAS registered testing laboratory. The tests listed below were carried out and the results are presented in Appendix E.

Table 2 Geotechnical Laboratory Testing

BS1377 Ref	Test Description	Number of tests
Part 2 Section 3	Moisture Content	68
Part 2 Sections 4 & 5	Atterberg Limit Determination	22
Part 2 Section 8	Particle Density	12
Part 2 Section 9	Particle Size Distribution	19
Part 4 Section 3	2.5 kg Compaction	8
Part 4 Section 3	4.5 kg Compaction	7
Part 4 Section 3	Vibrating Hammer Compaction	1
Part 4 Section 5	Moisture Condition Value	8
Part 4 Section 7	California Bearing Ratio at each compaction point	2
BS EN 1097-2	Determination of Los Angeles Coefficient	6
Part 7 Section 4	Shear Box Test	1
Part 7 Section 8	Determination of undrained shear strength in triaxial compression	5
ISRM SM for UCS 1979	Uniaxial Compressive Strength	2
ISRM SM for PL 1985	Point Load Index	6
In House Method	Slag Expansion Test	1

4.3 Chemical Laboratory Testing

Chemical testing as agreed with Nova was carried out on selected samples for determinands based on their identified Contaminants of Concern

Soil samples were recovered in amber glass jars and/or 1 - 2 kg plastic tubs as advised by the testing laboratory. Water samples were recovered into amber glass bottles as advised by the testing laboratory. Where samples were recovered for hydrocarbon analysis, the boreholes were first micro purged and samples recovered into amber glass bottles as specified by the testing laboratory. All samples were stored in temperature controlled conditions (<4°C) once collected and during despatch to the laboratory. Chemical Laboratory testing for soils was carried out using MCERTS accredited tests whenever possible failing this UKAS and/or ISO17025 accredited tests were used. For water samples UKAS and/or ISO17025 accredited tests were used. Details of the accreditation status for specific tests are presented on the laboratory analysis report sheets. A total of 37 No. soil and 2 No. water samples were analysed during this investigation, the results of which are presented in the Factual Report. Further water samples are to be analysed following upcoming monitoring visits

5 GROUND CONDITIONS

5.1 Ground Conditions

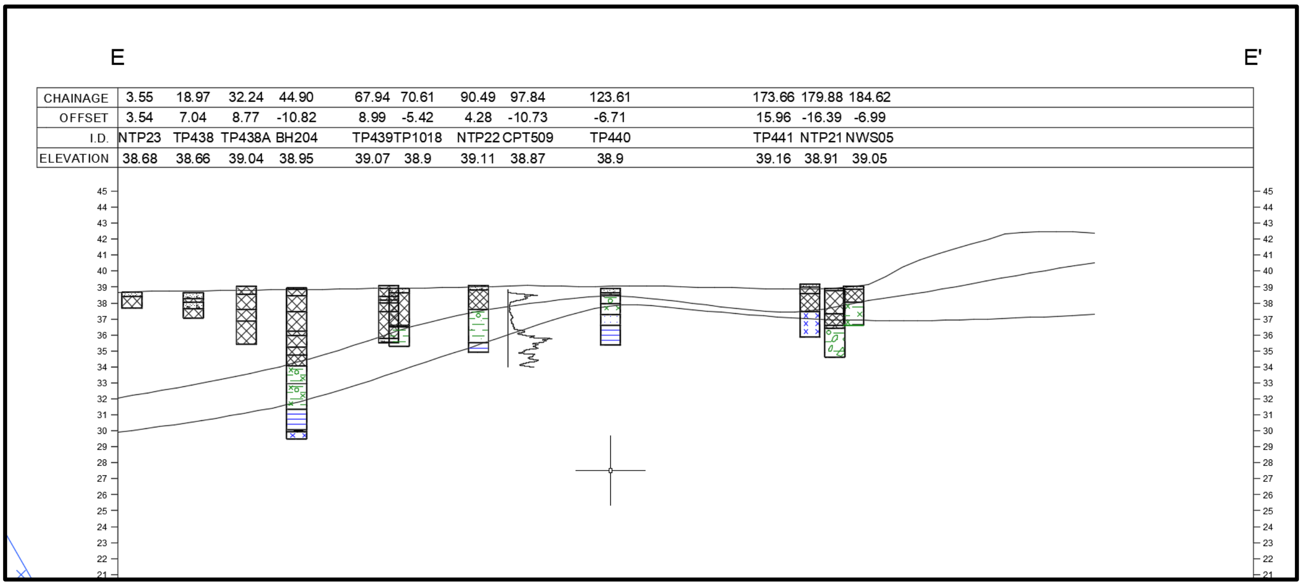
The ground conditions at the site were in general accordance with those anticipated and included Made Ground overlying weathered Pennine Middle Coal Measures (CLAY) overlying Pennine Middle Coal Measures (Mudstones and Siltstones). A summary of the ground conditions encountered in presented in Table 3 below.

Table 3 Summary of Ground Conditions

Strata & General Description	Depth Encountered (m bgl)	Thickness Range (m)
1 MADE GROUND - HARDSTANDING Strong light grey CONCRETE both reinforced and un-reinforced. (Not encountered in TP438A, TP439, TP446, TP447, TP449A or TP450	Ground Level	0.1 to 0.6
2 MADE GROUND Predominantly granular Made Ground, typically comprising loose locally medium dense, brown, grey and black fine to coarse sand (partly ash) with varying proportions of clay gravels and cobbles of brick, concrete, sandstone, limestone, glass, metal and clinker. Rare layers of firm dark grey gravelly sandy CLAY were encountered, particularly to the east of the site.	Ground Level to 0.6	0.1 to 4.9 (note previous BH R1001 found 8.2 m on western boundary)
3 PENNINE MIDDLE COAL MEASURES		
CLAY Generally firm becoming stiff with depth light grey, dark grey, brown and orangish brown slightly gravelly and gravelly silty CLAY. Locally with soft horizons. Absent in TP441.	0.38 to 4.9 m where present (8.2 m bgl in previous BH RO1001)	0.3 to 2.8 m where fully penetrated
ROCK Generally very weak locally extremely weak and medium strong grey SILTSTONE and MUDSTONE	1 to 7.7 (9 m bgl in previous BH RO1001)	

Geological cross sections across the Phase 1 site area have been generated at the positions shown on drawing ref 18012J-03-03 and the sections are presented on drawing ref 18012J-03-11. Elevations to the base of the Made Ground together with depths to the base of the Made Ground from existing ground levels are shown on drawings 18012J-03-05 & 18012J-03-06 respectively with depths from proposed Ground levels shown on drawing 18012J-03-07. The drawings show that the thickness of Made Ground increases in thickness from east to west (see Section E-E' extract on Fig 2 overleaf)

Figure 2 Section E-E' Increasing thickness of Made Ground towards west



5.2 Groundwater Condition

Groundwater was encountered during the investigation works as summarised in Table 4

Table 4 Summary of groundwater strikes during fieldworks

Hole Ref	Depth to GW Strike (m bgl)	Depth GW rose to / Rate	Strata/ (Comments)
BH101A	4.2	3.85	Made Ground
BH101A	6.7	6.5	Pennine Middle Coal Measures
BH102A	1.9		Pennine Middle Coal Measures
BH102A	11.8		Pennine Middle Coal Measures
BH201	4.1	4.1	Pennine Middle Coal Measures
BH202	6	3.5	Pennine Middle Coal Measures
BH203	3.2	3.2 (1.9 overnight)	Pennine Middle Coal Measures
BH204	7.6	3.5	Pennine Middle Coal Measures
TP 439	3.2		Made Ground (slight seepage)
TP440	3.5		Pennine Middle Coal Measures
TP441	1.7		Made Ground (Seepage)
TP443	3.5		Made Ground (Slight seepage)
TP444A	2.5		Made Ground (note in tank like structure)
TP445	2.4		Made Ground (Seepage)
TP446	3.3		Pennine Middle Coal Measures (Seepage)
TP448	3.9		Pennine Middle Coal Measures (Slight Seepage)

Note GW rise after 20 mins unless noted otherwise. BH102A approx. 10 m beyond southern boundary.

Groundwater conditions recorded during excavation of exploratory hole in previous investigations are summarised in Table 5.

Table 5 Summary of Groundwater Strikes – Previous Investigations

Hole Ref	Depth to GW Strike (m bgl)	Depth GW rose to / Rate	Strata/ (Comments)
NTP21	1.5	NR	Made Ground (Nova SI, - Seepage)
NTP24	< 5	NR	Made Ground (Nova SI, Visible on Pit Photos)
CP1002A	4.4	NR	Made Ground (Grontmij)
CP1002A	6.2	NR	Pennine Middle Coal Measures (Grontmij)
TP1012	3	NR	Pennine Middle Coal Measures (Grontmij)

NR = Not reported

Groundwater monitoring is ongoing at the site and will be presented in a separate addendum. A summary of groundwater monitoring to August 2018 is presented in Table 6.

Table 6 Summary of Groundwater Monitoring

Hole Ref	Depth to GW Min	Depth to GW Max	Response Zone Strata/ (Comments)
BH101A	3.69	3.72	Made Ground
BH101Aa	3.71	4.14	Pennine Middle Coal Measures
BH102A	1.3	1.36	Pennine Middle Coal Measures/ Made Ground
BH102A	3.07	3.08	Pennine Middle Coal Measures
BH201	Dry	Dry (>2.03)	Made Ground
BH202	Dry	Dry (>2.76)	Made Ground
BH203	0.93	1.31	Pennine Middle Coal Measures
BH204	3.22	3.26	Made Ground

BH102A approx. 10 m beyond southern boundary.

Groundwater monitoring recorded during previous investigations are summarised in Table 7.

Table 7 Summary of Groundwater Monitoring – Previous Investigations

Hole Ref	Depth to GW Min	Depth to GW Max	Response Zone Strata/ (Comments)
CP1001	2.99	3.21	Made Ground
CP1002A	3.21	4.0	Pennine Middle Coal Measures
NWS05	0.71	1.01	Made Ground
NWS08	2.15	2.44	Made Ground

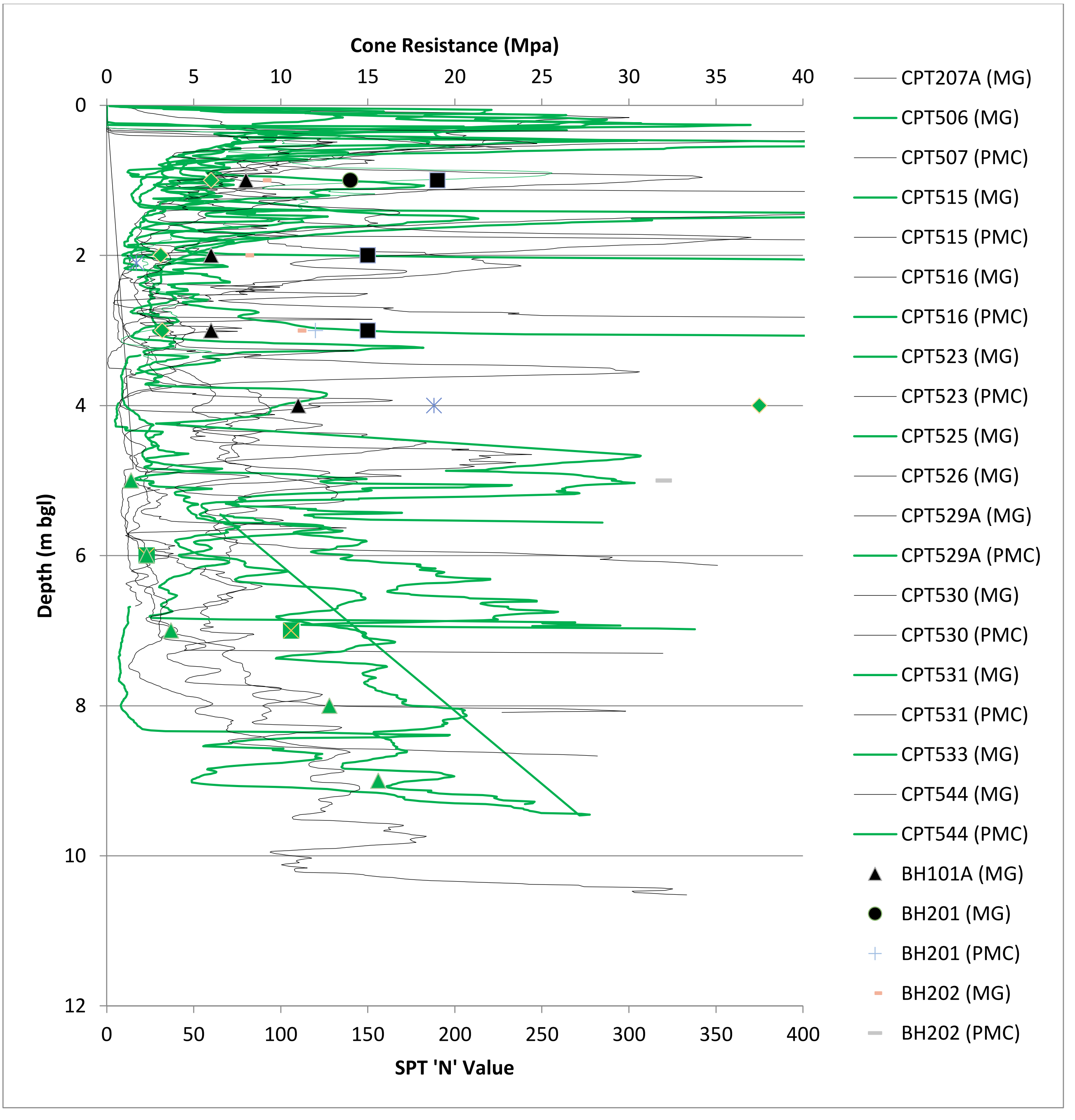
The groundwater data suggests two groundwater horizons, one within the Made Ground at depths of between 0.71 and 3.72 m bgl and one within the Middle Pennine Coal Measures at between 0.93 and 4.14 m bgl. The groundwater within the Made Ground consists of both perched water horizons with the Made Ground and a horizon at the base of the Made Ground and are likely to be encountered during excavation activities at the site. For design purposes a design groundwater level of 1 m bgl is recommended.

6 GEOTECHNICAL PARAMETER EVALUATION

6.1 Strength Plots

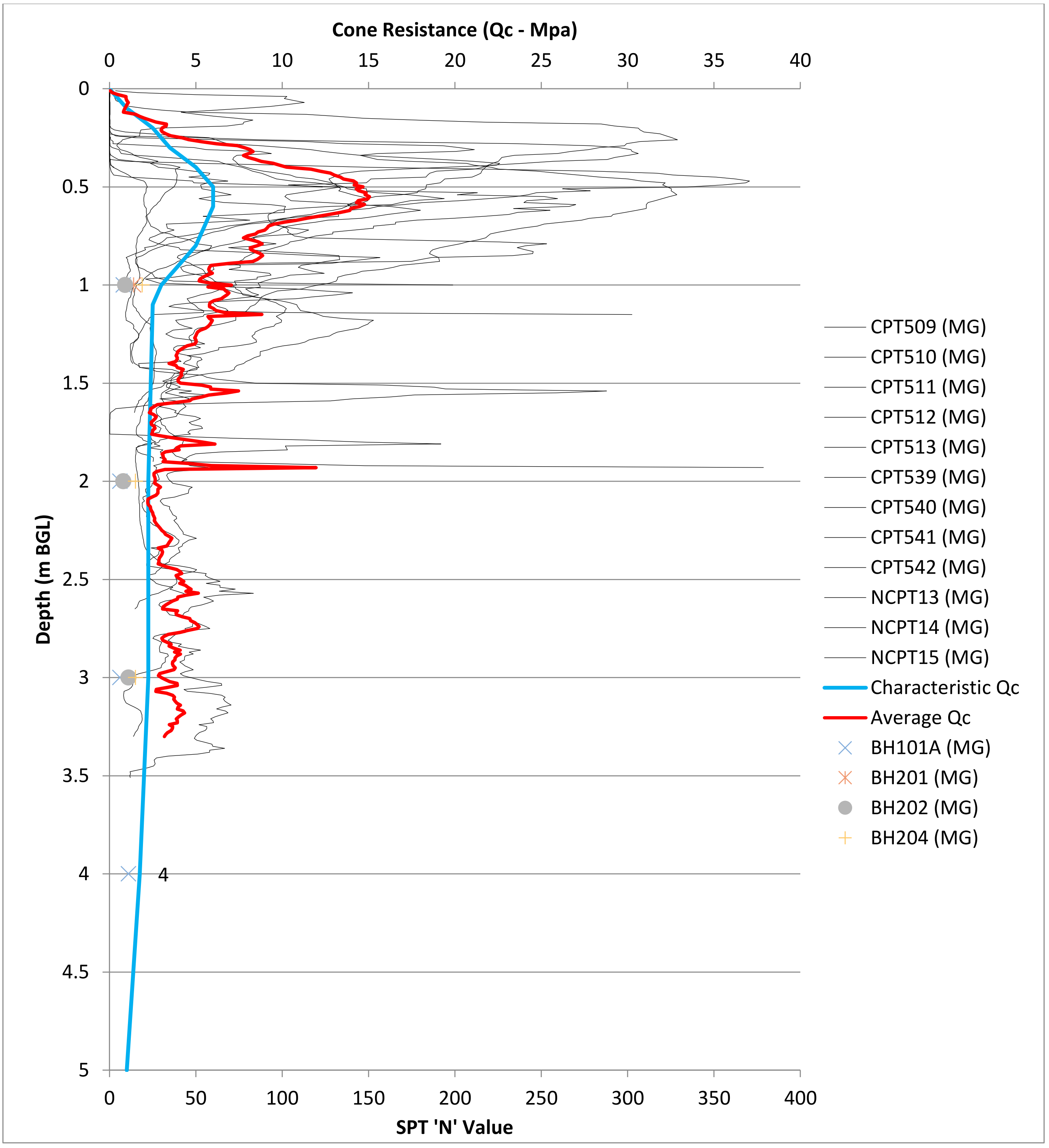
A series of strength with depth plots (represented by SCPT cone resistance and SPT data) are shown on Figures 3 to 6 including lines indicating parameter characteristic values. All data is shown on Figure 3, indicating high variability in strength with depth in both the Made Ground (black on plots) and Pennine Middle Coal Measures (green on plots).

Figure 3 SCPT Qc and SPT 'N' Values verses depth



For clarity data for the Made Ground only is presented on Figure 4. The Made Ground has been found to be very loose to very dense in the upper 1 m (note the higher Qc values are considered to be elevated due to the presence of cobbles) and generally loose below this depth.

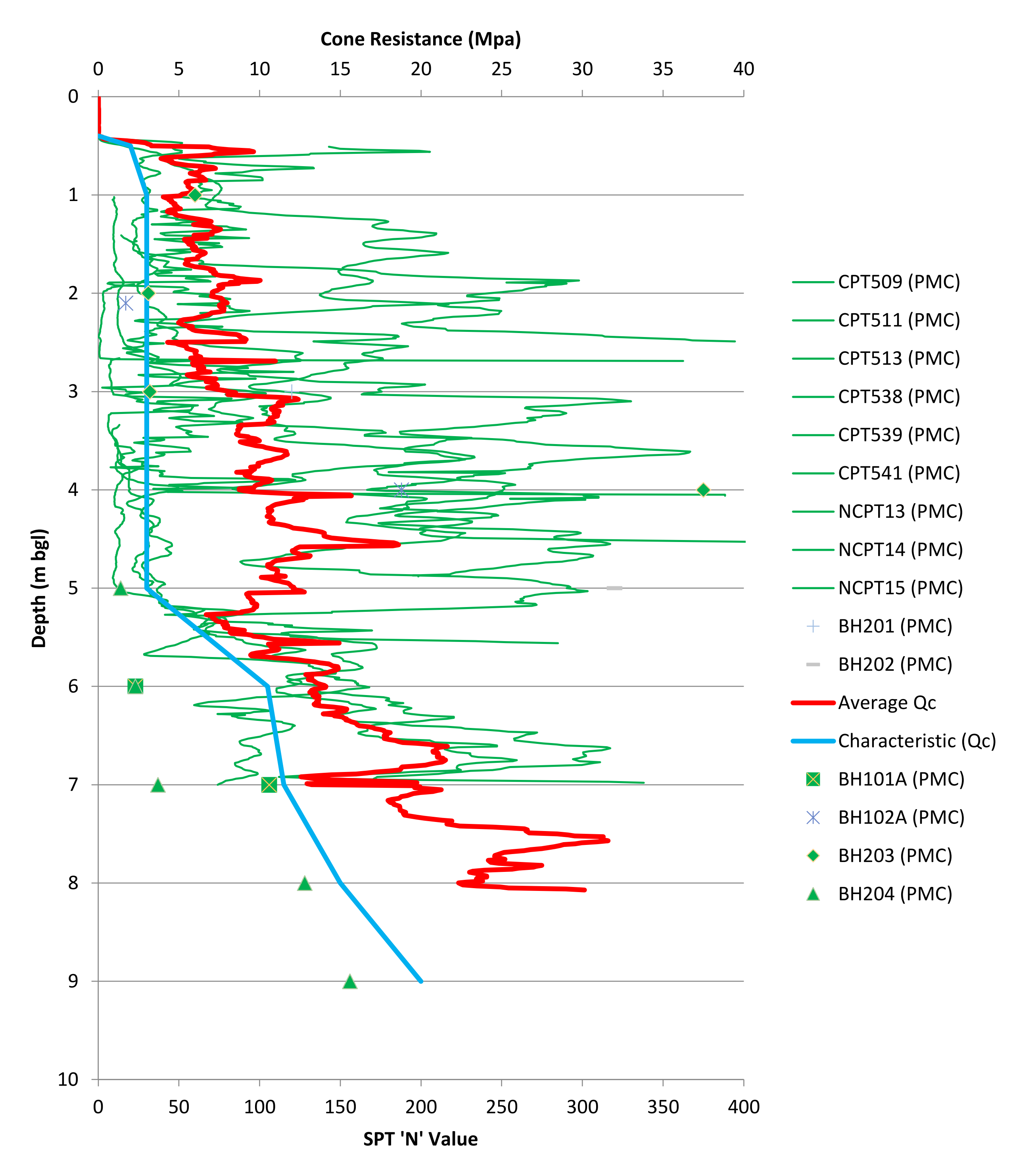
Figure 4 SCPT Qc and SPT 'N' Value with depth – MADE GROUND



Note – Made Ground proven to 8.2 m bgl on western boundary during previous investigations by others (no test data available)

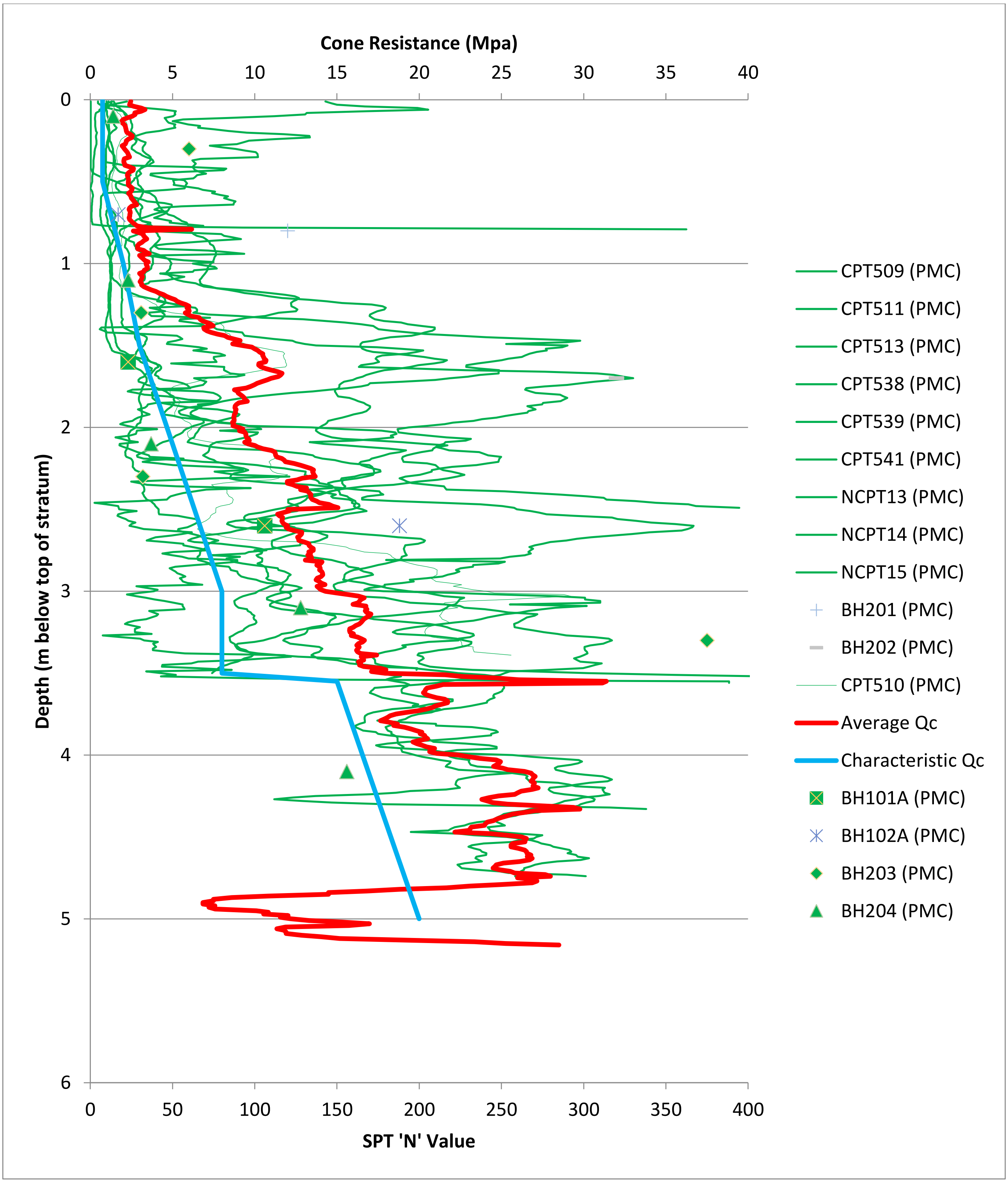
Data for the Pennine Middle Coal Measures are presented on Figure 5

Figure 5 **SCPT Qc and SPT 'N' Value with depth – PENNINE MIDDLE COAL MEASURES**



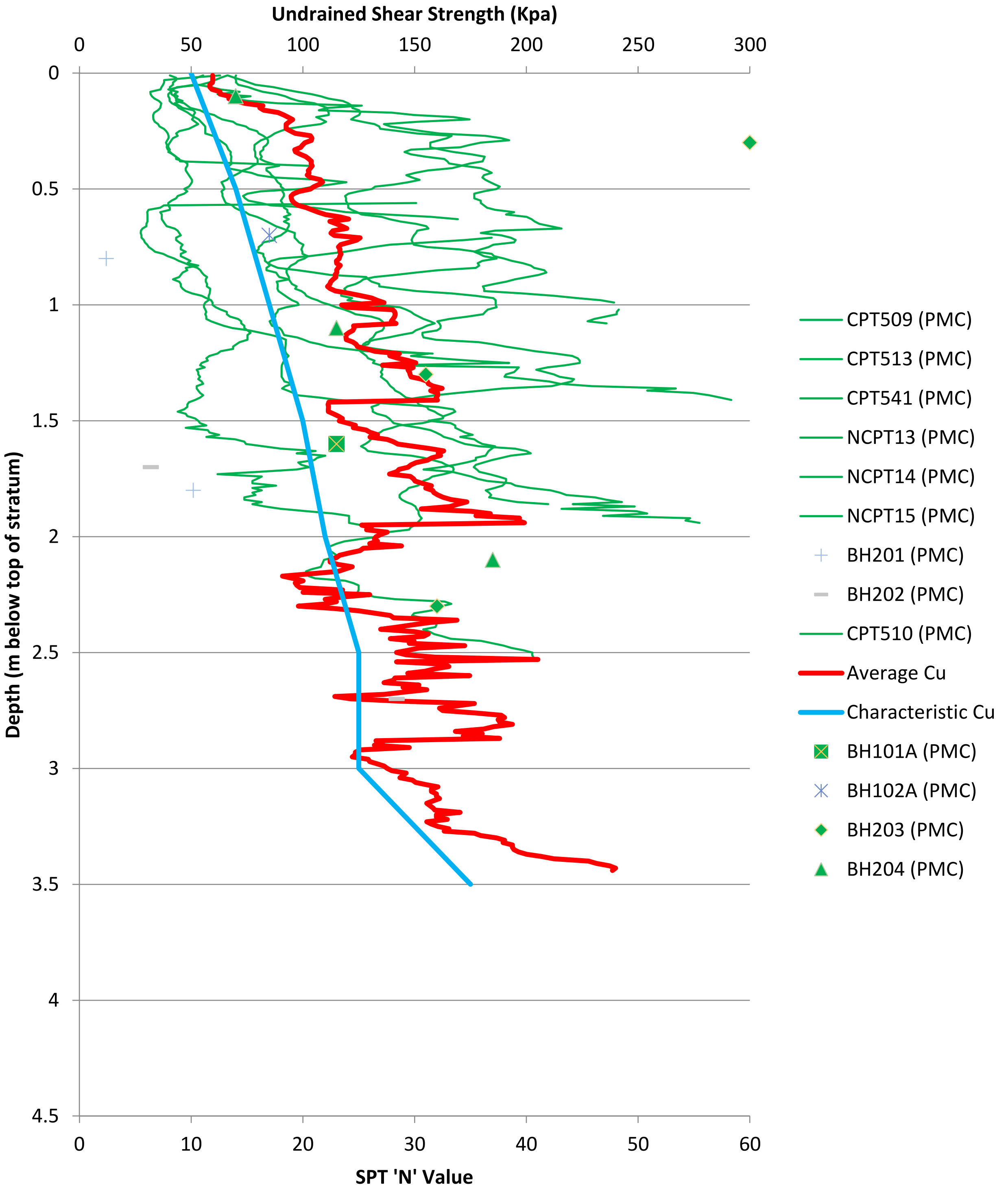
The data indicates a wide range of strengths with depth ranging from firm CLAY to very weak MUDSTONE, however the range of strengths is affected by the varying depth to the strata (upper layers have been removed and replaced with Made Ground towards the west of the site). To account for this an additional plot is presented on Figure 6 which shows the strength variation from the top of the deposit. This suggests a slightly clearer increase in strength with depth and weaker zone in the upper 1 m of the stratum..

Figure 6 SCPT Qc and SPT 'N' Value with depth from top of strata – PENNINE MIDDLE COAL MEASURES



A plot of undrained shear strength versus depth from the top of the stratum is shown on Figure 7 for the weathered PENNINE MIDDLE COAL MEASURES CLAY.

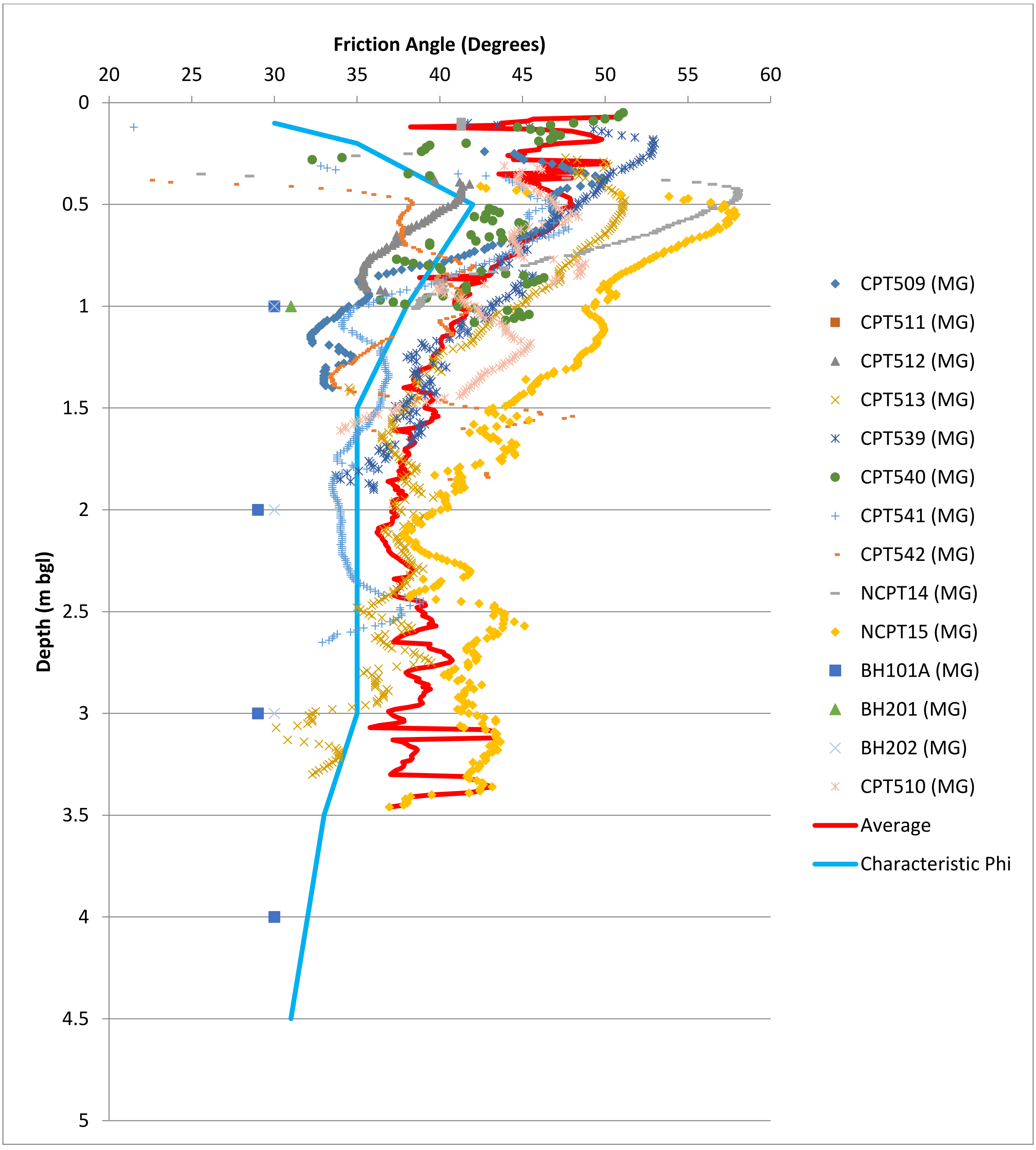
Figure 7 Plot of Derived Undrained Shear Strength with depth from top of stratum – PENNINE MIDDLE COAL MEASURES



Note that the Pennine Middle Coal Measures are present at shallow depth as extremely weak rock across much of the site (particularly to the east) and the plot represents the weather CLAY horizon only (where present – generally in the western half of the site).

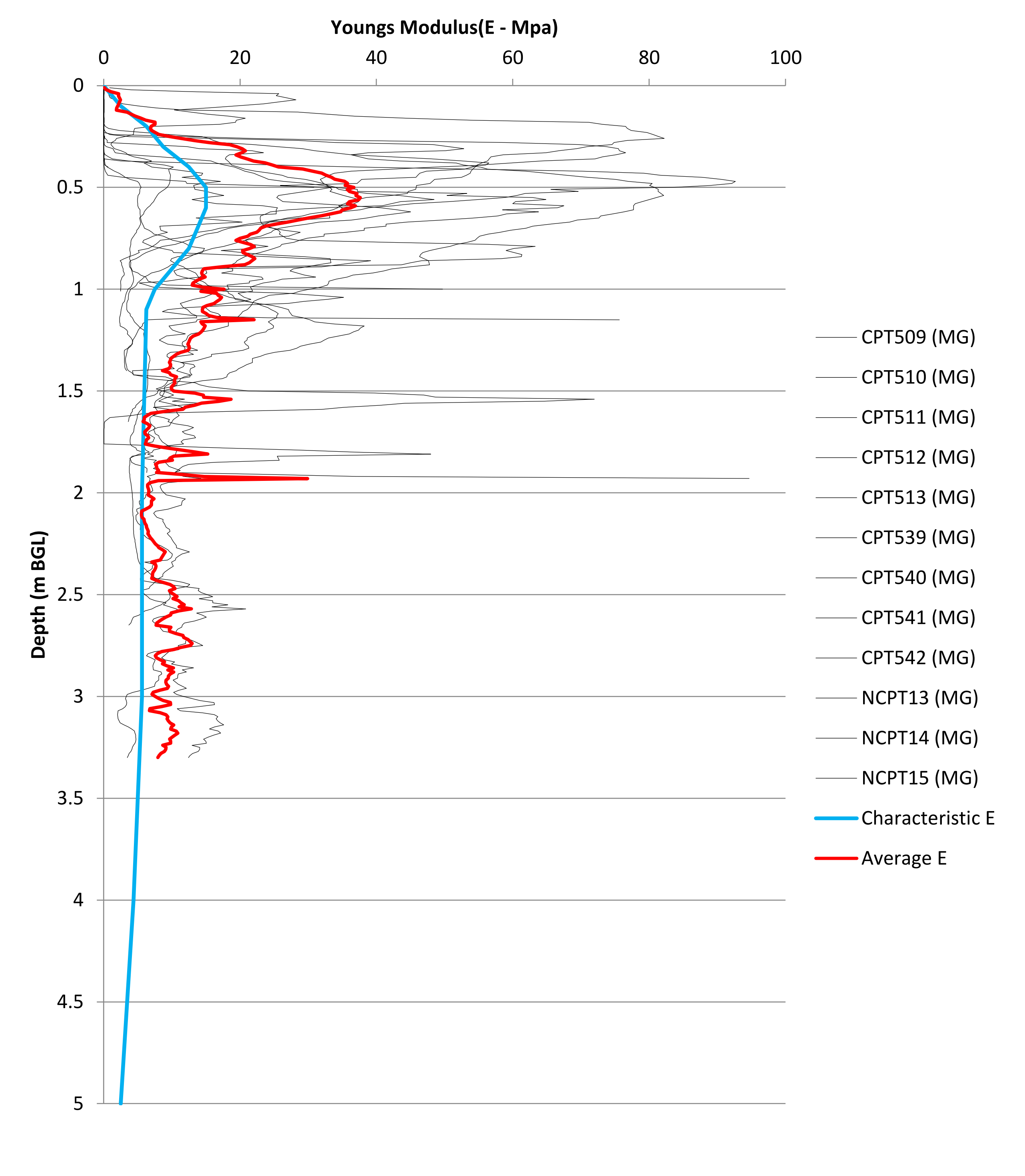
The Made Ground at the site has been found to be generally a coarse soil (in accordance with BS5930 and BS EN 1997-Part 2 conventions – Note some of the Made Ground is COHESIVE when viewed in the context of Earthworks Classifications – See Section 7). A plot of Derived friction angle vs depth for the Made Ground is shown on Figure 8.

Figure 8 Plot of Derived Friction Angle vs Depth (MADE GROUND)



CPT derived Youngs Modulus values for the Made Ground are shown on Figure 9.

Figure 9 Plot of Derived Youngs Modulus vs Depth – MADE GROUND



Derived Youngs Moduli value are relatively high (exceeding 20 MN/m^2) in the upper levels of Made Ground, however these are likely to be elevated due to coarse materials within the Made Ground. Youngs Modulus values drop off sharply in the deeper Made Ground where characteristic values of between 3 and 4 are considered appropriate.

6.2 Material Properties

Material properties from Laboratory and Insitu Testing is summarised in the following tables.

Table 8 Made Ground

Parameter (No of Tests)	Units	Min	Max	Average	Characteristic
Bulk Weight –	Mg/m^3	1.8 (Est – BS8002)	1.8 (Est – BS8002)	1.8 (Est – BS8002)	1.8
SPT 'N' Value (11)		6	19	11	8
Cone Resistance	MN/m^2	0.04	37	5.1	See Fig 4
Angle of Shearing Resistance	°	21.5 (based on CPT)	58^{+} (based on CPT)	38^{++}	See Fig 7
Moisture Content (15)	%	13	29	21	N/A
Liquid Limit (15)	%	52	61	56	N/A
Plastic Limit (12)	%	20	21	20	N/A
Plasticity Index (12)	%	21	32	26	N/A
Particle Density (5)	Mg/m^3	2.16	2.57	2.43	N/A
MCV (4)		7.3	13.8	10.3	N/A
Max Dry Density - 2.5 kg (3)	Mg/m^3	1.63	1.8	1.71	N/A
Optimum Moisture Content – 2.5 kg (3)	%	13	20	17	N/A
Max Dry Density - 4.5 kg (5)	Mg/m^3	1.78	1.91	1.83	N/A
Optimum Moisture Content – 4.5 kg (5)	%	11	14	12.6	N/A
Max Dry Density – Vibratory Hammer (4) -	Mg/m^3	TBC	TBC	TBC	N/A
Optimum Moisture Content – Vibratory Hammer (4)	%	TBC	TBC	TBC	N/A
Los Angeles Co-efficient (6)		Unsuitable	Unsuitable	Unsuitable	
Youngs Modulus^{+++}	MN/m^2	0.1	92.5	12.75	See Fig 8

+ Note Values > 45 degrees from CPT testing considered unreliable and likely to be affected by coarse soils

++ Values > 45 degrees removed from average calculation

TBC – To Be Confirmed - Test results outstanding

Table 9 Pennine Middle Coal Measures CLAY

Parameter (No of Tests)	Units	Min	Max	Average	Characteristic
Bulk Weight (2)	Mg/m^3	2.05	2.1	2.075	2.075
SPT 'N' Value (10)		12	60	31.5	25
Undrained Shear Strength - Lab (2) *	kN/m^2	30	101	66	60
Derived Undrained Shear Strength (>>)	kN/m^2	29.3	291	135	See Fig 8
Angle of Shearing Resistance (8)	°	22 (Est based on PI)	27 (Est based on PI)	25 (Est based on PI)	25
Effective Cohesion – Shear box (1)**	kN/m^2	6	6	6	3
Angle of Shearing Resistance - Shear Box (1)**	°	22°	22°	22°	22
Volume compressibility derived from CPT data (>>)	m^2/MN	0.01	0.24	0.06	0.07
Moisture Condition Value at NMC (4)		9.9	14.3	12.8	N/A
Moisture Content (28)	%	8.1	38	18.5	N/A
Liquid Limit (10)	%	40	65	49	N/A
Plastic Limit (10)	%	15	25	18	N/A
Plasticity Index (10)	%	20	40	31	N/A
Particle Density (7)	Mg/m^3	2.56	2.65	2.62	N/A
Max Dry Density - 2.5 kg (5)	Mg/m^3	1.75	1.92	1.85	N/A
Optimum Moisture Content – 2.5 kg (5)	%	13	14	13.4	N/A
Max Dry Density – Vibratory Hammer (4) -	Mg/m^3	1.91	1.91	1.91	N/A
Optimum Moisture Content – Vibratory Hammer (1)	%	16.8	16.8	16.8	N/A
Max Dry Density 4.5 kg (2)	Mg/m^3	1.81	1.83	1.82	N/A
Optimum Moisture Content 4.5 kg (2)	%	13	14	13.5	N/A

* Lab undrained shear strengths are considered unrepresentative of the weathered Penning Middle Coal measures and represent lower bound conditions

** C' of 3 kN/m2 and Phi' of 22 considered appropriate in combination

Note the parameters above apply to the CLAY layers generally within the upper 2 m of Pennine Middle Coal Measures – Location specific, refer to individual borehole records. In certain locations the clay layer is very thin or absent.

Table 10 Pennine Middle Coal Measures Rock

Parameter (No of Tests)	Units	Min	Max	Average	Characteristic
Bulk Weight	Mg/m^3	2.4	2.54	2.47	2.4
Moisture Content (2)	%	0.5	2.6	1.55	N/A
SPT ‘N’ Value (6) -top of deposit only		60	375 (extrapolated)	163	125
Uniaxial Compressive Strength (7)	MN/m^2	6.1	6.4	6.25	1.00*
Point Load Index (19)		0.01	0.23	0.07	0.05
UCS from PLI (19)	MN/m^2	0.2	4.6	1.4	1

7 GEOTECHNICAL ENGINEERING ASSESSMENT

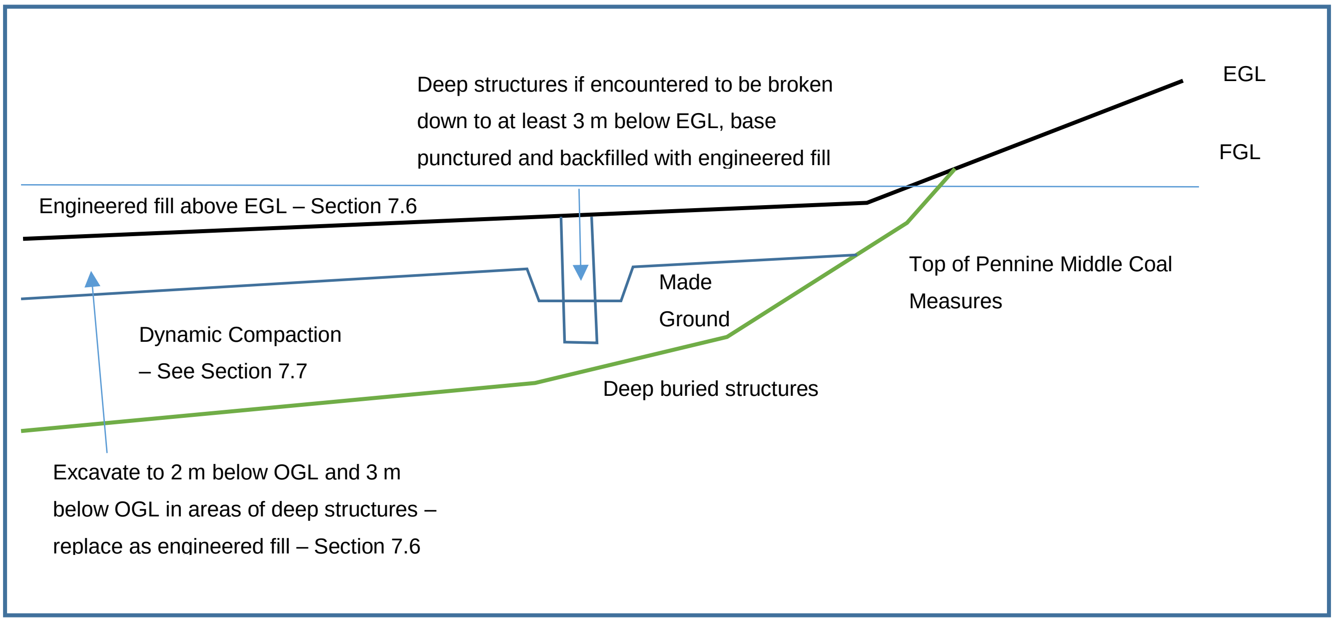
7.1 Development Proposals

A proposed development layout is shown on Figure 10 and building outlines on the exploratory hole plan is shown on Drawing 18012J-03-02. The proposals include two new industrial units with associated office areas, mezzanine flooring provision of car parking, access roads and hardstanding. Structural loadings are yet to be finalised however it is understood that Characteristic foundation loadings will not exceed 150 kN/m^2 and that foundation total and differential settlement limits of 25 mm and 15 mm respectively are required. Ground floor slabs will be designed to carry a Characteristic UDL of 50 kN/m^2 with a floor slab differential settlement tolerance of 1:500.

Figure 10 Proposed Development Layout

It is understood that the clients preferred solution to difficult ground conditions is to adopt an earthworks based solution (re-engineering Made Ground, cut and fill with appropriate compaction potentially in combination with dynamic compaction solutions). Piling and ground improvement by vibro-stone columns are not preferred by the client at the moment although we would recommend that these options remain under consideration as there may be financial and practical benefits. The design information presented in this report has been developed in consultation with BED and is suitable for preliminary (tender) design purposes. It does not substitute for a full and complete geotechnical design and should be validated, updated and expanded upon as appropriate by the responsible designer as part of the detailed design work for the project. The broad preliminary design concept is illustrated schematically in Figure 11.

Figure 11 Schematic Preliminary Design Concept



Note that the quantum of ground treatment required will reduce as the thickness of Made Ground reduces towards the east. Treatment would be limited to earthworks only to the east of the 2 m contour line shown on drawing ref 18102J-05-07 with the addition of dynamic compaction works to the west of the 2 m contour line.

7.2 Shallow Foundations

7.2.1 General

The Made Ground is not considered suitable for the imposition of foundation loadings in its current condition due to its variable composition, engineering properties and variable thickness. In building areas the Made Ground increases in thickness across the site (increasing from east to west – see Cross Sections A-A' to E-E' drawing ref 18012J-03-11 and Made Ground thickness contours drawings ref 18012J-03-05, 18012J-03-06 and 18012J-03-07) to approximately 4.5 m in thickness to the west of Unit 1 and approximately 5.5 m in thickness to the west of Unit 2.

Natural deposits comprising layers of the PENNINE MIDDLE COAL MEASURES (typically Stiff CLAY overlying extremely weak and very weak MUDSTONE) are present at shallow depth in the east of the site. The approximate extent of the shallow depth (< 2 m from proposed levels) PENNINE MIDDLE COAL MEASURES from proposed finished levels are shown on drawing ref 18012J-03-7. Foundations may be placed in the PENNINE MIDDLE COAL MEASURES CLAY (see Section 7.2.2) or in appropriately engineered structural fill (see Section 7.2.3)

7.2.2 Foundations Placed within PENNINE MIDDLE COAL MEASURES CLAY

For foundations placed at a minimum of 0.5 m below the top of the PENNINE MIDDLE COAL MEASURES CLAY a characteristic undrained shear strength of 70 kN/m^2 and characteristic bulk weight of 2.075 Mg/m^3 (or 1.8 Mg/m^3 for the over lying Made Ground) may be adopted. As a guide to foundation design ULS calculations have been carried out in accordance with BE EN 1997-1 for Design Approach 1, Combination 1 and Combination 2 and the results are shown in Table 11. These values are based on a centrally loaded (vertical load only) square pad 2 m x 2 m placed at depth of 0.5 m below the top of the PENNINE MIDDLE COAL MEASURES CLAY at a depth of 1 and 2 m below finished ground level. Values in the table are for verification against appropriately factored vertical loads.

Table 11 Design Approach 1, Combination 1 and Combination 2 ULS results (Rd) PMCM

Foundation Depth (m bgl)	DA1- Combination 1 ULS (kN)	DA2- Combination 2 ULS (kN)
1	1800 (450)	1306 (326.5)
2	1872 (468)	1378 (344.5)

Rd/A (Design resistance / foundation area given in brackets)

Selected preliminary characteristic loads supplied by BED are as follows – Unit 1 Office Column Loads (Column 1) 575 kN dead, 608 Imposed and Unit 1 Edge Column Load (Column Load) 148 Dead, 47 Live. For the 2 m x 2 m pads above at 1 m bgl an additional dead load of 88 kN will apply for foundation and backfill weight. DA 1 Combination 1 design loads will therefore be 1807 kN for Column 1 and 390 kN for Column 2 while DA1 Combination 2 design loads will be 1453 kN for Column 1 and 297 kN for Column 2. Column 1 would therefore not meet the design criteria for a 2 m x 2 m pad and a slightly larger pad 2.2 m x 2.2 m would be required in this case to satisfy ULS conditions (note that SLS requirements will in fact govern design and sizing see page 29). Similar verification checks will need to be carried out for detailed design for the various foundation configurations.

For information and comparison purposes safe bearing capacities for the same foundation configurations and parameter design values are presented in Table 12 (in accordance with BS8004) using an overall factor of safety of 3.

Table 12 Safe Bearing Capacities- PMCM

Foundation Depth (m bgl)	Safe Bearing Capacity (kN/m^2)
1	150
2	156

As a guide to foundation design, a SLS assessment has been carried out assuming a 2 m x 2 m foundation placed at 1 m below ground level (and 0.5 m into the top of the PENNINE MIDDLE COAL MEASURES CLAY) and assuming a 2 m thickness of CLAY beneath the foundation with mudstone beneath the clay with a total settlement limit of 25 mm. A characteristic coefficient of volume compressibility of 0.07 m^2/MN has been adopted for the assessment for the CLAY and a characteristic Constrained Modulus of 50 MN/m^2 adopted for the Mudstone.

Based on the conditions above the SLS condition would be satisfied for a total vertical load of 900 kN (225 kN/m^2). SLS validation is therefore likely to govern foundation design. (Note for a 3 m x 3 m foundation in the above conditions the SLS condition would be satisfied for a total vertical load of 1350 kN (150 kN/m^2)). **Foundations placed in the Pennine Middle Coal Measures CLAY may be initially sized assuming an SLS capacity of 150 kN/m^2** but full Eurocodes SLS and ULS verification will need to be carried out (and dimensions adjusted as necessary) at detailed design stage once the detailed loading conditions are known using the characteristic parameter values given in Section 6 and taking due notice of the changes in ground conditions across the site.

7.2.3 Foundations Placed within Engineered Structural Fill

The following section is based on the assumption that the Made Ground present beneath the building footprint is excavated to at least 2 m below finished ground levels suitably processed and recompacted to a suitable specification (see section 7.6 for further details) together with additional ground improvement works in areas of deeper Made Ground.

For foundations placed at a minimum of 1.0 m below ground levels within the engineered fill a characteristic angle of shearing resistance of 35 degrees and characteristic bulk weight of 1.8 Mg/m^3 for the over lying Made Ground may be adopted. A design groundwater level of 1 m bgl has been adopted. As a guide to foundation design ULS calculations have been carried out in accordance with BE EN 1997-1 for Design Approach 1, Combination 1 and Combination 2 and the results are shown in Table 13. These values are based on a centrally loaded (vertical loads only) square pad 2 m x 2 m placed 1 below finished ground level. Values in the table are for verification against appropriately factored vertical loads.

Table 13 Design Approach 1, Combination 1 and Combination 2 ULS results (Rd) FILL

Foundation Depth (m bgl)	DA1- Combination 1 ULS (kN)	DA2- Combination 2 ULS (kN)
1	4785 (1196)	2210 (552)

Rd/A (Design resistance / foundation area given in brackets)

For information and comparison purposes <u>safe</u> bearing capacities for the same foundation configurations and parameter design values are presented in Table 14 (in accordance with BS8004) are presented in Table 14 using an overall factor of safety of 3.

Table 14 Safe Bearing Capacity - FILL

Foundation Depth (m bgl)	Safe Bearing Capacity (kN/m^2)
1	400

Foundation loadings will be developed during progression of design, however as a guide to foundation design, a SLS assessment has been carried out assuming a 2 m x 2 m foundation placed at 1 m below ground level and assuming engineered and treated Made Ground to 4 m below foundation level with a total settlement limit of 25 mm. A characteristic drained Youngs Modulus of 20 MN/m^2 has been adopted for engineered Made Ground to 1 m below foundation level and 12.5 MN/m^2 for improved Made Ground beneath this depth.

Based on the conditions above the SLS condition would be satisfied for a total vertical load of 800 kN (200 kN/m^2). SLS validation is likely to govern foundation design particularly for larger foundations (Note for a 3 m x 3 m foundation in the above conditions the SLS condition would be satisfied for a total vertical load of 1260 kN (140 kN/m^2). **<u>Foundations placed in the Engineered Made Ground may be initially sized assuming an SLS capacity of 150 kN/m^2</u>** but full Eurocodes SLS and ULS verification will need to be carried out (and dimensions adjusted as necessary) at detailed design stage once the detailed loading conditions are known using the characteristic parameter values given in Section 6 and 7.6 and taking due notice of the changes in ground conditions across the site.

7.3 Pile Foundations

It is anticipated that a piled solution is not likely to be a cost effective solution for the proposed development. Piled foundations are nonetheless suitable at the site and given the generally shallow depth to competent Mudstone would generally be relatively short (generally between 5 and 10 m). Driven or bored piles may be considered and should piling be considered further the parameters provided in section 6 may be adopted for preliminary design.

As a guide to pile design should it be considered further, a 450 mm dia pile incorporating a 2 m rock socket (penetrating at least 2 m into the extremely weak Mudstone) would provide a safe working load in the region of 700 kN assuming an overall Factor of Safety of 2.5.

Appropriate pile testing is recommended to confirm the design assumptions in accordance with the recommendations presented in the ICE Specification for piling and embedded retaining walls – Third Edition. The advice of specialist piling contractors should be sought prior to design finalisation.

7.4 Floor slabs

Given the variability of the Made Ground it is not considered suitable for supporting ground bearing floor slabs in its current condition. Re-engineering of the Made Ground and ground improvement in areas of deeper Made Ground are recommended following which a characteristic CBR of 10 % (for granular soils) would be achievable and will allow the adoption of a ground bearing floor slab (see sections 7.6 and 7.7). Following ground treatment carried out in accordance with the preliminary design concept and meeting the criteria defined in sections 7.6 and 7.7, total slab settlement under the proposed UDL would be anticipated to be less than 25 mm with differential movement less than 1:500.

7.5 Stone Columns

Stone columns are considered a viable technical and potentially cost effective option. The generally granular composition of the Made Ground make the materials well suited to improvement by stone columns and their use would minimise potential difficulties associated with control of bulk earthworks in a variable deposit and potential issues associated with perched groundwater within the Made Ground materials (see section 7.6). Given the nature of the previous development at the site there is considerable potential for the presence of below ground obstructions that would need to be dealt with if stone columns are to be considered further. Should stone columns be considered further, the advice of specialist contractors should be sought.

7.6 Earthworks

7.6.1 Earthworks General

The following section is discussed in the context of the Manual of Contract Documents for Highways works, Volume 1, Series 600 Specification for Highways works.

7.6.2 Earthworks Made Ground

Made Ground materials encountered during the ground investigation works have been found to be mixed and composed of variable layers of mixed SANDs with some GRAVEL layers and occasional (albeit a minor proportion) of SILT and CLAY layers. The earthworks testing carried out on 12 samples of Made Ground materials is summarised in Table 15 together with the POTENTIAL classifications of the materials in the context of the Specification for Highways works on the basis of grading alone. It should be noted that the actual earthworks classification of a particular material is dependant on its grading, other material parameters (detailed in Table 6/1 of Series 600) AND on how the materials are used and compacted. Material classification is not therefore solely based on the material properties. .As a result (and as an example) a particular material may be USED as Class 1 general fill (compacted by Method Specification) if used in that manner and the identical material USED as Class 6N selected granular fill (compacted to end product specification). In this case all class 6N materials can be used as Class 1 but not all Class 1 materials can be used as Class 6N.

Table 15 Earthworks Classifications based on Particle Size Distribution

Sample Ref		Silt/Clay	Sand	Gravel	Cobble	Potential Series 600 Classification
TP441	1.2	74	14	12	0	2A or 2B, **7A**, 7E, 7F
TP438A	1	5.4	57.6	37	0	1A, 6E, 6F1, 6I, 6M, **6N**, **6P**
TP443	2	0.3	50.3	49.4	0	1A,6A, 6E, 6F1, 6I, 6J, 6M, **6N**, **6P**
TP445	0.7	9.2	64.6	26.2	0	1B, 6E, 6I, 6J, 6M, **6P**
TP450	1.5	13.5	42.2	44.3	0	1A, 6E, 6F1, 6I, 6J, **6N**, **6P**
TP439	2.2	11.3	47	41.7	0	1A, 6E, 6F1, 6I, 6J, **6N**, **6P**
TP443	1	22.2	42.7	35.1	0	2C, **7A**, 7D, 7E, 7F
TP447	2.1	9.2	63.7	27	0	1B, 6E, 6I, 6J, 6M, **6P**
TP448	1.5	4.4	49.9	45.6	0	1A,6A, 6E, 6F1, 6I, 6J, 6M, **6N**, **6P**
TP449	1	10.1	66.8	23.1	0	1B,6E, 6I, 6J, 6M, **6P**
BH101A	1.5 to 2	18.1	47.5	34.4	0	2C, **7A**, 7E
BH202	0.6 to 1	17.6	44.1	38.3	0	2C, **7A**,7D, 7E

Based on the anticipated earthworks ground solution for the site the classifications highlighted in **bold** and underlined represent the most likely use of the materials at the site (i.e as selected granular or selected cohesive fill placed to end product specification).

7.6.2.1 Earthworks Made Ground – Use as Class 7A1, 6N or 6P

Re-engineering of the Made Ground as Class 7A1 or Class 6N/6P structural fill is the clients preferred earthworks solution. Note that the cohesive Made Ground does not meet the plasticity requirements for a class 7A material so a class 7A1 sub-class is proposed. Suggested limits for incorporation into Table 6/1 of an earthworks specification for Class 7A1, 6N or 6P materials are given in Tables 16 to 18. Note that a full earthworks design and specification should be prepared as part of detailed design works.

Table 16 SHW- Table 6/1 Class 6N requirements

Class	General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601)	Material Properties for Acceptability (in Addition to use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements, Table 6/4 of SHW Series 600, Clause 612
				Property (See Exemptions in Previous Column)	Defined & Tested in Accordance with:	Acceptable Limits Within:*		
						Lower	Upper	
6N	Selected Well Graded Granular Material	Fill to Structures	Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well-burnt colliery spoil or any combination thereof. None of these constituents shall include any argillaceous rock. Recycled aggregate except recycled asphalt.	90) Grading ii) Uniformity coefficient iii) Los Angeles Coefficient iv) Effective angle of internal friction vi) Moisture Content	BS 1377: Part 2 (on-site) Clause 635 SHW Clause 636 BS 1377 Part 2	Tab 6/2 10 - 35 To Suit end product	Tab 6/2 - 40 To Suit End product	End product 95% of maximum dry density of BS 1377: Part 4 (vibrating hammer method Plate bearing test on 600 mm dia plate to settle less than 4 mm across stress range zero to 200 kN/m^2

Table 17 SHW- Table 6/1 Class 6P requirements

Class	General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601)	Material Properties for Acceptability (in Addition to use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements, Table 6/4 of SHW Series 600, Clause 612
				Property (See Exemptions in Previous Column)	Defined & Tested in Accordance with:	Acceptable Limits Within:*		
						Lower	Upper	
6P	Selected Well Graded Granular Material	Fill to Structures	Natural gravel, natural sand, crushed gravel, crushed rock, crushed concrete, well-burnt colliery spoil or any combination thereof. None of these constituents shall include any argillaceous rock. Recycled aggregate except recycled asphalt.	90) Grading ii) Uniformity coefficient iii) Los Angeles Coefficient iv) Effective angle of internal friction vi) Moisture Content	BS 1377: Part 2 (on-site) Clause 635 SHW Clause 636 BS 1377 Part 2	Tab 6/2 5 - 35 To Suit end product	Tab 6/2 - 60 To Suit End product	End product 95% of maximum dry density of BS 1377: Part 4 (vibrating hammer method Plate bearing test on 600 mm dia plate to settle less than 4 mm across stress range zero to 200 kN/m^2

Note that the Los Angeles Co-efficient requirements for 6N or 6P are appropriate if sufficient coarse aggregate is present in the materials

Table 18 SHW- Table 6/1 Class 7A1 requirements

Class	General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601)	Material Properties for Acceptability (in Addition to use of Fill Materials in Clause 601 and Testing in Clause 631) Property (See Exemptions in Previous Column)	Defined & Tested in Accordance with:	Acceptable Limits Within:* Lower	Upper	Compaction Requirements, Table 6/4 of SHW Series 600, Clause 612
7A1	Selected Cohesive Fill	Fill to structures	Any material or combination of materials, other than argillaceous rock and materials designated as Class 3 in the Contract	(90) grading (ii) mc (iii) Plasticity Index (iv) Liquid Limit (v) Undrained shear strength by hand shear vane	BS 1377: part 2 BS 1377: part 4 BS1377: Part 2 BS1377: Part 2 BS 1377: part 7	Tab 6/2 To suit end product 75 kPa	Tab 6/2 To suit end product 45 - 65	End product: Minimum requirement of 100 % of maximum dry density of BS1377: Part 4 (2.5kg rammer method) or a dry density corresponding to 5 % air voids at field moisture content whichever is lower. 90 % of results to achieve dry density/ air voids/ requirement and no result to fall below 10 % air voids or 90 % maximum dry density. Plate bearing test on 600 mm dia plate to settle less than 4 mm across stress range zero to 200 kN/m^2 (see paragraph 5.5.1)

Given the variability of the Made Ground control of the earthworks will be challenging and require a high degree of skill and care from a suitably experienced earthworks contractor (see Section 7.6.4). Testing should be carried out at a suitable frequency to capture that variability. A minimum rate of testing of one sample/Insitu test per 400 tonnes is suggested at this stage and to be regularly re-assessed during works which may result in increased or decreased testing frequencies.

Following earthworks meeting the criteria defined in Tables 16 and 17 a characteristic friction angle of 35 degrees and characteristic bulk weight of 1.8 Mg/m^3 and characteristic Youngs modulus of 20 MN/m^2 may be assumed for the granular Made Ground. For the cohesive Made Ground a characteristic undrained shear strength of 75 kN/m^2, characteristic bulk weight of 2.0 Mg/m^3 and characteristic co-efficient of volume compressibility of 0.05 m^2/MN may be assumed following earthworks meeting the criteria defined in Table 18.

7.6.3 Earthworks Pennine Middle Coal Measures CLAY

Pennine Middle Coal Measures have been encountered as CLAY materials in the upper 1 to 2 m (with local exceptions particularly to the east of the site where MUDSTONES were encountered at shallow depth). The POTENTIAL classifications of the materials in the context of the Specification for Highways works on the basis of grading and index properties is summarised in Table 19. It should be noted that the actual earthworks classification of a particular material is dependant on its grading, other material parameters (detailed in Table 6/1 of Series 600) AND on how the materials are used and compacted. Material classification is not therefore solely based on the material properties. As a result (and as an example) a particular material may be USED as Class 2 general cohesive fill (compacted by Method Specification) if used in that manner and the identical material USED as Class 7A selected cohesive fill (compacted to end product specification). In this case all class 7A materials can be used as Class 2 but not all Class 2 materials can be used as Class 7A.

Table 19 Earthworks Classifications based on Particle Size Distribution and Plasticity tests

Sample Ref		Potential Series 600 Classification
TP440	0.5	2B,**7A**,7E, 7I
TP442	1.2	2C, **7A,** 7E, 7I
TP443	3.5	U1A, 7E, 7I
TP445	3	2A, **7A**,7E, 7I
TP446	0.8	2B,**7A**,7E, 7I
TP446	1.3	2B,**7A**,7E, 7I
TP450	2.5	2A, **7A**,7E, 7I
BH203	0.7	1B, 6E, 6I, 6J, 6M, **6P**
TP440	1	2C, **7A,** 7E, 7I
TP450	3.9	2A, **7A**,7E, 7I

7.6.3.1 Earthworks Pennine Middle Coal Measures CLAY – Use as Class 7A1

Re-engineering of the Made Ground as Class 7A1 or Class 6N/6P structural fill is the clients preferred earthworks solution. Note that the Pennine Middle Coal Measures CLAY does not meet the plasticity requirements for a class 7A material so a class 7A1 sub-class is proposed. Suggested limits for incorporation into Table 6/1 of an earthworks specification for Class 7A1, given in Tables 20. Note that a full earthworks design and specification should be prepared as part of detailed design works.

Table 20 SHW- Table 6/1 Class 7A1 requirements

Class	General Material Description	Typical Use	Permitted Constituents (All Subject to Requirements of Clause 601)	Material Properties for Acceptability (in Addition to use of Fill Materials in Clause 601 and Testing in Clause 631)				Compaction Requirements, Table 6/4 of SHW Series 600, Clause 612
				Property (See Exemptions in Previous Column)	Defined & Tested in Accordance with:	Acceptable Limits Within:*		
						Lower	Upper	
7A1	Selected Cohesive Fill	Fill to structures	Any material or combination of materials, other than argillaceous rock and materials designated as Class 3 in the Contract	(90) grading (ii) mc (iii) Plasticity Index (iv) Liquid Limit (v) Undrained shear strength by hand shear vane	BS 1377: part 2 BS 1377: part 4 BS1377: Part 2 BS1377: Part 2 BS 1377: part 7	Tab 6/2 To suit end product 75 kPa	Tab 6/2 To suit end product 45 - 65	End product: Minimum requirement of 100 % of maximum dry density of BS1377: Part 4 (2.5kg rammer method) or a dry density corresponding to 5 % air voids at field moisture content whichever is lower. 90 % of results to achieve dry density/ air voids/ requirement and no result to fall below 10 % air voids or 90 % maximum dry density. Plate bearing test on 600 mm dia plate to settle less than 4 mm across stress range zero to 200 kN/m^2 (see paragraph 5.5.1)

7.6.4 Earthworks General Considerations

The earthworks testing and field observations have indicated that the Made Ground materials in particular are very variable and will prove to be a challenging material to work with form a perspective of earthworks control. Difficulties lie in the range of maximum dry densities that exist for the Made Ground materials (current lab data suggests a range of between 1.63 and 1.8 Mg/m^3 but based on field observations a wider variation should be anticipated) and the variation in natural moisture content throughout the materials (13 to 29 %) and in particular we would anticipate that there will be difficulties in selection of appropriate laboratory Maximum Dry Density results to relate to insitu density tests. It is critical therefore that earthworks are carried out by an earthworks contractor experienced in compaction control in such materials and that the works are closely supervised to ensure their successful implementation. Additionally it is likely that some of the Made Ground materials will require some measure of processing in order to be successfully incorporated into the works. It is strongly recommended that any prospective earthworks contractor carries out their own investigations to gain further understanding of the nature of the soils to be re-used at the site and from such works makes appropriate allowance for any processing measures considered necessary. GIVEN THE VARIABILITY OF THE SITE SOILS IT WILL BE BENEFICIAL TO MINIMISE THE VOLUMES OF MATERIALS INCORPORATED INTO EARTHWORKS THROUGH THE USE OF INSITU GROUND IMPROVEMENT TECHNIQUES WHERE POSSIBLE AND THIS SHOULD BE REFINED DURING DETAILED DESIGN.

Similar variations in properties exist for the Pennine Middle Coal, although site classification of the natural soils will be less difficult (albeit still require due skill and care). Moisture content control during earthworks will be of particular importance for materials used as Class 7A1 soils as the acceptable moisture content window is likely to be in a window of approximately 4 % in order to meet the class 7A1 end product compaction criteria.

Based on current groundwater data (which is ongoing and will be updated) groundwater levels are generally below 2.5 m from existing ground levels. However shallower groundwater was encountered during previous investigations carried out by NOVA consulting as shallow as 0.71 m bgl. While this shallow water may represent perched water horizons within the Made Ground they may also reflect seasonal variations. Groundwater control will be critical during any earthworks operations and it will be beneficial to limit the excavation depths where possible (2 m is suggested) to limit the magnitude of groundwater control measures and minimise the generation of high moisture content materials which will present problems for earthworks control.

An environmental assessment is being prepared by NOVA consulting which should be consulted with respect to contaminated land issues that may need to be accounted for during earthworks operations.

NOTE THAT IN AREAS OF DEEPER MADE GROUND IT IS RECOMMENDED THAT INSITU GROUND IMPROVEMENT WORKS ARE CARRIED OUT AT THE BASE OF THE ENGINEERED FILL – SEE SECTION 7.7

7.7 Dynamic Compaction

The ground conditions at the site are considered suitable for improvement by Dynamic Compaction methods. In the western half of the site the made ground thickness increases to approximately 5.5

m below existing ground level (at the current building edge of unit 2) and increasing further towards the western boundary. Light dynamic compaction (such as Rapid Impact Compaction or the similar proprietary CDC methods) is considered a viable solution to mitigate the risks associated with the deeper Made Ground in the west of the site. For building areas such treatment should be carried out for full building footprint and a 5 m perimeter around the building. Following such treatment (carried out from the underside elevation of any earthworks) a characteristic friction angle of 35 degrees, characteristic youngs modulus throughout the treated material of around 12.5 MN/m^2 and bulk density of 1.8 Mg/m^3 may be assumed. Note higher values may in fact be achievable so the advice of specialist subcontractors should be sought. During dynamic compaction works, any areas that do not respond appropriately to the selected technique will need to be identified and suitable alternative treatment carried out. For dynamic compaction works vibration issues may need to be addressed particularly with respect to the Terraced housing to the north of the site.

Conventional heavy dynamic compaction would also technically be suitable at the site, however issues associated with vibration and flying debris affecting the nearby public highway and residential properties would be more pronounced and may rule it out as a practical option for parts of the site.

Ground improvement by rolling dynamic compaction (such as High Energy Impact Compaction) may be considered as an alternative in non structural areas (yards and roads) to minimise long term differential movements under pavements. If this is adopted it is recommended that the upper 450 mm is placed (replaced) as engineered fill in accordance with section 7.6. Insitu rolling dynamic compaction is not generally considered suitable for materials intended to support foundation loadings.

Dynamic compaction works should be carried out in accordance with a suitable dynamic compaction specification that includes (amongst other details) details of testing to be carried out. For the preliminary design concept it is recommended that such testing includes pre and post DC SCPT testing to the full depth of the Made Ground at a minimum rate of one position per 500 m^2 to demonstrate that the treatment sufficiently affects the full depth of Made Ground and demonstrates a minimum cone resistance of 5 Mpa in granular soils and 1.5 Mpa in cohesive soils together with the friction angle and youngs modulus requirements stated above. Additionally Zone testing (pad maintained load test in general accordance with BS1377 Part 9 section 4.2) carried out on 2m x 2m plate loaded to 150 kN/m^2 should be carried out at a rate of 1 test per 5000 m^2 on the finished DC surface maintained for a period of at least 1 week with a total settlement limit of 15 mm.

Note that a sewer passes through the site in a west east direction which will need to be accounted for during detailed design.

7.8 Soils Stabilisation

The Made Ground materials at the site are generally unsuitable for Lime Stabilisation due to their predominantly granular nature. Cement stabilisation may however be considered in which case the soils would be treated as class 6E soils (see table 15) in accordance with the specification for highways works. The advice of specialist contractors should be sought if stabilisation is be considered further and a programme of suitability and design testing would need to be carried out to confirm stabilisation mix designs in accordance with the recommendations presented in Design Manual for Roads and Bridges Volume 4 Section 1 Part 6 – HA74/04.

7.9 Temporary Working Platforms

A temporary working platform may be required for support of large plant or cranes during construction. The parameters presented Section 6 may be used for temporary working platform design carried out in accordance with BRE470 with the appropriate parameters selected based on the actual level from which work is carried out. It is strongly recommended for any temporary working platform that the subgrade is proof rolled to identify any soft spots which should then be removed and replaced with suitably compacted granular fill. Plate bearing tests should be carried out on both on the subgrade and at finished platform level to confirm the design parameters.

7.10 Retaining Walls

Preliminary retaining wall design may be based on the parameters presented in Section 6 of this report, subject to due consideration of variations in ground conditions local to such structures. For simple design purposes for small walls (< 2 m retained height within the main site area) a characteristic friction angle of 35 degrees and characteristic bulk density of 1.8 Mg/m^3 may be assumed for re-engineered Made Ground and for Pennine Middle Coal measures CLAY a characteristic undrained shear strength of 70 kN/m^2, characteristic bulk unit weight of 2.0 Mg/m^3, characteristic drained cohesion of 3 kN/m^2 and characteristic friction angle of 22 degrees may be used. For larger boundary retaining walls (including an augered King Post wall proposed at the site boundary) these values may also be used for preliminary design, however additional structure specific investigation would be recommended to confirm local soil profiles and properties.

7.11 Pavement Design

Insitu plate CBR testing carried out on the existing Made Ground at the site have indicating a wide variation in CBR values of between 0.5 and 31 %. This variation is as would be anticipated for the mixed Made Ground materials. Following re-engineering as Class 6N or 6P a Characteristic CBR of 10 % would be considered appropriate for pavement and hardstanding design purposes. The Made Ground varies from being frost susceptible to non frost susceptible so it is recommended that design is based on it being frost susceptible with a minimum of 450 mm pavement construction (suitably adjusted for climate frost index) being recommended.

7.12 Soakaways

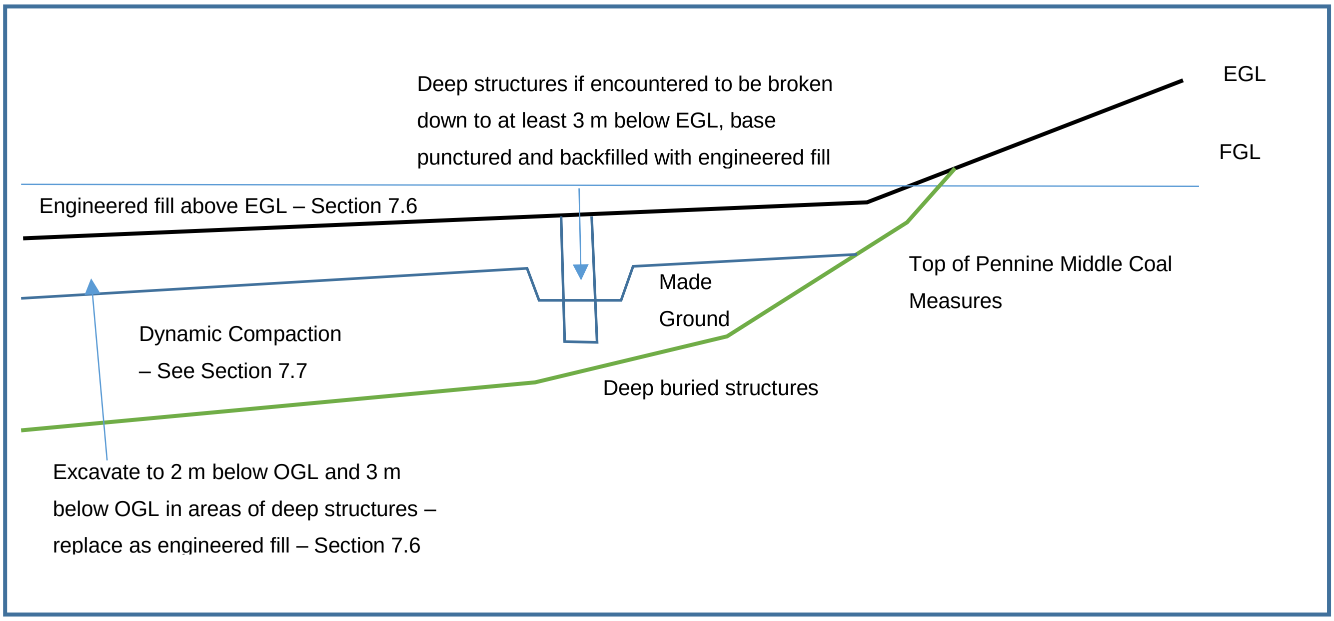
Soakaway testing in the existing Made Ground indicates infiltration rates of between 4×10^{-5} m/s and 4×10^{-4} m/s which indicates soakaways in the existing Made Ground may be feasible. However it should be noted that the properties of the Made Ground will be changed following any re-engineering and the values recorded are likely to be higher than those that will prevail following earthworks and ground improvement. Additionally it is recommended that the Environmental Consultant is consulted to determine if soakaways are allowable in light of the contamination issues at the site.

7.13 Buried Concrete

Testing for pH and water soluble sulphate revealed soil pH to range between 4.4 and 8.6 and soluble sulphate values of between 153 and 590 mg/l indicating that the soil conditions classify generally as DS1-AC1 with respect to attack on buried concrete in accordance with BRE Special Digest 1. However some of the Made Ground classifies as DS2- AC5Z due to localised acidic conditions. Given the bulk earthworks proposals, ongoing testing of earthworks materials should be carried out to confirm buried concrete classifications.

8 SUMMARY

- The proposed development at the site comprises 2 Industrial Units with associated hardstanding and roadways.
- The ground investigation has revealed underlying geology at the site to comprise Made Ground over Middle Pennine Coal Measures CLAY and Middle Pennine Coal Measures Mudstones and Siltstones.
- The Made Ground is largely granular (but with cohesive inclusions) and generally increases in thickness from east to west and is up to around 5.5 m in thickness to the west of Unit 2 and up to 8 m thick on the western boundary.
- Perched and shallow groundwaters are present at the site and careful attention should be paid to groundwater control issues including limiting excavation depths where possible.
- Based on the available information the Geotechnical Categorisation for the development is **CATEGORY 2 – CONVENTIONAL STRUCTURES WITH NO EXCEPTIONAL RISK** in accordance with BS EN 1997-1
- The Made Ground at the site is not suitable for carrying floor slab or foundation loadings in its current condition.
- The broad preliminary (tender) design concept has been developed in consultation with BE Design and is illustrated below (note a full and complete geotechnical design and should be validated, updated and expanded upon as appropriate by the responsible designer as part of the detailed design work for the project)



- The quantum of required treatment will decrease towards the east of the site where the Made Ground is thin or absent.

- Engineered fill should be placed to meet the requirements of Section 7.6 and dynamic compaction works carried out to meet the requirements of section 7.7.
- Following such treatment total settlement of floor slabs should not exceed 25 mm with differential settlement < 1:500.
- Initial foundation sizings may be based on a bearing pressure of 150 kN/m^2 with full Eurocodes ULS and SLS verifications to be carried out to refine sizing at detailed design stage.
- Insitu ground treatment by rolling dynamic compaction may be used in non structural areas (yards and other pavement areas) in combination with recompaction of the upper 450 mm in accordance with the requirements of section 7.6.
- A characteristic CBR of 10 % may be assumed for the suitably re-engineered granular Made Ground and 5 % for the suitably re-engineered cohesive Made Ground.
- Stone columns are technically viable and may be considered if financially favourable.
- Soil stabilisation (cement stabilisation) may be considered at the site.
- Preliminary retaining wall design may be based on the parameters presented in Section 6 of this report, subject to due consideration of variations in ground conditions local to such structures. For larger boundary retaining walls (including an augered King Post wall proposed at the site boundary) these values may also be used for preliminary design, however additional structure specific investigation would be recommended to confirm local soil profiles and properties at the site boundary and to assist with design of boundary slopes.
- Given the variability of the materials encountered at the site, earthworks operations will require a high degree of skill and care and it will be beneficial where possible to minimise earthworks volumes. The Environmental Consultants reports (in preparation) should be referred to once available to confirm any contaminated land implications for the earthworks operation.

- Soil conditions classify generally as DS1-AC1 with respect to attack on buried concrete in accordance with BRE Special Digest 1. However some of the Made Ground classifies as DS2- AC5Z due to localised acidic conditions. Given the bulk earthworks proposals, ongoing testing of earthworks materials should be carried out to confirm buried concrete classifications.

For **Discovery CE Limited**

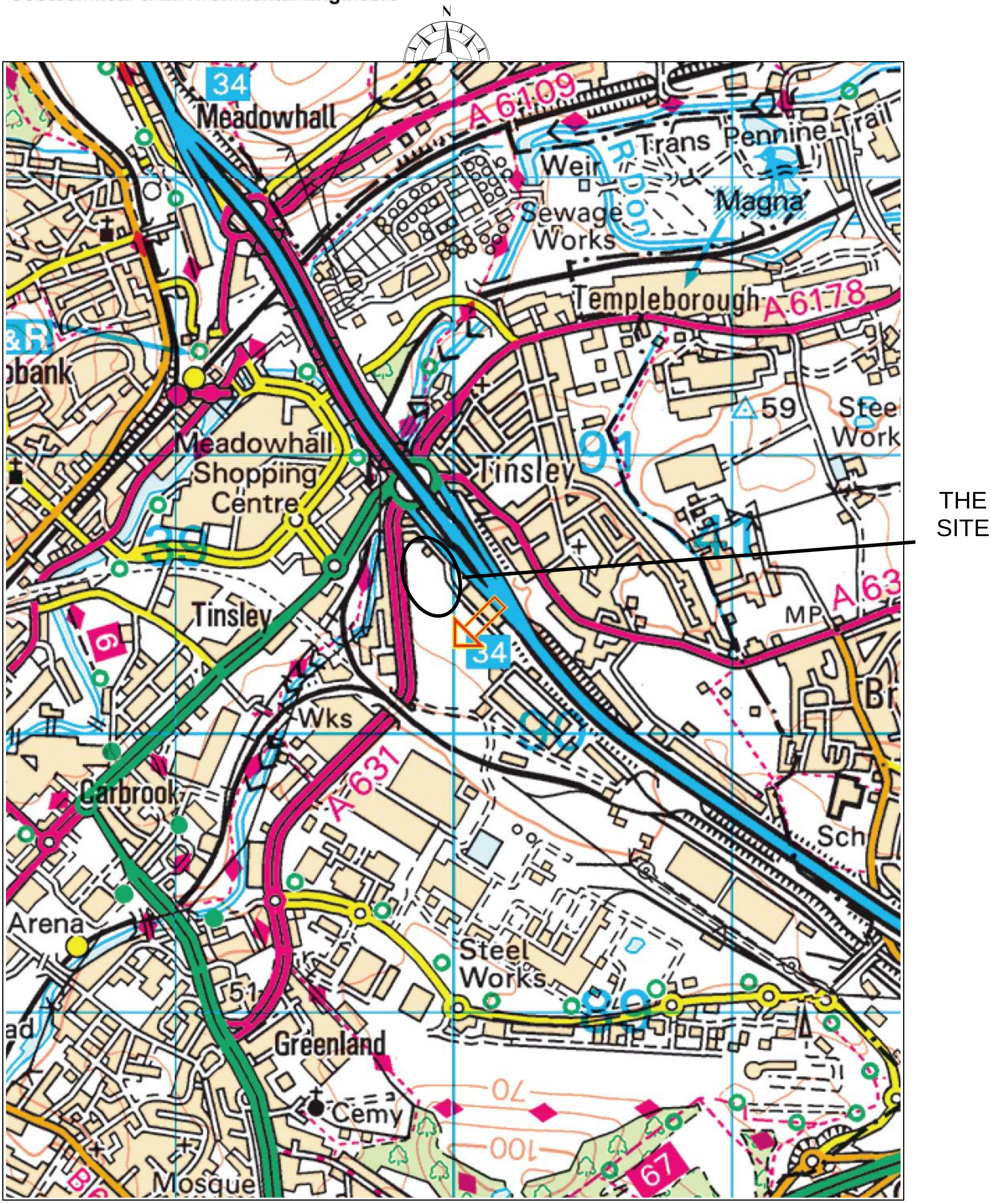
Cathl Gillespie
BEng, MSc (Eng)
Director

Peter Smith
BSc, Msc (Eng), MICE, CEng
Director

APPENDIX A - FIGURES

Discovery CE

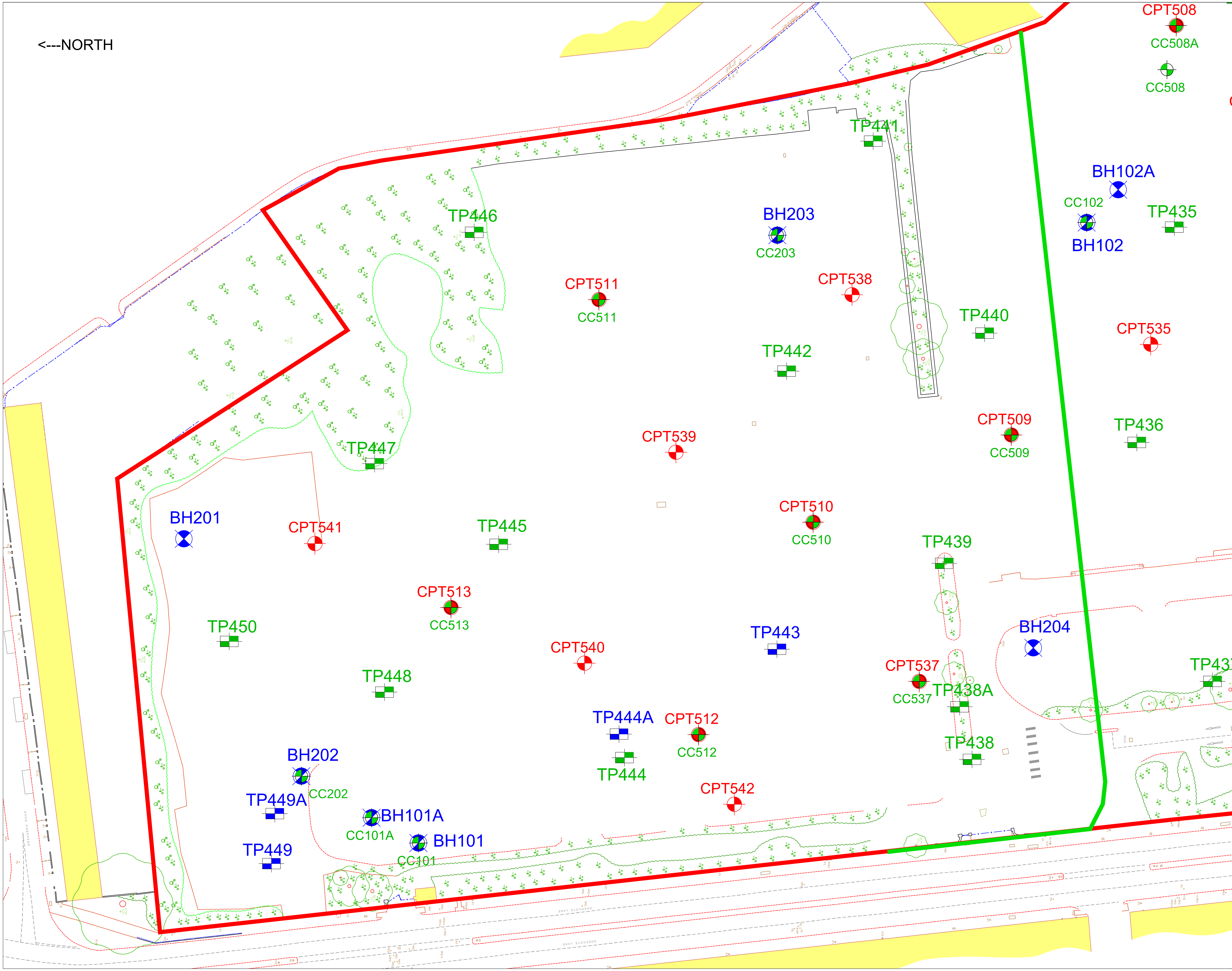
Geotechnical & Environmental Engineers



Reproduced from the Ordnance Survey 1:50,000 scale Landranger with the permission of Ordnance Survey on behalf of The Controller of Her Majesty's Stationery Office,

Figure A1
Key Plan
Site: PHASE 1, PEEL LOGISTICS SHEFFIELD
Client: PEEL LOGISTICS PROPERTY
Report No: 18012J

APPENDIX B - DRAWINGS



General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

Positions marked are as surveyed on completion of fieldwork.

Legend to symbols

DCE 2018 Investigation

BH101	Cable Percussion & Rotary Borehole
BH201	Cable Percussion Borehole
TP401	Machine Excavated Trial Pit
TP444	Machine Excavated Trial Pit (Soakaway)
CPT511	SCPT Test

Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS

Project

PHASE 1, PEEL LOGISTICS
SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
13/09/2018	18012J-03-01	NTS
Drawn By	**Checked by**	**Sheet Size**
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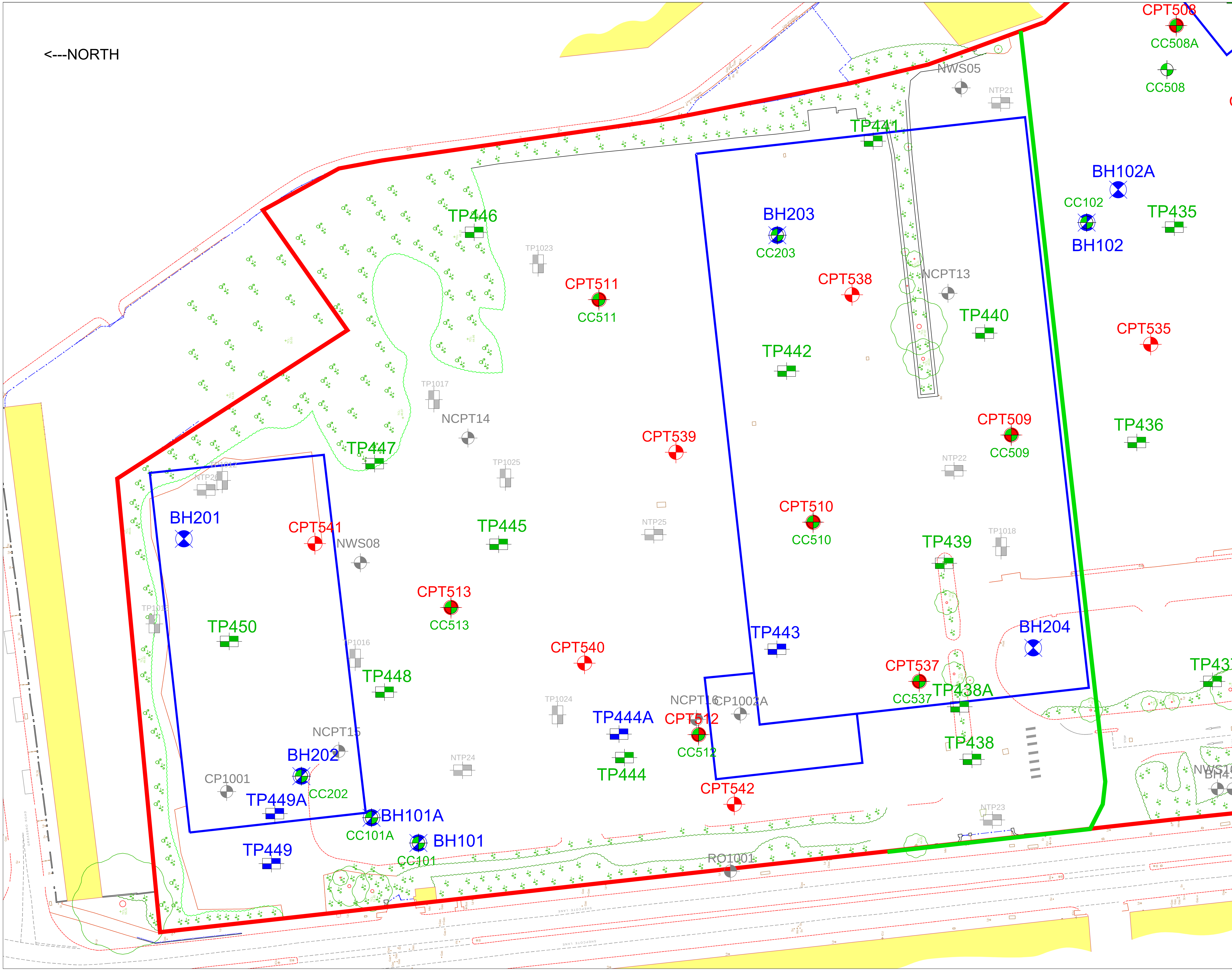

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Proposed building outlines taken from Michael Sparks Associates Drawing No. 30847-PL-201, titled 'Peel Logistics Park, Sheffield, Site Layout Plan', dated August 2017.

Legend to symbols

DCE 2018 Investigation

- BH101 — Cable Percussion & Rotary Borehole
- BH201 — Cable Percussion Borehole
- TP401 — Machine Excavated Trial Pit
- TP444 — Machine Excavated Trial Pit (Soakaway)
- CPT511 — SCPT Test

Previous Investigation

- BH25 — URS Cable Percussion Borehole, 1998 - 2005
- R3 — URS Rotary Borehole, 1998 - 2005
- CP1007 — Grontmij Cable Percussion Borehole 2009
- RO1003 — Grontmij Rotary Borehole 2009
- TP1022 — Grontmij Trial Pit 2009
- NTP15 — Nova Trial Pit 2015
- NR04 — Nova Rotary Borehole 2015
- NWS01 — Nova Window Sample Borehole 2015
- NCPT19 — Nova SCPT 2015

Proposed Building Outline

Site Boundary

Revision	Description

Title

PROPOSED DEVELOPMENT LAYOUT & AS BUILT INVESTIGATION POSITIONS

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
13/09/2018	18012J-03-02	NTS
Drawn By	**Checked by**	**Sheet Size**
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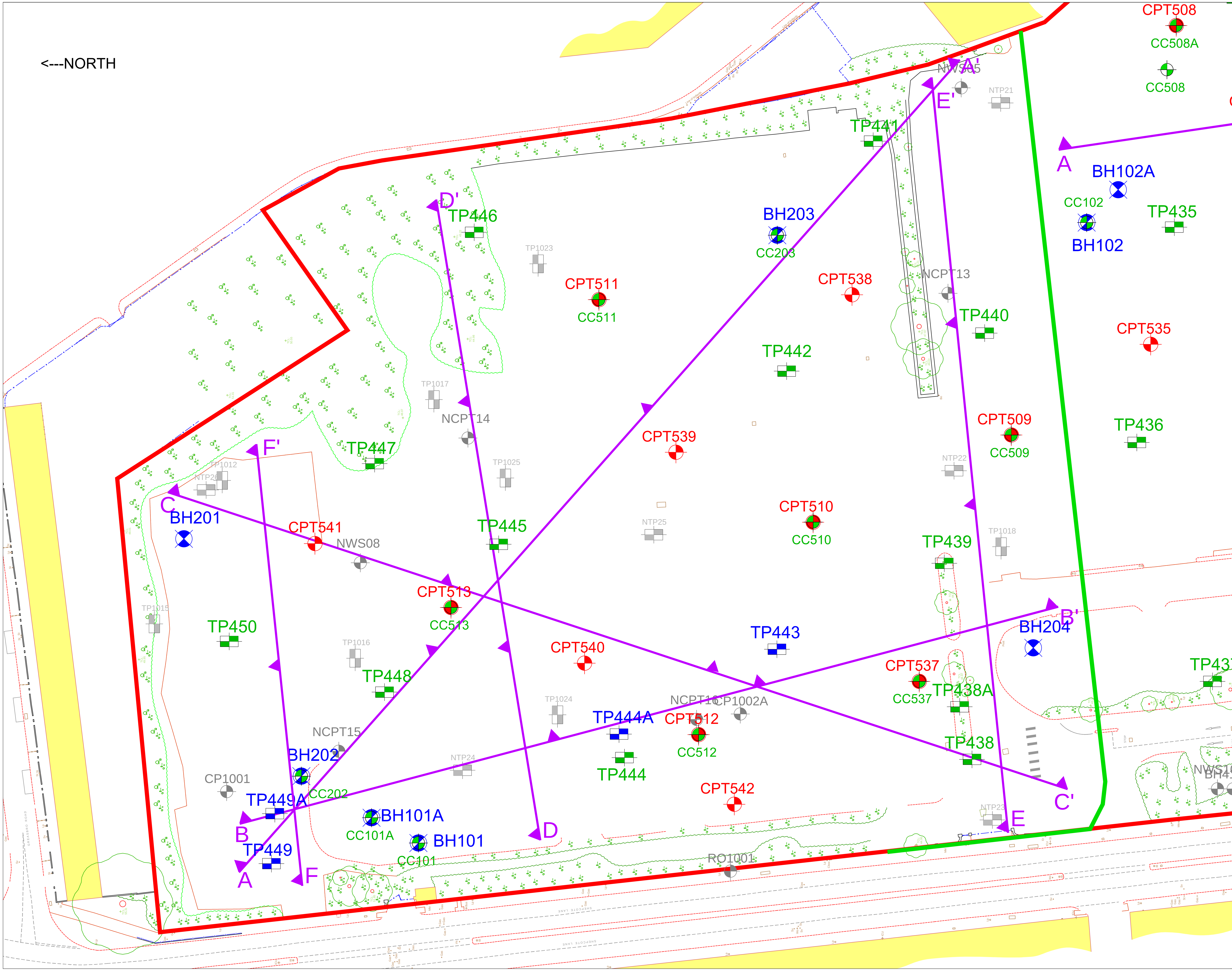

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Legend to symbols

DCE 2018 Investigation

- BH101 Cable Percussion & Rotary Borehole
- BH201 Cable Percussion Borehole
- TP401 Machine Excavated Trial Pit
- TP444 Machine Excavated Trial Pit (Soakaway)
- CPT511 SCPT Test

Previous Investigation

- BH25 URS Cable Percussion Borehole, 1998 - 2005
- R3 URS Rotary Borehole, 1998 - 2005
- CP1007 Grontmij Cable Percussion Borehole 2009
- RO1003 Grontmij Rotary Borehole 2009
- Grontmij Trial Pit 2009
- NTP10 Nova Trial Pit 2015
- NR04 Nova Rotary Borehole 2015
- NWS01 Nova Window Sample Borehole 2015
- NCPT19 Nova SCPT 2015
- B B' Cross Section Line
- Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS & CROSS SECTION LINES

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
20/09/2018	18012J-03-03	NTS
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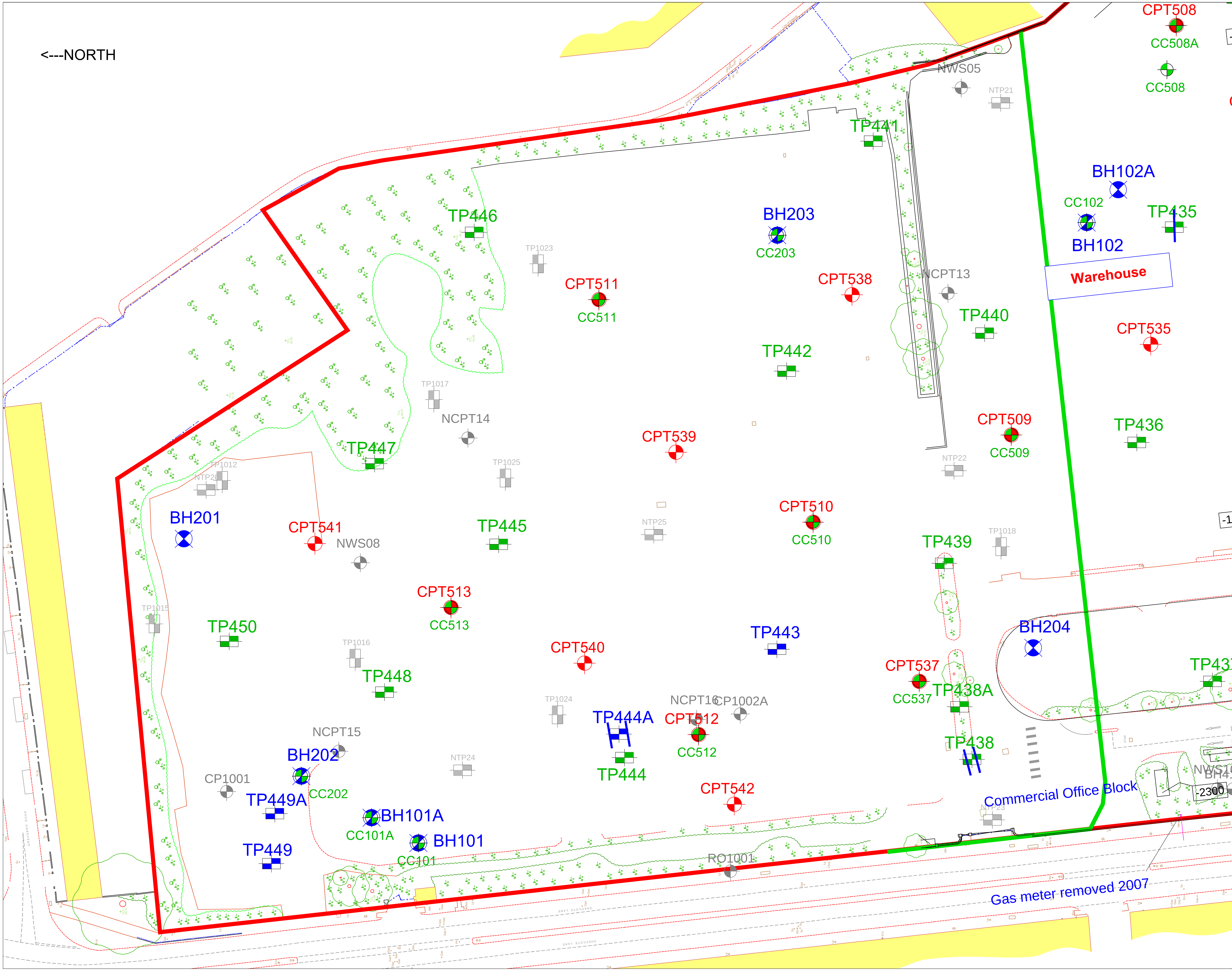

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Buried features marked as encountered or as taken from drawings supplied by Outokumpu and may be indicative only.

Legend to symbols

DCE 2018 Investigation

- BH101 — Cable Percussion & Rotary Borehole
- BH201 — Cable Percussion Borehole
- TP401 — Machine Excavated Trial Pit
- TP444 — Machine Excavated Trial Pit (Soakaway)
- CPT511 — SCPT Test

Previous Investigation

- BH25 — URS Cable Percussion Borehole, 1998 - 2005
- R3 — URS Rotary Borehole, 1998 - 2005
- CP1007 — Grontmij Cable Percussion Borehole 2009
- RO1003 — Grontmij Rotary Borehole 2009
- TP1022 — Grontmij Trial Pit 2009
- NTP15 — Nova Trial Pit 2015
- NR04 — Nova Rotary Borehole 2015
- NWS01 — Nova Window Sample Borehole 2015
- NCPT19 — Nova SCPT 2015
- Buried Wall Encountered During Fieldwork
- Site Boundary

Revision	Description

Title: AS BUILT INVESTIGATION POSITIONS & BURIED FEATURES

Project: PHASE 1, PEEL LOGISTICS SHEFFIELD

Client: PEEL LOGISTICS PROPERTY

Discovery CE — Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
13/09/2018	18012J-03-04	NTS
Drawn By	**Checked by**	**Sheet Size**
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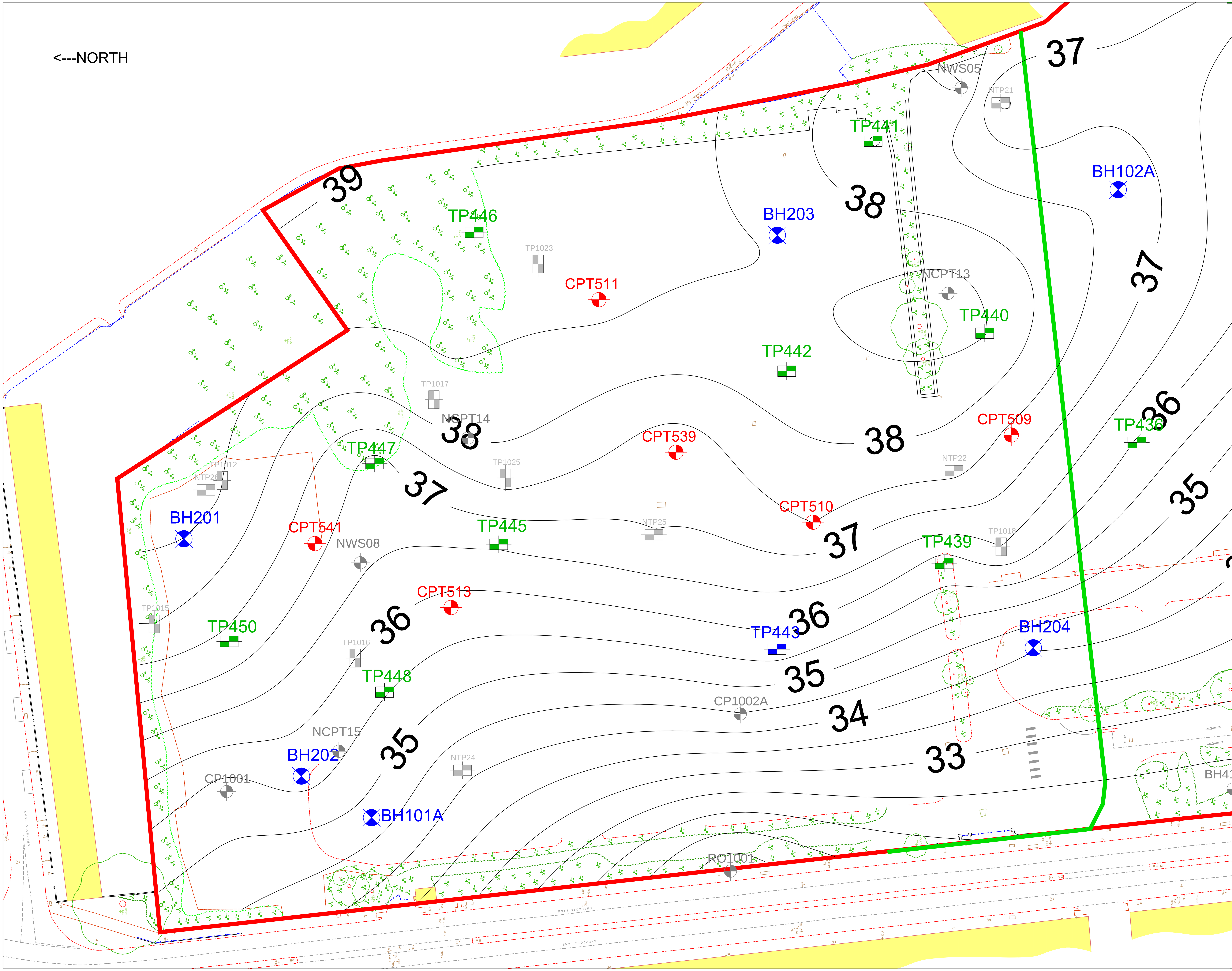

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 — Cable Percussion & Rotary Borehole
- BH201 — Cable Percussion Borehole
- TP401 — Machine Excavated Trial Pit
- TP444 — Machine Excavated Trial Pit (Soakaway)
- CPT511 — SCPT Test

Previous Investigation

- BH25 — URS Cable Percussion Borehole, 1998 - 2005
- R3 — URS Rotary Borehole, 1998 - 2005
- CP1007 — Grontmij Cable Percussion Borehole 2009
- RO1003 — Grontmij Rotary Borehole 2009
- TP1022 — Grontmij Trial Pit 2009
- NTP15 — Nova Trial Pit 2015
- NR04 — Nova Rotary Borehole 2015
- NWS01 — Nova Window Sample Borehole 2015
- NCPT19 — Nova SCPT 2015

Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS & BASE OF MADE GROUND (M AOD)

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-05	NTS
Drawn By	**Checked by**	**Sheet Size**
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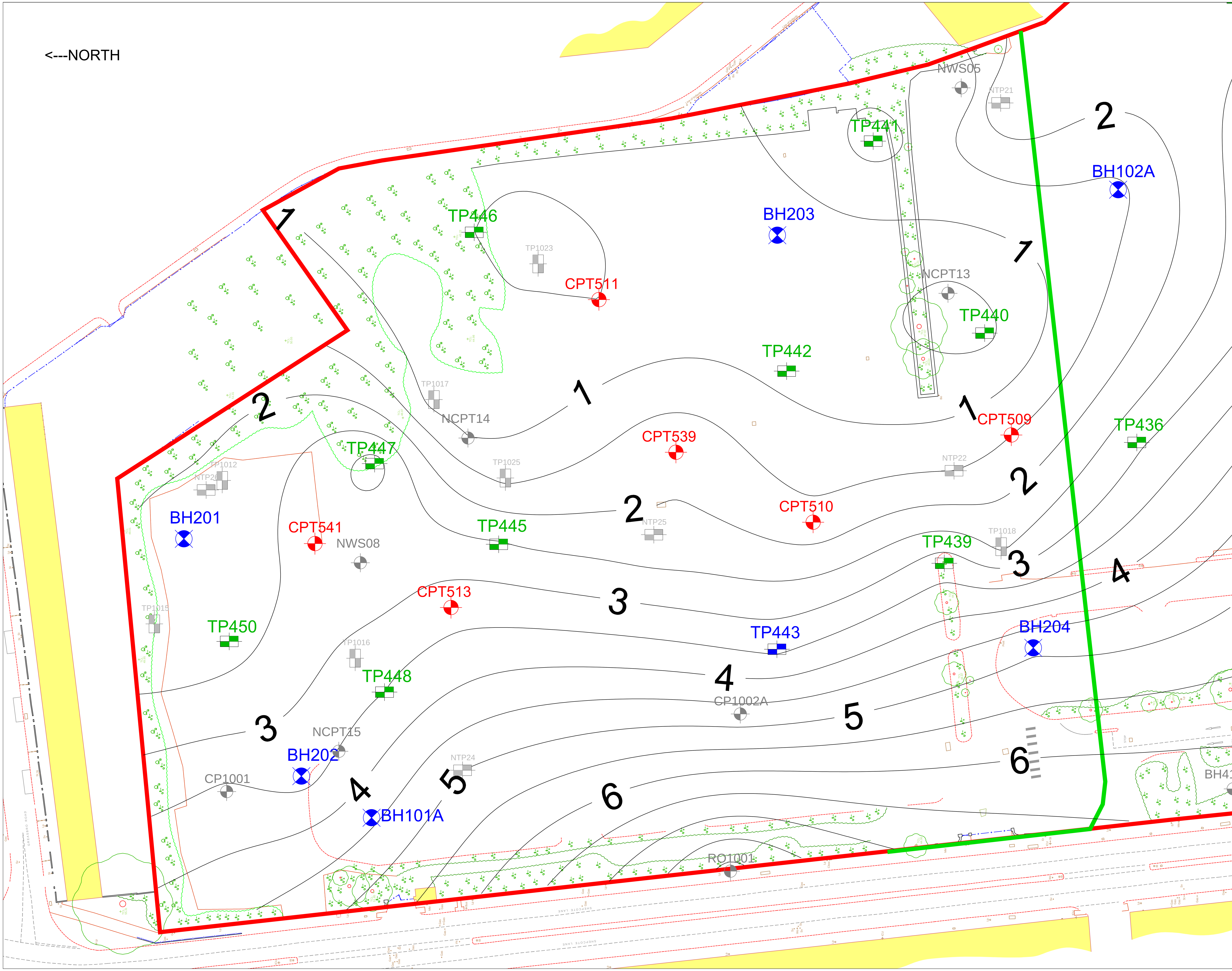


General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 Cable Percussion & Rotary Borehole
- BH201 Cable Percussion Borehole
- TP401 Machine Excavated Trial Pit
- TP444 Machine Excavated Trial Pit (Soakaway)
- CPT511 SCPT Test

Previous Investigation

- BH25 URS Cable Percussion Borehole, 1998 - 2005
- R3 URS Rotary Borehole, 1998 - 2005
- CP1007 Grontmij Cable Percussion Borehole 2009
- RO1003 Grontmij Rotary Borehole 2009
- TP1022 Grontmij Trial Pit 2009
- NTP15 Nova Trial Pit 2015
- NR04 Nova Rotary Borehole 2015
- NWS01 Nova Window Sample Borehole 2015
- NCPT19 Nova SCPT 2015

Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS & BASE OF MADE GROUND (M BGL)

Project

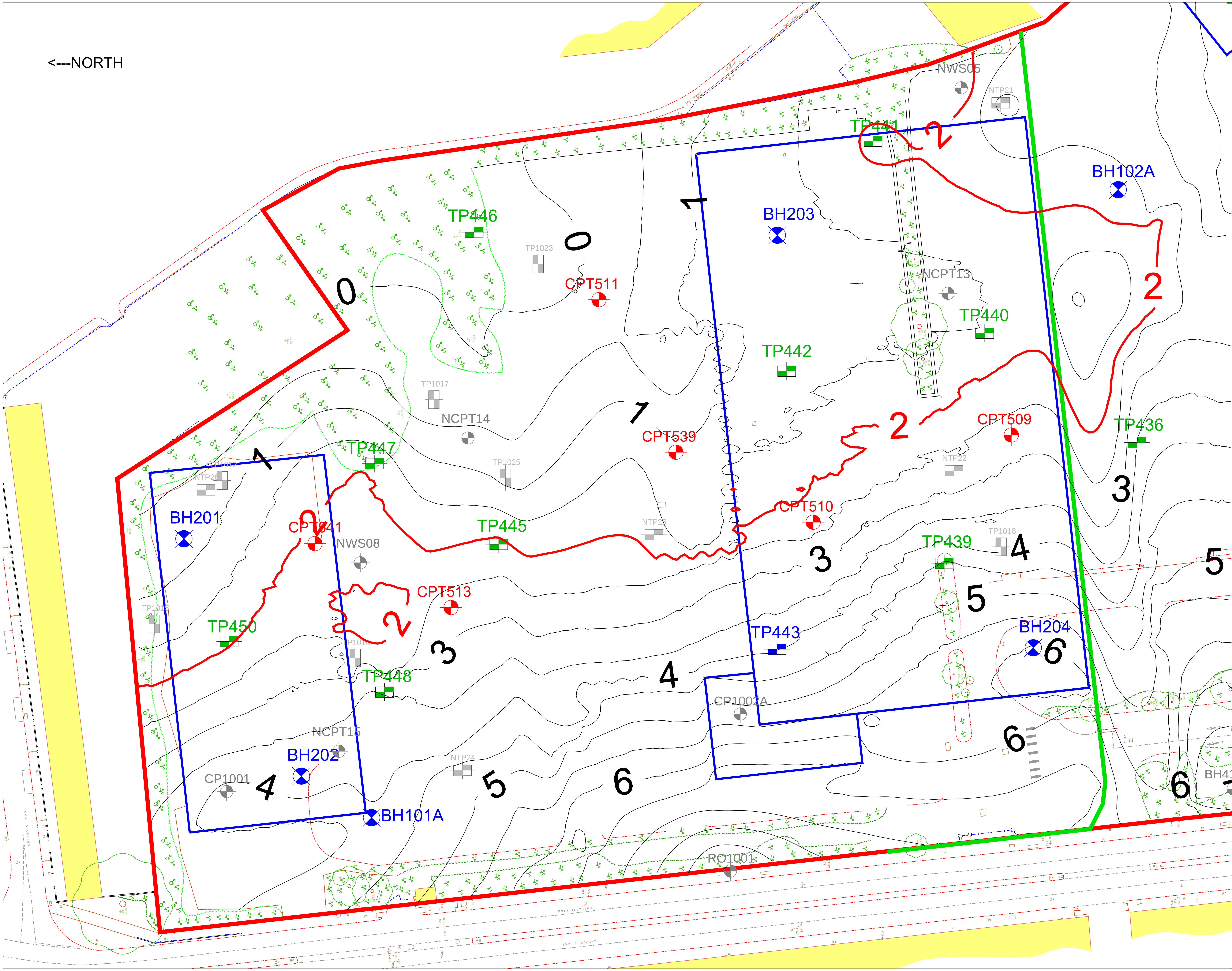
PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-06	NTS
Drawn By	Checked by	Sheet Size
MF	CG	A1



General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 Cable Percussion & Rotary Borehole
- BH201 Cable Percussion Borehole
- TP401 Machine Excavated Trial Pit
- TP444 Machine Excavated Trial Pit (Soakaway)
- CPT511 SCPT Test

Previous Investigation

- BH25 URS Cable Percussion Borehole, 1998 - 2005
- R3 URS Rotary Borehole, 1998 - 2005
- CP1007 Grontmij Cable Percussion Borehole 2009
- RO1003 Grontmij Rotary Borehole 2009
- TP1022 Grontmij Trial Pit 2009
- NTP15 Nova Trial Pit 2015
- NR04 Nova Rotary Borehole 2015
- NWS01 Nova Window Sample Borehole 2015
- NCPT19 Nova SCPT 2015

Proposed Building Outline

Site Boundary

Revision	Description

Title

BASE OF MADE GROUND BELOW PROPOSED FINISHED LEVELS (M)

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-07	NTS
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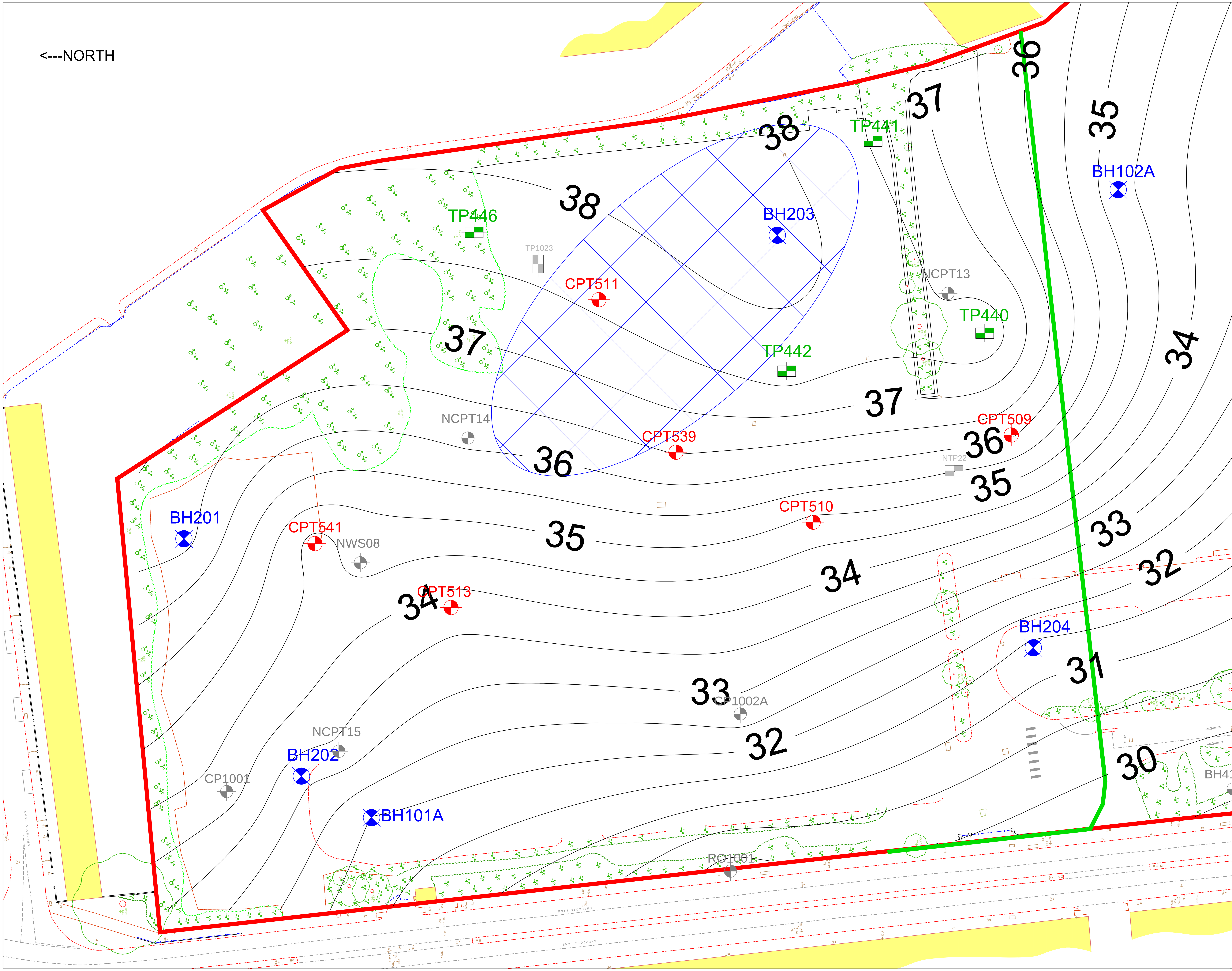

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 — Cable Percussion & Rotary Borehole
- BH201 — Cable Percussion Borehole
- TP401 — Machine Excavated Trial Pit
- TP444 — Machine Excavated Trial Pit (Soakaway)
- CPT511 — SCPT Test

Previous Investigation

- BH25 — URS Cable Percussion Borehole, 1998 - 2005
- R3 — URS Rotary Borehole, 1998 - 2005
- CP1007 — Grontmij Cable Percussion Borehole 2009
- RO1003 — Grontmij Rotary Borehole 2009
- TP1022 — Grontmij Trial Pit 2009
- NTP15 — Nova Trial Pit 2015
- NR04 — Nova Rotary Borehole 2015
- NWS01 — Nova Window Sample Borehole 2015
- NCPT19 — Nova SCPT 2015

Localised area of stiff silt extending to approximately 4 m bgl (35 m AOD) within upper layers of Pennine Middle Coal Measures Formation.

Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS & TOP OF ROCKHEAD (M AOD)

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-08	NTS
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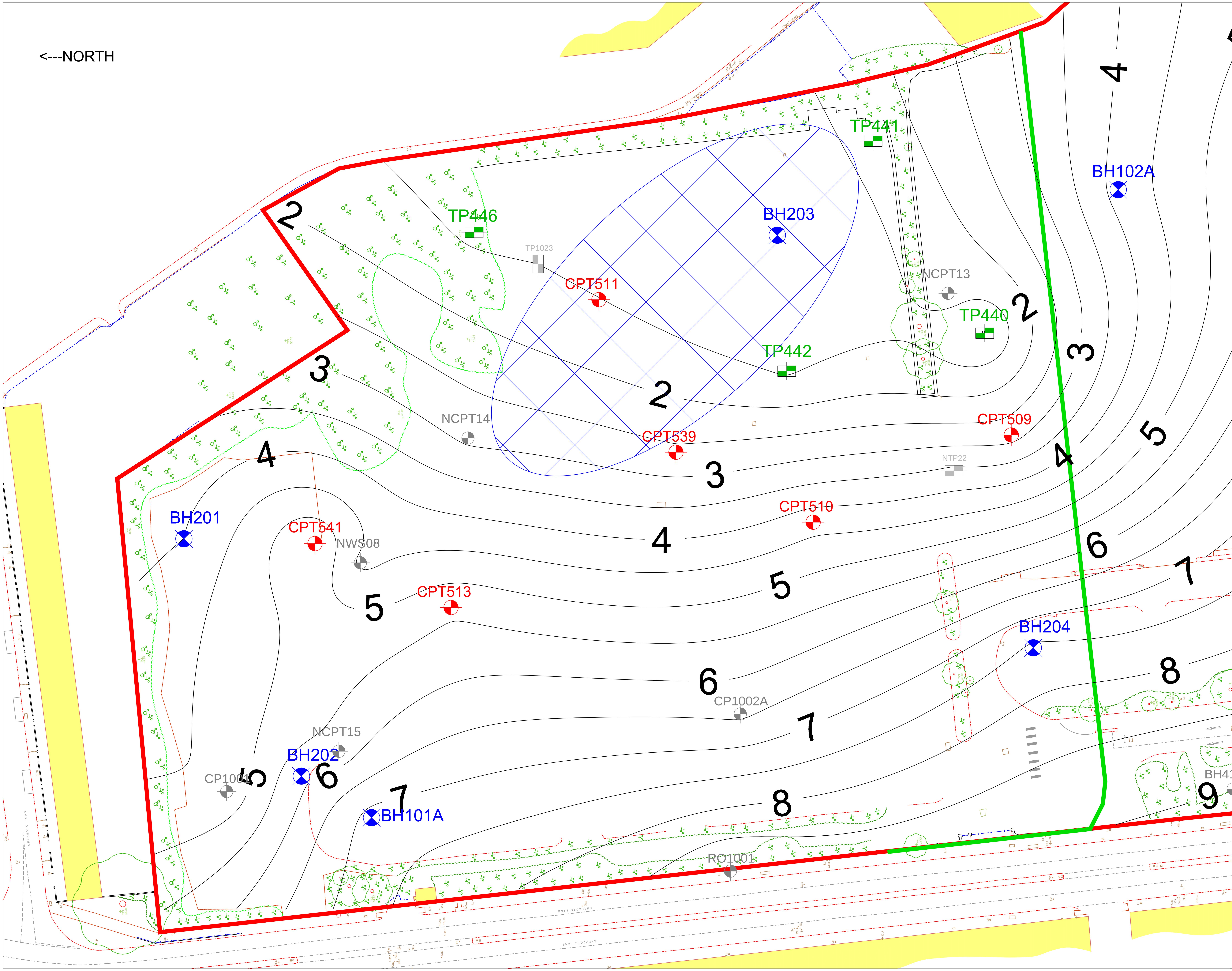

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 Cable Percussion & Rotary Borehole
- BH201 Cable Percussion Borehole
- TP401 Machine Excavated Trial Pit
- TP444 Machine Excavated Trial Pit (Soakaway)
- CPT511 SCPT Test

Previous Investigation

- BH25 URS Cable Percussion Borehole, 1998 - 2005
- R3 URS Rotary Borehole, 1998 - 2005
- CP1007 Grontmij Cable Percussion Borehole 2009
- RO1003 Grontmij Rotary Borehole 2009
- TP1022 Grontmij Trial Pit 2009
- NTP15 Nova Trial Pit 2015
- NR04 Nova Rotary Borehole 2015
- NWS01 Nova Window Sample Borehole 2015
- NCPT19 Nova SCPT 2015

Localised area of stiff silt extending to approximately 4 m bgl (35 m AOD) within upper layers of Pennine Middle Coal Measures Formation.

Site Boundary

Revision	Description

Title

AS BUILT INVESTIGATION POSITIONS & TOP OF ROCKHEAD (M BGL)

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-09	NTS
Drawn By	**Checked by**	**Sheet Size**
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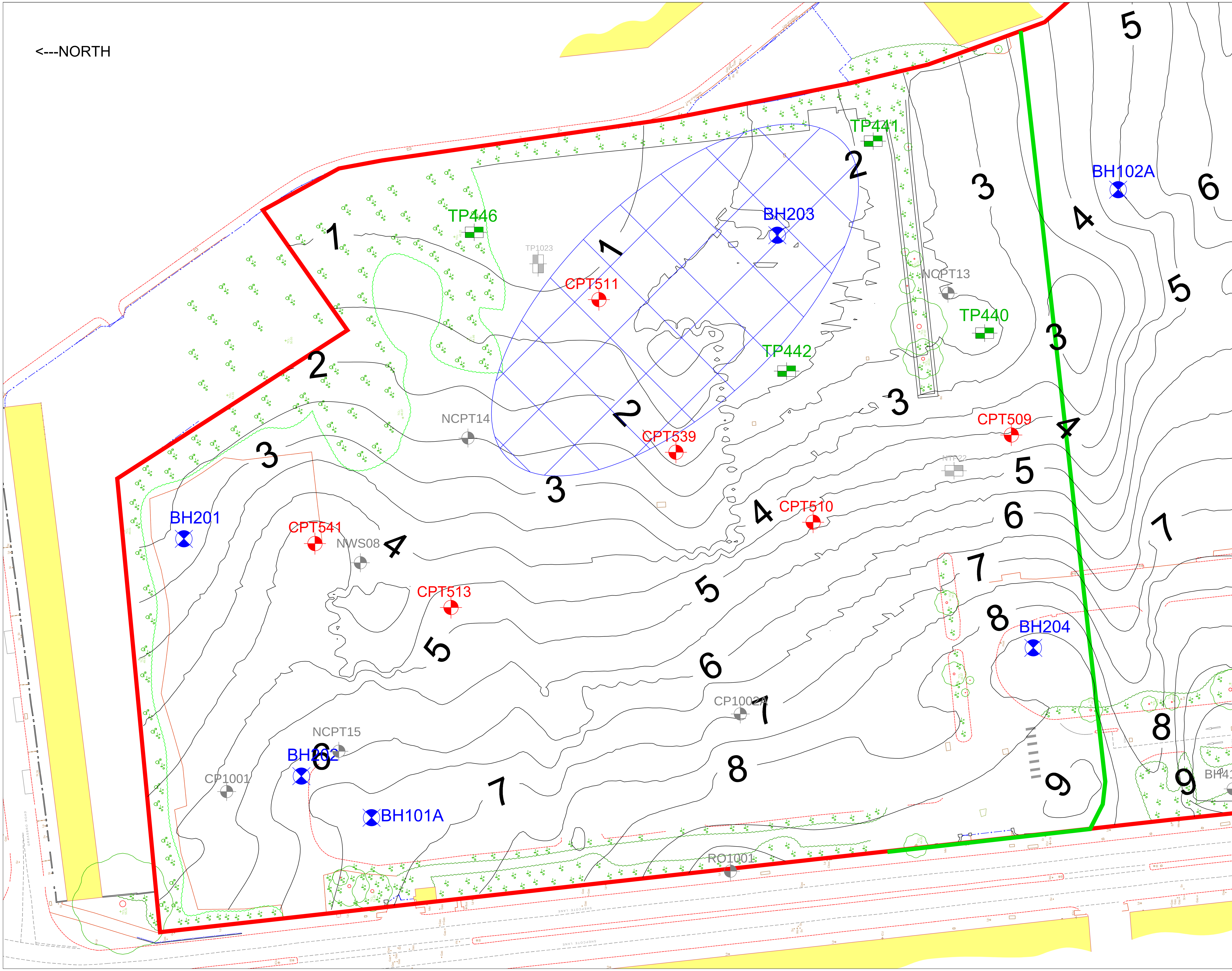

General notes

Base survey taken from Greenhatch Drawing No. 27512_T_UG, titled 'Peel Logistics Park Utility Survey', dated 15 / 08 / 17.

DCE positions are as surveyed on completion of fieldwork. Previous investigation positions are taken from coordinates on logs or from position drawings.

Contour lines are plotted based on interpolation between investigation positions and are indicative only. Ground conditions have been confirmed in investigation positions only.

Legend to symbols

DCE 2018 Investigation

- BH101 Cable Percussion & Rotary Borehole
- BH201 Cable Percussion Borehole
- TP401 Machine Excavated Trial Pit
- TP444 Machine Excavated Trial Pit (Soakaway)
- CPT511 SCPT Test

Previous Investigation

- BH25 URS Cable Percussion Borehole, 1998 - 2005
- R3 URS Rotary Borehole, 1998 - 2005
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- RO1003 Grontmij Rotary Borehole 2009
- TP1022 Grontmij Trial Pit 2009
- NTP15 Nova Trial Pit 2015
- NR04 Nova Rotary Borehole 2015
- NWS01 Nova Window Sample Borehole 2015
- NCPT19 Nova SCPT 2015

Localised area of stiff silt extending to approximately 4 m bgl (35 m AOD) within upper layers of Pennine Middle Coal Measures Formation.

Site Boundary

Revision	Description

Title

TOP OF ROCKHEAD BELOW PROPOSED FINISHED LEVELS (M)

Project

PHASE 1, PEEL LOGISTICS SHEFFIELD

Client

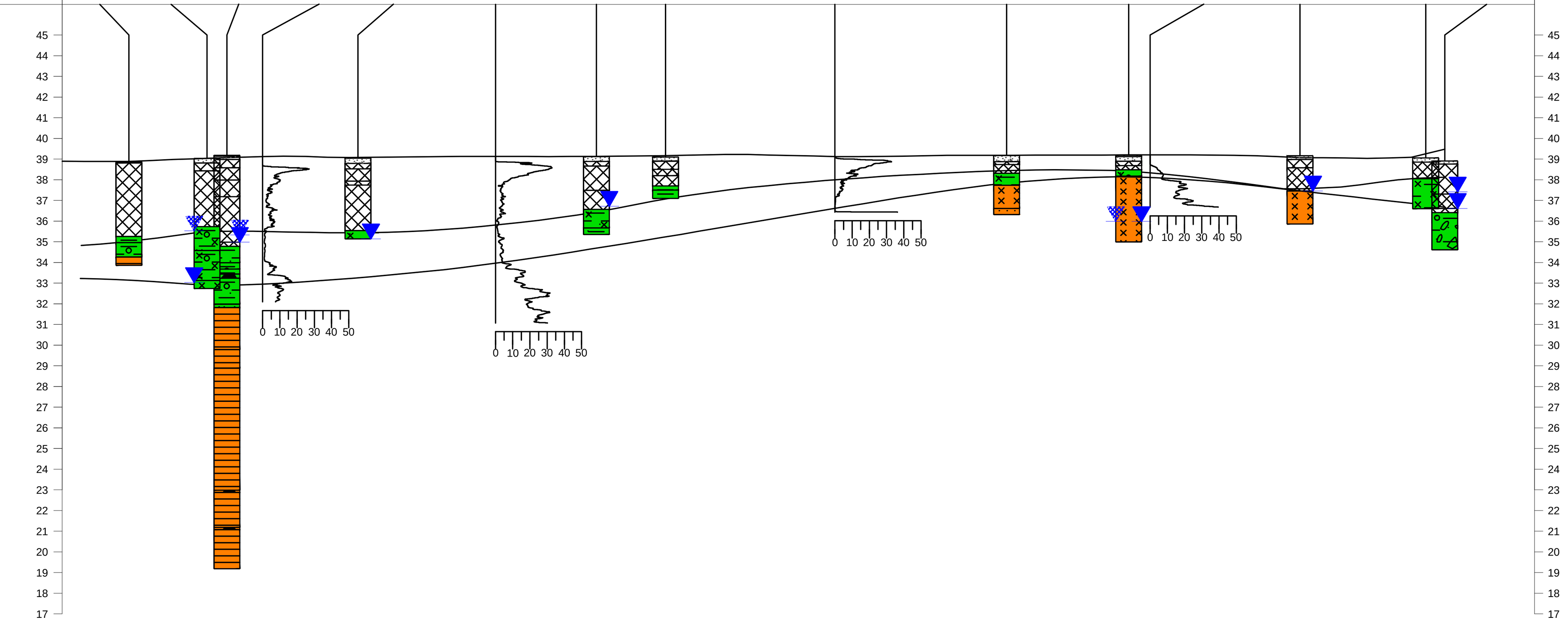
PEEL LOGISTICS PROPERTY

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
29/08/2018	18012J-03-10	NTS
Drawn By	**Checked by**	**Sheet Size**
MF	CG	A1

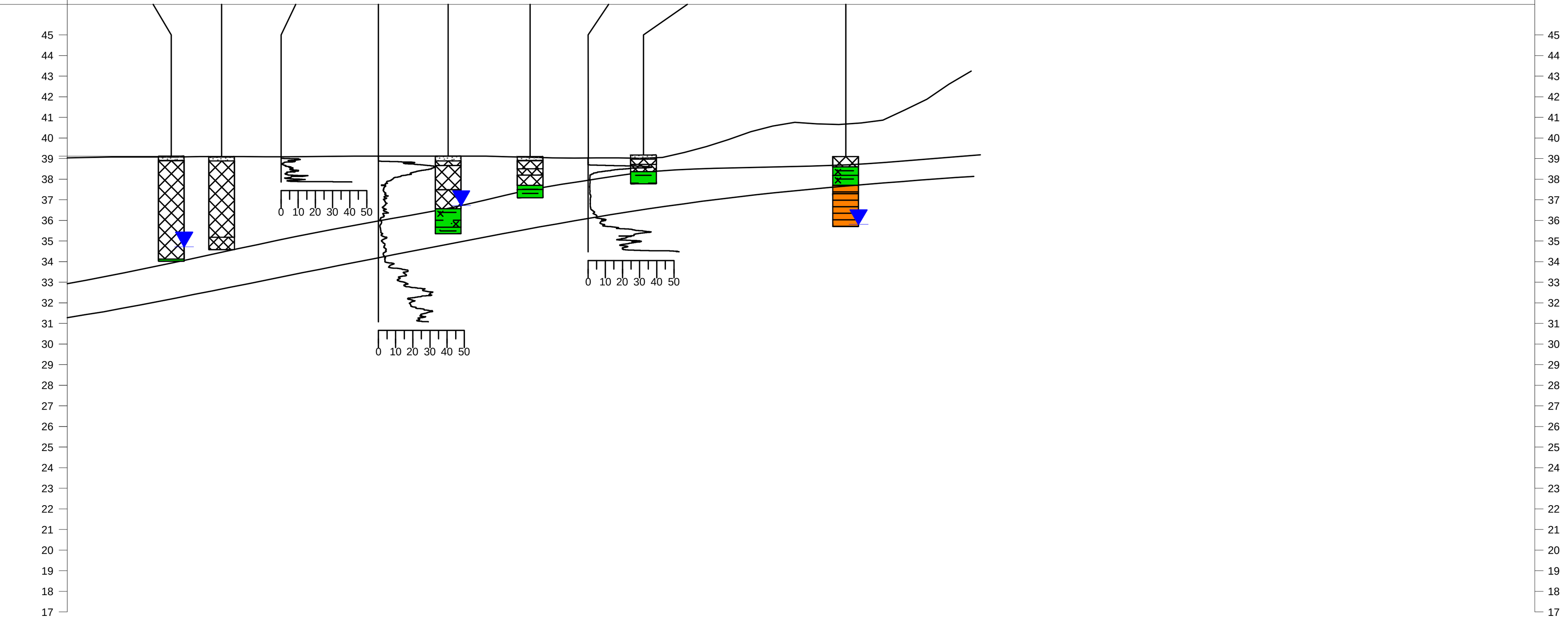
A — A'

CHAINAGE	12.92	28.05	31.88	38.80	57.26	83.86	103.38	116.76	149.54	182.75	206.37	207.62	239.54	263.85	267.56
OFFSET	15.54	4.24	-15.59	1.39	2.64	4.25	5.80	15.43	-11.91	-19.09	4.96	-18.64	2.67	-4.81	-14.66
I.D.	CP1001	BH202	BH101A	NCPT15	TP448	CPT513	TP445	TP1025	CPT539	TP442	BH203	CPT538	TP441	NWS05	NTP21
ELEVATION	38.86	39.03	39.18	39.1	39.04	39.12	39.12	39.1	39.13	39.17	39.18	39.17	39.16	39.05	38.91



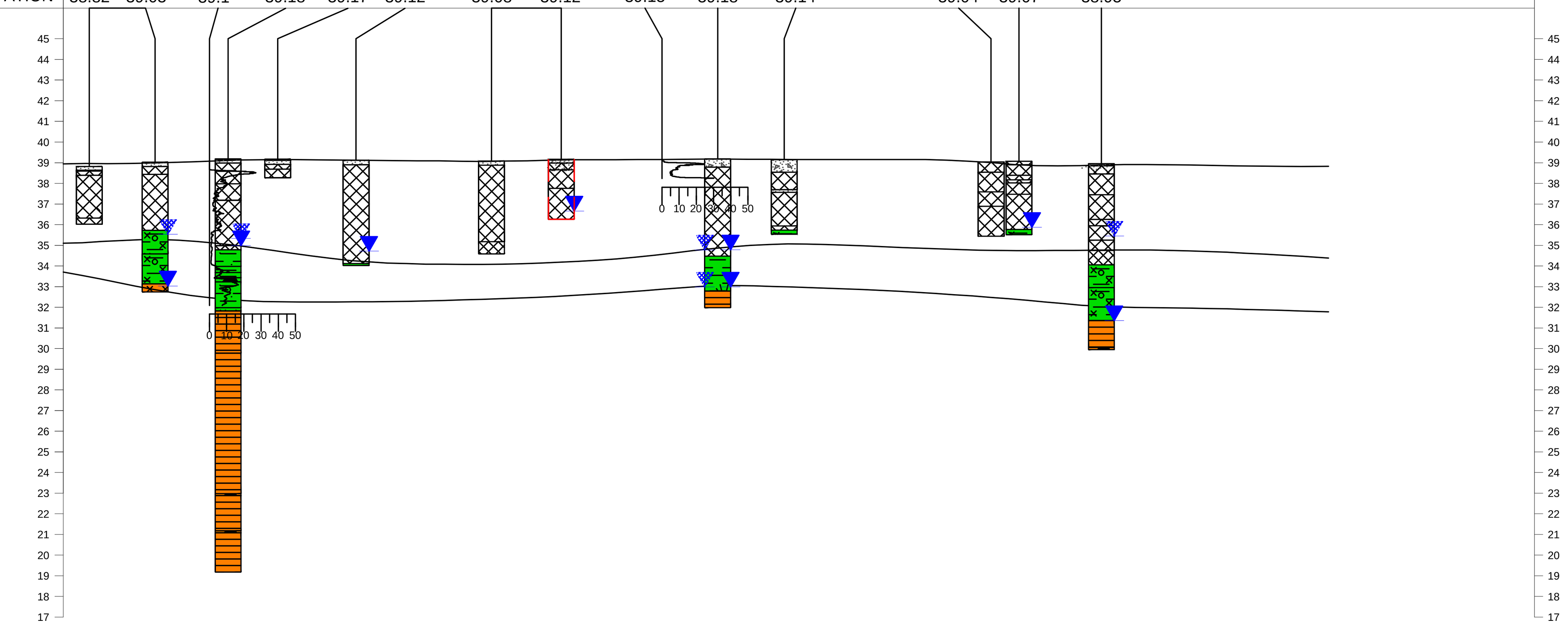
D — D'

CHAINAGE	20.18	29.96	41.50	60.41	73.95	89.87	101.12	111.85	151.13
OFFSET	16.22	-9.18	-17.84	12.58	-1.57	-5.85	1.72	8.51	-7.98
I.D.	NTP24	TP1024	CPT540	CPT513	TP445	TP1025	NCPT14	TP1017	TP446
ELEVATION	39.12	39.08	39.03	39.12	39.12	39.1	39.05	39.17	39.1



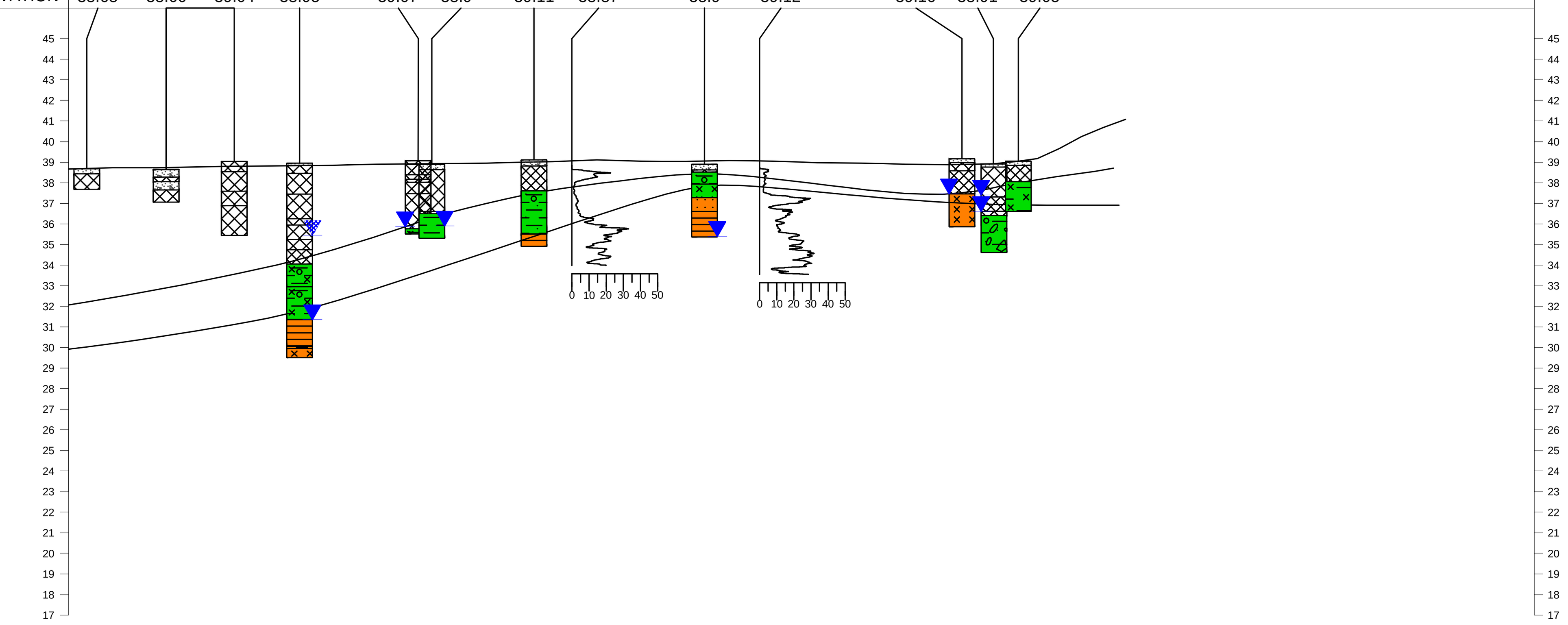
B — B'

CHAINAGE	5.04	17.75	28.29	31.91	41.52	56.69	82.93	96.24	115.92	126.71	139.59	179.67	185.08	201.02
OFFSET	-11.54	7.49	11.05	-6.91	-15.94	-1.33	5.91	-8.57	-4.03	-5.49	7.68	-17.68	17.61	-8.25
I.D.	TP449	BH202	NCPT15	BH101A	BH101	NTP24	TP1024	TP444A	NCPT16	CP1002A	TP443	TP438A	TP439	BH204
ELEVATION	38.82	39.03	39.1	39.18	39.17	39.12	39.08	39.12	39.15	39.18	39.14	39.04	39.07	38.95



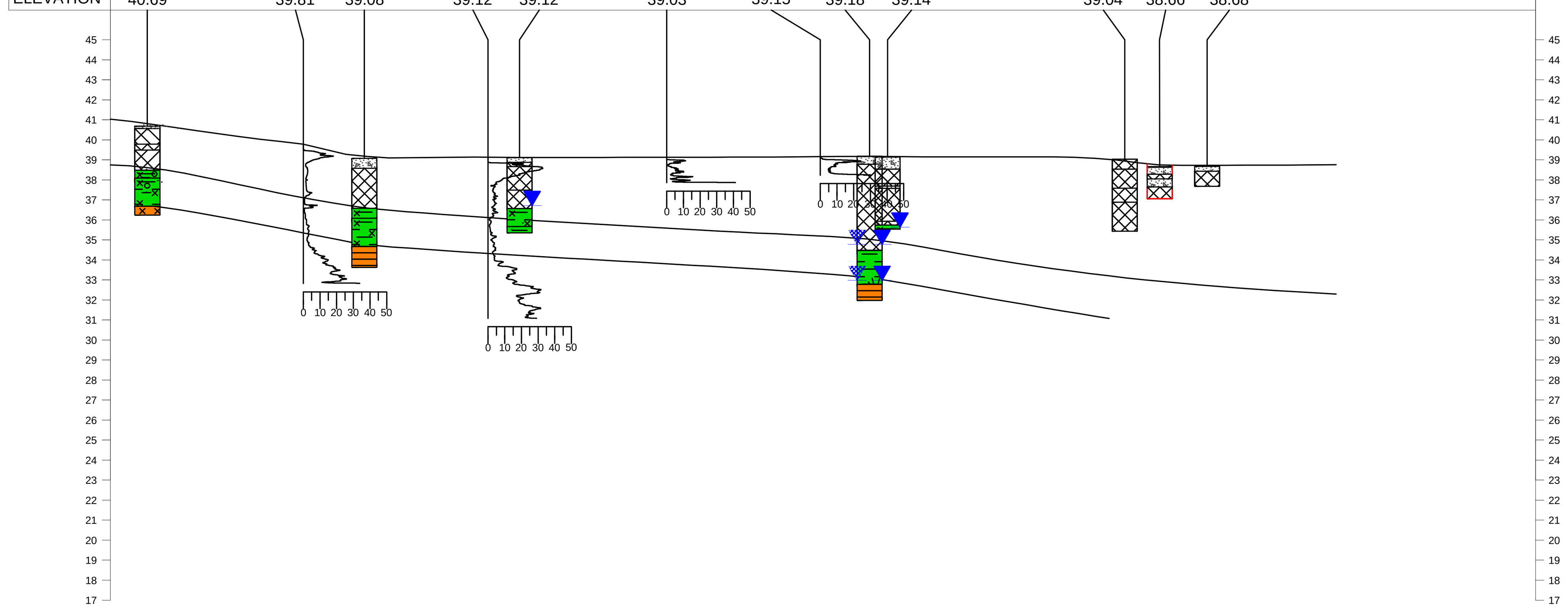
E — E'

CHAINAGE	3.55	18.97	32.24	44.90	67.94	70.61	90.49	97.84	123.61	134.32	173.66	179.88	184.62
OFFSET	3.54	7.04	8.77	-10.82	8.99	-5.42	4.28	-10.73	-6.71	1.34	15.96	-16.39	-6.99
I.D.	NTP23	TP438	TP438A	BH204	TP439	TP1018	NTP22	CPT509	TP440	NCPT13	TP441	NTP21	NWS05
ELEVATION	38.68	38.66	39.04	38.95	39.07	38.9	39.11	38.87	38.9	39.12	39.16	38.91	39.05



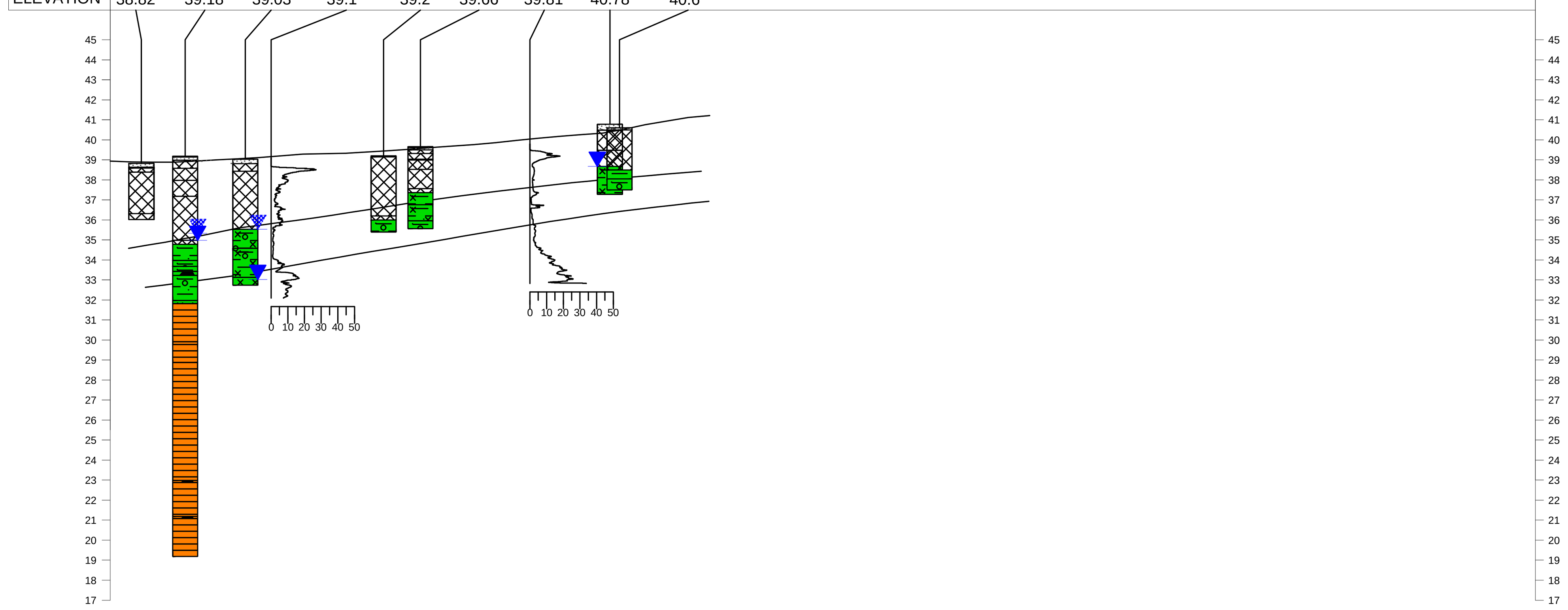
C — C'

CHAINAGE	7.38	38.55	50.76	75.49	81.80	111.20	141.91	151.75	155.34	202.77	209.75	219.24
OFFSET	-9.73	-0.68	-1.66	-5.13	13.41	-7.86	-12.40	-7.73	10.34	10.99	-0.42	-13.07
I.D.	BH201	CPT541	NWS08	CPT513	TP445	CPT540	NCPT16	CP1002A	TP443	TP438A	TP438	NTP23
ELEVATION	40.69	39.81	39.08	39.12	39.12	39.03	39.15	39.18	39.14	39.04	38.66	38.68



F — F'

CHAINAGE	6.25	14.99	27.02	32.18	54.67	62.03	83.92	99.90	101.83
OFFSET	7.01	-18.82	-2.60	-12.46	-18.85	11.71	-11.89	13.53	9.32
I.D.	TP449	BH101A	BH202	NCPT15	TP1016	TP450	CPT541	NTP26	TP1012
ELEVATION	38.82	39.18	39.03	39.1	39.2	39.66	39.81	40.78	40.6



General notes

For cross section locations see DCE drawing No. 18012J-03-03.

All units are in metres unless otherwise shown.

Strata boundaries between boreholes are based on interpolation between investigation positions from 3D modeling and are illustrative and subject to confirmation. The possibility of significant variations occurring between exploratory holes cannot be discounted and additional assessment may be necessary. Ground conditions have been confirmed in investigation positions only.

Groundwater levels are based on the conditions encountered during drilling works. Groundwater levels will be subject to seasonal variation.

For detailed records, please refer to the relevant exploratory hole log.

Legend to symbols

Material Types

- Topsoil
- Made Ground
- Pennine Middle Coal Measures gravelly CLAY
- Pennine Middle Coal Measures Silty CLAY
- Pennine Middle Coal Measures CLAY
- Pennine Middle Coal Measures MUDSTONE
- Pennine Middle Coal Measures SILTSTONE
- Pennine Middle Coal Measures SANDSTONE
- Pennine Middle Coal Measures COAL

Symbols and Connectors

- Strata Boundary
- Water Strike During Drilling
- Drilling Strike Rise Level
- Buried Structure Outline
- 0 10 20 30 40 50 CPT Cone Resistance (MPa)

Revision	Description

Title

Phase 1
Cross Sections A-A' to F-F'

Project

Peel Logistics Sheffield
Ground Investigation

Client

Peel Logistics Property

Discovery CE
Geotechnical & Environmental Engineers

Date	Drawing No.	Scale
20/09/2018	18012J-03-11	1:1000 HOR 1:250 VER
Drawn By	Checked by	Sheet Size
CG	MF	A1