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BRAZENNOSE HOUSE

GEOTECHNICAL AND CONTAMINATED LAND INTERPRETATIVE REPORT





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INTERPRETATIVE REPORT

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1. INTRODUCTION

1.1. Brief

This report presents the geotechnical and contaminated land interpretation of the ground investigation at Brazennose House, located in Mulberry Street, Manchester. The site is centred on the approximate National Grid Reference SJ 837981. This report makes use of the findings of a ground investigation designed and supervised by Ramboll together with background information (Section 1.5) made available about the site.

The site location is shown on Figure 1.1.

The ground investigation was designed by Ramboll, and the exploratory hole locations are shown on drawing 1620000899-GT-01. The site investigation works were undertaken by TerraConsult Limited (TCL). The site work commenced on 2nd October 2015 and was completed on 12th October 2015.

This report details the findings of the ground investigation and includes a series of geotechnical and contaminated land conclusions and recommendations relating to the potential risks and constraints on development.

1.2. Site Description

The site is roughly rectangular in shape and covers an area of approximately 0.2 hectares. The site is bound to the north, west and east by Mulberry Road with Brazennose Street to the south which is pedestrianised.

Brazennose House is an eight storey mixed use (commercial and retail) building which is largely vacant. The building comprises two linked sections, Brazennose House West and Brazennose House East each with its own access.

The existing building comprises an eight storey structure with a single storey basement beneath its entire footprint and a two storey basement beneath its western end. Car parking is provided in the upper basement level accessed from a ramp on the northern side of the building. The lower basement houses a boiler room, oil tank room, storage rooms and an electrical sub-station.

Two above ground tanks are located within the oil tank room which were connected to two boilers located in an adjacent room for supplying hot water to the building. The boilers have been decommissioned and it is understood the pipework from the oil tanks has been disconnected, but oil residues are still likely to be present in the tanks.

It is understood that surveying has identified asbestos containing materials within the existing building fabric.

1.3. Proposed Development

It is proposed to demolish this and construct a seven storey steel framed structure with a single storey basement. It is understood that the sub-basement will be filled in, and that the new basement will be constructed by partially reusing the existing retaining walls, and by construction of new sections.

1.4. Objectives

The objective of this report is to interpret the findings of the ground investigation reported in the factual report (TerraConsult, Report No. 2512R001-1, November 2015) for design purposes relating to the proposed development. The report presents geotechnical design parameters and assesses contaminated land risk for the detailed design of the development and provides an outline assessment of potential foundation solutions.

1.5. Report structure

This geotechnical and contaminated land interpretative report presents the results and interpretation of the ground investigation in relation to the proposed development for the site.

The scope of the investigative works is described in Section 2. The ground conditions encountered and assessment of the geotechnical parameters for each stratum are presented in Section 3. The chemical ground conditions relating the potential ground aggressivity (to buried concrete) are summarised in Section 4. Preliminary foundation design is presented in Section 5. Ground contamination – generic quantitive risk assessment is presented in Section 6. Ground gas assessment and contaminated land risk assessment are presented in Section 7 and Section 8 respectively. Section 9 provides conclusions and recommendations based on the findings of the investigation.

1.6. Existing Information

The report should be read in conjunction with the reports pertaining to the site listed in Table 1.1.

Table 1.1 Reports reviewed

Report	Author	Date
Ground Investigation Factual Report, 2512R001-1	TerraConsult	November 2015
Geotechnical and Geo-environmental Desk Study, 216574/REP/GEO001	Arup	July 2011

Information provided within an Arup Geotechnical and Geo-Environmental Desk Study report (July 2011) for the site along with published information indicates the following:

- Site history – the earliest historical OS map shows a number of buildings at the site with a timber yard at the eastern end. A north-south road (Hulme Street) is also shown towards the western end of the site. The 1886 Goad Insurance Plan shows the site use as offices, restaurant, shipping warehouse, stores and a basement. By 1891 the area west of Hulme Street is occupied by Albert Packing House with Brazennose Club occupying a building towards the centre of the site. Arup indicate that printing works is located off-site to the west of the Albert Packing House. By 1971 Hulme Street is no longer shown and the site has been redeveloped and occupied by Brazennose House.
- Published maps from the British Geological Survey show the site is underlain by bedrock comprising the Chester Pebble Beds of the Sherwood Sandstone Group which

is Triassic in age. Glacial Till is shown as overlying the bedrock in the eastern part of the site.
- The bedrock is classified as a Principal aquifer by the Environment Agency. The site is not located in a groundwater abstraction source protection zone.
- There are no surface water features at the site. The nearest identified surface water course is the River Irwell which is located approximately 320m to the northwest.
- No landfills or registered waste management sites have been identified within 500m.

No information has been obtained on ground conditions from previous ground investigations at the site. Four historical borehole records are provided on the British Geological Survey website for the area immediately south of Brazennose Street. Two of the logs show made ground to 4.1 to 4.35m bgl over a red-brown sand which becomes red-brown sandstone with occasional gravels. The other borehole logs show made ground to 1.46-3.32m bgl over a sandy gravel or sand and gravel to 4.27-5.97m bgl over highly to moderately weathered red-brown sandstone.

The fuel tanks, boilers and electrical substation in the basement to Brazennoese House are all situation over concrete flooring. Localised oil staining was observed on the pipework lagging along with some staining on the underlying concrete floor during a site visit. However, this staining did not appear to be widespread.

1.7. Constraints and Limitations

The information presented within this report is based on observations made on site during inspections of the ground investigation activities through the period of works and on the Factual Report.

This report has been prepared for the exclusive use of CDP Marshalls for the purpose of assisting them in evaluating the site in the context of the proposed development. This report should not be used in whole or part by any third parties without the express permission of Ramboll UK in writing.

Ramboll UK has endeavoured to assess all available information during this appraisal. The report summarises information from a number of external sources and Ramboll cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon.

The ground investigation has been undertaken using a number of exploratory holes located at positions determined from information obtained on the site history, current site use, proposed location of development works, the likely ground conditions and the current standards at the time the work was undertaken. Since the ground conditions are only known in detail at each exploratory hole location the ground conditions between holes have been interpolated. The actual nature of the ground may differ from our interpretation. The extent of the ground investigation carried out was to provide an overview of ground conditions on site and was limited to boreholes. No ground investigation was undertaken within the basement area. Therefore, no information has been obtained on the ground conditions at the above ground fuel tanks and electrical substation.

The proposed geotechnical design options and recommendations summarised in this report relate to details of the proposed development at the time of writing the report. Any substantial changes to the proposed design may require a reassessment of the implications of the risks identified and a review of the geotechnical design options.

Where substructure elements (e.g. piled foundations) are to be designed by parties other than Ramboll UK, the design parameters shall be derived from the Factual Report on Ground Investigation.

Ramboll UK does not accept responsibility for the design of any elements that have incorporated assumptions stated within this report where the responsibility for the design of such elements lies with a third party.

2. GROUND INVESTIGATION

2.1. Introduction

The ground investigation was designed by Ramboll UK to provide information on the underlying superficial and bedrock geology to inform the detailed design, ground works and construction of foundations for the development.

2.2. Fieldwork

The ground investigation was undertaken in general accordance with BS 5930:2015 and BS 10175:2011.

The fieldwork was undertaken in October 2015. The exploratory holes were carried out by TerraConsult under the permanent supervision of their own Site Engineer. Ramboll UK carried out regular site visits throughout the works. The exploratory holes were logged and sampled for geotechnical and contamination testing by TerraConsult.

The Ground Investigation comprised the following items of fieldwork;

- 3 No. cable percussion boreholes with rotary cored follow-on (BH101 to BH103);
- 3 No. Hand excavated trial pits (HP20, HP24 and HP25);
- Soil sampling for contamination and geotechnical laboratory testing;
- In-situ geotechnical testing and soil sampling for environmental and geotechnical purposes;
- Installation of combined gas and groundwater monitoring wells within the Made Ground and Bedrock to provide information on groundwater and ground gas;
- Groundwater sampling and laboratory testing; and
- Surveying of all exploratory hole/pit locations and elevations.

The locations are presented on Drawing 1620000899-GT-01.

The monitoring well installations were designed by Ramboll. The details (3 No. in BH101 to BH103) are presented on the borehole records.

The installations were tested for methane, carbon dioxide, oxygen and hydrogen sulphide. Installations were monitored for gas flow using a flow pod attached to the instrument and reported as gas flow in litres/hour.

Groundwater levels were also recorded during routine monitoring.

2.3. Sampling and In-Situ Testing

Bulk and small disturbed samples were extracted from the exploratory holes for soil description and laboratory testing. Standard Penetration Testing (SPT) and Cone Penetration Testing (CPT) was conducted at intervals through the depth of the cable percussive boreholes and CPTs were conducted at intervals through the depth of the rotary core boreholes. Rotary cored samples were obtained from the Sandstone for logging and laboratory testing.

2.4. Laboratory Testing

2.4.1. Geotechnical Testing

The samples collected from the exploratory holes were scheduled by Ramboll UK for the following geotechnical and chemical testing:

- Uniaxial Compressive Strength tests;
- Point Load Index Strength tests;
- BRE SD1 chemical testing suite for soil and water.

2.4.2. Soil Contamination Testing

9 no. soil samples (8 no. from the made ground and one from sand and gravel) were scheduled for the following parameters:

- Metals (see list below)
- pH
- Water Soluble Sulphate
- Total Organic Carbon
- Total cyanide
- Asbestos screen
- USEPA Speciated 16 Polyaromatic Hydrocarbons (PAHs)
- Speciated Petroleum Hydrocarbons (as TPHCWG)

Metals suite: arsenic, cadmium, chromium (III and VI), copper, mercury, lead, nickel, selenium and zinc

2.4.3. Groundwater Contamination Testing

One groundwater sample were obtained from bedrock at BH102 and tested for the following parameters:

- Metals (list as above for soil samples)
- pH
- Chloride
- Sulphate
- Total Organic Carbon
- Ammoniacal nitrogen
- Monohydric Phenols
- Total Cyanide
- Conductivity
- Hardness
- USEPA Speciated 16 PAHs
- Petroleum hydrocarbons (as TPHCWG)

2.5. Factual Reporting

The factual report on the ground investigation (TerraConsult, Report No. 2512R001-1, October 2015) was prepared on completion of the site works and testing. The report contains records of all boreholes and trial pits, in-situ testing and results of the laboratory testing. The factual report should be read in conjunction with this report.

3. GROUND CONDITIONS

3.1. Published Geology

BGS superficial 1:50,000 mapping shows that Glacial Till is present beneath the eastern half of the site and Glaciofluvial (i.e. Sand and Gravel) Deposits underly the western half of the site. BGS Solid geology 1:50,000 mapping shows that bedrock underlying the site is the Chester Pebble Beds Formation of the Sherwood Sandstone Group.

3.2. Geological Strata

Exploratory holes carried out on the site revealed Made Ground followed by Sand and Gravel overlying Sandstone. A summary of the geological strata encountered during the ground investigation is presented in Table 3.2.1.

Table 3.2.1 Summary of Geology Encountered During Ground Investigation

Stratum		Level of Top of Stratum [m AOD]	Thickness [m]
Made Ground (cohesive and granular)		+37.21 to +34.45	1.5 to 2.9
Sand and Gravel		+34.31 to +32.85	1.9 to 2.4
Sandstone	Weathered Zone	+31.91 to +30.95	0.6 to 4.9
	Intact Rock	+30.45 to +26.05	10.5 (proven)

The following report sections provide descriptions and design parameters derived from the in-situ and laboratory testing conducted during and after the Ground Investigation.

3.3. Made Ground

Made Ground (cohesive and granular) was encountered in all exploratory boreholes with thickness ranging from 1.5 m (BH102) to 2.9 m (BH101). Cohesive Made Ground generally comprised soft dark brown mottled red sandy gravelly CLAY, with the gravel fraction consisting of fine to coarse brick, concrete, coal and sandstone. Granular Made Ground comprised dark greyish brown mottled red very clayey gravelly fine to coarse Sand, with the gravel fraction consisting of fine to coarse ash, concrete, tarmacadam, brick, coal and sandstone.

Bituminous odours were noted associated with a black concrete in the made ground from BH101 (0.08m-0.15m bgl) and BH103 (0.14m-0.17m bgl).

3.3.1. In-situ Testing

Five SPTs were carried out in both types of Made Ground and showed SPT N values ranging from 9 (BH101) to 34 (BH102), however there is no appreciable increase with depth. Due to this variability in Made Ground, it is considered prudent to adopt a tentative N value of 12 for initial design considerations.

3.3.2. Strength Parameters

Where Made Ground is granular, the angle of internal friction has also been estimated from in-situ SPT testing using a correlation proposed by Peck, Hansen and Thornburn

(1953) in Stroud (1989) for a normally consolidated soil. Based on SPT N value of 12, the corresponding angle of internal friction, Ø'= 28°.

3.3.3. Stiffness

For the Made Ground a value for drained Young's Modulus for shallow foundations can be approximated by;

E'/N = 1.0 MPa

[Clayton, CIRIA Report 143, Standard Penetration Test (SPT): Methods and Use, 1995]

An E' value of 10 MPa is recommended based on SPT results for the Made Ground.

3.4. Sand and Gravel

Medium dense Sand and Gravel was encountered in all exploratory boreholes with thickness ranging from 1.9 m (BH102 and BH103) to 2.4 m (BH101). Sand is fine to coarse and Gravel is subangular to rounded fine to coarse of sandstone.

It should be noted that within the footprint of the existing building, it is likely that the Sand and Gravel stratum has been removed during construction of the basements.

3.4.1. In-situ Testing

Six SPTs were carried out in the Sand and Gravel which showed SPT N values ranging from 19 (BH102) to 50 (BH103); however there is no appreciable increase with depth. Due to this variability, a characteristic SPT N value of 26 is considered appropriate.

3.4.2. Strength Parameters

The angle of internal friction has also been estimated from in-situ SPT testing using a correlation proposed by Peck, Hansen and Thornburn (1953) in Stroud (1989) for a normally consolidated soil. Based on a design SPT N value of 26, the corresponding angle of internal friction, Ø'= 35°.

3.4.3. Stiffness

For the Sand and Gravel a value for drained Young's Modulus for shallow foundations can be approximated by;

E'/N = 1.0 MPa

[Clayton, CIRIA Report 143, Standard Penetration Test (SPT): Methods and Use, 1995]

An E' value of 26 MPa is recommended based on SPT results for the design of shallow foundations.

3.5. Weathered Sandstone

Weathered sandstone was identified in all three boreholes and comprises very dense clayey gravelly sand with the gravel fraction comprising fine to coarse clasts of sandstone.

The top of the weathered sandstone ranges from 3.40mbgl (31.05 mAOD) to 5.30 mbgl (31.91 mAOD) with a thickness between 0.6 m and 4.9 m.

3.5.1. In Situ Testing

Five SPTs were carried out within the weathered sandstone which all refused (N value greater than 50).

3.5.2. Strength Parameters

Based on the SPT results a friction angle (angle of internal friction) of 40° is recommended for the weathered sandstone.

3.5.3. Stiffness

Using the correlation given in 3.4.3 above, a drained Young's Modulus in the order of 50 MPa can be taken for the weathered sandstone for preliminary design.

3.6. Sandstone

Sandstone was encountered in all exploratory holes. The Sandstone encountered was typically described as very weak locally extremely weak dark brownish red thinly laminated fine to coarse Sandstone with frequent inclusions of rounded fine to coarse sandstone Gravel.

The depth of the top of the sandstone ranged from 3.40 mbgl (30.45 mAOD) to 10.01 mbgl (27.20 mAOD). The full extent of this stratum was not explored, but was proven to a thickness of 15 m.

3.6.1. Classification

Total core recovery (TCR) is the ratio of total core recovered to the length of the core run. This could be solid and non-intact rock as defined in BS5930 (2015). The result of the total core recovery is reproduced in Figure 3.5.1. TCR results within the bed rock ranged from 45% to 112%. (values greater than 100% are possible due to material lost from previous core runs being incorporated into the subsequent run).

Solid core recovery (SCR) is the ratio of solid core recovered to the length of the core run. The result of solid core recovery (SCR) is reproduced in Figure 3.5.2.

The Rock Quality Designation (RQD) is the ratio of solid core pieces longer than 100 mm to the length of core run. RQD represents the in-situ rock mass quality and can be used to determine rock mass parameters as in Sections 3.5.2 and 3.5.3. The RQD results are reproduced in Figure 3.5.3.

Based upon the results shown in Figure 3.5.3, the RQD ranges from 0% to 71%, indicating a general rock mass quality of very poor to fair (Tomlinson 2001).

The moisture content of the Sandstone ranges from 9.2% to 12.0%, and the recorded values are shown in Figure 3.5.4.

The bulk densities of the Sandstone were found to range from 2.21 Mg/m^3 to 2.36 Mg/m^3 and are shown in Figure 3.5.5. A characteristic design value of 2.3 Mg/m^3 has been taken for this stratum.

3.6.2. Strength Parameters

Six Unconfined Compressive Strength (UCS) tests were undertaken on appropriate core samples taken from the intact Sandstone, with the results ranging from 7.3 MN/m^2 to 25.3 MN/m^2. These results are shown in Figure 3.5.6.

Based upon the results shown in Figure 3.5.6, the strength of the Sandstone is weak to moderately weak (BS 5930:2015).

Point load index tests undertaken on samples from the Sandstone recorded $I_{s(50)}$ point load indices from 0.11 MN/m^2 to 0.53 MN/m^2 (parallel sample orientation i.e. vertical to the core) and from 0.07 MN/m^2 to 0.22 MN/m^2 (perpendicular sample orientation i.e. horizontal to the core). These results are shown in Figure 3.5.7.

The site-specific correlation between the results of the unconfined compressive strength and point load tests has been developed, for which a correlation factor of 40 is considered appropriate to obtain unconfined compressive strength values from point load test results. The results of the unconfined compressive strength tests and the factored point load tests are shown in Figure 3.5.8. A commonly accepted factor of 20 to 24 is often appropriate however in this case the site specific results show good correlation.

Based upon the results shown in Figure 3.5.8, the recommended value for unconfined strength of the intact Sandstone is:

Unconfined Compressive Strength = 7 MN/m^2

The unconfined compressive strengths obtained from laboratory tests on small discrete rock samples does not take into account the in-situ fracturing state of the rock mass and are closer to the strength of an unfractured intact rock. The strength of the fractured rock mass will therefore be a function of the intact rock strength and the degree of fracturing.

Values of RQD can be used to obtain a mass factor (j) by which the intact strength is then multiplied by to calculate the in-situ rock mass strength. Based upon the values of RQD recorded within the borehole logs and using the relationship developed by Farmer (1983, cited in CIRIA Report 181), the following value for mass factor is recommended:

Mass factor = 0.2

The recommended value for rock mass strength is:

Rock Mass Strength = 0.2 x 7 = 1.4 MN/m^2

3.6.3. Deformation Modulus

Deformation modulus of the rock mass has been calculated using the following equation suggested by Tomlinson, 7th edition and BS 8004:1986, Annex A.2:

$E_m = j \times M_r \times q_{uc}$

where, E_m = Deformation modulus

j= Mass factor related to discontinuity spacing (RQD)

q_{uc} = Unconfined compressive strength (UCS)

M_r = Ratio between deformation modulus and UCS

Based on the intact rock strength, rock mass factor of 0.2 and the modulus ratio of 150 (Tomlinson, 2008) for rocks of similar lithology, the deformation modulus of the sandstone is recommended:

Deformation modulus [MN/m^2] = 0.2 x 150 x 1.4 = 42 MN/m^2

3.7. Groundwater Monitoring

Three groundwater strikes were noted during the site works at 16.5 mbgl (BH101), 13.6 mbgl (BH102) and 16.0 mbgl (BH103) within the bedrock.

Groundwater monitoring standpipes were installed in each borehole as shown in Table 3.7.1.

Four return visits to monitor groundwater levels in the well installations were undertaken; the results are shown in Table 3.7.1. Groundwater monitoring was undertaken by TerraConsult in order to provide further details on the groundwater regime beneath the site.

Based on the monitoring results, the recommended design groundwater level is 25 mAOD. It is noted that water was identified within BH101on one occasion however this is not considered to represent the sitewide groundwater level. If it represets groundwater within the surrounding soils this is likely to be a perched water body. This would be unlikely to result in significant flows into excavations, or to impose significant buoyant forces on any buried structure.

Table 3.7.1 Summary of Groundwater Monitoring

Exploratory Hole	Depth of response zone [mbgl]	Strata	Date	Water level [mbgl]	Ground level [mAOD]	Ground water level [mAOD]
BH01	1.0 – 4.0	Made Ground and, Sand and Gravel	23/10/2015	Dry	37.21	-
			29/10/2015	Dry	37.21	-
			05/11/2015	Dry	37.21	-
			13/11/2015	4.08	37.21	33.13
BH02	5.5 – 14.5	Sandstone	23/10/2015	9.90	34.45	24.55
			29/10/2015	9.78	34.45	24.67
			05/11/2015	9.79	34.45	24.66
			13/11/2015	9.71	34.45	24.74
BH03	1.0 – 4.0	Made Ground and, Sand and Gravel	23/10/2015	Dry	35.35	-
			29/10/2015	Dry	35.35	-
			05/11/2015	Dry	35.35	-
			13/11/2015	Dry	35.35	-

4. AGGRESSIVITY OF THE GROUND

Chemical analysis of the soil underlying the site was undertaken to establish the ground aggressivity to buried concrete. Sulphate and pH tests were carried out on soil samples from Made Ground, Sand and Gravel, and Sandstone layers.

The range of chemical analysis results for pH and water soluble sulphate content (2:1 water extract as SO_4) of the sols presented in Table 4.1.

Table 4.1 pH and Sulphate results

Stratum	Depth of sample [mbgl]	Exploratory hole ID	pH	Water soluble sulphate content (2:1 extract as SO_4) [mg/l]
Made Ground	0.15	BH103	8.46	50
	0.25	BH101	9.54	30
	0.50	BH101	7.93	190
	0.50	BH102	7.73	40
	1.30	BH101	7.61	260
	1.00	BH102	9.39	80
	1.00	BH103	8.37	890
	2.00	BH102	8.10	40
	2.00	BH103	9.52	410
Sand and Gravel	2.0	BH102	7.8	50
	4.0	BH101	8.0	29
Sandstone	4.0-5.50	BH102	7.9	10
	4.50	BH103	8.0	24
	6.50	BH101	8.0	43
	6.50	BH103	7.9	15
	7.0-8.50	BH102	7.7	13
	9.0-10.50	BH103	8.0	<10
	9.50	BH101	7.9	16
	15.0-16.0	BH103	8.1	11

In order to determine the ACEC class of concrete required the pH and Sulphate tests have been interpreted following the guidelines given in BRE Special Digest 1.

The results (Table 4.1) place the Made Ground within Design Sulphate Class DS-2 and the Aggressive Chemical Environment for Concrete (ACEC) AC-2 assuming mobile water conditions. The Sand and Gravel and Sandstone are seen to fall within Design Sulphate

Class DS-1 and the Aggressive Chemical Environment for Concrete (ACEC) AC-1 assuming mobile water conditions.

A site wide Design Sulphate Class of DS-2 and an Aggressive Concrete Environment Classification (ACEC) of AC-2 is considered appropriate.

5. PRELIMINARY FOUNDATION DESIGN

The current proposal is to demolish the existing building and to fill the lower basement void before constructing foundations, currently anticipated to comprise piles, for the new structure. The choice of fill, and its degree of compaction should be considered carefully as this will have an impact on the choice of piling technique.

The following section presents a summary of the development with regard to preliminary foundation solutions. The preliminary pile and pad foundation designs were based on in-situ testing, soil and rock descriptions recorded on the exploratory hole records, the laboratory test results and the interpreted ground model described in Section 4. Note that a detailed foundation design is outside the scope of this report.

5.1. Piled Foundations

If a piled solution is selected it is anticipated that construction will commence below existing ground level (i.e. piling will commence from the existing basement level), therefore consideration of the support from the Made Ground and the Sand and Gravel is not required.

It is considered that CFA or bored cast in-situ piles would be appropriate for the ground condition identified.

5.1.1. Shaft Resistance

Following guidance presented in Tomlinson (2008):

Shaft resistance within the weathered sandstone is calculated using the equation:

$$\text{Shaft resistance, } q_s = K_s \sigma'_v \tan\delta A_s$$

(where K_s is a coefficient of earth pressure, σ'_v is the average effective overburden pressure, δ is the friction angle at the pile/soil interface and A_s is the surface area of the shaft)

The shaft resistance of piles socketing into rock is:

$$\text{Shaft resistance, } q_s = \alpha\beta q_{uc} A_s$$

(where α is a function of the unconfined compressive strength of the intact rock, β is a function of the mass factor, and q_{uc} is the unconfined compressive strength of the intact rock)

5.1.2. Base Resistance

Based upon guidance by Tomlinson (2008), the ultimate base resistance of piles bearing onto rock can be estimated by consideration of RQD and UCS:

$$\text{Base resistance, } q_{ub} = 0.33 \times q_{uc} \text{ (when RQD is 0 – 70\%)}$$

However once the pile is socketed greater than about four diameters base resistance ceases to make a significant contribution to the pile capacity.

5.1.3. Pile Capacity

Table 5.1 presents preliminary axial pile capacities for bored/CFA piles, varying with socket length to inform preliminary substructure design and costing for the proposed development. It has been assumed that all piles terminate in the intact Sherwood Sandstone.

Table 5.1 Preliminary Pile Capacity

Socket Length [m]	Allowable Capacity [kN] [EC7 DA1 C2]		
	450 mm	600 mm	750 mm
3.0	980	1310	1640
4.0	1300	1740	2180
5.0	1630	2170	2710
6.0	1950	2600	3250

Note that the top of the intact Sherwood Sandstone was found at an approximate level of 30.5 mAOD in all boreholes undertaken during the Ground Investigation, with the exception of the BH102 (in the middle of the site) where the top of the intact Sherwood Sandstone was encountered at a level of 26.0 mAOD.

As the above capacities all rely on skin friction with no contribution from the pile base, tension capacity will be in the same order as compression capacity.

5.2. Shallow Foundations

Considering the variable nature of Made Ground, the use of ground bearing slabs and pad foundations is not recommended on this stratum. However, ground bearing slabs and pad foundations may be placed on the natural Sand and Gravel (Glaciofluvial Deposits) layer where it is still present (i.e. outside the existing building footprint). Areas of soft or otherwise unsuitable material should be locally removed and replaced with a compacted structural fill and the formation should be inspected and if possible, proof rolled.

The bearing resistance on Sand and Gravel has been calculated as;

$$R/A' = c'N_c b_c s_c i_c + q' N_q b_q s_q i_q + 0.5 \gamma' B' N_\gamma b_\gamma s_\gamma i_\gamma \quad \text{[EC7 Annex D]}$$

Allowable bearing resistance for foundations constructed in the weathered sandstone beneath the existing basement floor, based on EC7 DA1 Combination 2, for different sizes of footings are presented in Table 5.2.

Table 5.2 Allowable Bearing Resistance on Sand and Gravel

Footing Size [m x m]	Allowable Bearing Resistance [kN/m^2] [EC7 DA1 C2]
1.5 x 1.5	650
2.0 x 2.0	750
2.5 x 2.5	840
3.0 x 3.0	935

6. GROUND CONTAMINATION – GENERIC QUANTITIVE RISK ASSESSMENT

6.1. Introduction

The results of the testing for soil, groundwater and ground gas for the site have been screened against the following assessment criteria:

- Human Health: Assessment criteria derived using data from Suitable 4 Use Levels (S4ULs) prepared by LQM/CIEH (2014) and DEFRA Category 4 Screening Levels for Land Affected by Contamination. Based on a 'Commercial' Land Use with a sandy loam soil comprising 2.5% soil organic matter – the made ground comprises predominantly granular material with an average soil organic matter of 3.3 % (1.9 % TOC) after excluding the two highest results (13.6 % and 16 %) which are likely to be associated with tarmacadam in the samples.
- Water Quality: UK Drinking Water Standards (UK DWS) as the underlying bedrock is classed as a Principal aquifer. Environmental Quality Standards (EQS) have been used where Drinking Water Standards are not available although the nearest identified surface water course (the River Irwell) is located 315m from the site.
- Buried Plastic Water Pipes: A comparison has been undertaken against thresholds for polyethylene (PE) pipe outlined in Table 1 of United Utilities Water (September 2012) Supplementary Guidance for the Selection of Water Pipes in Land Potentially Affected by Contamination. United Utilities note this is based in principle on the UK Water Industry Research (UKWIR) "Guidance for the Selection of Water Supply Pipes to be used in Brownfield Sites" (Ref 10/WM/03/21), published in January 2011.
- Phytotoxicity (toxicity to plants): BS3882 2015 Specification for topsoil and requirement for reuse for a soil pH>7 (based on the soil testing results for pH)

The assessment criteria outlined above for human health and water quality have been used to provide an initial screen of chemical test results and it is likely these assessment criteria will be conservative. The findings from the assessment are shown below.

6.2. Soil Contamination

The concentrations of all of the metals and inorganic contaminants tested are below their respective assessment criteria for a commercial end use.

Screening for asbestos was undertaken all of the soil samples. No asbestos fibres were detected by the laboratory.

Testing for PAHs (as sum of 16 compounds) ranged from <0.08 mg/kg to 529 mg/kg. The highest concentration of PAHs were obtained from samples of made ground in BH101 (263 and 425 mg/kg) and BH103 (405 and 529 mg/kg) which were noted as containing inclusions of 'tarmacadam' – the sample from BH013 at 0.15m (425 mg/kg) was from a black concrete with a bituminous odour.

The highest individual concentration was 107 mg/kg for phenanthrene from made ground in BH103 at 1.0 mbgl. Two results for dibenzo(ah)fluoranthene in BH103 (0.15 m and 1.0 m) exceed the assessment criteria for a commercial land use. The results obtained for PAHs are indicative of a coal derived source.

Four samples of made ground were tested for petroleum hydrocarbons, with concentrations (as sum of TPH CWG) ranging from <0.1 mg/kg (BH102 at 1.0m) to 2248

mg/kg (BH103 0.15 m). None of the results for aliphatic and aromatic fractions from the TPHCWG testing exceed their respective assessment criteria for a commercial land use.

6.3. Buried Drinking Water Pipes

Exceedances have been obtained of the threshold criteria for buried polyethylene drinking water pipes in three samples for EC10-EC16 (BH101 at 0.5m, BH103 at 0.15 m and 1.0 m) and two samples for EC16-EC35 (BH101 at 0.5 m and BH103 at 1.0 m) range petroleum hydrocarbons.

6.4. Plants in Areas of Soft Landscaping

No exceedances were obtained of the assessment criteria in BS3882 for potentially phytotoxic metals (copper, nickel and zinc).

6.5. Groundwater Assessment

One groundwater sample was recovered from the bedrock at BH102 with BH101 and BH103 being dry during sampling. The chemical testing results are still awaited from the laboratory.

7. GROUND GAS ASSESSMENT

7.1. Methodology

The gas regime at the site has been characterised using the guidelines provided in CIRIA Report C665 (2007) and BS8485:2015.

7.2. Ground Gas Data

Four rounds of gas monitoring have been completed. The monitoring sheets are provided in Appendix 1 within the TerraConsult Factual Report.

The results for methane were below the lower instrument detection limit with the exception of 0.6 % during the third round of monitoring from made ground in BH103.

The results for carbon dioxide have ranged from 0.1 % to 2.7 %, with the highest concentrations from made ground in BH101 (0.8 % to 2.7 %).

All of the peak and steady state flow rates were <0.1 litres per hour with the exception of BH103 during the fourth monitoring round where 0.1 litres per hour was recorded.

7.3. Classification of Ground Gas Regime

The Gas Screening Values derived using the peak flow rates and peak results for methane and carbon dioxide for each well are consistent with Characteristic Situation 1 – Very Low Risk in BS8485 (2015).

7.4. Workplace Exposure Limit Assessment

The gas monitoring results for carbon dioxide, carbon monoxide and hydrogen sulphide have been assessed against the short term and long term workplace exposure limits as indicated by the Health and Safety Executive in Workplace Exposure Limits HSE EH40/2005.

Results have been obtained for carbon dioxide from BH101 which exceed the long (0.5 %) and short term (1.5 %) exposures limits.

10 ppm of carbon monoxide was obtained from BH101 during the fourth gas monitoring visit. However, this would not exceed the workplace exposure limit for carbon monoxide.

8. CONTAMINATED LAND RISK ASSESSMENT

8.1. Conceptual Site Model

The information presented in the previous sections of this report have been collated and evaluated to refine the preliminary conceptual site model.

8.1.1. Sources

The potential contamination sources are summarised in Table 8.1.

Table 8.1 Potential Sources

Source	Comments
Made Ground/ Landfill	**Soil** • Human health – locally elevated PAHs in made ground • Buried Concrete – locally elevated results consistent with DS-2 for made ground / fill • Buried Drinking Water Pipes – elevated petroleum hydrocarbons • Phytotoxicity – no exceedances **Water Environment** • Principal Aquifer – to be confirmed chemical testing results have been received
	Ground/Landfill Gas • Human health – gas results consistent with Characteristic Situation 1 from the made ground and bedrock. • Exceedences of the workplace exposure limits for carbon dioxide in made ground from BH101.

8.1.2. Receptors

The site-specific receptors that could potentially be affected by the contamination hazards are summarised in Table 8.2.

Table 8.2 Potential Receptors

Feature	Comments
ON SITE	
Human health	Current and future site users Construction and service maintenance workers.
Controlled waters	Collyhurst Sandstone – Principal aquifer: No surface water features at the site
Buried concrete	Existing and new foundations introduced during the development works
Buried plastic drinking water pipes	Introduced as part of the development works
Plants in areas of landscaping	The site currently comprises hard cover and it is not anticipated that any extensive areas of soft landscaping would also be introduced as part of a future development.
OFF SITE	
Human health	Off-site users

Feature	Comments
Controlled waters	Collyhurst Sandstone – Principal aquifer Nearest surface water is River Irwell c.320m from the site

8.1.3. Pathways

In order for the contaminants identified in this site investigation to reach potential receptors, there has to be a viable pathway for the contaminant. Potential pathways were identified within the preliminary conceptual site model and are discussed further in Table 8-3 below in relation to the identified source impacts and receptors identified.

Table 8.3 Potential Pathways

Receptor	**Pathway**
Human Health	Direct contact with contaminants in soils (site users, construction and maintenance workers)
	Inhalation of dusts and vapours (site users on and off-site, construction and maintenance workers)
	Migration of ground gas or vapours into buildings or confined spaces (site users, construction and maintenance workers)
Controlled Waters	Leaching and vertical migration of soil contaminants to groundwater in Glaciofluvial deposits or bedrock
	Introduction of preferential pathways for contaminant migration due to foundations – shallow pad foundations have been assumed
Buried concrete and drinking water pipes	Lateral migration of contaminants via groundwater to surface water courses

8.2. Qualitative Risk Assessment

Potential pollutant linkages are identified using the source-pathway-receptor framework detailed above. An assessment of the potential significance of each linkage is then made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

This qualitative hazard assessment has been undertaken in accordance with guidance provided in the following document:

NHBC/EA/CIEH (2008). Guidance for the Safe Development of Housing on Land Affected by Contamination. R&D Publication 66.

Table 8-4 summarises the pollutant linkages and risk ratings associated with the proposed development. The potential risks are based on the assumption that no additional mitigation measures will be introduced for contamination.

The risks for controlled waters will need to be confirmed when the groundwater test results are available.

Table 8.4: Qualiative Risk Assessment

Potential Source	Pathway	Potential Receptor	Probability	Consequence	Risk Classification
On-Site Sources					
Made Ground	Ingestion, Inhalation and/or Dermal Contact	Construction / Maintenance Workers	Low	Medium	**Moderate to Low** – potential that contaminants could be encountered during excavations or ground works during development works in made ground.
		Current and Future Site Users	Unlikely	Medium	**Low** – limited exceedances of assessment criteria in shallow soils for PAHs. Potential risk to future site users is considered low as the development will comprise hard cover – unlikely to be a pathway.
	Migration of gas into confined spaces	Construction / Maintenance Workers	Low	Medium	**Moderate to Low** – locally elevated carbon dioxide have been obtained from wells installed into made ground which could represent a risk in confined spaces, including excavations.
		Future Site Users	Unlikely	Medium	**Low** – results for methane and carbon dioxide consistent with Characteristic Situation 1 indicating that gas protection measures should not be required as part of a future development.
	Plant Uptake	Landscaping Plants	Unlikely	Minor	**Very Low** – no exceedances obtained for potential phytotoxic metals and development will comprise hard cover.
	Chemical Attack	Water Supply Pipes	Likely	Mild	**Moderate to Low** – exceedances of threshold limits for PE pipe obtained from made ground for petroleum hydrocarbons.
		Buried Concrete	Low	Mild	**Low** – locally elevated sulphate in made ground.
	Vertical migration to Aquifers	Groundwater - Bedrock	To be Confirmed	Medium	**To Be Confirmed** – No shallow groundwater has been identified in made ground or underlying sand and gravels. No low permeability strata has been identified between the made ground and bedrock but the presence of hard cover limits the potential for infiltration and subsequent leaching of soil contaminants.
	Lateral migration in groundwater	River Irwell via Groundwater	To be Confirmed	Medium	**To Be Confirmed** – The River Irwell is located approx. 320m from the site. No groundwater was encountered in shallower strata.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Geotechnical

A summary of the site stratigraphy is presented in Table 9.1.

Table 9.1 Summary of Stratigraphical Progression Identified During the Ground Investigation

Stratum		Level of Top of Stratum [m AOD]	Thickness [m]
Made Ground (cohesive and granular)		37.21 to 34.45	1.5 to 2.9
Sand and Gravel		34.31 to 32.85	1.9 to 2.4
Sandstone	Weathered Zone	31.91 to 30.95	0.6 to 4.9
	Intact Rock	30.45 to 26.05	10.5 (proven)

Note that the exising upper basement floor level is at approximately 34.4 mAOD (east) and 33.7 mAOD (west). The lower basement floor is at approximately 29.7 mAOD.

Preliminary pile capacities are shown in Table 9.2. The preliminary pile capacities are indicative and will be developed further in preparation of the overall pile scheme once the structural loads and layout have been finalised. It has been assumed that all piles terminate in the unweathered Sherwood Sandstone.

Table 9.2 Preliminary Pile Capacity

Socket Length [m]	Allowable Capacity [kN] [EC7 DA1 C2]		
	450 mm	600 mm	750 mm
3.0	980	1310	1640
4.0	1300	1740	2180
5.0	1630	2170	2710
6.0	1950	2600	3250

Pile load tests are recommended to allow refinement of the foundation design and allow for the reduction in conservatism within the design.

According to Table C2 of BRE Special Digest 1 – Concrete in Aggressive Ground (BRE, 2005), for water/soil extract, brownfield, mobile water and a pH, a design sulphate class of DS-2 and an aggressive chemical environment for concrete (ACEC) of AC-2 are considered appropriate for the site.

The method and materials used for backfilling the lower basement will need consideration as this may influence the piling technique to be used in this area. Alternatively the backfill may be designed so as to provide sufficient strength to carry the new structure on spread foundations.

9.2. Contaminated Land

No potentially significant contaminating land uses have been identified at the site.

A disused boiler room with associated above ground oil tanks and an electrical sub-station are located in the western end of the existing basement to Brazennose House.

Localised evidence of oil staining has been identified on lagging to the oil tank pipework and on concrete hard standing beneath the concrete floor. Whilst it was not possibleto undertake ground investigation in this part of the site, based on the limited amount of hydrocarbon contamination noted and presence of a concrete floor to the basement, the potential for contaminants to have migrated into soils beneath the basement is considered low.

No specific requirement for soil or groundwater remediation has been identified from the ground investigation.

Human Health – Site Users

The concentration of contaminants were below their respective assessment criteria for a commercial end use with the exception of locally elevated dibenzo(ah)fluoranthene were obtained from two samples of shallow made ground in BH103. This appears to be associated with presence of black concrete or tarmacadam. However, based on the existing and proposed presence of hard cover following development, a risk should exist to future site user from soil contamination.

No asbestos fibres were detected by the laboratory in any of the soil samples tested.

The results obtained from gas monitoring are consistent with Characteristic Situation 1 in BS8485:2015 and no special protection measures should be required for ground gas as part of the development.

Human Health – Construction / Maintenance Workers

The presence of PAHs and petroleum hydrocarbons in shallow made ground in BH101 and BH103 could represent a risk to construction or maintenance workers during excavations.

Locally elevated carbon dioxide has been obtained from made ground / sand and gravel in BH101 which exceed the long and short term workplace exposure limits and could represent a risk to workers in confined spaces.

Therefore, it would be necessary to ensure that the appropriate health and safety measures are adopted, including for ground gas in confined spaces.

Controlled Waters

A standing shallow groundwater table has not been encountered in the made ground or sand and gravels. Groundwater is present in the bedrock at approximately 9.70-9.90 m bgl (24.55 m to 24.74 m AOD).

No existing low permeability strata has been identified between the bedrock and made ground. Therefore, it is unlikely that development would result in the creation of new preferential pathways for contaminant migration to bedrock. The presence of hard cover at the site will limit the potential for infiltration and subsequent leaching of soil contaminants.

No surface water courses have been identified close to the site, the nearest is the River Irwell approximately 320 m distance.

One groundwater sample has been obtained from the bedrock in BH102 for chemical testing as wells installed into the made ground / sand and gravels were dry.

The chemical testing results for groundwater are still awaited from the laboratory. The risks to groundwater from contamination will need to be confirmed once these have been received.

Buried Drinking Water Pipes

Elevated concentrations of petroleum hydrocarbons have been identified in shallow made ground (samples up to 1 m depth) from BH0101 and BH103 which exceed United Utilities' threshold criteria for PE pipes. This indicates that protection measures are likely to be required for buried plastic drinking water pipes which could include the introduction of a suitable backfill material into service trenches and upgrading water pipes to a proprietary material such as "protectaline".

It would be necessary to agree the requirements for buried drinking water pipes with the relevant water authority prior to commencing installation.

Mitigation – Excavations and Stockpiling

Mitigation measures would still be required to minimise off-site migration of contaminants during the construction work phase, in particular airborne dust/vapours/odours or run-off generated by excavation works and stockpiling.

Waste

It will be necessary to confirm the waste classification of any materials removed off-site for disposal.

Unexpected Contamination

A method statement should be prepared for dealing with any unexpected areas of contamination should this be encountered during the demolition or construction works, particularly in the area of the above ground tanks and electrical substation. Such a method statement is likely to include:

- Watching brief during demolition and construction works
- The Contractor stopping work in that area to discuss the findings and proposed plan of action
- Liaising with Regulators to agree proposals for dealing with this material

It is possible that chemical testing could be required to confirm the nature of any contamination.

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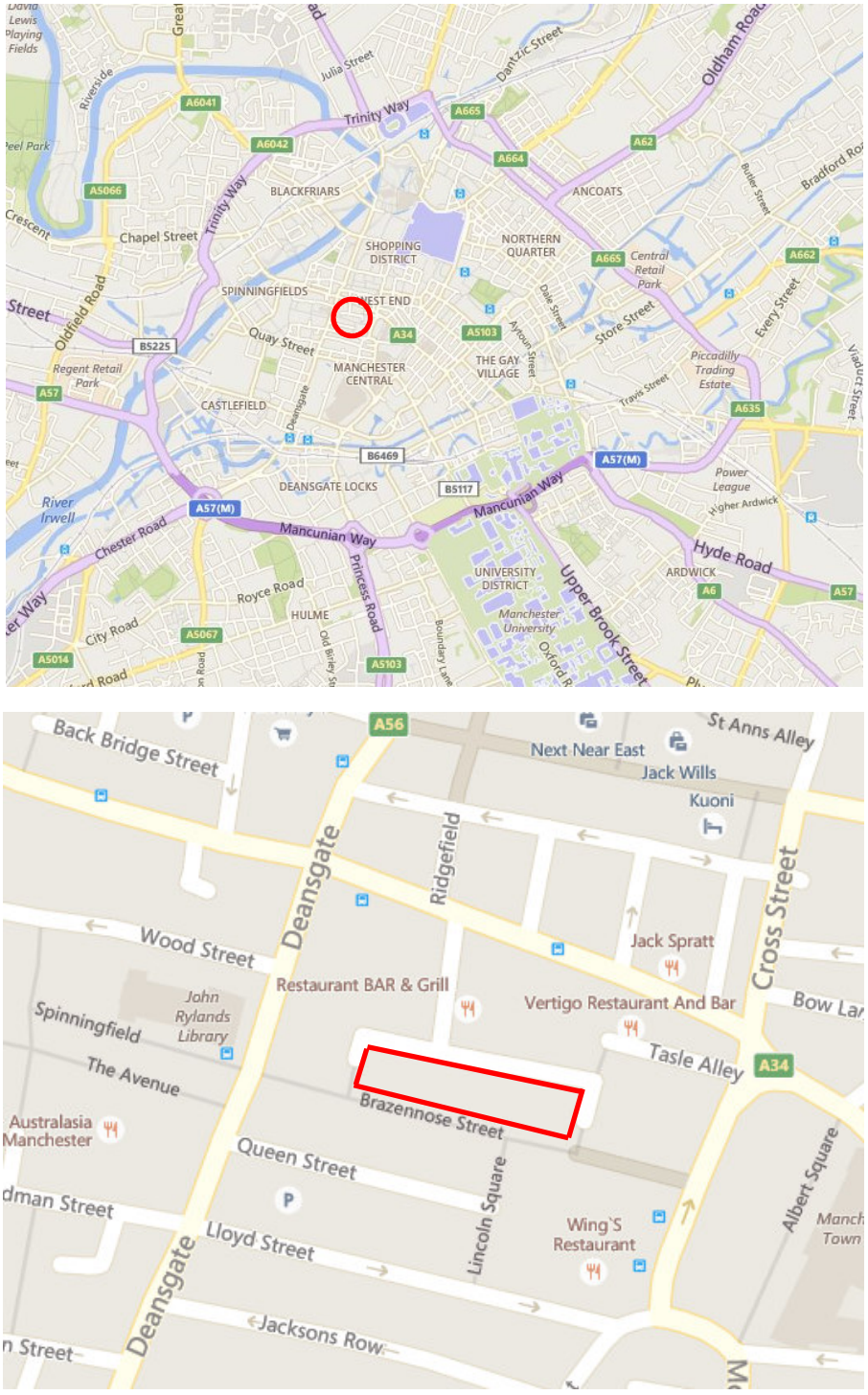


Figure 1.1 Site Location Plan (Red Marked Area)

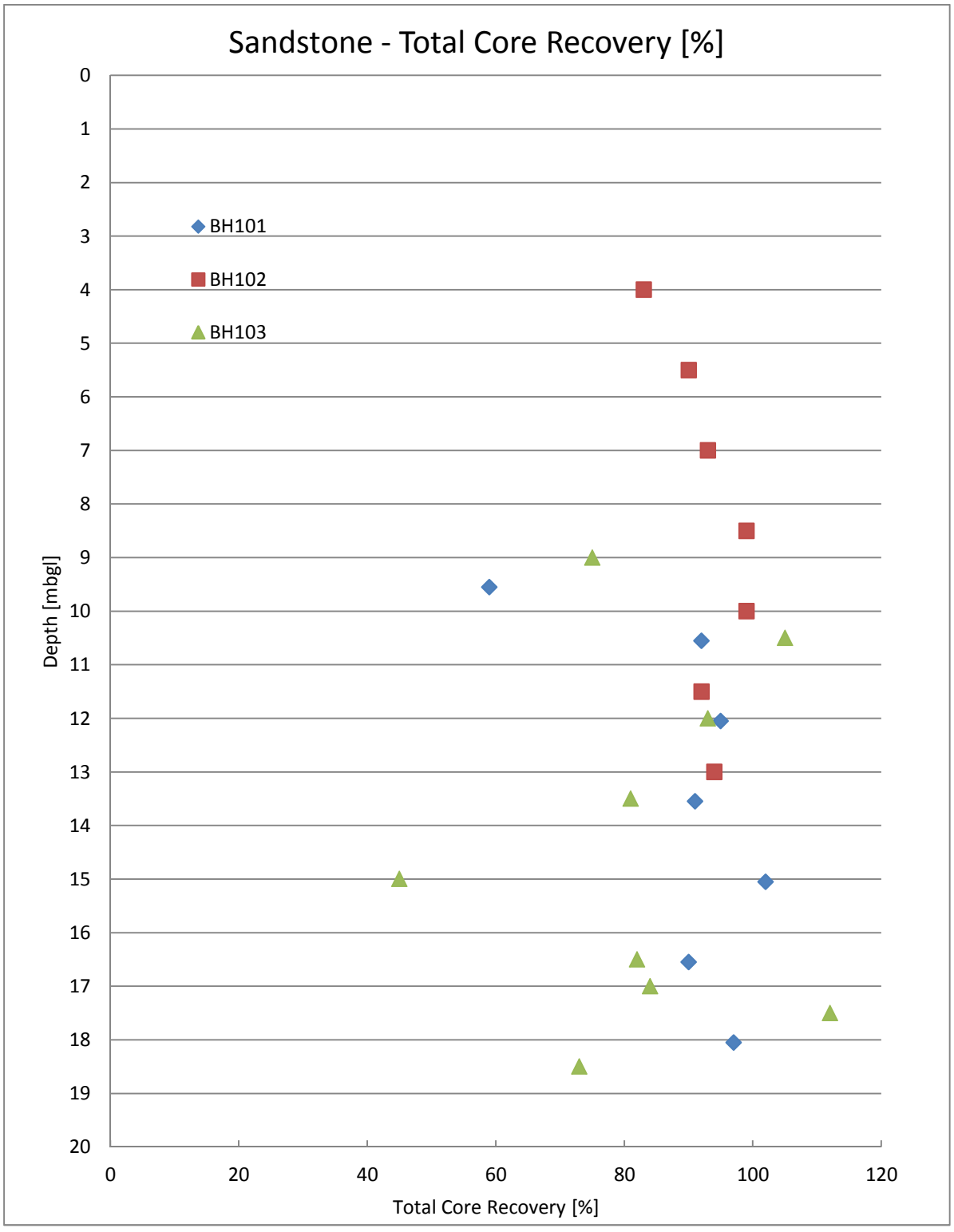


Figure 3.5.1 Sandstone – Total Core Recovery

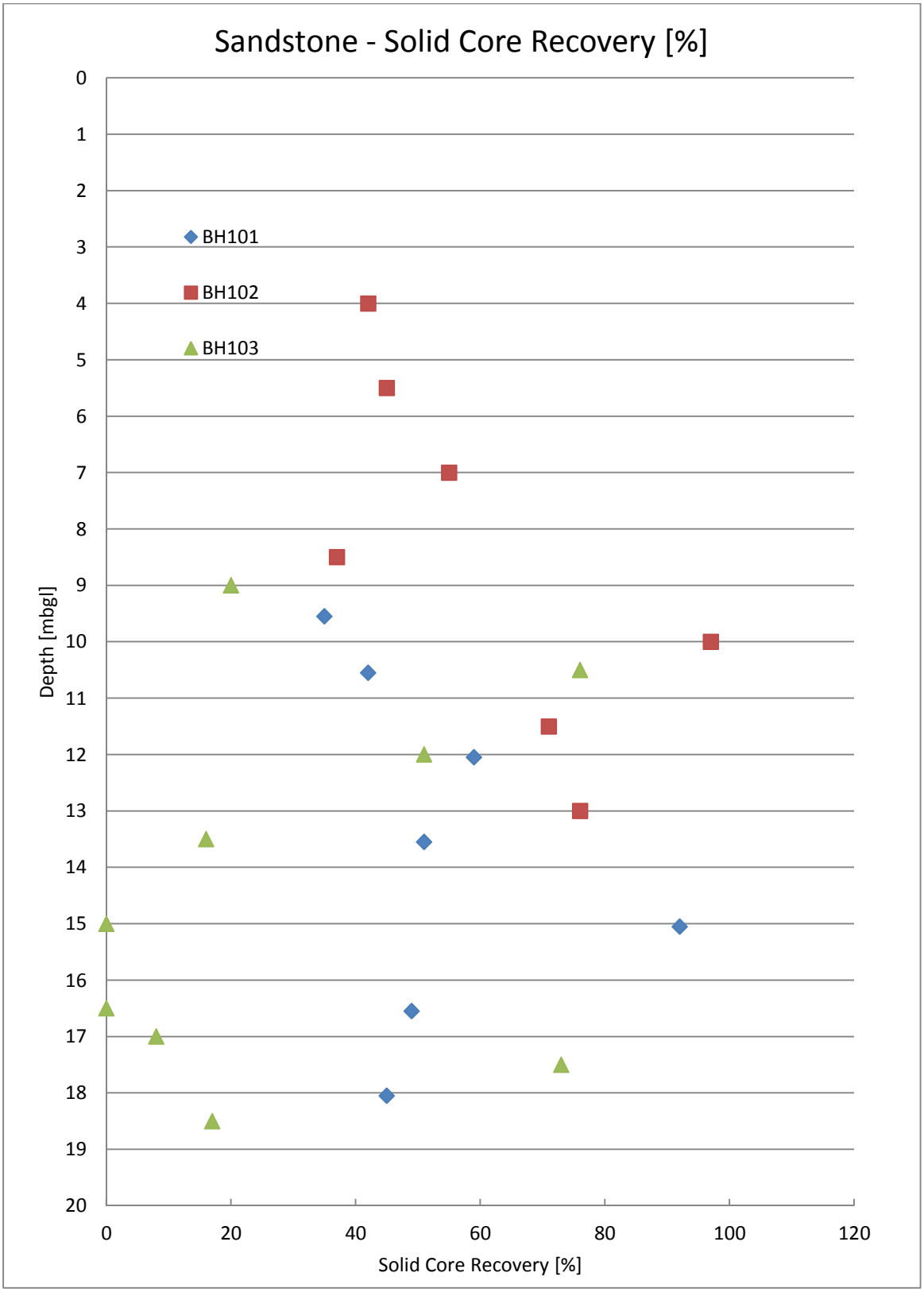


Figure 3.5.2 Sandstone – Solid Core Recovery

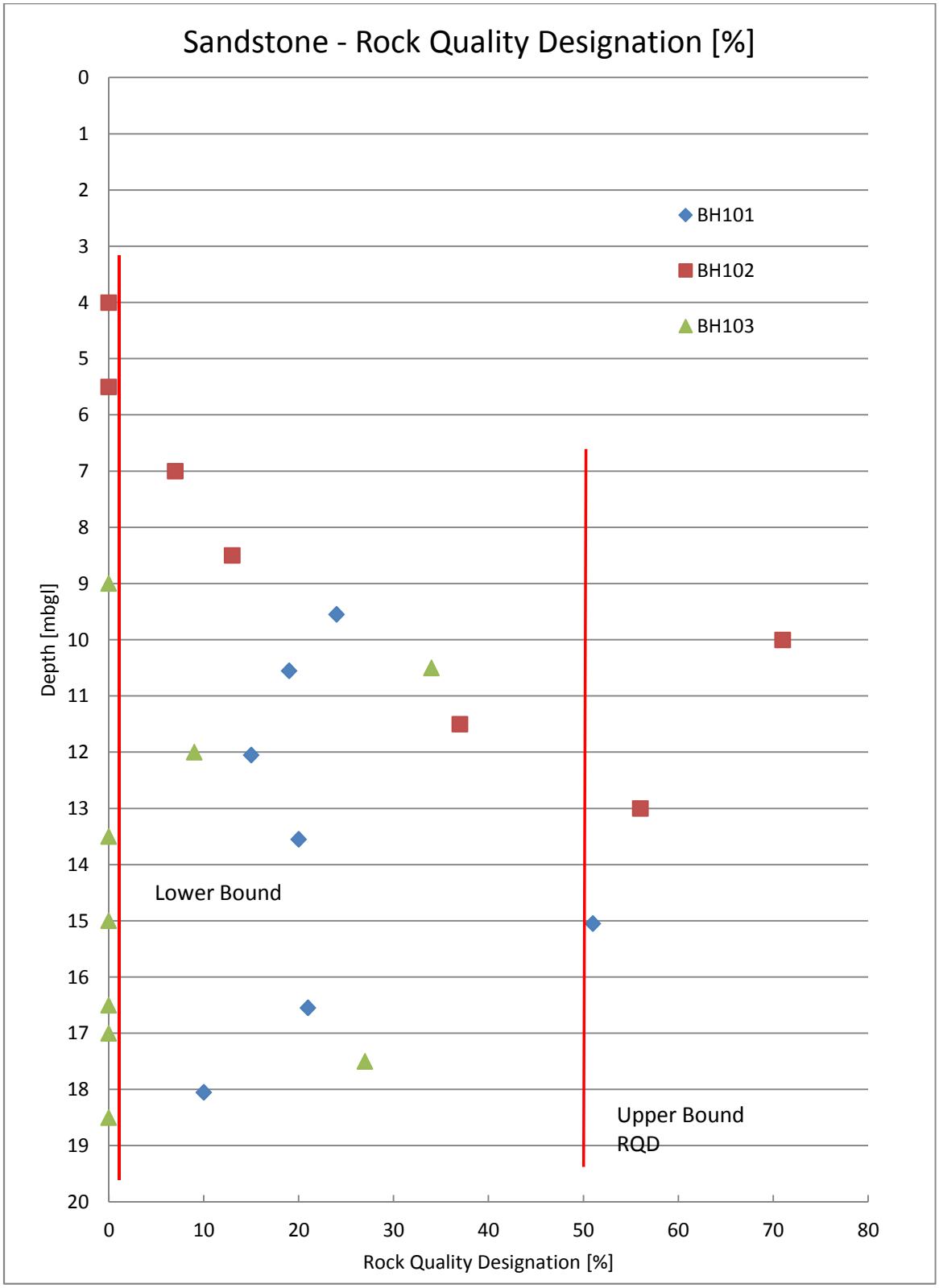


Figure 3.5.3 Sandstone – Rock Quality Designation

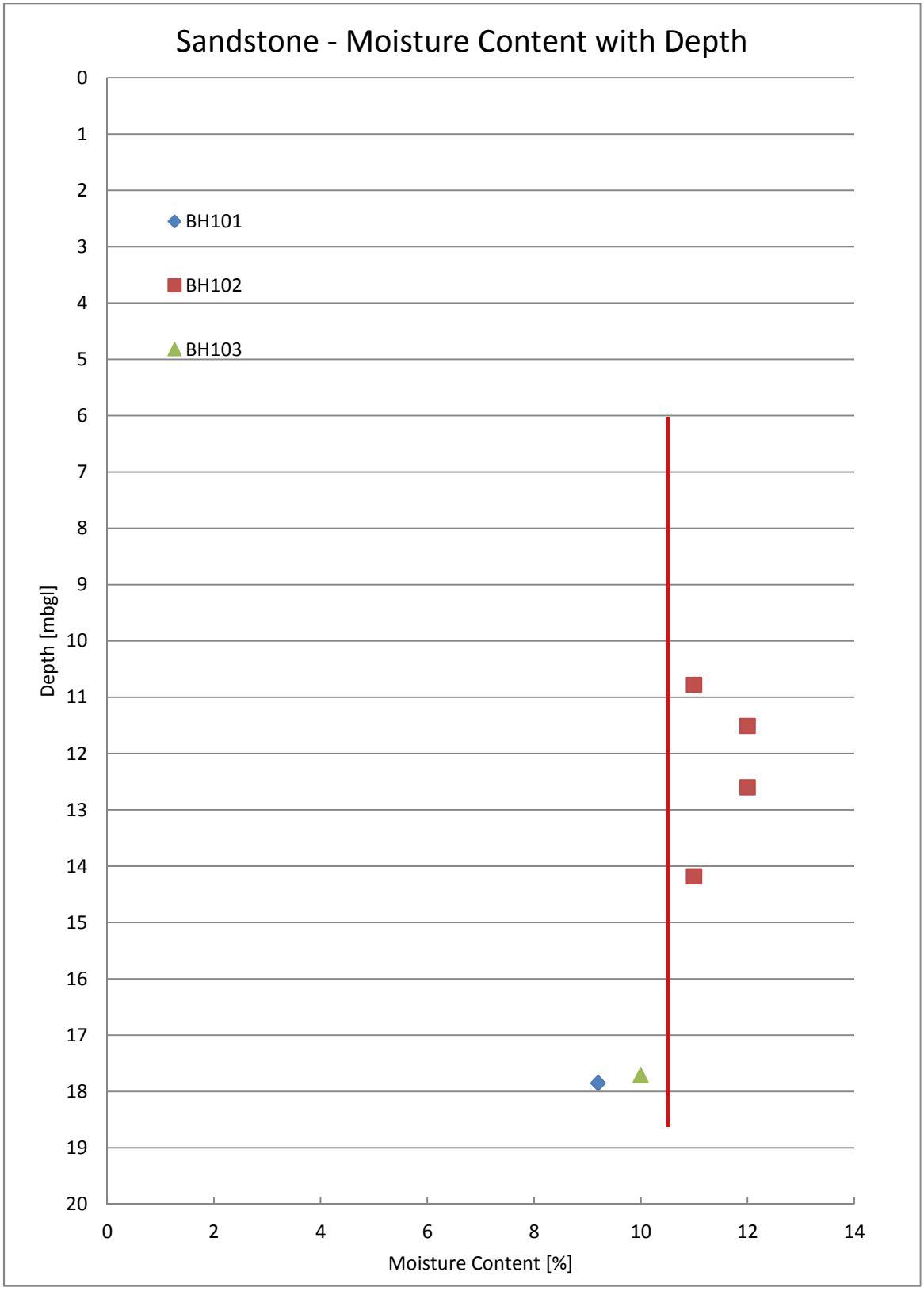


Figure 3.5.4 Sandstone – Moisture Content with Depth

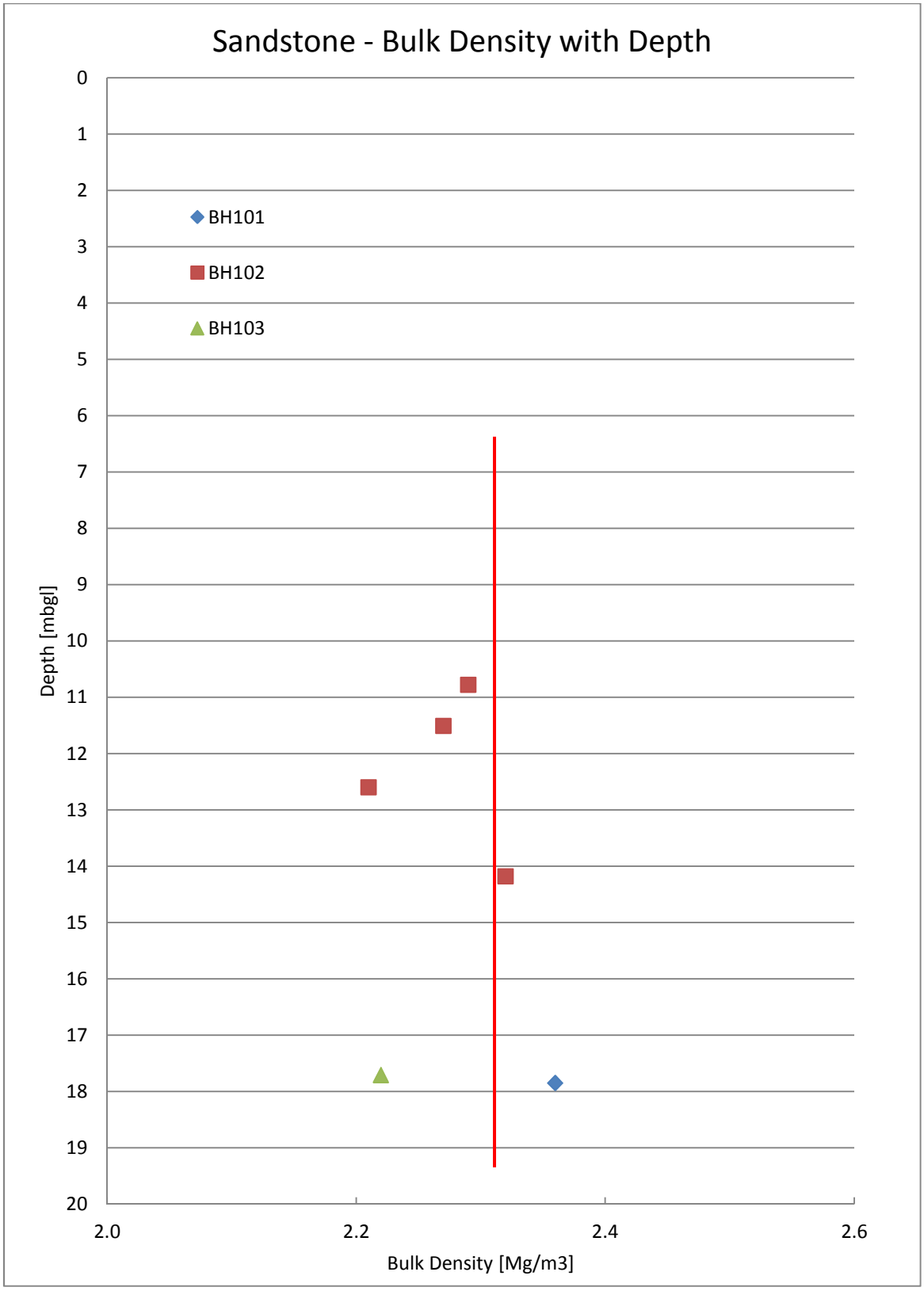


Figure 3.5.5 Sandstone – Bulk Density with Depth

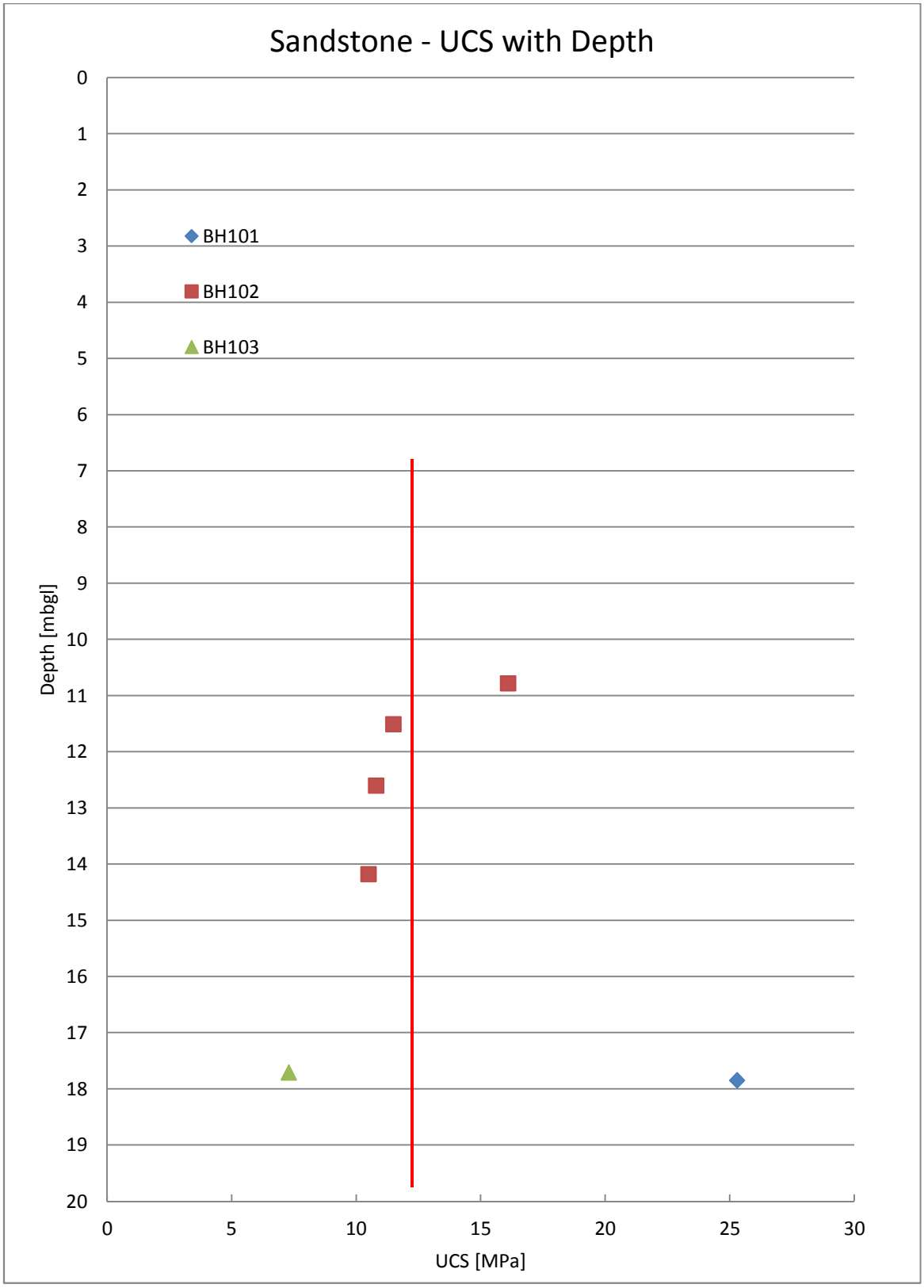


Figure 3.5.6 Sandstone – Intact Unconfined Compressive Strength with Depth

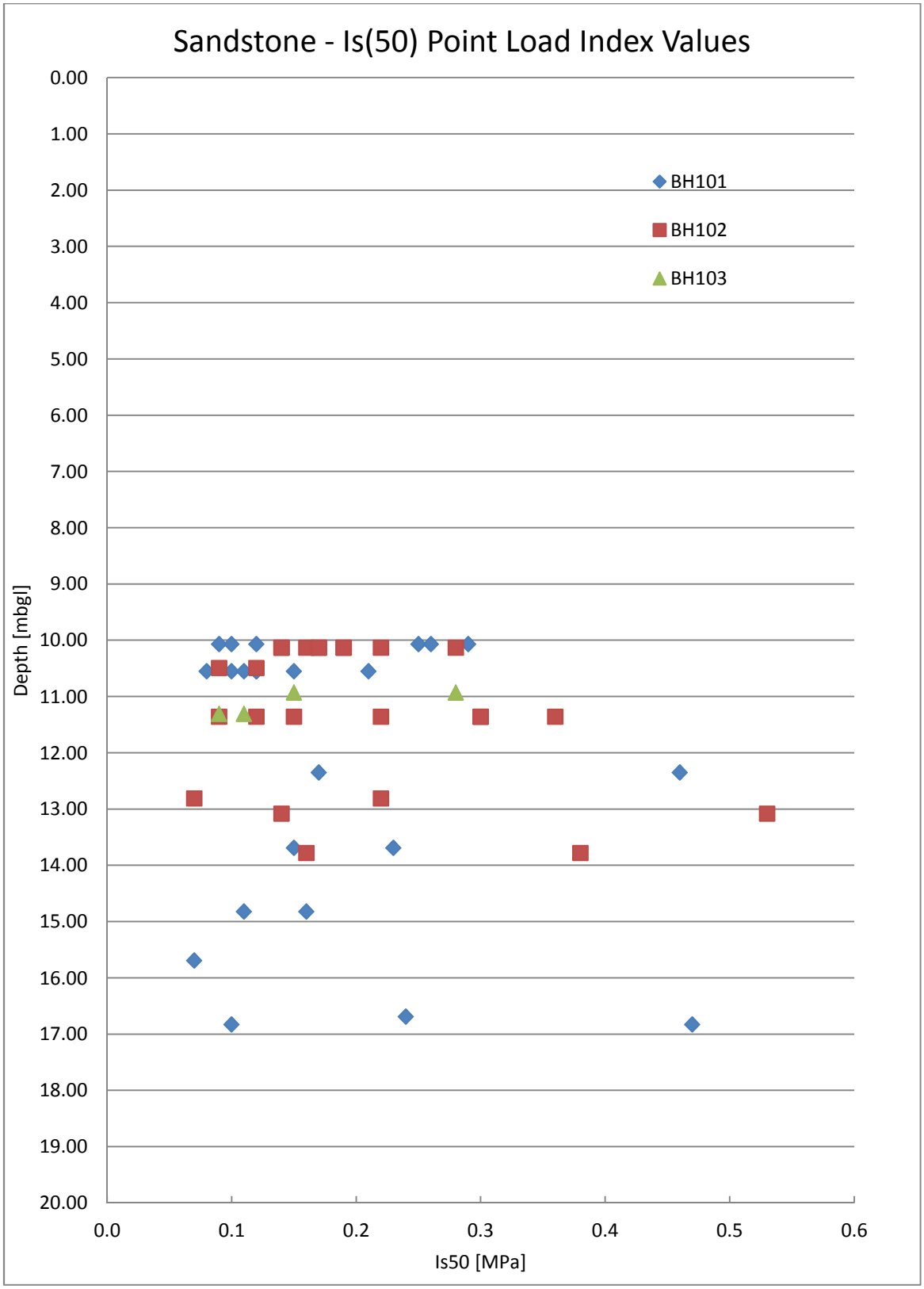


Figure 3.5.7 Sandstone – Point Load Index Values

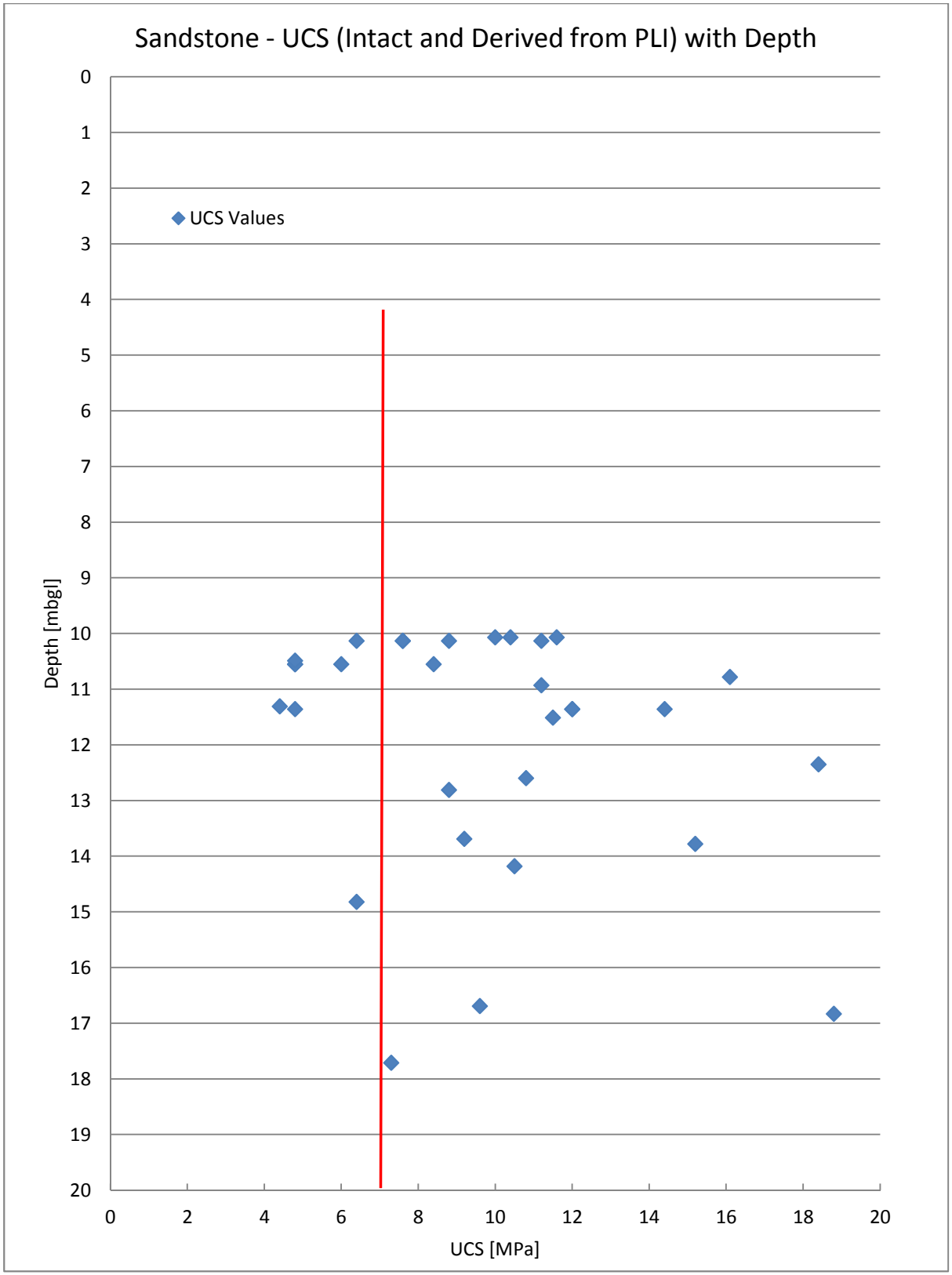
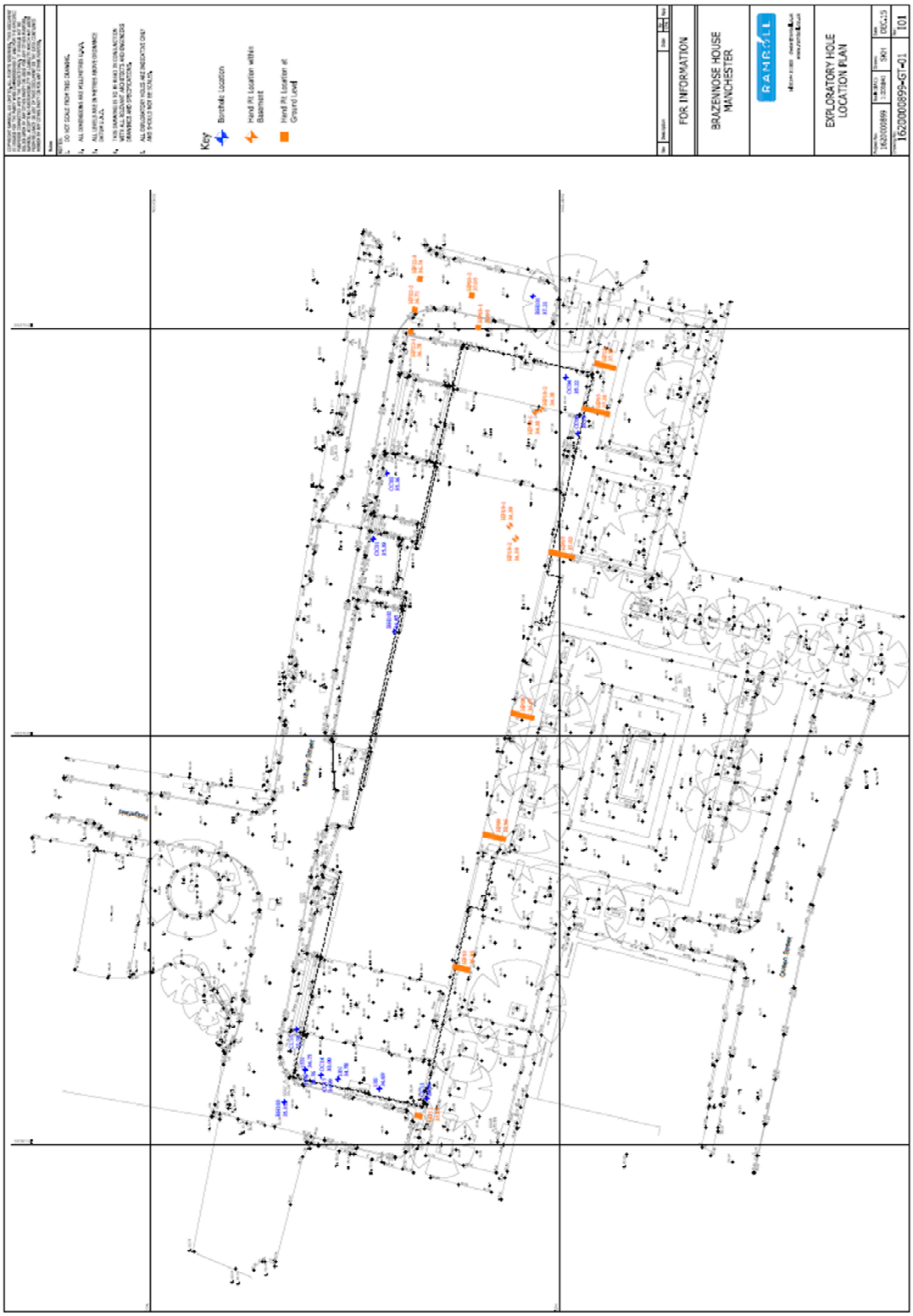


Figure 3.5.8 Sandstone – UCS (Intact and Derived from PLI) with Depth



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