ASTI Substation Site – LT521 Fasnakyle Ground Investigation Report

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Scottish & Southern Electricity Networks Transmission
LT521

ASTI Substation Site – LT521 Fasnakyle
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Ground Investigation Report

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1. Introduction

1.1 Scheme Background

Scottish & Southern Electricity Networks Transmission (SSEN) propose to construct a new 400kV substation at a site approximately 3.0km south of Tomich in the Scottish Highlands. The proposed substation is referred to as Fasnakyle substation for the purpose of this report but is also known as Bingally substation.

The proposed substation is required to allow the upgrade of the existing Beauly to Denny overhead line to accommodate a second 400kV circuit and support the wider connection of offshore renewables and the transition to a low carbon energy network.

The scope of the works associated with the proposed substation is listed below:

- Construction of a new approximately 380m x 295m earthworks platform to accommodate the new 400kV substation and associated access roads and equipment;
- Installation of two new super grid transformers;
- A new substation control building;
- Construction of a new access road to the site and associated earthworks;
- Connection to the existing Beauly to Denny 400 kV overhead line;
- Connection of the new and current substations via approx. 8km of 132kV underground cables.

SSEN designed a ground investigation (GI) to assess the ground conditions and geotechnical risks associated with the development and provide information for detailed design. A preferred site had not been identified when the GI scope was developed, so an extended site was investigated as part of the works. The proposed cable route and new access road were not investigated as part of the ground investigation. A separate ground investigation may be required for these works at a later stage.

Jacobs UK Ltd (Jacobs) were appointed in October 2023 as Investigation Supervisor for the ground investigation, tasked with providing technical supervision of the GI site works, checking the GI factual report and preparing a Ground Investigation Report summarising the ground conditions for the scheme.

The ground investigation was undertaken by Igne, formerly known as Raeburn Drilling and Geotechnical Ltd, with the findings summarised in their factual report for the works.

1.2 Scope and Objective of the Report

This Ground Investigation Report (GIR) has been produced in accordance with the requirements of section 6 (Ground Investigation Report) of Eurocode 7: Geotechnical Design – Part 2 (BS EN 1997-2:2007) [1]. In addition, the requirements of CD 622 [2] and SH 4/89 [3] have been taken into consideration where applicable.

The purpose of the GIR is as follows:

- To provide a general account of the ground conditions in the study area;
- Summarise the publicly available geotechnical and geo-environmental information available for the project, including information provided by SSEN;
- To present and summarise the in situ and laboratory test data, and comment on their potential impact on the construction of the substation;

- To present a ground model for the study area;
- To present a preliminary geo-environmental assessment;
- To identify constraints within the study area from a geotechnical and geo-environmental perspective; and
- Summarise the various ground risks by means of a geotechnical risk register.

1.3 Site Description

The site for the proposed substation is located south west of Inverness, approximately 3.0km south of Tomich in the Scottish Highlands. The site is approximately 14km west of Invermoriston and centred at approximate National Grid Reference (NGR) NH 30494 24406.

At the time of the GI two separate locations were being considered for the substation within the Fasnakyle site, referred to as 'Site D' and 'Site D Alternative'. In this report both 'Site D' and 'Site D Alternative' are considered as 'the site' and the information presented as site wide and is not subdivided into the two subsections. The site location and potential substation locations are shown in Figure 1-1 and Figure 1-2

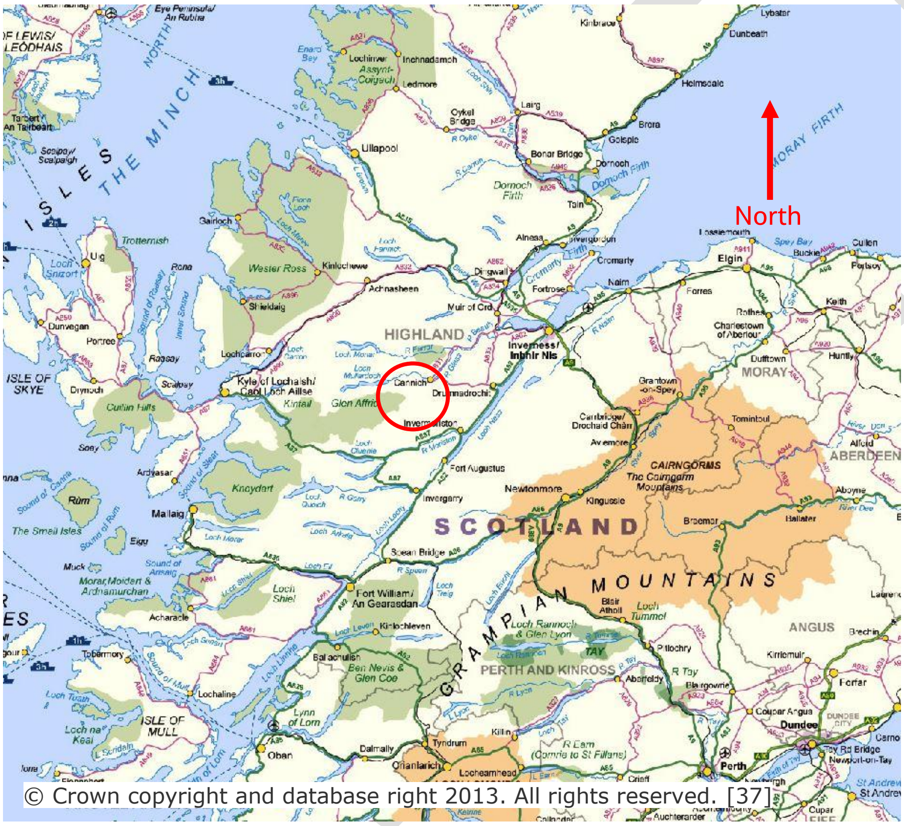

Figure 1-1 - Fasnakyle Substation - Site Location

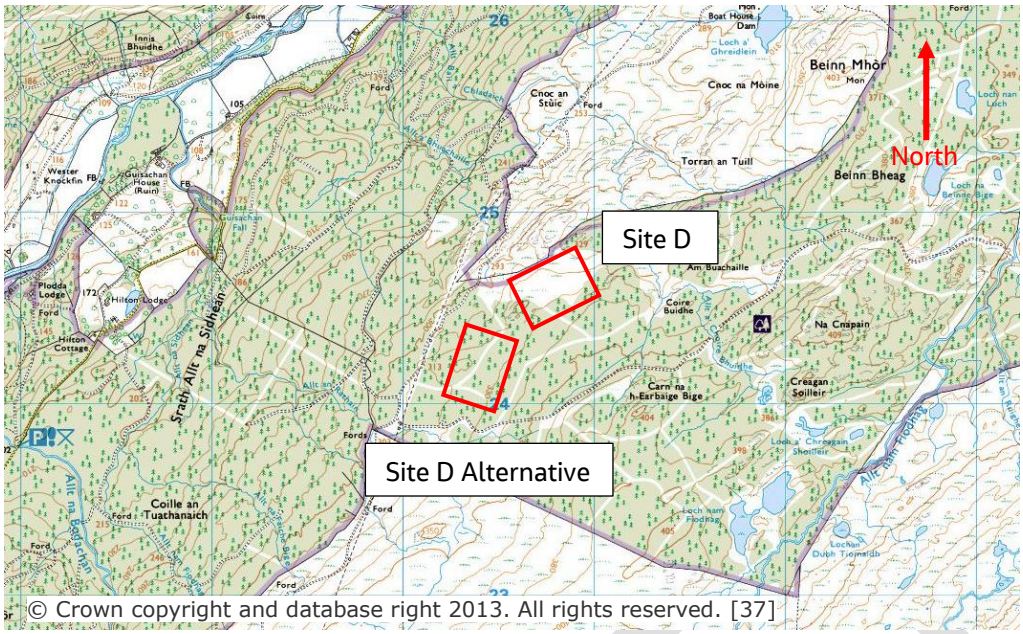

Figure 1-2 - Fasnakyle Substation – Potential Substation Locations

Both potential substation locations are located predominantly on felled commercial forest land; however, moorland and occasional craggy rock outcrops are present to the north affecting the Site D location. The site is bounded by the felled commercial forest to the north, south and east. To the west, the site is bounded by the existing Beauly to Denny overhead line.

The site generally rises from the west to the east towards Beinn Mhòr, which peaks at 403m AOD approximately 1.7km east of the site. Site D rises approximately 32m to a maximum level of approximately 339.0m AOD, and Site D Alternative rises approximately 25m to a maximum level of 340m AOD.

There are several drainage ditches recorded across the site, mostly along former firebreaks and brash tracks between sections of tree plantations. The drainage ditches on site generally flow from east to west given the general topography change in this direction.

1.4 Geotechnical Category

BS EN 1997-1 [4] defines three different Geotechnical Categories for structures:

- Category 1 – small and relatively simple structures.
- Category 2 – conventional types of structures and foundations with no exceptional risk or difficult soil or loading conditions.
- Category 3 – structures or parts of structures, which fall outside the limits of geotechnical categories 1 and 2.

Based on the proposed development, Geotechnical Category 2 is recommended for the proposed scheme.

1.5 Report Format

The format of this report broadly follows the suggested format of a Ground Investigation Report in Appendix F of CD 622 "Managing Geotechnical Risk" [2]. This is the standard applied for highways projects, nevertheless has relevance to this scheme which includes similar elements of highways schemes such as earthworks.

The Geotechnical Risk Register presented in Appendix C of this report uses the Project Risk Register format provided by SSEN.

1.6 Limitations

The findings contained within this report are based on the information obtained from a variety of sources and third parties (including the GI contractor) as detailed in the report, which are considered reliable. Nevertheless, the authenticity and reliability of the information cannot be fully guaranteed. Furthermore, it is possible that the research carried out, whilst fully appropriate to meet the requirements of the brief, may not indicate the full extent of the ground conditions across the site, and the existence of other information sources. Assuming such sources exist, their information could not have been used in the formulation of the findings presented in this report.

The information contained within this report is based on factual information available at the time of writing. The following limitations and exceptions relating to this report should also be observed:

(i) No Preliminary Sources Study Report (PSSR) is available for the site. All sources have been identified at the time of writing with no reference to any previous reports.

(ii) This report is based on information contained within the version of the Final Factual Report and AGS data file received on 21st March 2024. The Final Factual Report and AGS file require a small number of corrections to the report prior to its finalisation, which are outstanding at the time of writing.

(iii) Discussions of soil properties is based on the available GI information at the time of writing. However, as with any GI, unforeseen ground conditions that were not recorded within the available exploratory hole information cannot be ruled out.

(iv) Factual information only is presented in the summarising tables and graphical form to assist with the selection of design values of parameters. Design values of soil and rock parameters shall be determined by the Scheme Designer and be appropriate to the design approach and proposed solution.

2. Existing Information

Reference has been made to the existing desk study information contained within the following in preparation of this report:

- LT521 Pre-construction Information Report [5]
- LT521 Ground Investigation Technical Specification Report [6]

2.1 Walkover Survey

A site walkover was undertaken by Jacobs personnel across several days in November 2023 at the start of the ground investigation field works.

The main objective of the site walkover was to check potential access routes for GI and check proposed GI locations. As part of the walkover survey, relevant geotechnical observations were made for future use in the Ground Investigation Report.

The following observations were made during the walkover survey:

- Evidence of recent tree felling was observed across the majority of the site, extending from the southern site boundary to approximately halfway up Site D. The tree felling has left an irregular ground surface with many tree stumps and logs at the surface.
- The northern half of Site D consists of open moorland, bound by a deer fence to the northwest. Frequent rock outcrops were observed across this area of the site.
- Localised standing water and very soft ground was frequently observed across the site suggesting the majority of the site may be underlain by peat deposits.
- Two rock outcrops were observed in the west of Site D Alternative and the western boundary of Site D on areas of local high ground suggesting shallow bedrock is likely to be present in these areas.
- A small watercourse was observed at the northern end of Site D Alternative, running approximately southeast to northwest.
- Several drainage ditches were identified, mostly along former firebreaks and brash tracks between sections of tree plantations. The drainage ditches on site generally flow from east to west given the general elevation change in this direction.
- The existing Beauly to Denny 400kV overhead line was observed to the west of the site, running approximately north to south and bounding the southern half of the site to the west.

2.2 Historical Development of the Area

A review of the site history was carried out using historical maps available from the National Library of Scotland [7]. The review was carried out using historic Ordnance Survey maps dating from 1752 to 1961, alongside British Geological Survey (BGS) from 1993 and 2012 [8]. A review of aerial imagery was also carried out using available imagery from Google Maps [9] dating from 1985 to 2020.

No historic buildings were noted within the boundaries of the site and there is no indication that the area has been used for anything other than forestry in the past. Aerial imagery suggest that the commercial forest was planted prior to 1989 and was deforested in 2016.

The Beauly to Denny overhead line first appears on the Ordnance Survey map series 1949-1973 and has remained in the same location to the present day, including when it was upgraded to the current 400kV /

275kV circuits in 2015. The access tracks are also first shown on the Ordnance Survey map series 1949-1973 and were likely constructed at the same time as the Beauly to Denny overhead line.

2.3 Geology

The anticipated geological conditions at the site have been derived from the following sources:

- BGS Geo-index online database – onshore map [10]
- Geological Survey of Scotland, 1:50,000 geological map series 73W, Invermoriston, Solid, 1993 [11]
- Geological Survey of Scotland, 1:50,000 geological map series 73W, Invermoriston, Superficial, 2012 [12]

2.3.1 Made Ground

The geological maps do not show the presence of Made Ground underlaying the site; however, localised Made Ground associated with the construction of the existing roads and stone tracks may exist at the site. Furthermore, Made Ground associated with the construction of the Beauly to Denny overhead line may be present in the form of temporary earthwork platforms, temporary drainage and access tracks and forestry land use.

2.3.2 Superficial Geology

The superficial geology is indicated by the BGS GeoIndex Map [10] to primarily consist of Glacial Till; however, a large area of "no information" is shown towards the northern end of the site suggesting that bedrock is at or near the surface within this area. In addition, large areas of Peat are shown sporadically throughout the site.

The Glacial Till is described on the BGS GeoIndex Map [10] as unsorted and unstratified drift, generally overconsolidated, deposited directly by and underneath a glacier without subsequent reworking by water from the glacier. Furthermore, it consists of a heterogenous mixture of clay, sand, gravel and boulders varying in size and shape.

The Peat is described on the BGS GeoIndex Map [10] as a partially decomposed mass of semi-carbonised vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.

2.3.3 Solid Geology

The solid geology is indicated by the BGS GeoIndex Map [10] to consist of metasedimentary rock of the Tarvie Psammite Formation, which is part of the Loch Eil Group. The nearest fault is located over 1km to the west of the site and is noted to outcrop in the valley floor.

The Tarvie Psammite Formation is described to be at least 2.5km thick, up to about 5.0km, and is described as predominantly psammite, thin-bedded, siliceous to micaceous and generally fine grained. Local, thin semipelite beds are muscovite-rich and locally migmatitic. Large quartzite lenses are also noted to occur, particularly near the base.

2.4 Historical Ground Investigation

According to the BGS GeoIndex [10], there are no historical boreholes within the site, but there are nine historical boreholes within 500m of the site, all associated with the design and construction of the upgrade to the Beauly to Denny overhead line. The historical boreholes within 500m of the site are listed below in Table 2-1.

Table 2-1 - Summary of historic boreholes

Borehole	Description	Depth (m)
NH32SW1	Made Ground	0.40m
	Sand and Gravel	1.10m
	Weathered Psammite / Broken Rock *	2.50m
	Psammite	14.40m
NH22SE1	Peat	0.80m
	Sand	1.50m
	Sand and Gravel *	2.00m
	Sand *	4.00m
	Psammite	16.00m
NH22SE2	Peat	0.70m
	Sand and Gravel*	2.00m
	Sand*	2.90m
	Weathered Psammite*	6.00m
NH22SE3	Peat	0.60m
	Sand and Gravel*	1.70m
	Sand*	3.60m
	Weathered Psammite*	6.00m
NH22SE4	Peat	0.70m
	Sand and Gravel*	2.00m
	Sand*	3.90m
	Psammite*	6.00m
NH32NW54	Peat	1.10m
	Sand and Gravel*	1.70m
	Psammite	13.70m
NH32NW55	Peat	1.00m
	Sand and Gravel*	2.80m
	Psammite*	6.00m
NH32NW56	Peat	1.00m
	Sand and Gravel*	1.80m
	Psammite*	6.00m
NH32NW57	Peat	1.00m
	Sand and Gravel*	1.30m
	Psammite	13.30m
*** Description based on drilling observations only.**		

2.5 Hydrology

A watercourse was identified while on site that was not identified on any available information. The watercourse is located immediately adjacent to the northern boundary of Site D Alternative and runs southeast to northwest. Several drainage ditches were observed to run along former fire breaks or brash tracks. The drainage ditches generally flow east to west.

No watercourses are classified within 500m of the site on SEPA's Water Classification Hub [13].

Loch Beinn a' Mheadhoin, Loch an Eang, Loch nan Eun, and Loch ma Stac are located 5.5km, 4.8km and 3.2km respectively. All three are all recorded as being in good condition [13].

A review of the Scottish Environmental Protection Agency (SEPA) Flood Map [14] indicates there is no risk of fluvial flooding within 1km of the site. There is medium to high risk of surface flooding in localised areas across the site.

2.6 Hydrogeology

The 1:625,000 Hydrogeology Mapping included in the BGS GeoIndex [10] indicates that the area is underlain by impermeable Precambrian rocks, generally without groundwater except at shallow depth. The geology is therefore considered a low productivity aquifer with small amounts of groundwater in near surface weathered zone and secondary fractures.

The SEPA Water Classification Hub [13] records the site to be within the Northern Highlands groundwater body (ID: 150701) which has an overall status of "good".

2.7 Mining & Quarrying

The Coal Authority interactive map viewer [15] indicates the site to lie outside the Coal Authority consultation area and not to be located within a coalfield area.

A historic quarry is located in Tomich, recorded as Guisachan Quarry, and is currently marked as inactive. The quarry is first shown on the 1968 OS map [7] in its present day location.

2.8 Unexploded Ordnance

A pre-desk study unexploded ordnance (UXO) threat assessment was undertaken by Zetica and is included in Appendix D [[16], at the request of SSEN, in advanced of the ground investigation works at the site. The pre-desk study assessment report concluded that there is an unlikely potential to encounter UXO. Accordingly, a detailed desk study was not deemed necessary for the site.

2.9 Utilities

Utility information was obtained by SSEN as part of the pre-construction information package issued in advance of the ground investigation works.

The Beauly to Denny high voltage power line (400kV and 275kV) is shown on the utility plans provided at the western edge of the site, as observed on site. No other overhead or underground utilities are shown within 100m of the site.

2.10 Statutory Designations

Scotland's Historic Environment Pastmap website [8] records no historic buildings or protected sites within the site boundary, though Tomich Village on the access road to the site is marked as a conservation area.

2.11 Land Contamination

There is the potential for discrete areas of Made Ground to be encountered during development works associated with the existing power line access tracks/infrastructure and forestry land use. No additional potential sources of contamination have been identified.

The UK Health Security Agency records [17] indicate there is a maximum radon potential of 1-3% in the vicinity of the site. However, the site is less than 100 metres from a region where radon potential is over 30%.

NatureScott SiteLink indicates that the site is not located within 1km of an SSSI, SAC, SPA or any other area of interest [18].

An assessment of potential contamination is provided in Section 6.

3. Field and Laboratory Studies

3.1 Ground Investigations

A Ground Investigation (GI) was undertaken for the LT521 Fasnakyle project between 06 November 2023 and 15 January 2024. The GI was undertaken by Igne (formerly Raeburn Drilling Geotechnical Ltd) on behalf of SSEN with Jacobs undertaking the role of Investigation Supervisor. The findings of the investigation are contained in the following report:

- Proposed LT521 Fasnakyle 400 kV Substation, Report on Ground Investigation, Igne, XXXX 2024.

3.1.1 Aim of Ground Investigation

The aim of the ground investigation was to provide information on the ground and groundwater conditions at the site to establish a ground model for design, to assist in identifying a preferred location for the proposed substation and to investigate and quantify the geotechnical and geo-environmental conditions at the site. A further aim of the investigation was to enable soil classification and derivation of geotechnical and geochemical parameters of the encountered materials for the design of the earthworks and structures associated with the proposed new substation.

3.1.2 Design of Ground Investigation

The design of the GI was undertaken by SSEN. In Jacobs' capacity as Investigation Supervisor, where additional geotechnical constraints were identified during the investigation, changes to the design scope were made following discussion with SSEN. Further details on the scope changes are provided in Section 3.2.1.

3.2 Description of Fieldwork

The scope of works for this ground investigation, including the amendments to the scope discussed in Section 3.2.1, was as follows:

- 25 No. dynamic sample boreholes with in situ testing and rotary core follow-on in bedrock to a maximum depth of 15m below ground level (bgl).
- 38 No. machine excavated trial pits.
- Peat probing on a 10m x 10m grid across the site.
- 6 No. in situ thermal resistivity tests.
- 1 No. Soakaway tests.
- 13 No. Gas and groundwater monitoring installations.
- Geotechnical, chemical, and geo-environmental laboratory testing.

The locations of the exploratory holes are shown on the Site Plan provided in Igne's factual report for the works [19], and on the plans provided in Appendix A.

3.2.1 Development of Ground Investigation

During the GI, the scope of the works was amended to investigate additional geotechnical constraints identified on the site and to remove locations deemed no longer required. The following changes were made to the original scope:

- Several locations were moved within the southern end of the site to provide greater coverage within the site boundary. In addition, additional boreholes (BH27 and BH28) and trial pits (TP31 to TP37) were added to the scope to compensate for the increased spacing between exploratory positions and provide further information in the southeast of the site.
- Additional boreholes were carried out at BH24A and BH26A due to BH24 and BH26 not collecting samples within the superficial deposits.
- BH01, BH05, BH06, BH07 and BH10 were removed from the ground investigation scope as the southern site (Site D Alternative) was identified as the preferred location for the substation during the works, and therefore, these positions were no longer required.
- 6 No. boreholes were drilled with a smaller diameter core barrel (BH02, BH03, BH11, BH12, BH14, BH17) to increase the Contractor's productivity and reduce the overall site works programme.
- An additional trial pit (TP36A) was carried out to locate bedrock at TP36 as the trial pit terminated at shallow depth after encountering buried logs and could not be advanced.
- 15 No. thermal resistivity tests were scheduled, however due to shallow bedrock and unsuitable material, only 6 no. were completed (at TP10, TP15, TP26, TP28, TP30 and TP37).
- 6 No. soakaway tests were scheduled, however due to shallow bedrock and unsuitable superficial deposits, only 1 No. was completed (at TP28).

3.2.2 In Situ Testing and Sampling

The following in situ testing was undertaken during the ground investigation works to determine the geotechnical and chemical properties of the materials encountered on site.

- 26 No. Standard Penetration Tests (SPTs) were carried out within the boreholes using a split barrel sampler to obtain an indication of the relative density of the granular soils. Tests were undertaken from the base of the hand dug inspection pit to bedrock.
- 6 No. in situ thermal resistivity tests were carried out within selected trial pits to determine the thermal resistivity of the in situ soils for the design of buried cables.
- 1 No. soakaway test was undertaken within TP28 to obtain an indication of the soil infiltration rate for use in the design of Sustainable Urban Drainage System (SUDS) features.
- Recovery of disturbed samples from all exploratory holes and hand pits for geotechnical, geochemical and geo-environmental laboratory testing.

3.3 Laboratory Testing

The laboratory testing was carried out by Terra Tek Ltd. who hold UKAS Accreditation for the scheduled tests. A list of the geotechnical, geochemical and geo-environmental tests schedules is provided below in Table 3-1 and Table 3-2.

Table 3-1 - Summary of Geotechnical Tests

Geotechnical Tests – Soil	Geotechnical Tests – Rock
Moisture Content	Los Angeles Abrasion value
Liquid and Plastic Limit	Slake Durability
Particle Size Distribution Tests	Magnesium Soundness
Moisture Content Tests	Aggregate Crushing Value
California Bearing Ratio	Point Loads
One-dimensional Consolidation Tests	Unconfined Uniaxial Compressive Strength
Compaction Testing	Micro Deval
Thermal Resistivity	Resistance to fragmentation
Organic Matter	Water absorption
BRE Suite B	BRE Suite B
PH Value	Flakiness Index
Sulphate Content (2:1)	

Table 3-2 - Summary of Geo-Environmental Tests

Geo-Environmental Tests
Metals (Arsenic, Boron, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Zinc)
Inorganic Suite
TPHCWG/VPHCWG
TPHCWG Aliphatic/Aromatic Split
Polyaromatic Hydrocarbons (PAH) (USEPA 16)
VOCs/VOCs(BTEX)
Asbestos

4. Ground Summary

Soil and rock units have been classified using the available geological maps and information gathered during the ground investigation including soil and rock descriptions, in situ and laboratory testing across the entire site (both Site D and Site D Alternative). The soil and rock classifications and geology codes assigned are given in Table 4-1 in stratigraphic order. A geology code has been assigned to all descriptions made during the ground investigation.

Table 4-1 - Site Geology Codes

Stratum	Reference Code 1	Reference Code 2	Geological Classification
Topsoil	TPS	TPS	Topsoil
Peat	PT	PEAT	Peat
Glacial Deposits	GD	GD-G	Granular Glacial Deposits
Weathered Bedrock	WR	WR-WR	Weathered Bedrock
Bedrock	BR	BR-IGN	Igneous Intrusion
		BR-MSED	Metasedimentary

4.1 Ground Model

A 3D ground model has been produced using the computer software, Leapfrog Works. A topographic survey provided by SSEN was incorporated into the model and the AGS file was used to build the ground model in Leapfrog. Geology Reference Code 1 was used to create the ground model to show the bedrock; glacial and peat deposits across the site, bedrock types have not been differentiated. Cross Sections A-A', B-B', C-C' and D-D' indicating the general stratigraphy across the site are provided in Appendix A, with a layout plan indicating their location.

The following assumptions have been made in developing the Leapfrog model and cross sections:

- The peat probe locations were not surveyed; therefore, their coordinates were plotted onto the topographic survey to determine the ground level at each probe location.
- Topsoil was encountered in TP16 and TP27 only and has therefore been excluded from the model.
- Weathered bedrock was encountered in localised areas throughout the site. Due to the method of triangulation used by the software, the thickness of weathered bedrock was overestimated by the software. As a result, the weathered bedrock has not been included in the cross sections in Appendix A.
- Bedrock has been assumed at the base of the trial pits where the pit terminated on 'possible bedrock'.
- The sections have been cut through the southern area of the site; with the understanding that the substation is likely to be located at 'Site D Alternative' (see Figure 2).

4.2 Stratigraphy

The general ground conditions at the site comprises Peat overlying Granular Glacial Deposits and bedrock, predominately comprising psammite of the Tarvie Psammite Formation with occasional igneous intrusions. Locally the Peat was found to be directly overlying bedrock.

Bedrock was encountered at shallow depths across the site, typically less than 3m below exiting ground level. Locally bedrock was recorded at or near the surface, with an occasional thin layer of weathered bedrock also recorded.

4.3 Topsoil (TPS-TPS)

Topsoil was encountered in exploratory holes TP16 and TP27 only, recorded to a maximum depth of 0.30m below existing ground level. The Topsoil was described as brown gravelly sandy silty TOPSOIL and dark brown sandy locally spongy fibrous peaty TOPSOIL within TP16 and TP27 respectively.

No in situ testing was carried out within the Topsoil and no laboratory testing was undertaken on samples of the Topsoil obtained from the above trial pits.

4.4 Peat (PT-PT)

Peat was encountered across the site within 13 No. boreholes and in all trial pits, except for TP16 and TP27 where Topsoil was encountered above the Granular Glacial Deposits. Suspected Peat was also encountered within the 5,991 No. peat probes undertaken across the site.

Peat was encountered from ground level to a maximum depth of 3.50m (BH28) within the boreholes and trial pits. The Peat was typically described as dark brown slightly sandy plastic amorphous locally spongey fibrous PEAT.

The Von Post codes used to describe the Peat within the site ranges from H2 to H8, where H2 indicates that the material is almost entirely undecomposed and the plant matter remains are still easily identifiable. H8 indicates the Peat is very highly decomposed and contains a large quantity of amorphous material and very indistinct plant structure.

The data from the peat probes has been used to prepare contour plots and peat thickness heat maps for the site. These contour plots and heat maps are provided within Appendix A.

The peat probes carried out across the site suggest the Peat is typically less than 2m in thickness; however, local areas of deeper Peat exist across the site. A significant area of deep Peat was recorded at the northern end of the site, with a maximum depth of 7.82m recorded in PP5078.

4.5 Granular Glacial Deposits (GD-G)

Granular Glacial Deposits was encountered across most of the site within 19 No. boreholes and 32 No. trial pits. The Granular Glacial Deposits was typically encountered beneath the Peat or Topsoil, ranging in thickness from 0.10m (TP22) to 2.70m (BH18), and was recorded to a maximum depth of 5.00m (BH28).

The deposits are typically described as medium dense to very dense brown or grey silty fine to coarse SAND and fine to coarse angular to subangular GRAVEL of psammite and granite with low to medium cobble and boulder content. Cobbles and boulders are generally angular to subangular of psammite and granite. Local areas of high cobble and boulder content are also recorded on the logs.

4.6 Weathered Bedrock

Weathered bedrock was recorded within 11 No. boreholes and 13 No. trial pits across the site. The weathered bedrock was not extensively recorded and was found in localised areas beneath the Granular Glacial Deposits.

The weathered bedrock is generally described as an “obstruction (possible rock)” on the trial pit logs and is typically 0.10m in thickness. It is believed this 0.10m thick layer shown at the base of the 13 No. trial pits has been artificially included to show bedrock at the base of the trial pit log, and it is unlikely the trial pits encountered a consistent 0.10m thick weathered bedrock layer across the site.

The majority of the weathered bedrock recorded on the borehole logs is based on the driller's description as the boreholes were commonly advanced by rotary percussive methods and therefore it was not possible to obtain samples for logging. It is likely that several of these occurrences have been incorrectly logged and the borehole was actually advanced through very dense Granular Glacial Deposits or fractured bedrock.

Samples of suspected weathered bedrock were obtained from 3 No. boreholes and was typically described as light brown granite or psammite recovered as gravelly SAND or sandy GRAVEL.

In the boreholes, the weathered bedrock was generally recorded beneath the Peat or Granular Glacial Deposits at depths between 0.40m and 3.10m below ground level, with thicknesses between 0.20m (BH12) and 2.70m (BH09).

A localised area of deeper weathered bedrock was encountered in the southeast of the site, where the weathered bedrock was recovered as sand or gravel if the borehole was advanced by rotary percussive methods, or as non-intact core if recovered by rotary core follow-on. The weathered bedrock was recorded to depths of 4.40m bgl in BH22 and 7.60m bgl in BH25. Where the weathered bedrock was cored, it was described as weak locally medium strong pinkish grey psammite, distinctly weathered evident as a reduction in strength, recovered as non intact.

4.7 Bedrock

Bedrock was encountered within all boreholes at the site at depths between ground level (BH19 and BH20) and 7.60m bgl (BH25). Within the trial pits probable bedrock was encountered at depths between 0.30m (TP09) and 3.00m bgl (TP28). Trial pits TP11, TP17, TP26 and TP36 terminated at depths of 1.50m, 2.50m, 2.00m and 1.40m bgl respectively without encountering bedrock.

The bedrock at the site was found to be primarily a metasedimentary rock with occasional igneous intrusions, details of which are provided in Sections 0 and 4.7.2.

4.7.1 Metasedimentary Bedrock

Psammite was encountered in all boreholes across the site at depths between ground level (BH19 and BH20) and 13.10m bgl (BH25). The engineering description provided for the psammite was found to vary across the site, broadly falling into two groups typically described as:

- Medium strong to very strong grey PSAMMITE with occasional subhorizontal or subvertical quartz veins (up to 20mm). Moderately, locally slightly or highly weathered evident as localised orange brown staining on the fracture surfaces and rare clay, sand or gravel infilling on the fracture surfaces.
- Very weak to moderately weak grey and brown PSAMMITE with rare subvertical quartz veins (up to 10mm). Moderately, locally highly weathered evident as orange brown staining on fracture surfaces, localised reduction in strength on fracture surfaces, with occasional sand or gravel infilling on the fracture surfaces.

Typically, one to three fracture sets were recorded within the psammite bedrock with evidence of low and high angle bedding fractures throughout. These typically ranged from:

- Shallow dipping 10-30° closely locally medium spaced, planar and smooth, locally rough fractures.
- 60-90° medium locally closely spaced, planar and smooth, locally stepped and rough fractures.

A single occurrence of pelite was recorded in borehole BH26 at the southern end of the site between 3.00m and 8.60m bgl. The pelite is described as weak to strong, predominantly moderately weathered evident as orange brown staining on the fracture surfaces, local reduction in strength on the fracture surfaces and local gravel infill on the fracture surfaces. For the purpose of the ground model the pelite has been included with the psammite.

4.7.2 Igneous Bedrock

Granite was encountered in 13 No. boreholes across the site at depths between 1.10m (BH11) to 8.40m bgl (BH24) with thicknesses varying between 0.20m (BH15) and 5.00m bgl (BH02). The engineering description provided for the granite was found to vary across the site, broadly falling into two groups typically described as:

- Weak and moderately weak, locally medium strong, pinkish brown granite. Moderately locally highly weathered evident as orange brown staining on the fracture surfaces and a reduction in strength on the fracture surfaces.
- Medium strong to very strong pinkish brown or pinkish grey granite. Slightly to moderately weathered evident as orange brown staining on the fracture surfaces and localised reduction in strength on the fracture surfaces.

Typically, one to three fracture sets were recorded within the granite bedrock with evidence of low and high angle bedding fractures throughout. These typically ranged from:

- Shallow dipping 10-40° closely spaced, planar and smooth, locally rough fractures.
- 60-80° closely locally medium spaced, planar and smooth, locally stepped and rough fractures.

4.8 Groundwater Strikes

Groundwater strikes were observed in 16 No. boreholes and 24 No. trial pits at the site in the Peat and Granular Glacial Deposits between 0.10m (TP34) and 3.20m bgl (BH28). No groundwater observations were recorded during rock coring due to the use of water flush.

Within the trial pits the groundwater was described as a slow seepage, slow flow and steady flow, but some occurrences of a fast flow were also recorded.

The groundwater strikes were monitored for 20 minutes within 5 No. boreholes with rises between 0.00m (BH24A) and 0.95m (BH15) generally recorded; however, the groundwater in BH28 rose to the surface after being struck towards the base of the Peat at 3.20m bgl.

Table 4-2 - Summary of groundwater strikes

Exploratory Hole ID	Water Strike (mbgl)	Rise (mbgl)
BH12	1.80	N/A
BH13	1.10	N/A
BH14	1.30	0.80
BH15	1.30	0.35
BH16	1.40	1.00
BH17	3.20	N/A
BH18	2.60	N/A
BH21	1.20	N/A
BH22	0.50	N/A
BH23	0.50	N/A
BH24	0.65	N/A
BH24A	0.50	0.50
BH25	0.30	N/A
BH26A	0.30	N/A
BH27	1.95	N/A
BH28	3.20	0.00
TP01	1.00	N/A
TP05	0.70	N/A
TP06	0.30	N/A
TP10	0.30	N/A
TP11	1.50	N/A
TP15	1.20	N/A
TP17	2.50	N/A
TP20	0.50	N/A
TP21	0.40	N/A
TP22	0.30	N/A
TP23	0.40	N/A
TP24	0.20	N/A
TP25	0.40	N/A
TP26	0.20	N/A
TP28	2.90	N/A
TP29	1.90	N/A
TP30	0.20	N/A
TP31	0.40	N/A
TP33	0.50	N/A
TP34	0.10	N/A
TP35	0.50	N/A
TP36	1.40	N/A
TP36A	0.80	N/A
TP37	0.40	N/A

4.9 Groundwater Monitoring

Gas and groundwater monitoring instrumentation was installed in selected boreholes across the site to provide groundwater level and gas concentration data. Details of boreholes with gas and groundwater monitoring instrumentation, together with the monitoring results are provided in the Factual Report (E1) and reproduced in Figures GW-01 and GW-02 in Appendix B.

Gas and groundwater monitoring was undertaken in available boreholes during the site works and in the post site monitoring between January and March 2024. Further monitoring data is expected for April 2024. A summary of instrumentation and groundwater monitoring is provided in Table 4-3. Gas monitoring results are summarised in Section 6.

Table 4-3 – Groundwater Monitoring Levels

Exploratory Hole ID	Installation		Stratigraphic Unit	Monitored Level			
	Type	Response Zone (mbgl)		Deepest		Shallowest	
				m bgl	m AOD	m bgl	m AOD
BH02	SP	1.75-6.25	Bedrock – Granite	5.06	319.15	0.42	323.79
BH04	SP	2.00-7.50	Bedrock – Granite and Psammite	0.54	324.48	0.42	324.60
BH08[(1)]	SP	2.10-6.80	Bedrock – Granite and Psammite	0.00	334.07	+0.30	334.37
BH11	SP	1.60-6.10	Bedrock – Granite and Psammite	4.85	325.74	3.55	327.04
BH14	SP	1.80-6.75	Bedrock – Psammite	0.36	305.70	0.11	305.95
BH16	SP	2.40-7.25	Bedrock – Granite and Psammite	0.70	324.72	0.54	324.88
BH18	SP	1.00-2.60	Granular Glacial Deposits	1.98	314.77	0.50	316.25
BH21	SP	3.10-8.00	Bedrock – Granite and Psammite	0.36	326.13	0.25	326.24
BH22	SP	2.00-11.50	Bedrock – Granite and Psammite	0.85	332.99	0.69	333.15
BH23	SP	2.50-6.50	Bedrock – Psammite	0.30	315.70	0.00	316.00
BH25	SP	1.00-6.60	Weathered Bedrock – Granite and Psammite	0.20	331.85	0.16	331.89
BH26	SP	1.00-3.00	Granular Glacial Deposits	0.80	314.26	0.00	315.06
BH27	SP	3.10-9.90	Bedrock – Granite and Psammite	0.43	331.26	0.16	331.53

Notes:

(1) Artesian groundwater was recorded in BH08 on 30/01/2024, at +0.3m above ground level.

5. Engineering Properties

5.1 Introduction

The in situ and laboratory test results for each material type identified in Section 4 are summarised in a series of tables in the following sections and, where appropriate, in figures, which are presented in Appendix B of this report.

Standard Penetration Tests within boreholes were undertaken to obtain an indication of the relative density of granular soils. The energy ratio of the SPT hammer was recorded by the contractor during the GI. The SPT values reported within this GIR have taken the energy ratio into consideration and the correction factor given within BS EN 22467-3 [20] has been applied to the raw SPT 'N' values to provide SPT N_{60} values within this report.

5.2 Topsoil

No in situ testing was carried out within the Topsoil. Laboratory testing in the form of thermal resistivity/conductivity was undertaken on one sample of the Topsoil obtained during the GI; however, as this was described as a peaty topsoil, the results have been included within the Peat in Section 5.3.

5.3 Peat

In situ testing in the form of thermal resistivity/conductivity and SPTs were carried out within the Peat deposits at the site. Laboratory testing was undertaken on selected samples collected from the exploratory holes. The in situ and laboratory test results are summarised in Table 5-15.1.

Table 5-1 - Summary of In Situ and Laboratory Test Results for Peat

Test (Units of measurement)		No. Tests	Results				Figure Ref (Appendix B)
			Minimum	Maximum	Median	Mean	
In-Situ Thermal Conductivity (W/Km)		2	1.251	1.325	1.288		TR-02
In-Situ Thermal Resistivity (Km/W)			0.754	0.799	0.777		
SPT (N_{60} Values)		1	1				SPT-01
Water Content (%)		18	19	1353	521	545	MC-01
Bulk Density (Mg/m^3)		5(1)	0.99	1.86	1.23	1.31	N/A
Dry Density (Mg/m^3)		5(1)	0.18	1.48	0.50	0.62	
pH		5	4.0	5.0	4.5	4.5	
Organic Matter (%)		14	12.6	24.4	19.2	18.8	
Sulphate, water soluble (as SO_4) (mg/l)		5	13	76	45	42	
Acid Soluble Sulphate (%)		4	0.12	0.51	0.27	0.29	
Laboratory Thermal Conductivity (W/Km)	NMC	3	0.59	1.66	0.77	1.00	TR-02
	DRY		0.04	0.24	0.14	0.14	
Laboratory Thermal Resistivity (Km/W)	NMC	3	0.60	1.68	1.30	1.19	
	DRY		4.15	22.25	7.20	11.20	

Notes:

(1) Results obtained from laboratory thermal resistivity/conductivity tests and a single oedometer test.

A single one dimensional consolidation (oedometer) test was carried out on a sample of Peat from BH17 and returned an Mv value of 3.46m^2/MN at the existing overburden pressure, suggesting the material is highly compressible. Reference should be made to the test plot provided in Igne's factual report for the detailed test results.

5.4 Granular Glacial Deposits

In situ testing in the form of thermal resistivity/conductivity, SPTs and a single Soakaway test were carried out within the Granular Glacial Deposits at the site. Laboratory testing was undertaken on selected samples collected from the exploratory holes. The in situ and laboratory test results are summarised in Table 5-2.

Table 5-2 - Summary of In Situ and Laboratory Test Results for Glacial Granular Deposits

Test (Units of measurement)		No. Tests	Results				Figure Ref (Appendix B)
			Minimum	Maximum	Median	Mean	
In-Situ Thermal Conductivity (W/mK)		4	0.717	5.232	1.453	2.214	TR-03
In-Situ Thermal Resistivity (mK/W)			0.191	1.395	0.737	0.765	
SPT (N_{60} Values)		13	23	72	50	51	SPT-02
Water Content (%)		10	6	338	25	53	MC-02
Bulk Density (Mg/m^3) (1)		14	1.60	2.20	2.03	2.01	N/A
Dry Density (Mg/m^3) (1)		14	1.05	2.01	1.79	1.71	
Liquid Limit (%) (2)		2	33	34	33.5		
pH		7	5	7	6	6	
Organic Matter (%)		4	2.1	25	3.5	8.5	
Sulphate, water soluble (as SO_4) (mg/l)		7	9	36	24	21	
Acid Soluble Sulphate (%)		7	0.02	0.05	0.03	0.03	
Laboratory Thermal Conductivity (W/mK)	NMC	11	0.55	2.16	1.54	1.46	TR-03
	DRY		0.06	0.31	0.23	0.21	
Laboratory Thermal Resistivity (mK/W)	NMC	11	0.46	1.77	0.65	0.81	
	DRY		3.17	16.66	4.32	6.20	
California Bearing Ratio (%)		3	2	60	13	25	N/A
Optimum Moisture Content (%)	4.5kg	4	7.7	16	9.45	10.65	COM-01
Maximum Dry Density (Mg/m^3)	4.5kg	4	1.61	2.06	1.98	1.91	
Shear Strength - Angle of shearing resistance (°)		1	40				N/A
Shear Strength - Cohesion (kPa)			8				

Notes:

(1) Results obtained from laboratory thermal resistivity/conductivity tests, CBR tests and shear box tests.

(2) 2 No. Atterberg tests were carried out on samples of the Granular Glacial Deposits, all of which confirmed the material to be non plastic.

22 No. Particle Size Distribution tests (PSDs) were carried out on samples of the Granular Glacial Deposits (Figure PSD-01) and show the material is generally well graded with a fines content ranging from 2% to 33%.

The SPT N_{60} values indicate that the material is typically dense to very dense (Figure SPT-02); however, a single occurrence of medium dense material was encountered in BH18 at 1.20m bgl.

1 No. Soakaway test was performed adjacent to TP28 within the Granular Glacial Deposits; however, the soil infiltration rate could not be determined. Reference should be made to the test plot provided in Igne's factual report for the detailed test results.

5.5 Weathered Bedrock

In situ testing in the form of SPTs were carried out within the Weathered Bedrock at the site. Laboratory testing was undertaken on selected samples collected from the exploratory holes. The in situ and laboratory test results are summarised in Table 5-3.

Table 5-3 - Summary of In Situ and Laboratory Test Results for Weathered Bedrock

Test (Units of measurement)	No. Tests	Results				Figure Ref (Appendix B)
		Minimum	Maximum	Median	Mean	
SPT (N_{60} Values)	8	50				SPT-03
pH	1	1				N/A
Sulphate, water soluble (as SO_4) (mg/l)	1	11				
Acid Soluble Sulphate (%)	1	0.02				

A single PSD test was carried out on a sample of the Weathered Bedrock (PSD-02) and shows the material to be generally gap graded with a fines content of 9%.

5.6 Metasedimentary Bedrock

The bedrock encountered during the GI was comprised predominately of Psammite. A summary of the rock quality is presented in Table 5-4 and a summary of the laboratory test results undertaken on selected samples of the psammite is provided in Table 5-5**Error! Reference source not found.**.

Table 5-4 - Summary of Rock Quality for Metasedimentary Bedrock

Core Quality	No. Tests	Results				Figure Ref (Appendix B)
		Minimum	Maximum	Median	Mean	
Total Core Recovery (TCR)	140	60	100	100	99	N/A
Solid Core Recovery (SCR)	140	0	100	84	76.3	
Rock Quality Designation (RQD)	140	0	95	28	34.5	
Fracture Index (FI)	140	3	NI/>20[(1)]	9	10.4	

Notes:

(1) NI and >20 values assigned a value of 20 in calculations of median and mean to prevent skewing of results by their exclusion.

Table 5-5 - Summary of Laboratory Test Results for Metasedimentary Bedrock

Test (Units of measurement)	No. Tests		Results				Figure Ref (Appendix B)
			Minimum	Maximum	Median	Mean	
Point Load Tests (Is_{50}) (kPa)	145		0.04	14.55	4.76	4.41	PLT-02
Unconfined Compressive Strength (MPa)	20		10	98	51	51	UCS-02
Los Angeles Coefficient	4		21	37	21.5	25.3	N/A
Slake Durability Index (%)	4		82.8	98.6	97.9	94.3	
Aggregate Crushing Values	4		15	18	16	16.3	
Soundness by Magnesium Sulphate	3		8	12	12	10.7	
Flakiness Index	1		22				
Micro Deval	1		57				
Water Absorption (%)	1		0.8				
Acid Soluble Sulphate (%)	4	0.02	1.13		0.06	0.32	

Notes:

(1) The PLT tests were carried out on both axial and diametral orientations, as well as a small number on irregular lump samples where full core was not available.

(2) 5 No. Standard Penetration Tests were undertaken at rockhead, all of which recorded refusal (i.e. SPT N>50).

Based on the Fracture Index and UCS information, the excavatability of the metasedimentary bedrock has been categorised as 'easy' to 'very hard ripping' following the method of assessment provided in Pettifer and Fookes [21]. Reference should be made to the excavatability plot (EX-02) provided in Appendix B.

5.7 Igneous Bedrock

The occasional igneous intrusions encountered during the GI comprised of Granite. A summary of the rock quality is presented in Table 5-4 and a summary of the laboratory test results undertaken on selected samples of the psammite is provided in Table 5-5**Error! Reference source not found.**.

Table 5-6 - Summary of Rock Quality for Igneous Bedrock

Core Quality	No. Tests	Results				Figure Ref (Appendix B)
		Minimum	Maximum	Median	Mean	
Total Core Recovery (TCR)	34	85	100	100	99.3	N/A
Solid Core Recovery (SCR)	34	0	100	82	77.1	
Rock Quality Designation (RQD)	34	0	100	42	36.6	
Fracture Index (FI)	34	2	NI/>20(1)	10	10.9	

Notes:

(1) NI and >20 values assigned a value of 20 in calculations of median and mean to prevent skewing of results by their exclusion.

Table 5-7 - Summary of Laboratory Test Results for Igneous Bedrock

Test (Units of measurement)	No. Tests	Results				Figure Ref (Appendix B)
		Minimum	Maximum	Median	Mean	
Point Load Tests (Is_{50}) (kPa)	32	0.18	8.8	3.9	3.5	PLT-01
Unconfined Compressive Strength (MPa)	3	12	26	21	20	UCS-01
Soundness by Magnesium Sulphate	1	11				N/A

Notes:

(1) The PLT tests were carried out on both axial and diametral orientations, as well as a small number on irregular lump samples where full core was not available.

Based on the Fracture Index and UCS information, the excavatability of the ignous bedrock has been categorised as 'easy ripping' following the method of assessment provided in Pettifer and Fookes [21]. Reference should be made to the excavatability plot (EX-01) provided in Appendix B.

6. Assessment of Potential Contamination

6.1 Introduction

A review of the GI information has been undertaken to assess potential contamination risks and constraints associated with the proposed works to be undertaken at the site. This land contamination assessment has been undertaken generally in accordance with BS 10175:2011+A2:2017 [22] and relevant technical guidance including Land Contamination Risk Management (LCRM) [23].

In accordance with the above approach, a preliminary risk assessment was initially completed, including a review of the plausible site sources, pathways and receptors.

Potential sources, pathways and receptors relevant to the preliminary Conceptual Site Model (CSM) are detailed below.

6.2 Potential Sources of Land Contamination

Historical mapping consulted as part of the initial desk study showed no potential contamination sources to be present within the site area with no Made Ground deposits recorded during the recent GI.

There is the potential for discrete areas of Made Ground to be encountered during development works associated with the existing power line access tracks/infrastructure and forestry land use.

6.3 Potential Pathways and Receptors

Works to be undertaken at the site will include the excavation of topsoil and superficial deposits to allow the construction of the new 400kV substation, transformers, substation control building and associated underground cable connections and utilities.

It is proposed that any excavated soil/rock materials will be potentially re-used on site with any geotechnically or chemically unsuitable materials requiring off-site disposal.

A number of potential exposure and migration pathways have been identified for the site, along with potential receptors that may be at risk. These are discussed below

- Construction Workers – During the excavation works, construction workers may be exposed to subsurface soils and shallow groundwater, therefore, if present, any contaminants in both surface and deeper soils and/or groundwater may pose a potential risk through dermal contact with soil, ingestion of contaminants or inhalation of ground gas and soil vapour (primarily during below ground works / excavations).
- Site End Users – Future site users may be impacted by soils re-used on site for landscaping purposes which may pose a potential risk through dermal contact / ingestion of contaminants. The inhalation of ground gas and soil vapour (primarily within buildings) should also be considered.
- Buildings and infrastructure on site and off site – Potential to be impacted by ground gas and soil vapour – potential creation of off-site migration pathways.

Potential exposure pathways and subsequent receptors that have been excluded from the CSM are detailed below:

- Water Environment – (surface water and groundwater) The Water Environment has not been considered given the lack of potential land contamination sources and nature of the construction works proposed, as it is assumed any pathways will already be in place.

The assessment of risks posed by the works are detailed in the following sections.

6.4 Assessment of Risks to Construction Workers and Site End Users from Soils

Chemical analysis results for the soils have been compared against published Generic Assessment Criteria (GAC). To provide an indication of the potential acute risks to human health which would apply to short term exposure for construction workers, where available, soil analysis results have been compared against the SoBRA Acute Generic Assessment Criteria (AGAC) (Version 2.0, July 2020). For other determinands where acute criteria are not available, GACs relating to chronic risk to human health for residential end use without plant uptake have been used as a screening tool to indicate the potential presence of potentially harmful contaminants.

Whilst the scheme will primarily comprise hardstanding and substation/transformer infrastructure, it is proposed that areas of soft landscaping are incorporated into the design that may result in the site end users coming into contact with site soils. Therefore the soil chemical analysis results been assessed against Generic Assessment Criteria (GAC) for a conservative commercial/industrial end use scenario.

The following hierarchy of published GAC sources has been used:

- SoBRA, Acute Generic Assessment Criteria. Version 2.0, July 2020 (Construction Workers only) [24]
- Land Quality Management (LQM) / Chartered Institute of Environmental Health (CIEH), S4ULs for Human Health Risk Assessment, 2015 [25]
- Department for Environments, SP1010 – Development of Category 4 Screening Levels (C4SLs) for Assessment of Land Affected by Contamination, Contaminated Land: Applications in Real Environments (CL:AIRE), 2014 (lead only) [26]
- EIC/AGS/CL:AIRE Soil Generic Assessment Criteria for Human Health Risk Assessment, 2010 [27]

It should be noted that where the GAC values are soil organic matter (SOM) dependent, the lowest most conservative assessment criteria for a 1% soil organic matter have been used as a range of organic matter values have been recorded (0.4 to 18%).

Risks to Construction Workers

A comparison of available soil chemical results did not note any exceedances of the AGACs.

It should be noted that speciation analysis was not undertaken and therefore the most conservative GAC value for chromium VI has been used within the assessment which is unlikely to be present at the site given the noted history. However, further speciated analysis will be required to investigate what species of chromium is present within the soils across the site to confirm that it is present in the less toxic chromium III form. It should be noted that the GAC value for chromium VI is 6mg/kg compared to a value of 910mg/kg for chromium III.

Exceedances of residential (without plant uptake) GAC values were recorded in soils (both Made Ground and natural deposits) for chromium with exceedances recorded in 24 of the 26 samples analysed. A maximum concentration of 37mg/kg was recorded in TP014 @ 0.5m which was taken with natural silty sand and gravel.

All other chemical determinands were recorded below the relevant assessment criteria. No asbestos containing materials were identified within the samples screened.

Residual risks to construction workers from soils can be controlled by use of safe systems of work by the appointed Contractor and, as a last resort, by use of Personal Protective Equipment (PPE). These should focus on the minimisation of dust generation, ingestion and dermal contact.

The risks posed to construction workers should be considered during the design and construction stages of the scheme as more information becomes available and construction methods are finalised.

Risks to Site End Users

A single exceedance of the commercial/industrial end use GAC value for chromium was recorded in TP014 @ 0.5m with a concentration of 37mg/kg recorded.

As previously stated, speciation analysis was not undertaken and therefore the most conservative GAC value for chromium VI has been used within the assessment (33mg/kg) compared to a value of 8,600mg/kg for chromium III. Chromium concentrations should be re-assessed pre-construction and mitigation measures applied if required.

Risks to end users from soil contamination can be managed by ensuring that any soils re-used on site are not exposed and clean imported soils are placed at the surface to provide a suitable growing medium.

6.5 Assessment of Risks to Construction Workers and End Users from Groundwater

Resting groundwater levels across the site area have been recorded to be near the ground surface and therefore the primary pathways for exposure of construction workers during site works will be through direct contact and/or accidental ingestion of groundwater primarily within excavations.

Groundwater analysis has not been undertaken during the GI works therefore characterisation of the groundwater through comparison with published Generic Assessment Criteria (GAC) to provide an indication of the potential acute risks to human health which would apply to short term exposure for construction workers has not been undertaken. However, due to the absence of potential contamination sources, it is considered unlikely that, contaminated groundwater will be encountered within the site area.

Residual risks to construction workers from groundwater can be controlled by use of safe systems of work by the appointed Contractor and, as a last resort, by use of Personal Protective Equipment (PPE). These should focus on the minimisation of ingestion and dermal contact.

The risks posed to construction workers should be considered during the design and construction stages of the scheme as more information becomes available and construction methods are finalised.

6.6 Assessment of Risks to Construction Workers and End Users from Ground Gas

Gas monitoring was undertaken at 13 No. locations to assess any potential risks to construction workers from exposure to potentially asphyxiating or flammable gas concentrations within any below ground works and/ or within confined spaces.

The monitoring was undertaken over three rounds with a range in atmospheric pressure between 950 and 987mbar. Flow rates were variable over rounds with peak flow rates ranging from negative 0.5 l/hr (BH21) to 3.1 l/hr (BH02).

Risks to Construction Workers – Ground Gas

Ground gas levels were compared to published thresholds considered appropriate for the protection of construction and maintenance workers. To assess potential risks posed to construction workers during below ground works the monitoring results have been screened against assessment criteria as follows:

- Carbon dioxide, carbon monoxide and hydrogen sulphide: Workplace Exposure Limits (WELs) for long-term and short-term exposure in accordance with Health and Safety Executive (HSE), 'EH40/2005 Workplace Exposure Limits.

- Methane: methane is potentially explosive in air, and concentrations have been compared with the Lower Explosive Limit (LEL) of 5 % v/v and Upper Explosive Limit (UEL) of 15 % v/v.
- Oxygen: in accordance with the Mines and Quarries Act 1954 sufficiency of oxygen is deemed as concentrations of 19 % v/v in air and above. As such oxygen concentrations have been compared to this defined sufficiency of oxygen threshold value.

Full ground gas results are presented in the GI Factual Report and with exceedances summarised below:

- Methane concentrations did not exceed either the LEL and UEL.
- The short term and long term exposure limits for carbon dioxide, carbon monoxide and hydrogen sulphide were not exceeded.
- Depleted oxygen concentrations (below 19 %v/v) were recorded in all 13 locations monitored with a minimum concentration of 15.2%v/v being recorded in BH02.

The results show that ground conditions at the site are unlikely to present a potential asphyxiating or explosive risk to construction workers.

However, due to the presence of peat deposits across the site, ground gas risks may warrant further consideration during below ground or confined space working should this be undertaken.

It is recommended that appropriate risk assessments and working methods should be developed and adopted by the Contractor during below ground site construction works including excavations and piling with due consideration of the wider site setting. This should include as a minimum, gas monitoring undertaken prior to any entry into excavations, confined spaces or below ground structures and use of personal gas monitors to detect explosive gases or depleted oxygen levels and the use of PPE including respiratory protective equipment (RPE) as a last resort.

The risks posed to construction workers should be considered during the design and construction stages of the scheme as more information becomes available and construction methods are finalised.

Risks to Site End Users – Ground Gas

As detailed above, elevated flow rates and/or ground gas concentrations have not been recorded across the proposed scheme construction area. However, as stated above, due to the presence of peat deposits across the site area, the design of building and/or substructures proposed to be included within the proposed development and the final scheme design should take cognisance of the ground gas regime at the site. An assessment of the risks posed should be undertaken in accordance with CIRIA C665 'Assessing risks posed by hazardous ground gases to buildings' and BS 8485 'Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings' and suitable gas mitigation measures incorporated into the final building design if required.

6.7 Materials management of soils and groundwater

From current development proposals, it is proposed that soil materials are excavated to allow construction of the new 400kV substation, transformers, substation control building and associated underground cable connections and utilities. It is proposed that any excavated soil/rock materials will be potentially re-used on site with any geotechnically or chemically unsuitable materials requiring off-site disposal.

Soil disposal options should be considered during the design and construction stages of the project as more information becomes available and construction methods are finalised. The management of any excess peat arisings will also require appropriate consideration. Further sampling and full Waste Acceptance Criteria (WAC) testing should be undertaken to determine a provisional classification of the material for disposal in line with BS EN 12457 (multipart document) [28].

It should also be noted that individual landfill sites have specific conditions for accepting waste detailed in their licences; therefore, it should be confirmed with them at an early stage that they can accept these materials for disposal. The final waste classification for the soils will be determined by the receiving landfill operator.

The risks posed to surface waters should be considered during the design and construction stages of the scheme as more information becomes available and construction methods are finalised. Potential risks to surface waters from all construction activities including the use of imported soils/ reused soils should also be reviewed. This should include the management of groundwater migration, sediment/silt runoff and the discharge of groundwater during dewatering activities.

7. Geotechnical Risk Register

The detailed assessment of the ground conditions carried out as part of the Ground Investigation Report has identified geotechnical risks that have the potential to impact detailed design of the proposed LT521 Fasnakyle scheme.

A Geotechnical Risk Register has been produced based in the SSEN project risk register format and presented within Appendix C.

The Geotechnical Risk Register provided within Appendix C reflects the current level of understanding of the geotechnical and geo-environmental aspects of the study area.

8. Engineering Assessment

As described in Section 1.1, the aim of the project is to upgrade the existing Beauly to Denny overhead line to accommodate a second 400kV circuit, which necessitates the need for a new substation at Fasnakyle.

In accordance with Eurocode 7 (BS EN 1997-1 [4]), the project falls under Geotechnical Category 2, which includes conventional types of structures and foundations with no exceptional risk or difficult ground or loading conditions.

While 'Site D Alternative' has been identified as the preferred location for the substation, the site layout and foundation locations are unknown at the time of writing. A substation platform level of 327.8m AOD has been confirmed by the Client, which would require significant earthworks to achieve on the side long ground present at the site. Generally, upfilling would be required across much of the platform area to achieve the proposed platform level, but cutting would be required to the east.

It is expected that the platform and upfill material would comprise suitable imported fill and site won materials where the latter is deemed to be suitable for re-use. The GI suggests the cutting to the east of the proposed platform is likely to be in bedrock, so there is an opportunity to win material in this area for re-use. An earthwork strategy should be developed for the site to understand the earthworks balance and identify opportunities to minimise waste and disposal costs on the project.

A key risk at the site is the presence of Peat and how this will be addressed within the detailed design. The Peat has been found to have a low strength and be highly compressible, which could result in excessive total or differential settlement or bearing failure beneath the platform if the Peat is not removed or improved. A Peat Management Plan may be required depending on the proposed solution.

Reference should be made to the Preliminary Engineering Assessment Report for further details on the above.

9. Conclusions

SSEN propose to build a new 400kV substation south of Tomich in the Scottish Highlands. A ground investigation was undertaken to determine the ground conditions at the proposed substation location and to establish geotechnical risks to the project. The proposed new underground cable and new access road were not investigated as part of the GI and have not been considered in this report. A separate ground investigation may be required for these works.

The GI has shown the ground conditions at the site typically consists of Peat overlying Granular Glacial Deposits and bedrock, predominately comprising psammite with occasional granite intrusions. Bedrock was encountered at shallow depths across the site, typically less than 3m below ground level. Locally bedrock was recorded at or near the surface, with an occasional think layer of weathered bedrock also recorded.

The key geotechnical risks are provided within the geotechnical risk register as outlined in Section 7 and are summarised below.

- The presence of peat which have low bearing capacity and may result in excessive total or differential settlement or bearing failure if not removed. These deposits are likely to have reduced trafficability for earthworks plant.
- Groundwater levels are indicated to be shallow across the site, with a local area of artesian groundwater recorded. These could cause issues during construction, particularly in areas of excavation.
- With the exception of forestry and the existing SSE infrastructure, the site has not been developed with no made ground encountered during the ground investigations. No significant pollutant linkages are considered to be present in relation to the proposed commercial land use - no remedial measures are therefore likely to be required.
- No elevated ground gas concentrations have been recorded across the site in gas monitoring undertaken thus far – due to the presence of peat deposits across the site area there is the potential for asphyxiating conditions to be encountered, further assessment may be required with respect to entry to excavations/confined spaces and the building design.

It is expected that the following will be required to for the detailed design:

- Confirmation of the loads that will be imposed by the various substation infrastructure.
- A full re-use assessment based on the proposed end use of the material likely to be excavated during construction, to determine whether it can be safely re-used on site and/or to determine status should off-site disposal be required.
- Development of a groundwater and surface water monitoring programme during construction works as part of the Construction Environmental Management Plan (CEMP) to determine the impact of construction activities on the water environment.

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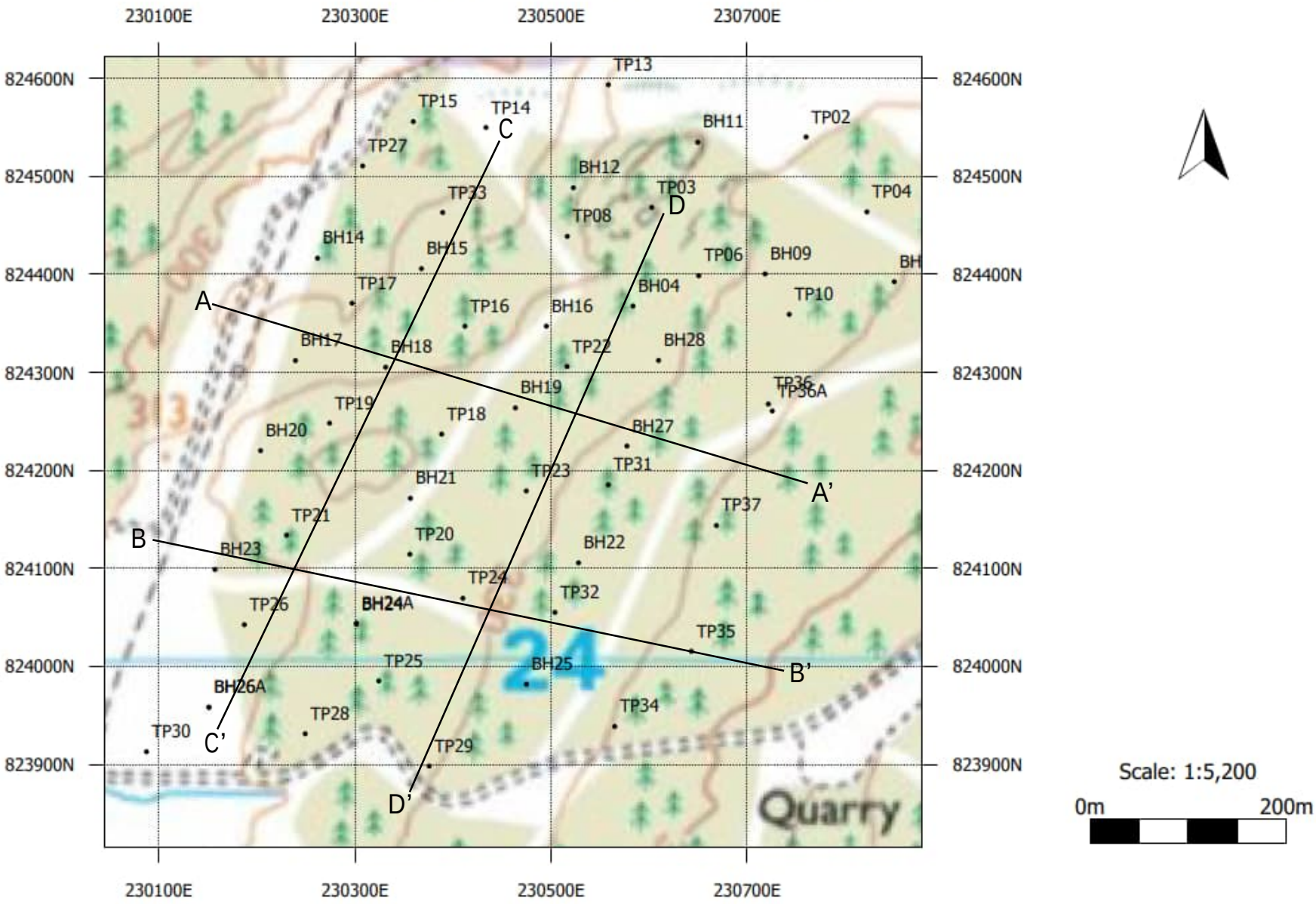
Appendix A. Drawings

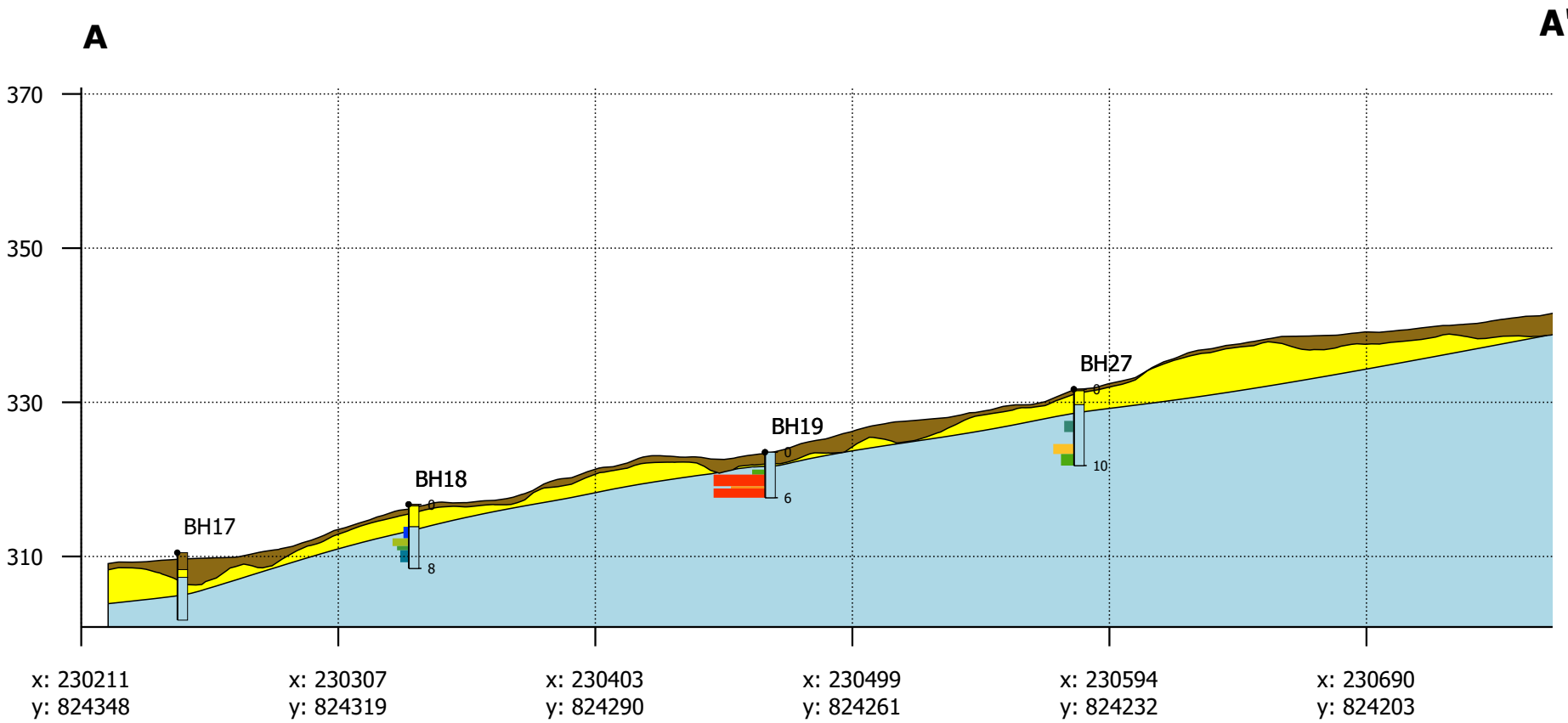
Cross Section Location



Scale: 1:5,200

0m 200m

A-A' Cross Section



Notes:
Exploratory holes shown on the section are within 40m of the section line.
Depths of boreholes are shown as meters below ground level.

Legend

RQD

8 26 44 62 80

GM

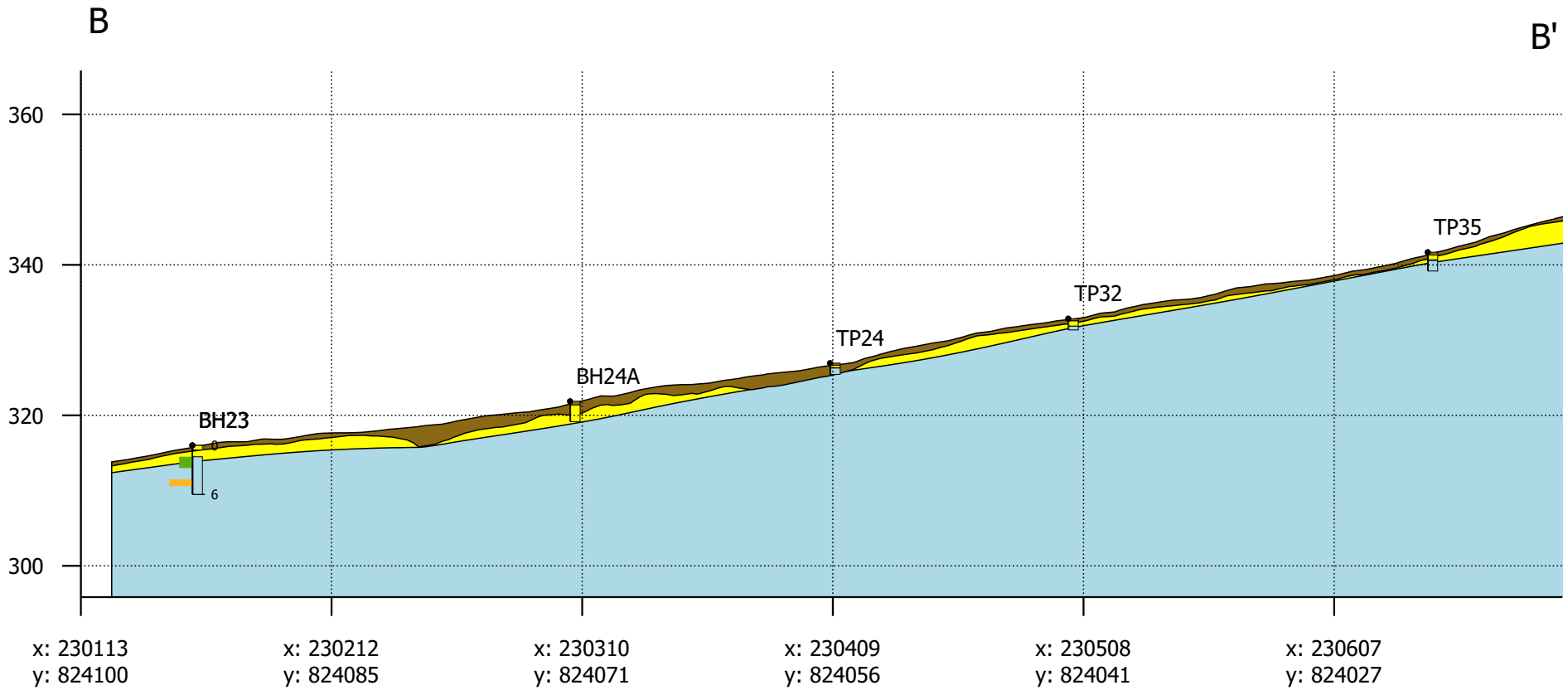
PT BR
GD

Location

A: 230211, 824348
B: 230759, 824182

Scale: 1:2,500
Vertical exaggeration: 3x
0m 100m

B-B' Cross Section



Notes:
Exploratory holes shown on the section are within 40m of the section line.
Depths of boreholes are shown as meters below ground level.

Legend

RQD

8 26 44 62 80

GM

PT BR

GD

Location

A: 230113, 824100

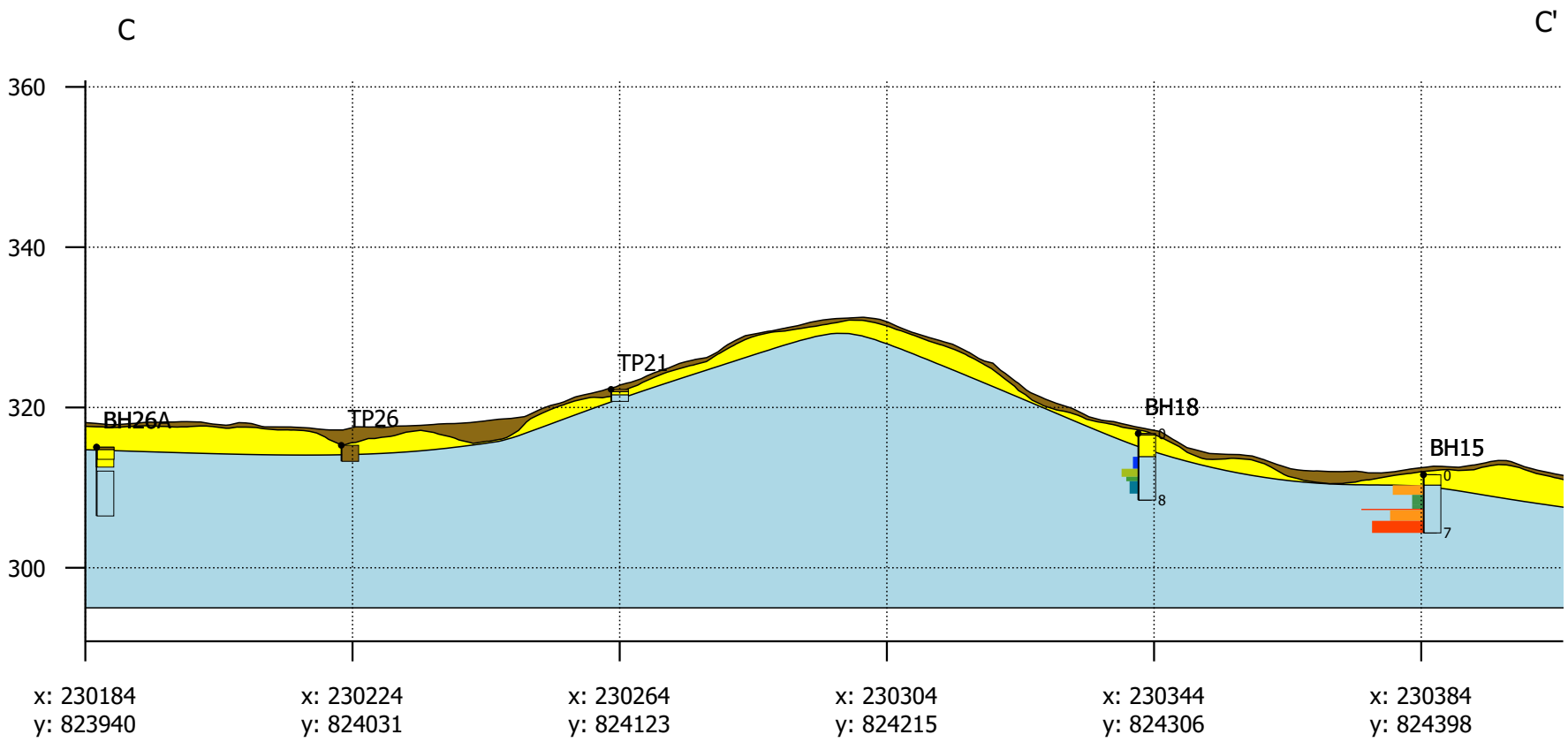
B: 230697, 824014

Scale: 1:2,500

Vertical exaggeration: 3x

0m 100m

C-C' Cross Section



Notes:
Exploratory holes shown on the section are within 40m of the section line.
Depths of boreholes are shown as meters below ground level.

Legend

RQD

8 26 44 62 80

GM

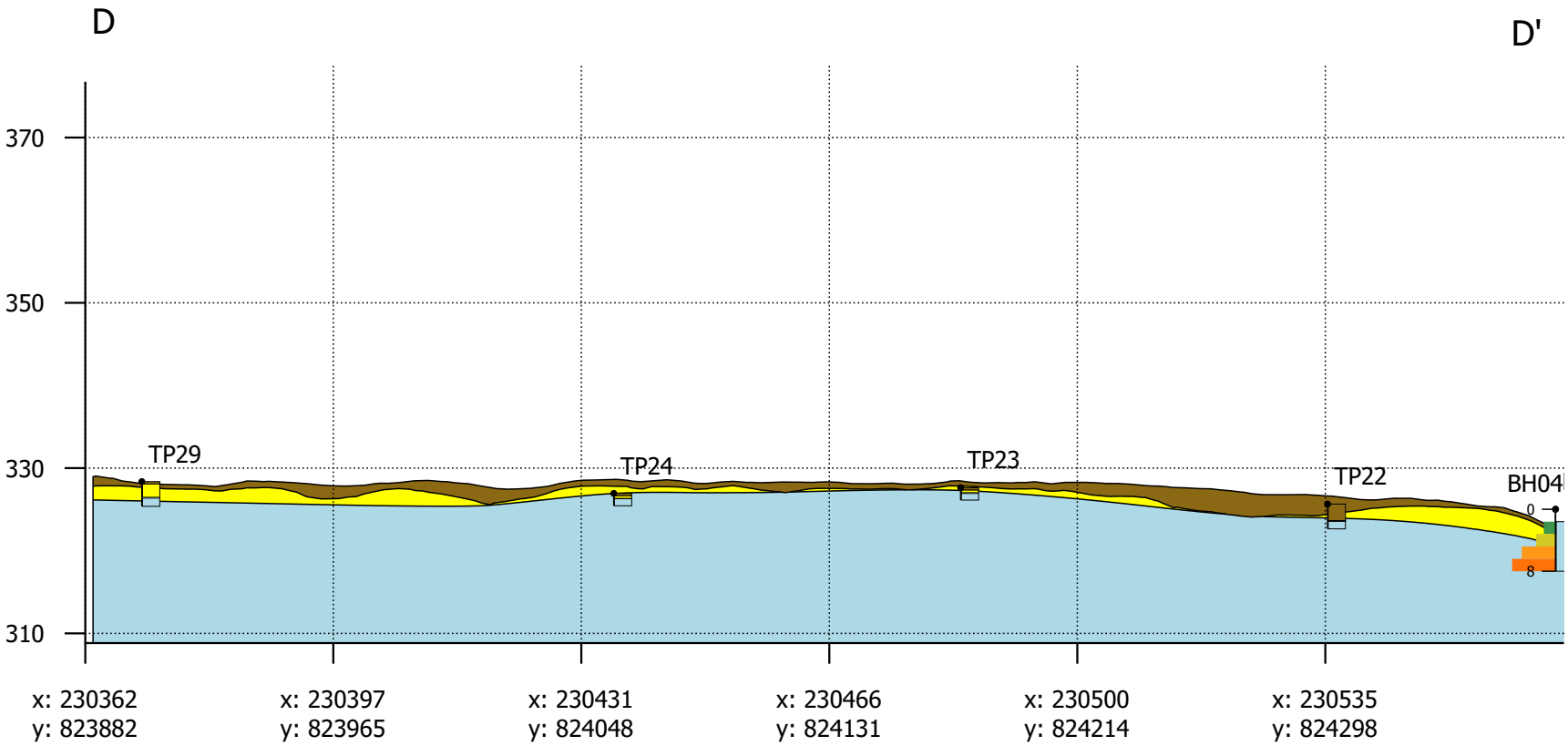
PT BR
GD

Location

A: 230184, 823940
B: 230405, 824447

Scale: 1:2,500
Vertical exaggeration: 3x
0m 100m

D-D' Cross Section



Notes:
Exploratory holes shown on the section are within 20m of the section line.
Depths of boreholes are shown as meters below ground level.

Legend

RQD

8 26 44 62 80

GM

PT BR

GD

Location

A: 230362, 823882

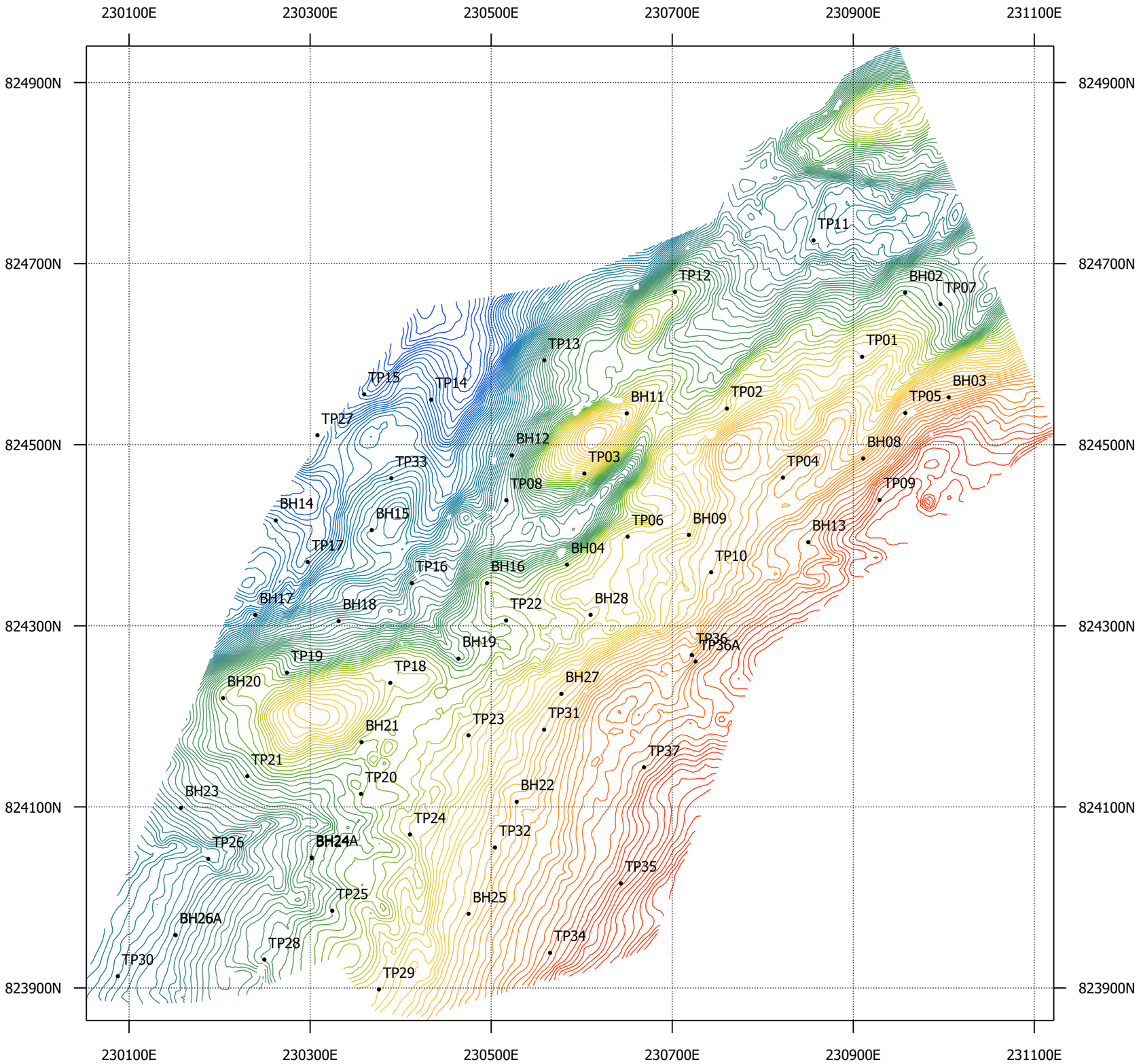
B: 230568, 824378

Scale: 1:2,500

Vertical exaggeration: 3x

0m 100m

Contour Map- Elevation at base of Peat



Legend

GM: GD - PT contacts contours

GM: GD - PT contacts contours

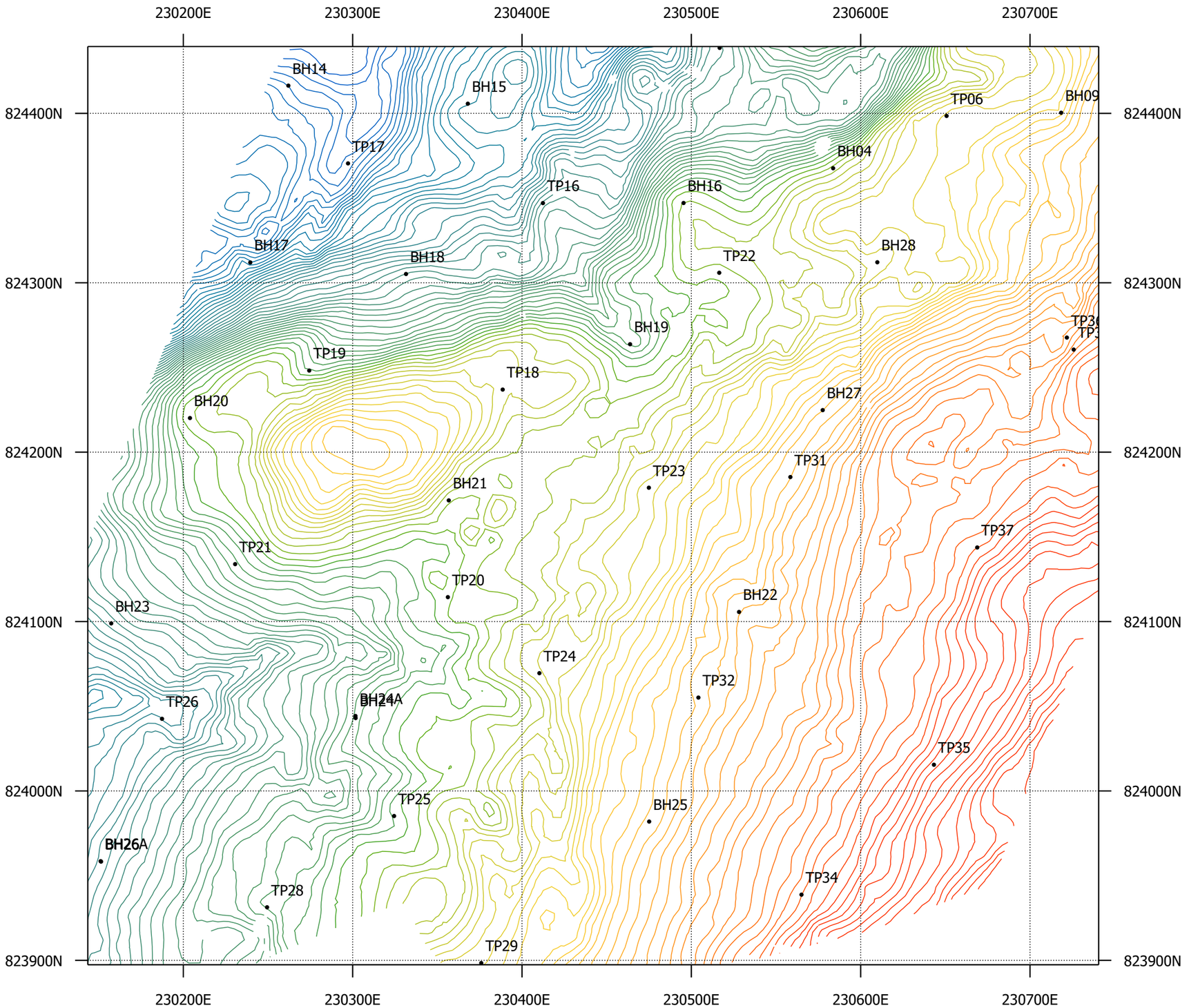
297.5 308.1 318.8 329.4 340

Note: Contours are spaced at 0.50m intervas

Scale: 1:4,600

0m 300m

Contours- Southern Site



Legend

GM: GD - PT contacts contours

GM: GD - PT contacts contours

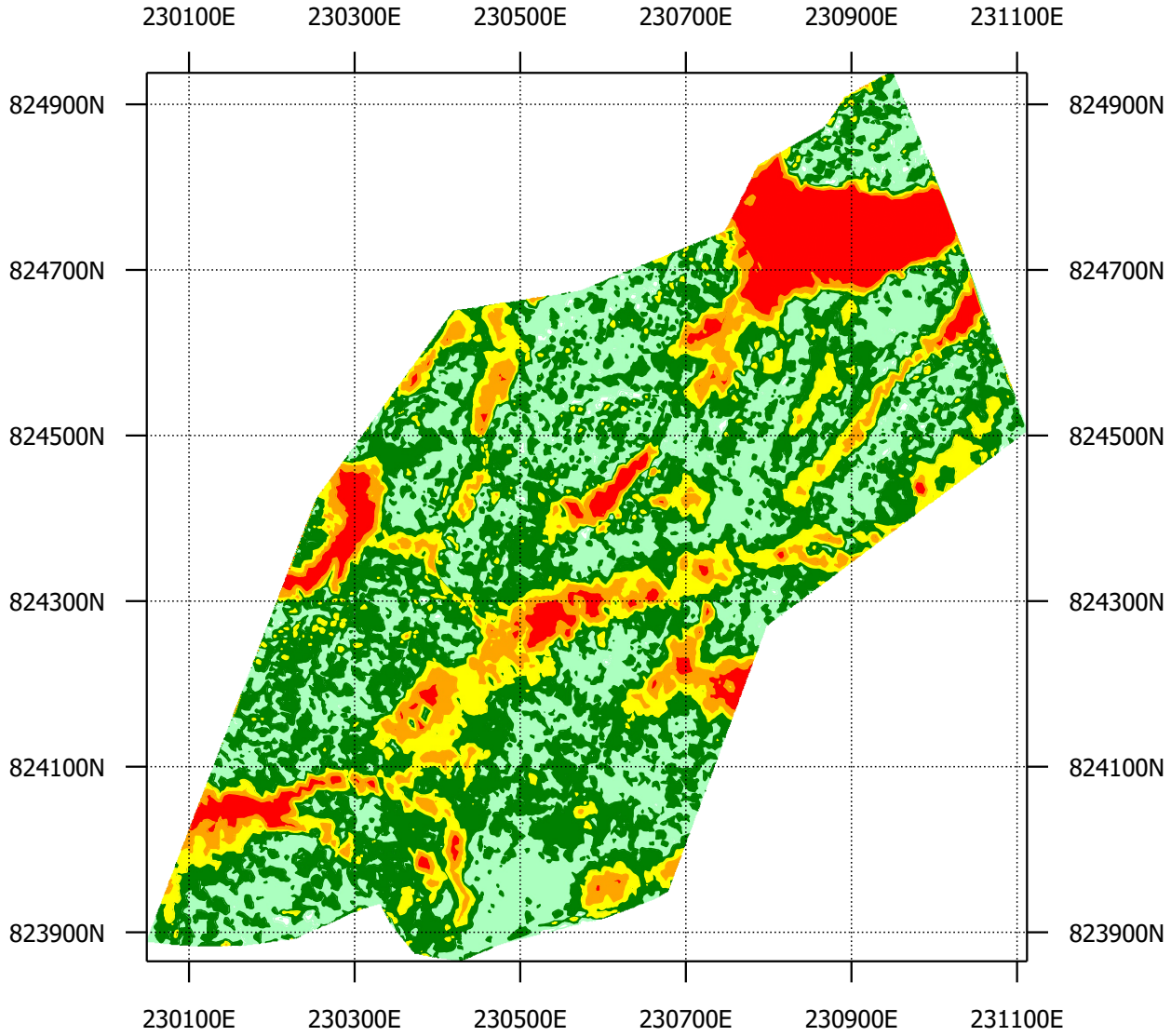
297.5 308.1 318.8 329.4 340

Note: Contours are spaced at 0.50m intervas

Scale: 1:2,500

0m 200m

Peat Thickness Heat Map



Location

230049, 824938, 0

231112, 824938, 0

Location Details - Peat Base Depth outside Model Boundary contours

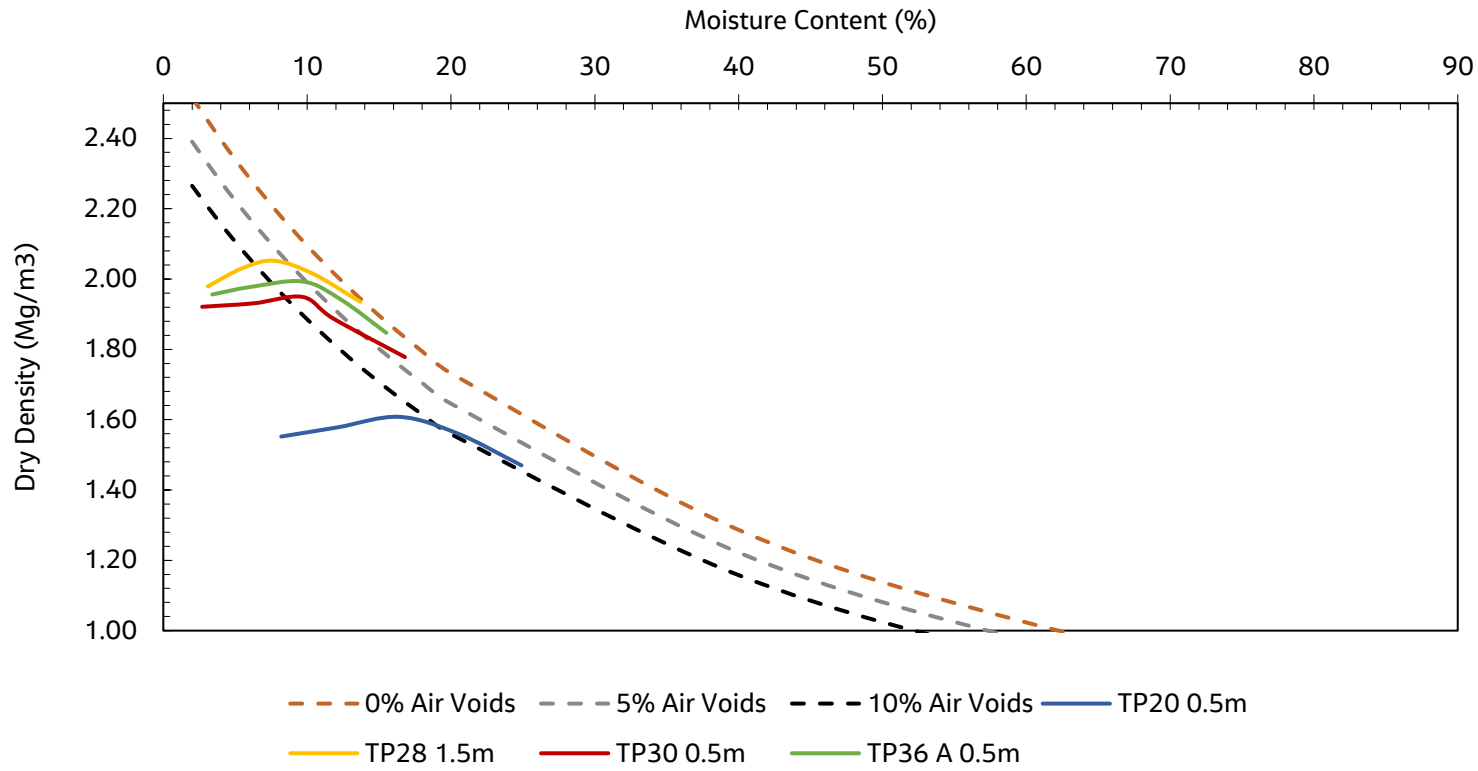
< 0.5 < 1.5 > 2

< 1 ≤ 2

Scale: 1:8,500

0m 300m

Appendix B. Figures



Notes:

Air void lines can only be shown on individual test sheets. Please refer to Factual Report for individual test sheets.

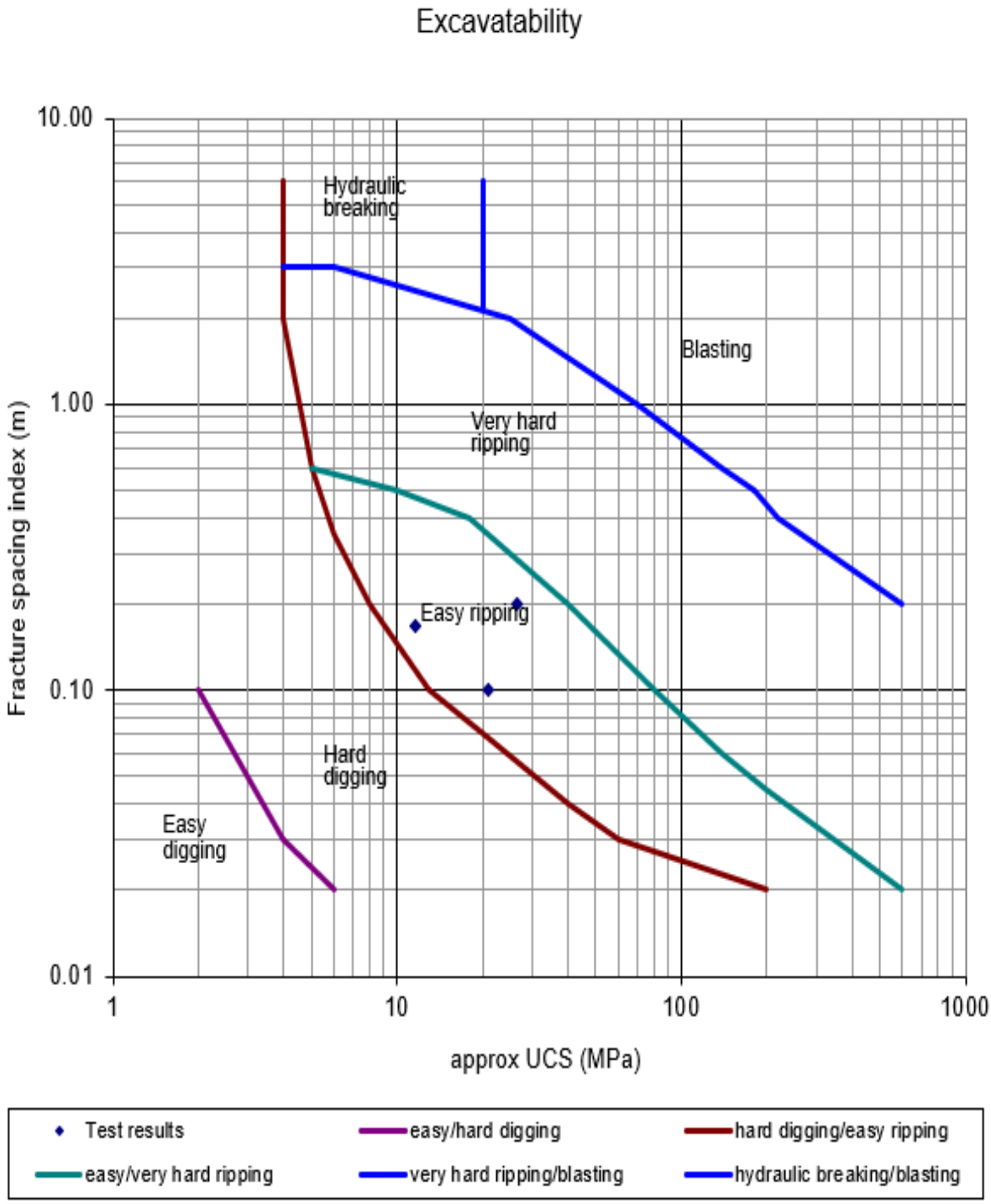
Client

Scottish & Southern Electricity Networks Transmission

Project

ASTI Substation Site – LT521 Fasnakyle

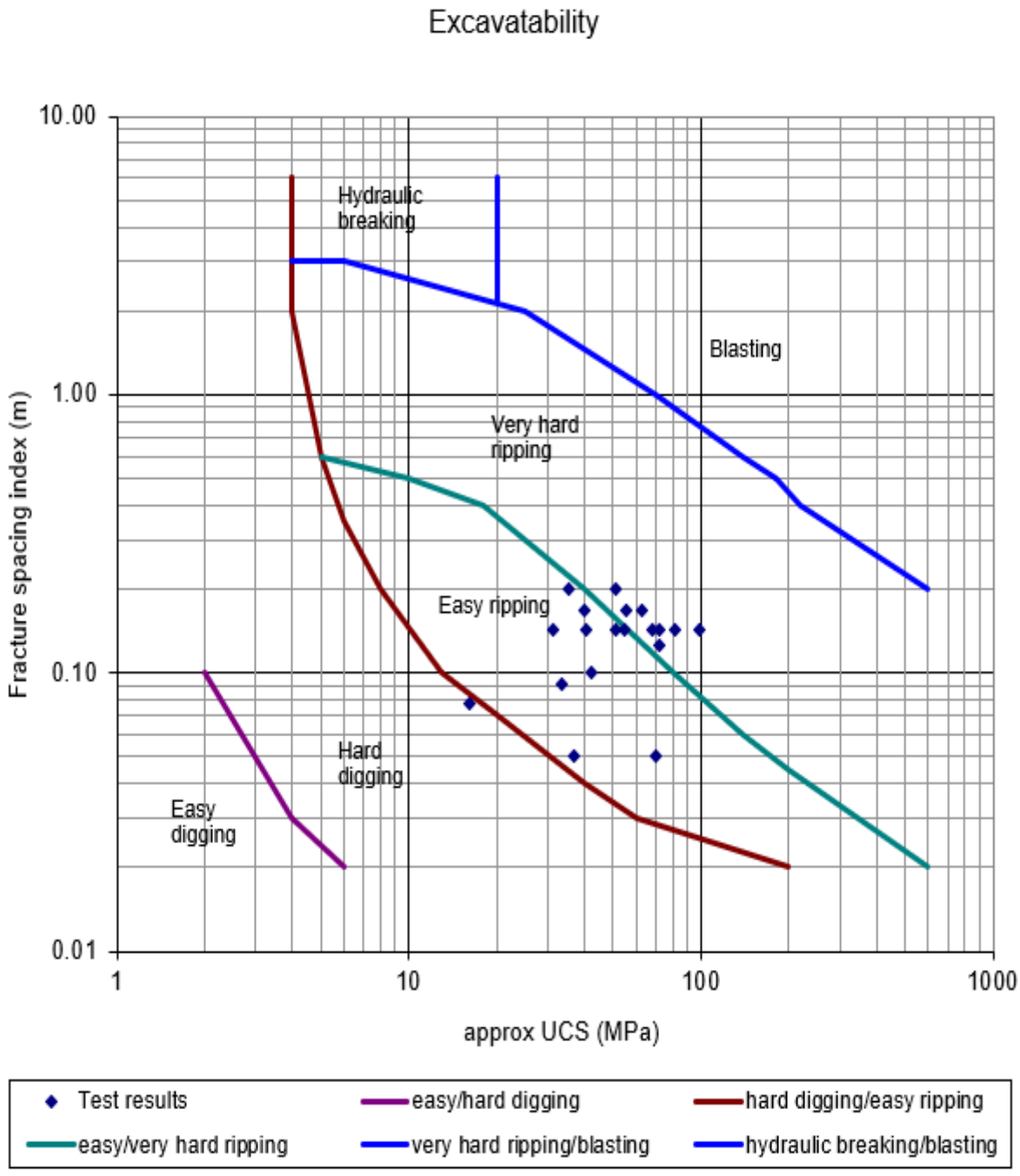
Title:	Dry Density v. Moisture Content *Granular Glacial Deposits*	
Jacobs No.:	B2468300	
Section:		Rev
Figure No.:	COM-01	0



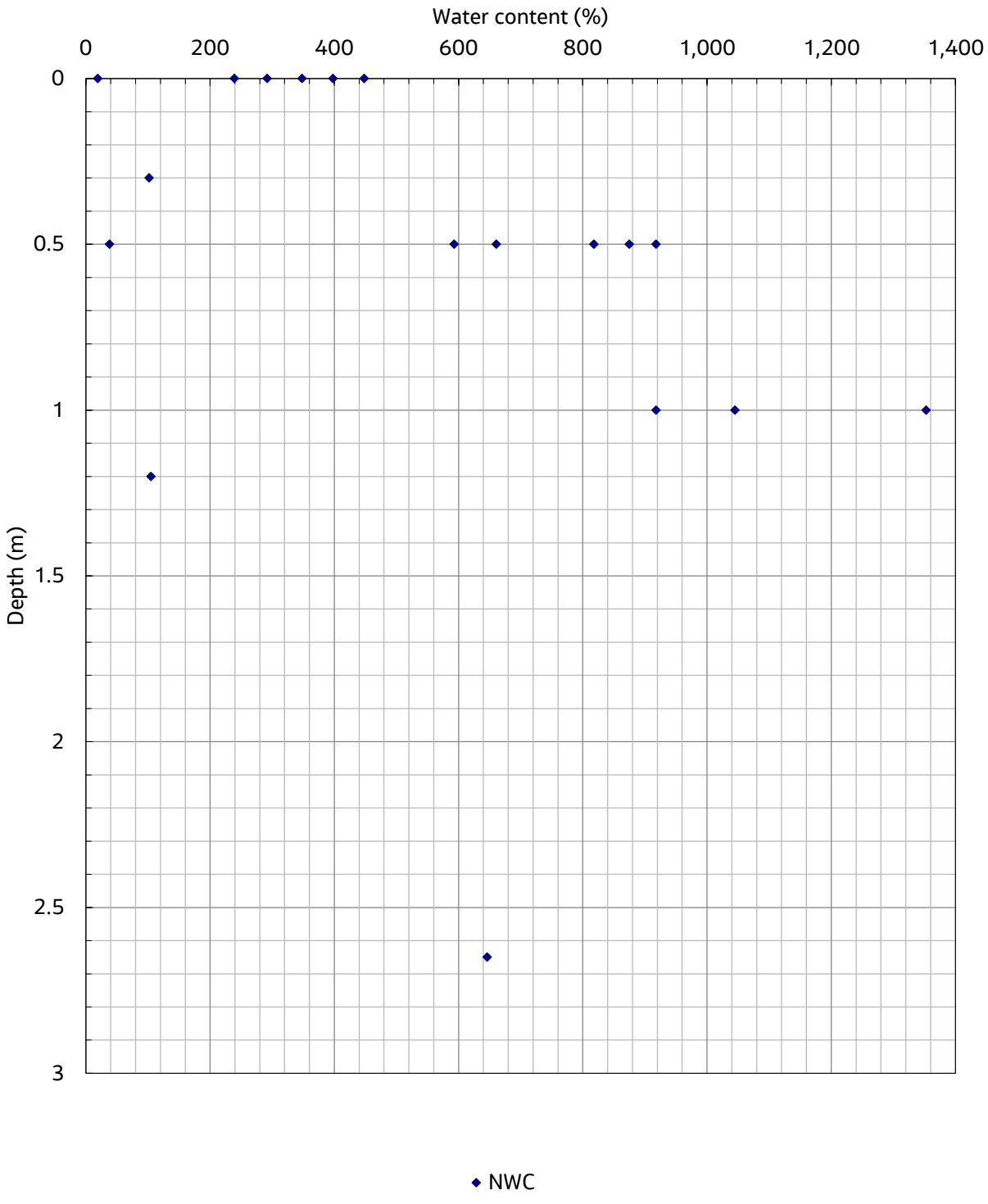
Jacobs

Notes:

Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Excavatability *Igneous Bedrock*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	EX-01	Rev 0



Jacobs	Notes:		
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Excavatability *Metasedimentary Bedrock*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	EX-02	Rev 0



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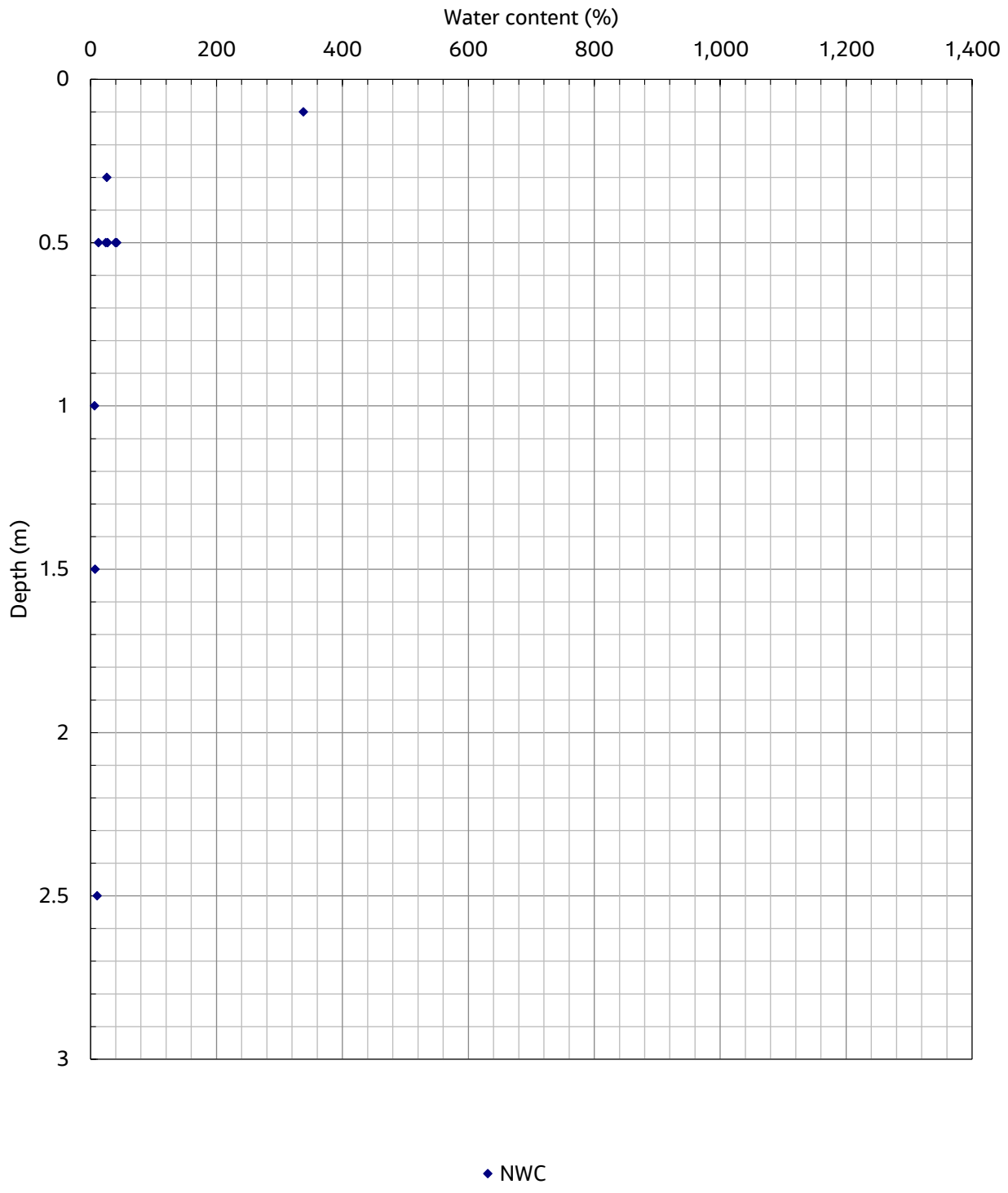

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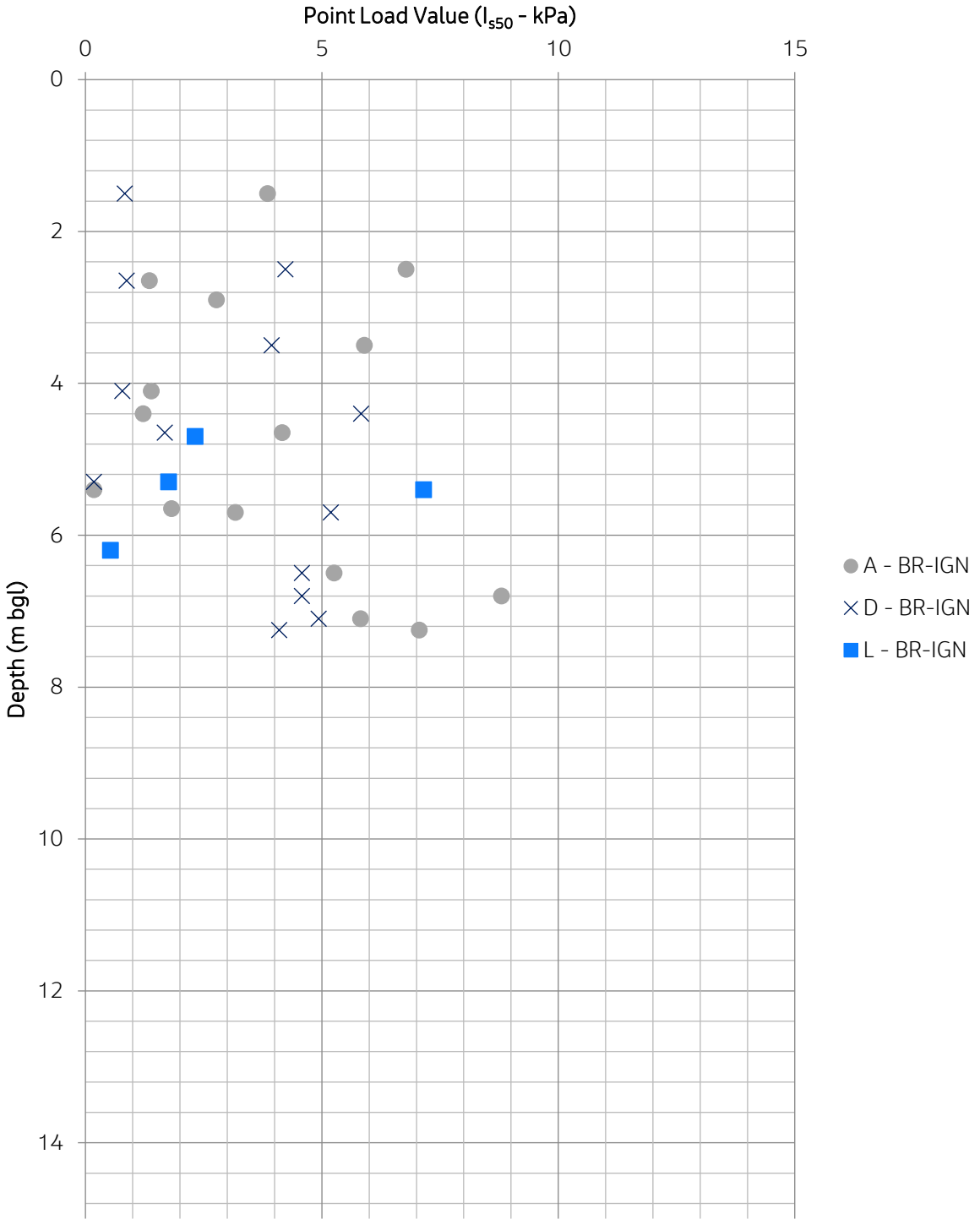
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Moisture Content vs Depth *Granular Glacial Deposits*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	MC-02	Rev 0



Notes:
Corrected Is_{50} used.
Units: kPa

Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Point Load Test vs Depth *Igneous Intrusion*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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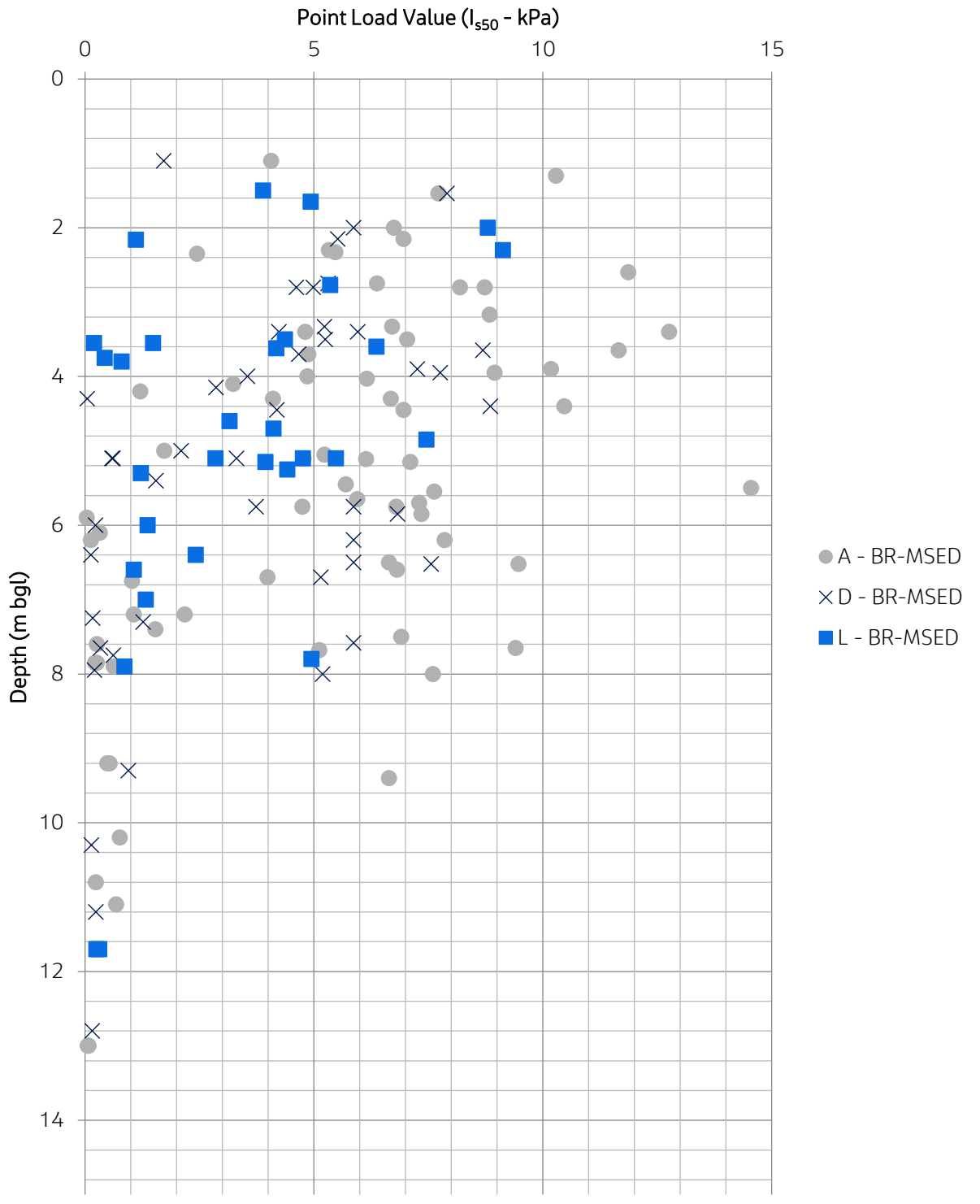

Jacobs

Notes:
Corrected Is_{50} used.
Units: kPa

Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Point Load Test vs Depth *Metasedimentary*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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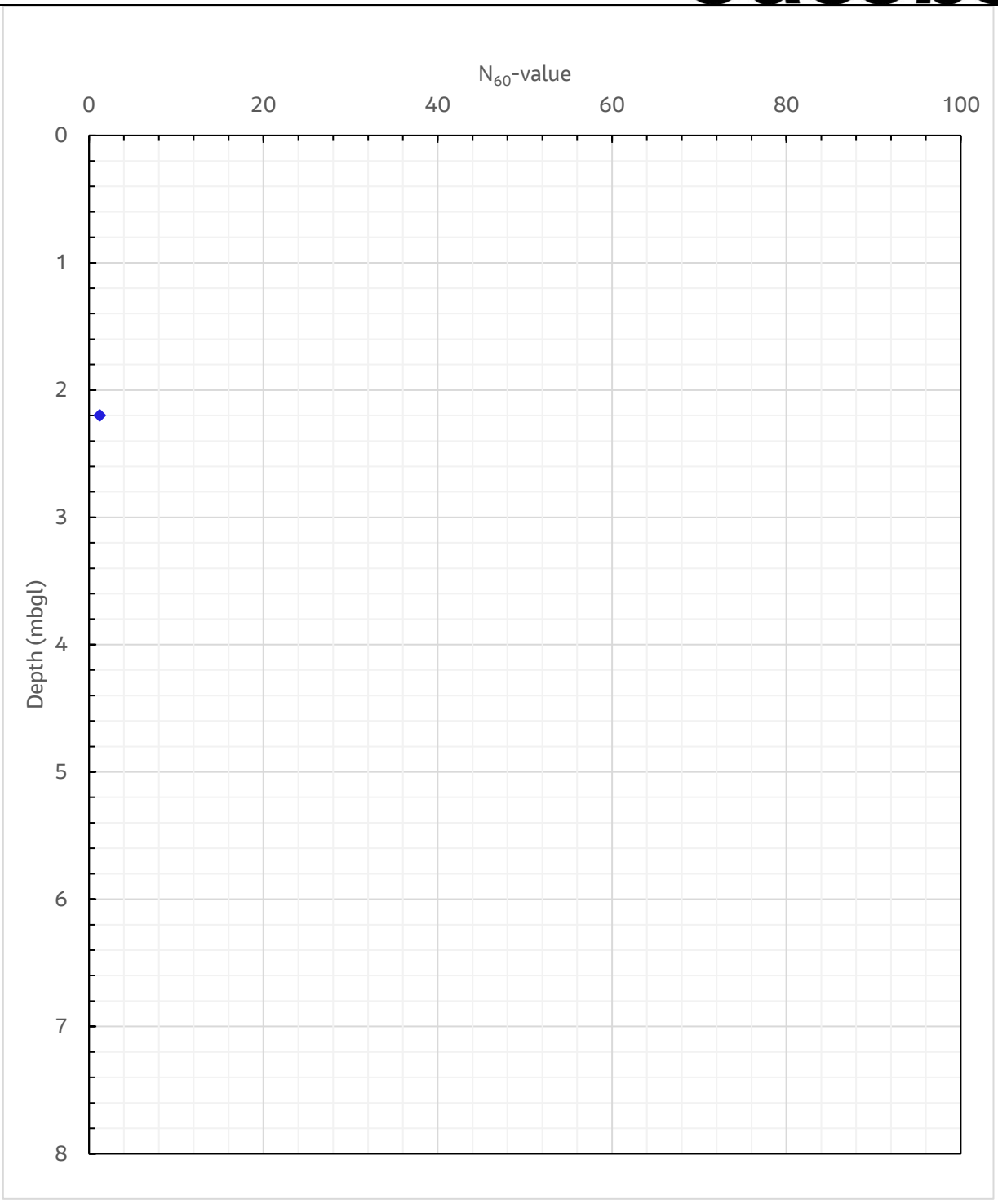
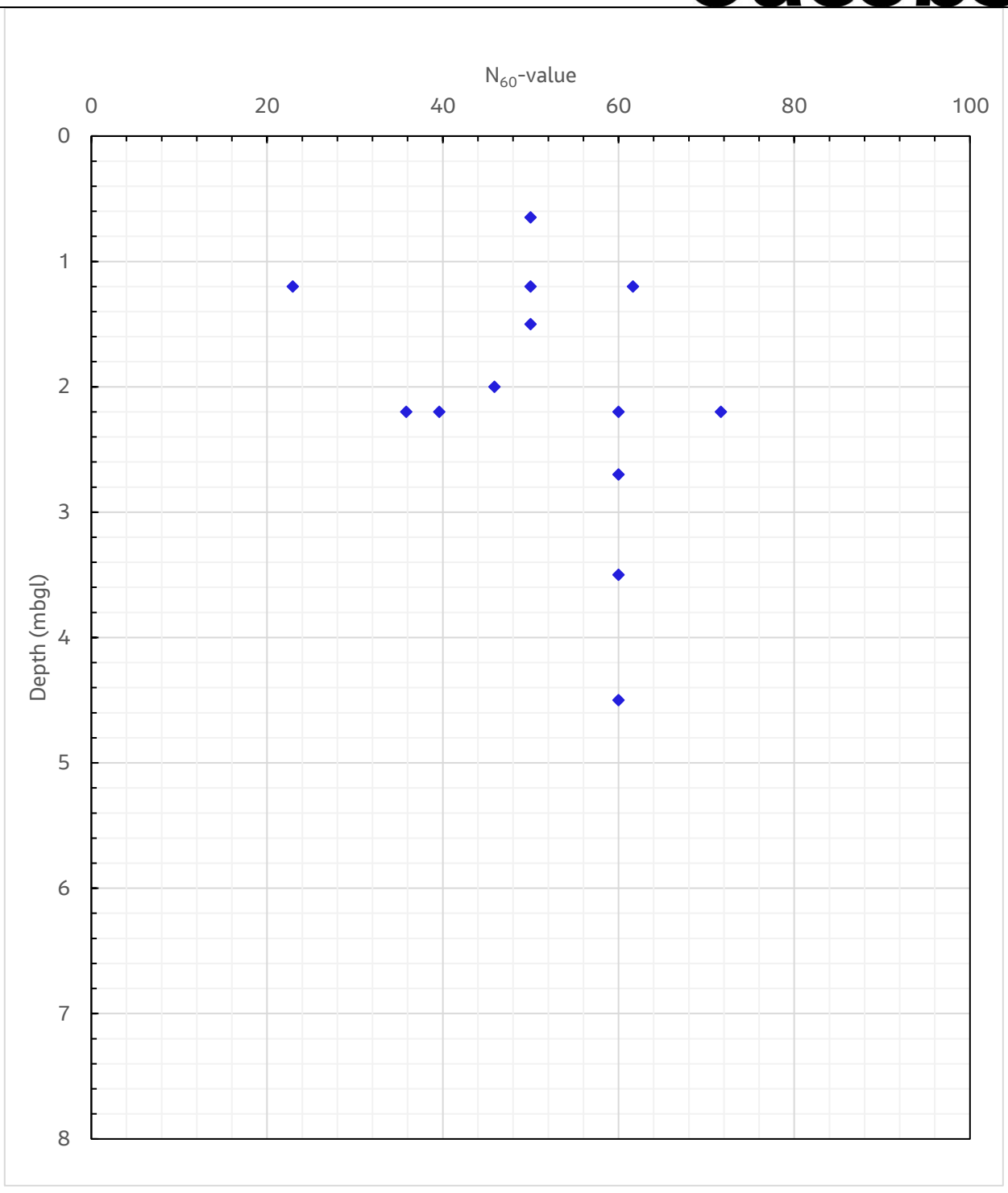


Jacobs	Notes:		
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	SPT N_{60} Value vs Depth *Peat*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	SPT-01	Rev 0



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Client Scottish & Southern Electricity Networks Transmission	Figure Title:	SPT N_{60} Value vs Depth *Granular Glacial Deposits*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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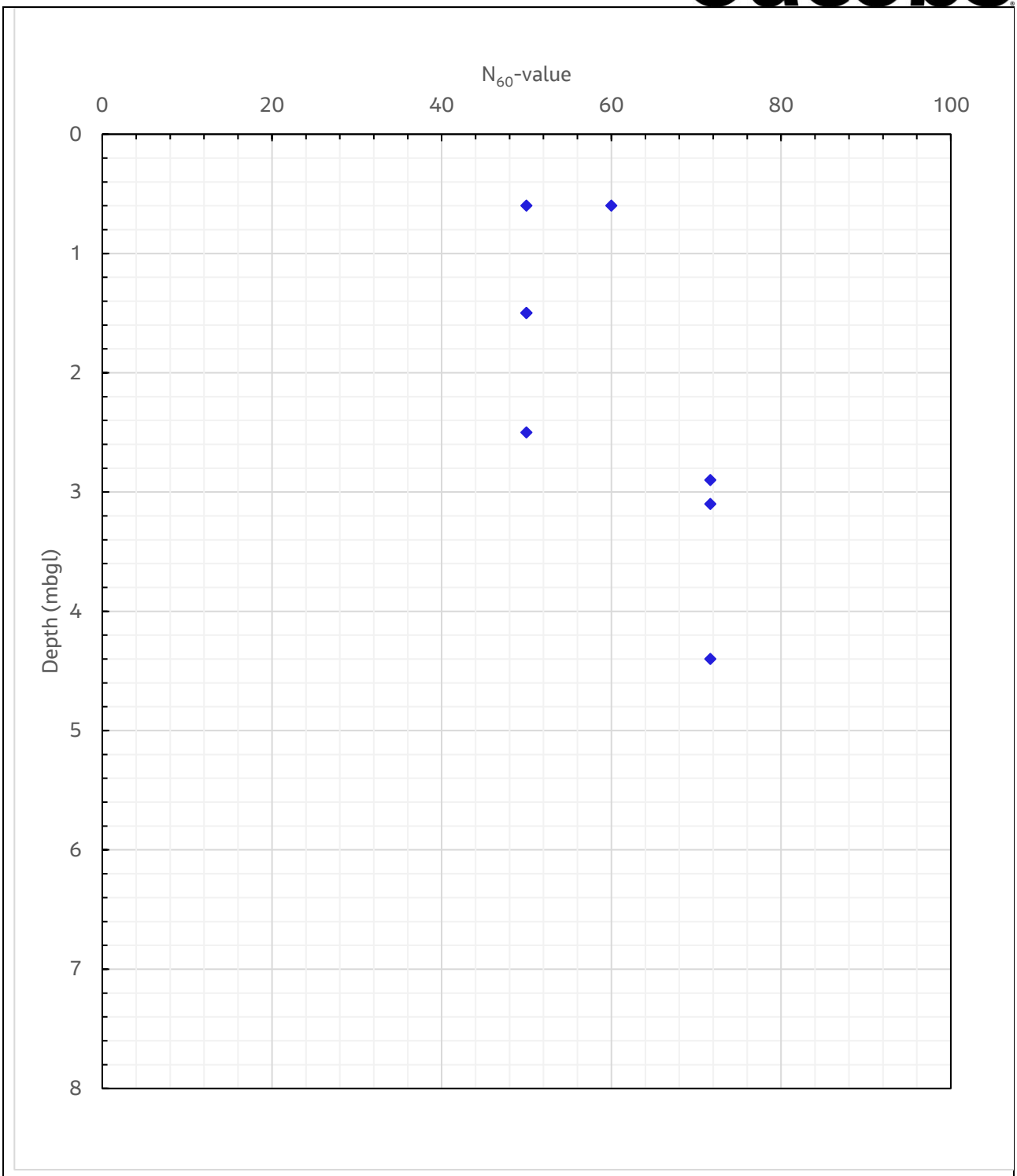

Jacobs	Notes:		
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	SPT N_{60} Value vs Depth *Weathered Rock*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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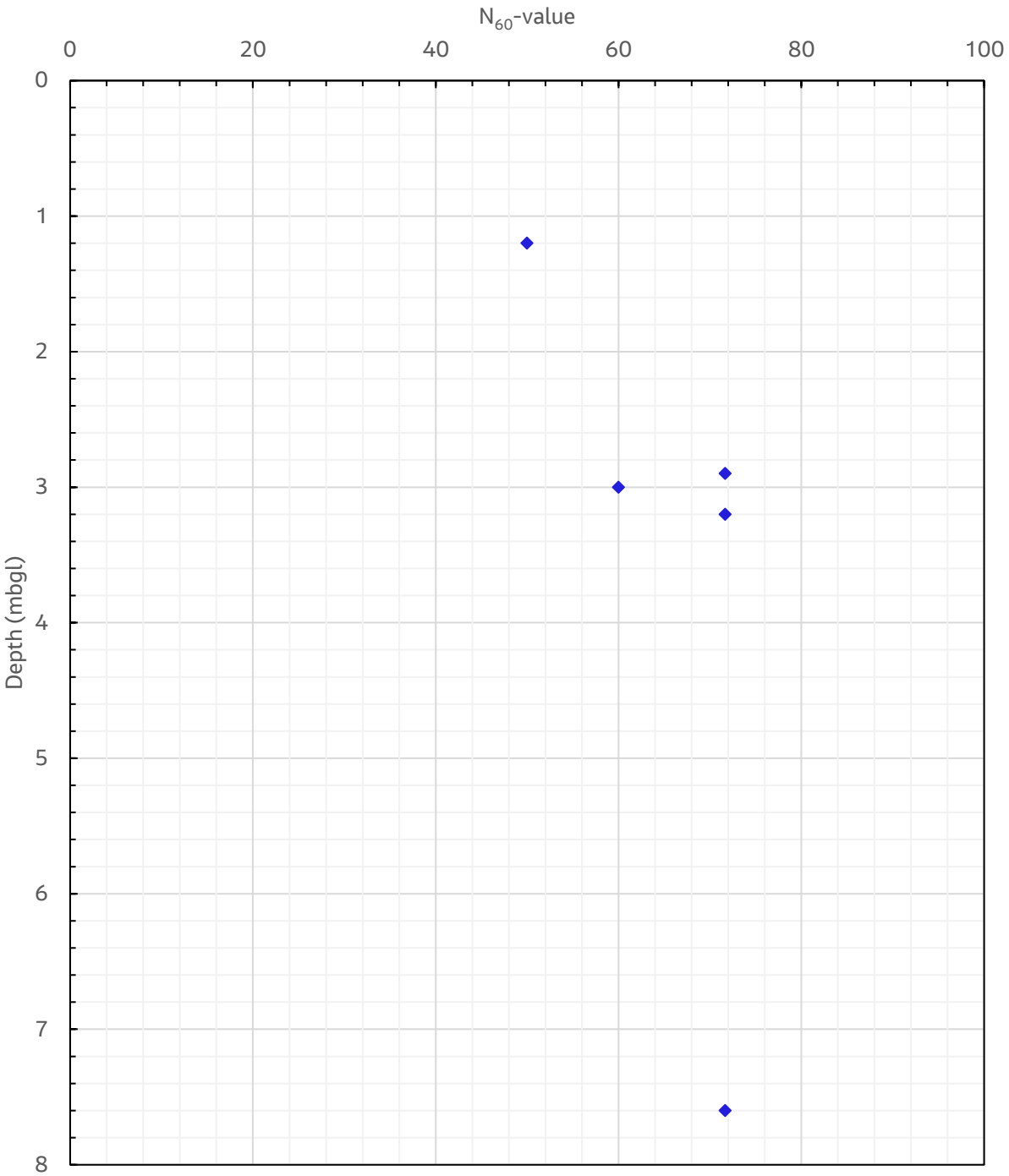

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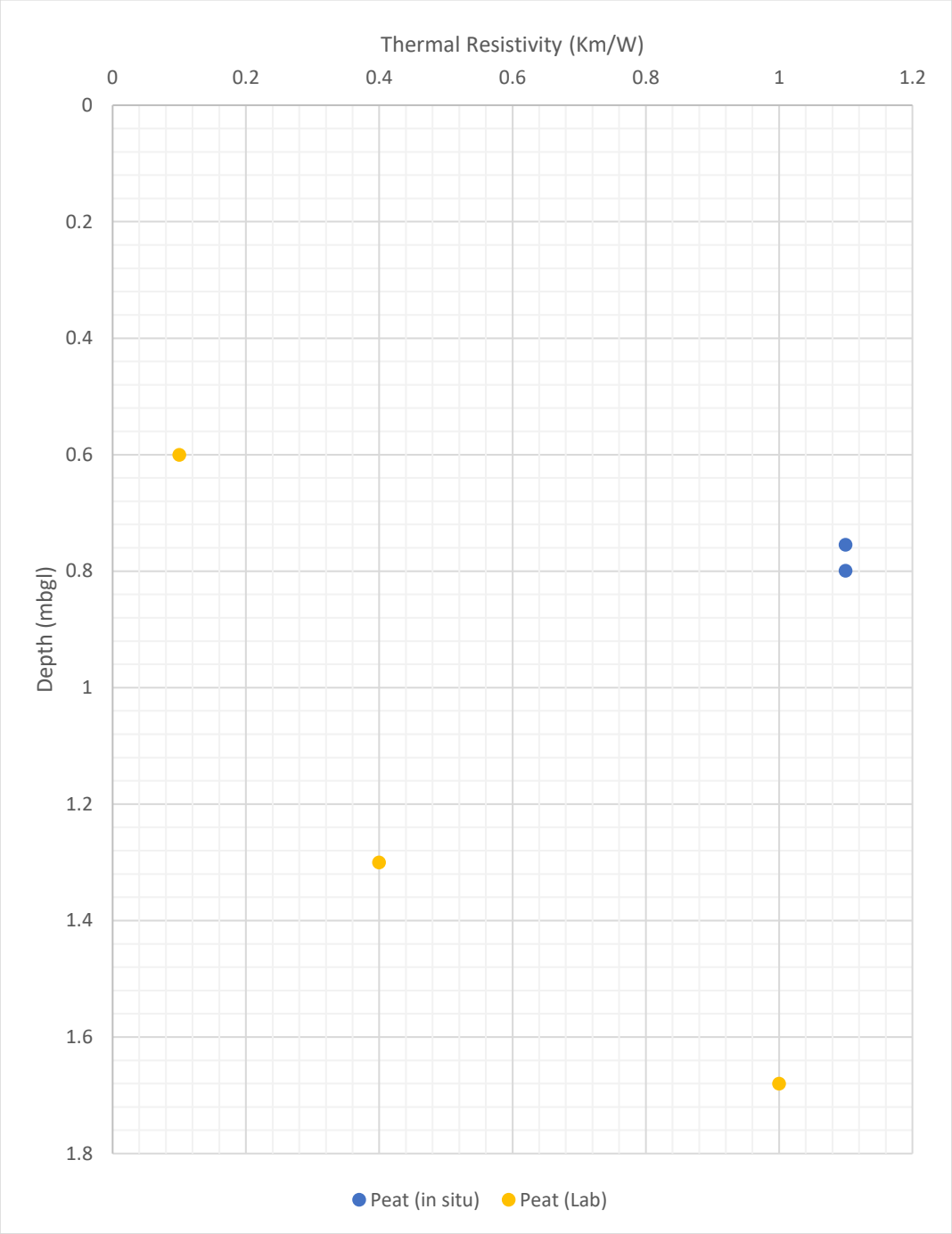

Notes:			
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Thermal Conductivity vs Thermal Resistivity *Peat*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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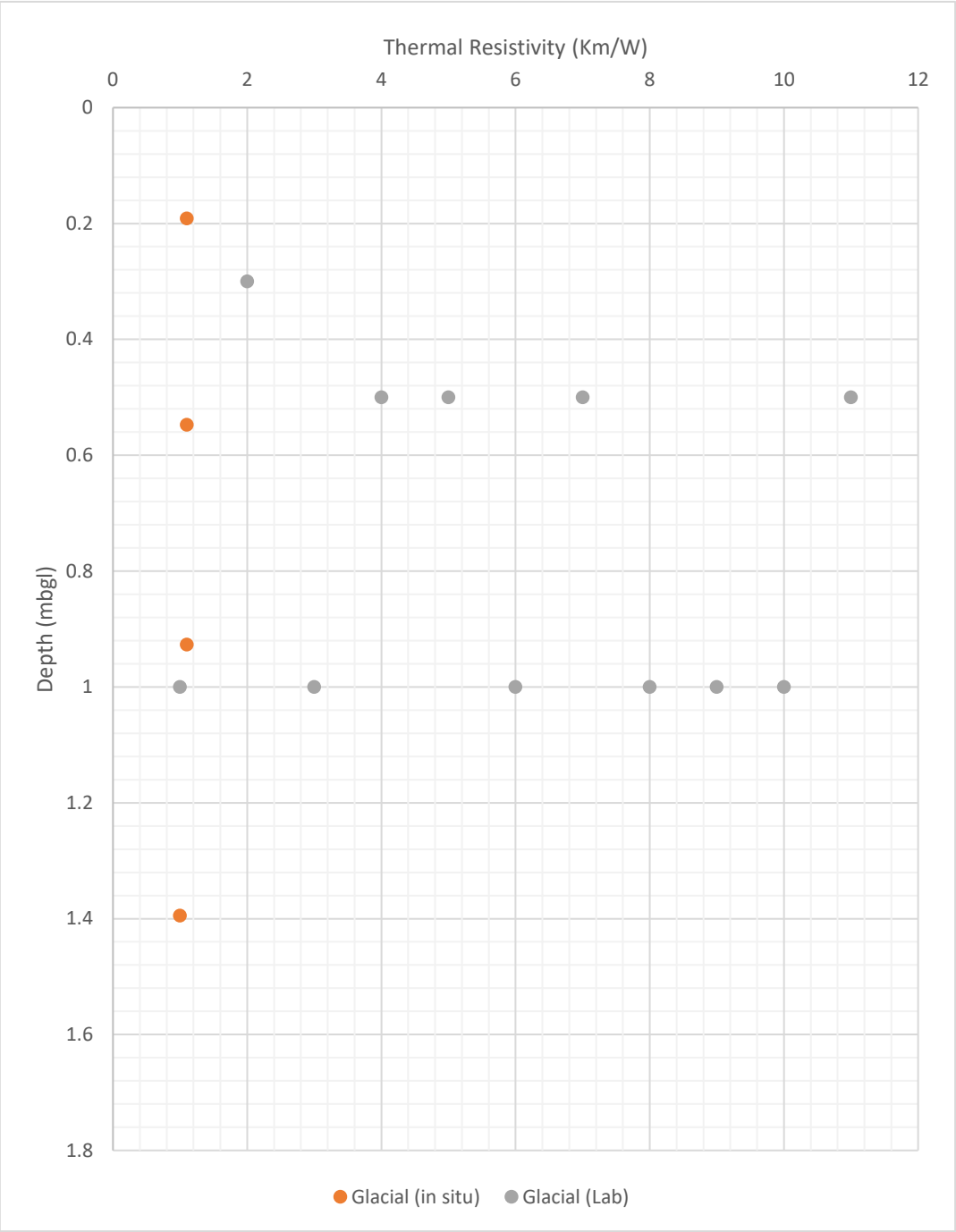

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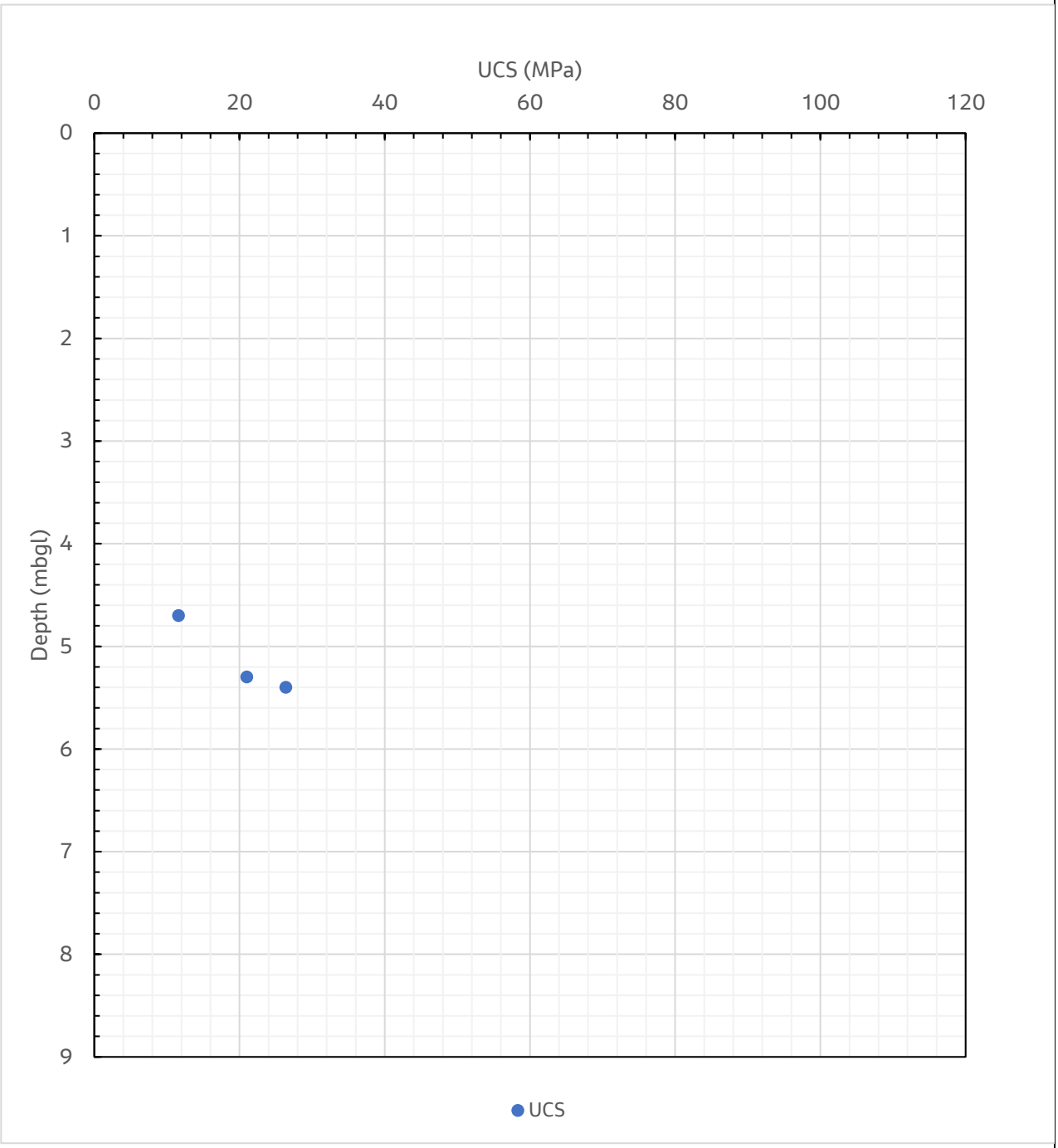
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Thermal Conductivity vs Thermal Resistivity *Granular Glacial Deposits*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	TR-02	Rev 0



Jacobs	Notes:		
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Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
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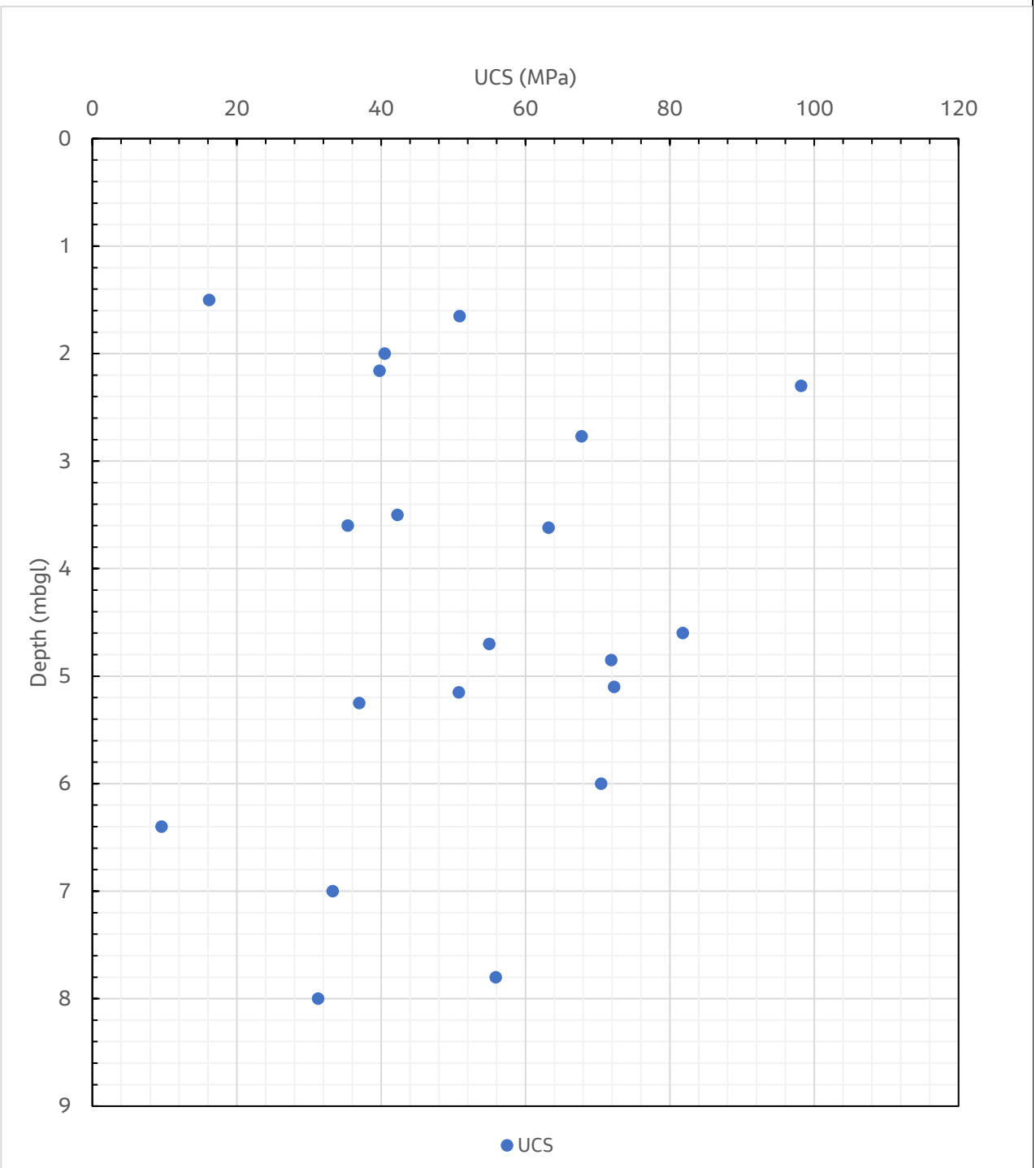

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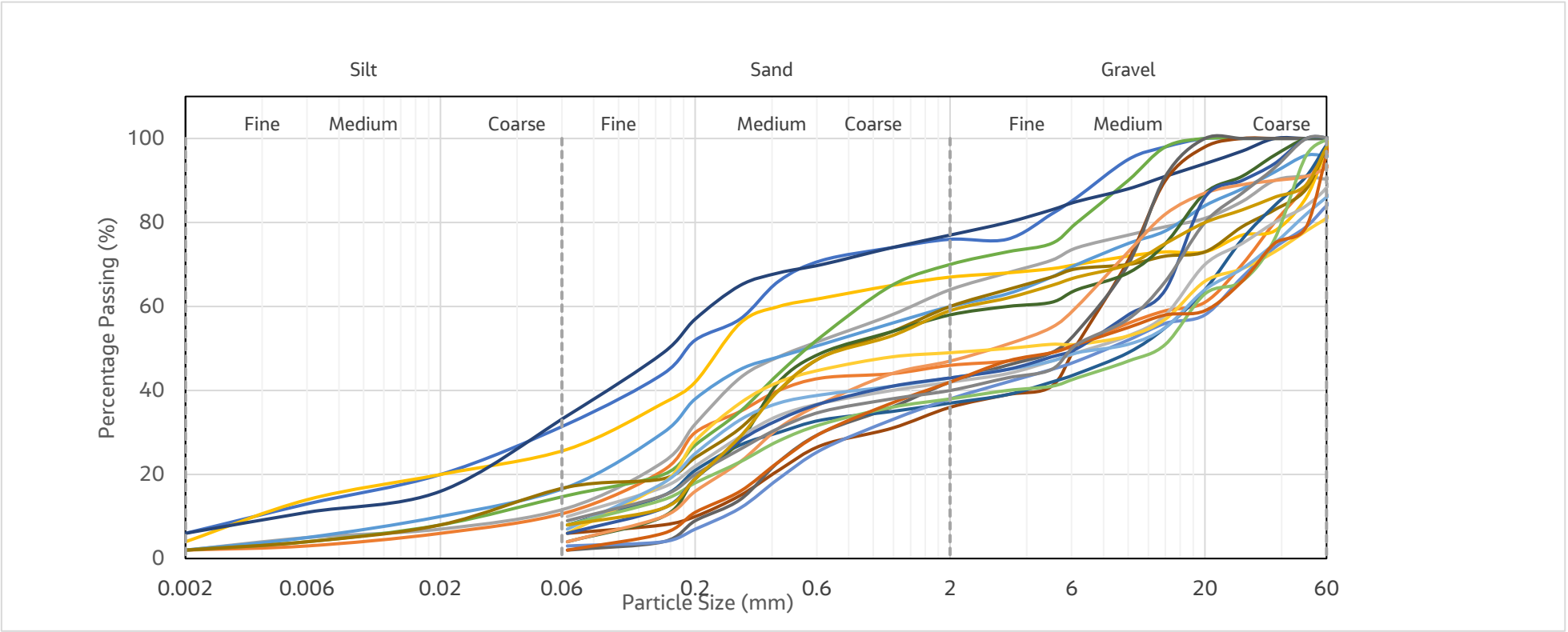
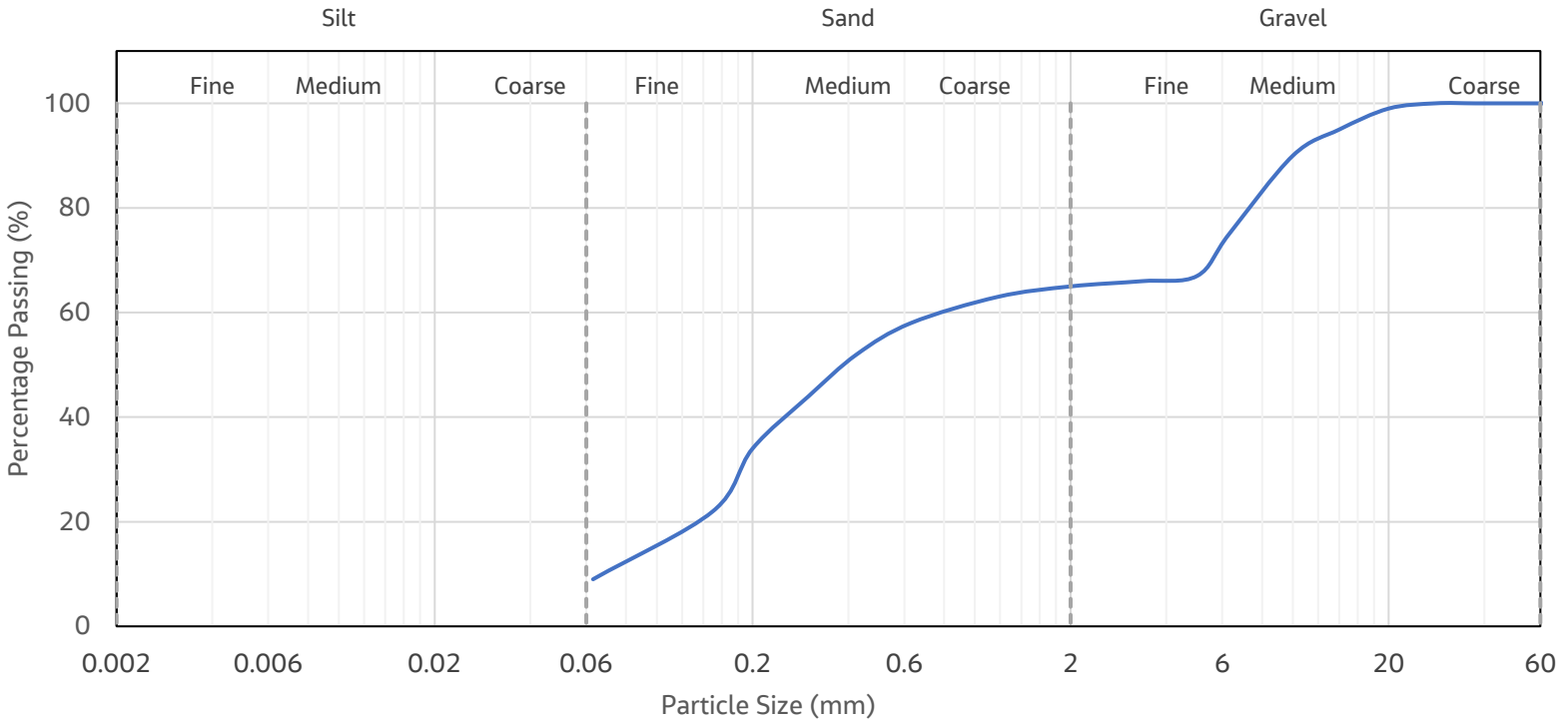
Client Scottish & Southern Electricity Networks Transmission	Figure Title:	UCS vs Depth *Metasedimentary Bedrock*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	UCS-02	Rev 0



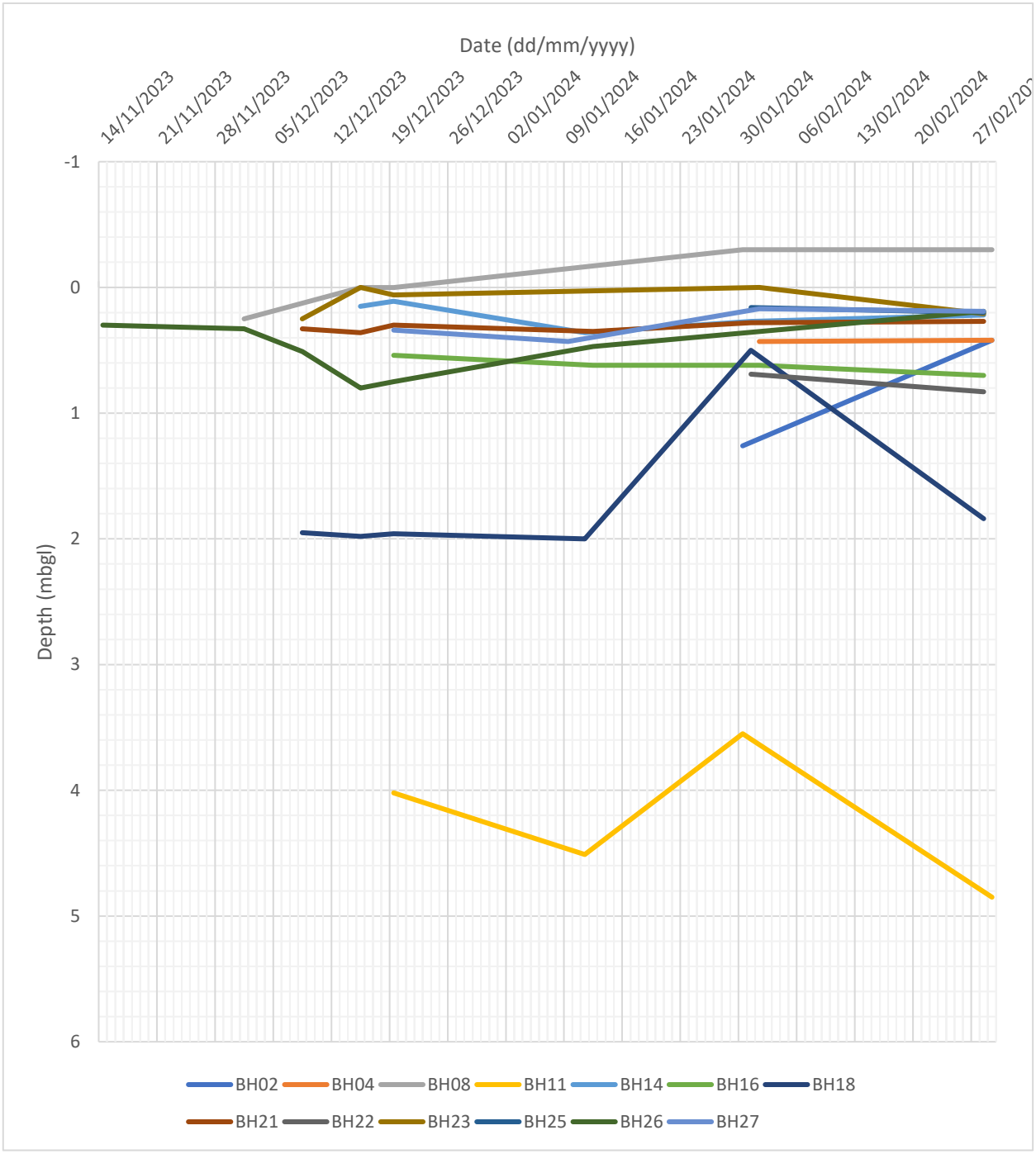
Notes:

Client: Scottish & Southern Electricity Networks Transmission		Title:	Particle Size Distribution *Granular Glacial Deposits*
Project: ASTI Substation Site – LT521 Fasnakyle		Jacobs No.:	B2468300
		Section:	Rev
		Figure No.:	PSD-01 | 0



Notes:

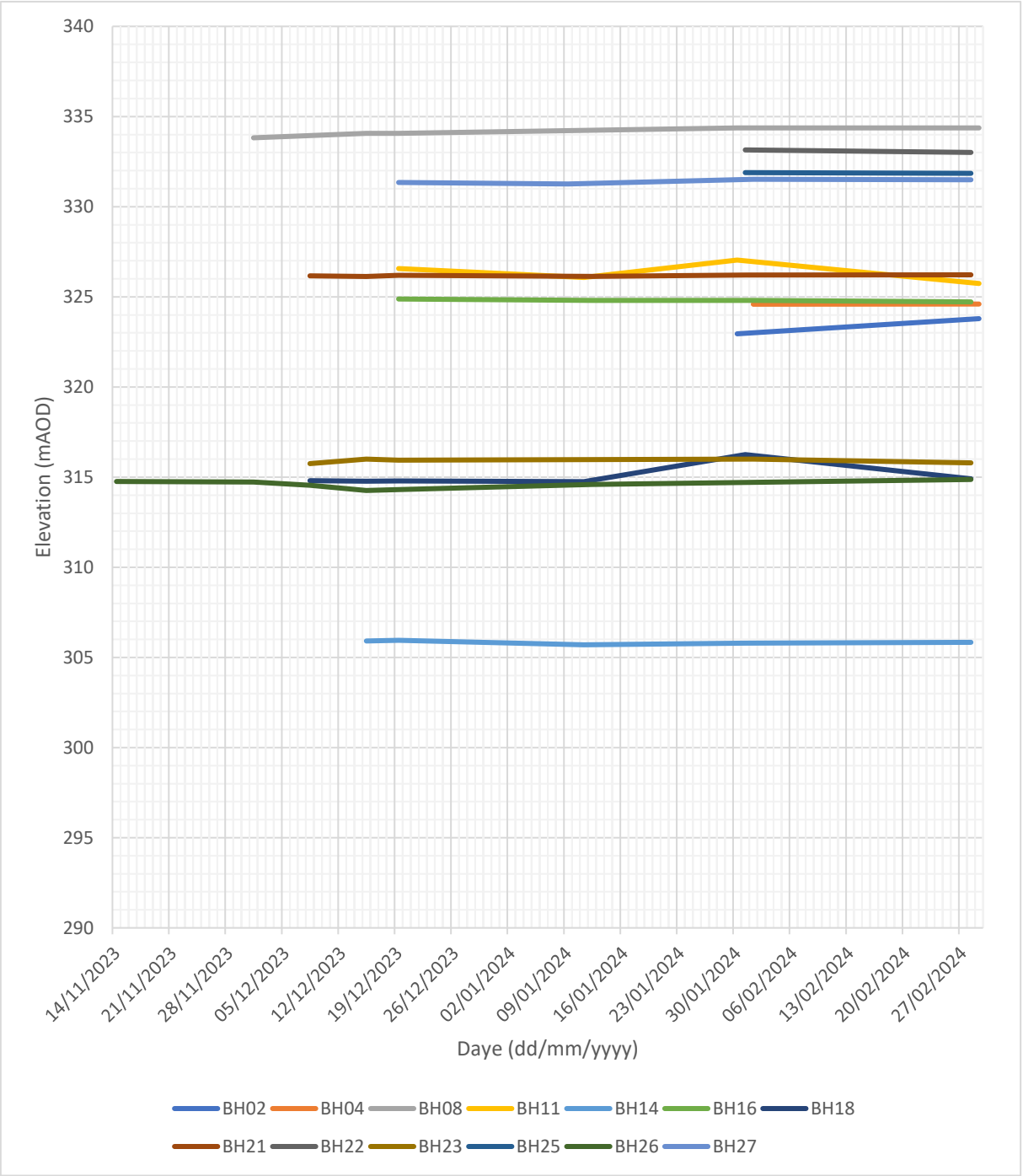
Client: Scottish & Southern Electricity Networks Transmission		Title:	Particle Size Distribution *Weathered Bedrock*
Project: ASTI Substation Site – LT521 Fasnakyle		Jacobs No.:	B2468300
		Section:	Rev
		Figure No.:	PSD-02 / 0



Jacobs

Notes:
BH08 recorded artesian water on 30/01/2024 and 29/04/2024

Client SSEN	Figure Title:	Groundwater monitoring vs Depth *All*	
Project Fasnakyle 400kV Substation	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	GW-01	Rev 0



Jacobs

Notes:
BH08 recorded artesian water on 30/01/2024 and 29/04/2024

Client Scottish & Southern Electricity Networks Transmission	Figure Title:	Groundwater monitoring vs Elevation *All*	
Project ASTI Substation Site – LT521 Fasnakyle	Jacobs No.:	B2468300	Not to Scale
	Figure No.:	GW-02	Rev 0

Appendix C. Geotechnical Risk Register

Appendix D. Pre Desk Study UXO Assessment

Pre-Desk Study Assessment

Site:	LTS21, Knockfin, Scotland
Client:	Jacobs
Contact:	James Wilkes
Date:	8th November 2023

Pre-WWI Military Activity on or Affecting the Site	None identified.
WWI Military Activity on or Affecting the Site	None identified.
WWI Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ■ Transport infrastructure and public utilities.
WWI Bombing	None identified on the Site.
Interwar Military Activity on or Affecting the Site	None identified.
WWII Military Activity on or Affecting the Site	Ad hoc military training is known to have occurred in rural areas of Scotland during WWII. No readily available records have been found to indicate that military training took place on the Site.
WWII Strategic Targets (within 5km of Site)	The following strategic targets were located in the vicinity of the Site: ■ Transport infrastructure and public utilities.
WWII Bombing Decoys (within 5km of Site)	None.
WWII Bombing	During WWII the Site was located in the Landward Area (LA) of Inverness-shire, which officially recorded 94No. High Explosive (HE) bombs with a bombing density of less than 0.1 bombs per 405 hectares (ha). No readily available records have been found to indicate that the Site was bombed.
Post-WWII Military Activity on or Affecting the Site	None identified.
Recommendation	A detailed desk study, whilst always prudent, is not considered essential in this instance.
Further information	For information about Zetica's detailed UXO desk studies and other UXO services, please visit our website: www.zeticauxo.com. Details and downloadable resources covering the most common sources of UXO hazard affecting sites in the UK can be found here. If you have any further queries, please don't hesitate to get in contact with us at uxo@zetica.com or 01993 886 682.