Appendix E2
Ground Investigation Report

Ground Investigation Report

Tallaght/Clondalkin to Centre CBC 0809
BCIDA-ACM-ERW_GI-0809_XX_00-RP-CE-0001

National Transport Authority

Project reference: 60599126
Project number: 60599126
BCIDA-ACM-ERW_GI-0809_XX_00-RP-CE-0001

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1. Executive Summary

To be updated in a future revision.

2. Introduction

2.1 Scope and objective of the report

The BusConnects Dublin - Core Bus Corridors Infrastructure Works (herein after called the CBC Infrastructure Works) involves the development of continuous bus priority infrastructure and improved pedestrian & cycling facilities on sixteen radial core corridors in the Greater Dublin Area,

The National Transport Authority (NTA) have appointed AECOM in association with Mott Macdonald to undertake the design of the infrastructure works for Package A of the BusConnects Programme. Package A includes the following four Core Bus Corridors (CBC):

- Clongriffin to City Centre (CBC 01);
- Lucan to City Centre (CBC 06);
- Clondalkin to Drimnagh (CBC 08); and
- Tallaght to City Centre (CBC 09).

This Ground Investigation Report (GIR) has been prepared in support of the scheme preparation for CBC 08 and CBC 09.

The geotechnical input to the scheme follows the procedures set out in TII Managing Geotechnical Risk DN-ERW-03083

The report provides a summary of the desk study and commentary on the findings of ground investigations that have been undertaken for the proposed route. A summary of factual data, which have been gathered for the scheme, is provided with interpretation of design parameters.

This report should be read in conjunction with the following document:

- Preliminary Sources Study Report: Bus Connects Corridor Route 08 Clondalkin to Drimnagh and Route 9: Greenhills to City Centre dated December 2019 and herein referred to as the PSSR.

Two specific preliminary ground investigations have been undertaken to date, as follows:

- Bus Connects Route 9 Tallaght/Clondalkin to City Centre conducted between 29th September and 29th October 2020
- Bus Connects Route 8 Tallaght/Clondalkin to City Centre conducted between 13th and 22nd October 2020

The above preliminary ground investigations were carried out, by Causeway Geotech, to inform the geotechnical design of key structures in support of the planning application. A further stage of preliminary investigation is proposed following submission of the planning application.

This Ground Investigation Report is based on the results of the above ground investigations.

The report uses the scheme chainage system shown on the proposed alignment plan included in Appendix A.

2.2 Description of the project (including site description)

This Ground Investigation Report is based on the proposed route alignment shown on the drawings contained within Appendix A.

2.2.1 Site description

Table 1 summarises the proposed works to CBC 09.

Table 1. CBC 09 Scheme, Bridges and Structures

Earthworks Reference/Chainage	High Level General Description	Relevant Structures Reference and Drawings
Section 1 Belgard Square South Junction to Belgard Square East Junction (Ch A0 to A800)	Localised pavement reconstruction/ widening works and roundabout reconstruction works.	Not applicable
Section 2 Belgard Square East Junction to TUD Access Road (Ch A800 to A2100)	No widening works - localised junction modifications.	Not applicable
Section 3 TUD Access Road to Airton Road (Ch A2100 to A2450)	Road widening on outbound lane. Culvert modification works at Ch A2220.	Not applicable
Section 4 Airton Road to Mayberry Road (Ch A2450 to A2950)	Road widening on inbound lane. 2 m - 1.5m high retaining wall/landscaped embankment proposed throughout. New road construction works (widening by approx. 7-10 m)	CBC09-RW04 Retaining Wall drawing: BCIDA-ACM-SPW_SQ-0009_RW_00-DR-CR-0001
Section 5 Mayberry Road to M50 overbridge via new Parkview bypass road (Ch A2950 to A3650)	New road construction on existing grassed area	Not applicable
Section 6 M50 Overbridge (ChA3650 to A3950)	New concrete road bridge with piled abutment substructures & central pier over M50	Greenhills Road/M50 Overbridge
Section 7 Ballymount Road Lower extension (ChA3950 - A4350)	At grade widening of Greenhills Road. New link road from ChA4100 to A4350 linking Greenhills road with Ballymount Ave..	Not applicable
Section 8 Ballymount Road Lower to Calmount Road (Ch A4350 - 4700)	At grade road widening and pavement reconstruction	Not applicable
Section 9 Calmount Road (Ch 4700 - A5200)	At grade road widening and pavement reconstruction	Not applicable

Earthworks Reference/Chainage	High Level General Description	Relevant Structures Reference and Drawings
Section 10 Calmount Road Extension to Greenhills Road (Ch A5200 - A5650)	New road construction on existing grassed area. New retaining walls required and stabilised earthworks embankments.	CBC09-RW05 Retaining Wall drawing BCIDA-ACM-STR_GA-0009_RW_09-DR-CB-0101 - CBC09-RW06 Retaining Wall drawing BCIDA-ACM-SPW_SQ-0009_RW_00-DR-CR-0001 – CBC09-RW01 CALMOUNT ROAD Retaining Wall 1 Drawing CBC09-RW05 RETAINING WALL BCIDA-ACM-STR_GA-0009_RW_09-DR-CB-0101 CBC09-RW02 CALMOUNT ROAD Retaining Wall 2 drawing BCIDA-ACM-STR_GA-0009_RW_09-DR-CB-0111
Section 11 Calmount Ave Greenhills Road roundabout (Ch C300 - C600)	New roundabout construction and extension of Calmount Avenue to Greenhills Road. Existing Greenhills Road to be lowered.	Not applicable
Section 12 Greenhills Road to Drimnagh Road via Walkinstown Roundabout and Walkinstown Road (Ch A5650 - A6800)	At grade road widening & pavement reconstruction	Not applicable
Section 13 Drimnagh Road to Grand Canal via Crumlin Road (Ch A6800 - A9250)	At grade road widening & localised pavement reconstruction	CBC09-RW03 LONG MILE ROAD Retaining Wall drawing BCIDA-ACM-STR_GA-0009_RW_10-DR-CB-0101
Section 14 Grand Canal to ChristChurch via Cork St, St Luke's Ave, Dean St and Patrick St (Ch A9250 - A11450)	At grade road widening & localised pavement reconstruction	Not applicable
Section 15 Bunting Road to Grand Canal via Kildare Road & Clogher Road (Ch D0 - E 2440)	At grade road widening & localised pavement reconstruction	Not applicable

Table 2 summarises the proposed works to CBC 08

Table 2. CBC 08 Scheme, Bridges, and Structures

Earthworks Reference/Chainage	High Level General Description	Relevant Structures Reference and Drawings
Section 1 Woodford Walk to Naas Road (Ch A0 to A2050)	Localised pavement reconstruction/ widening works and modification works to multiple junctions. 177m long 0.6m high retaining wall on Nangor Road south.	Not Applicable
Section 2 Naas Road Junction & Bridge (Ch A2050 to A2400)	2.5 - 2m high retaining walls for road widening on Nangor Road/Naas Road & new bridge ramps.	CBC008-ST01 NAAS ROAD Retaining Wall NO.1 drawing BCIDA-ACM-STA_GA-0008_RW_03-DR-CR-0101 CBC008-ST01 NAAS ROAD PEDESTRIAN & CYCLE drawing BCIDA-ACM-STR_GA-0008_BR_03-DR-CB-0101 CBC008-ST01 NAAS ROAD Retaining Wall NO.2 drawing BCIDA-ACM-STA_GA-0008_RW_03-DR-CR-0111 CBC008-RW4 Retaining Wall drawings BCIDA-ACM-STR_GA-0008_RW_00-DR-CB-0501
Section 3 Naas Road Junction to Kylemore Road Junction (Ch A2400 to A3000)	Localised pavement reconstruction/ widening works and junction modification works.	Not Applicable
Section 4 Walkinstown Avenue Ch A3000 to A3350)	Localised pavement reconstruction/ widening works and junction modification works.	Not Applicable
Section 5 Longmile Road Ch A3350 to A4100)	Localised pavement reconstruction/ widening works and junction modification works.	Not Applicable

2.3 Geotechnical Category of the Project

IS EN 1997-1 includes three geotechnical categories that may be introduced to establish the geotechnical design requirements.

- Geotechnical Category 1 is for small and relatively simple structures with negligible risk. These procedures should only be used where there is negligible risk in terms of overall stability or ground movement and in ground conditions, which are known from comparable local experience to be sufficiently straightforward. Additionally, in order to use these Category 1 procedures there must be no excavation below the water table.
- Geotechnical Category 2 is for conventional types of structure and foundations with no exceptional risk or difficult loading conditions. This includes spread footing, raft foundations, piled foundations, walls or other structures retaining or supporting water, excavations, bridge piers and abutments, embankments and earthworks, ground anchors and other systems and tunnels in hard, non-fractured rock and not subjected to special water tightness or other requirements.

- Geotechnical Category 3 includes structures or parts of structures, which fall outside the limits of Geotechnical Categories 1 and 2. This includes very large or unusual structures involving abnormal risks or unusual loading conditions, structures in high seismic areas and structures in area of probable site instability or persistent ground movements that require separate investigation or special measures.

Considering the guidance in IS EN 1997-1, it is considered that Geotechnical Category 2 is currently the most appropriate for the Scheme.

2.4 Other relevant information

The ground investigation is split into different phases of investigation. The initial phase was concerned with carrying out testholes at key locations to inform design to facilitate the planning phase of the project. It is anticipated that additional ground investigation, locations and spacings generally conforming to guidelines of EC7, will be carried out at later date.

3. Existing Information

3.1 Topographical maps

The topography of the site is generally relatively flat with elevations decreasing from South to North from approximately 110 m Ordnance Datum (OD) in Tallaght to 10 m OD in the city centre.

Greenhills Road is located near the Greenhills Esker, a ridge of sediment deposited by a stream that ran under, over, or within a glacier. Eskers can contain a wide variety of materials, with coarse-grained soils generally prevalent. Historical mapping shows gravel pits either side of Greenhills Road from approximately north of the M50 to approaching Walkinstown roundabout consequently leaving the road higher than the surrounding properties.

More information is available in the PSSR.

3.2 Geological Maps and memoirs

The available Solid and Drift Geological Map Sheets were reviewed along the proposed route corridor during the Preliminary Sources Study Reports. Information and map excerpts from this review are provided in the PSSR.

3.3 Aerial Photographs

Available aerial photographs for the route were reviewed and described in the PSSR.

3.4 Records of mines and mineral deposits

A review and commentary on mining and mineral deposits along the route alignment is contained in the PSSR.

3.5 Land Use and Soil Survey

The predominant land use along the proposed route is existing road and footpath infrastructure in an urban environment. Some widening is expected into existing residential and commercial properties

3.6 Archaeological and Historical Investigations

In CBC 09, Archaeological monitoring was conducted by Shanarc Archaeology during the excavation of R9TP01, R9TP02, R9TP04-R9TP07, R9TP10, R9TP11 and during excavation of inspection pits for R9CP03, R9CP04 and R9CP07-R9CP13a.

The findings of the monitoring are presented as a report in Appendix J of Bus Connects Route 9 Tallaght/Clondalkin to City Centre Ground Investigation dated December 2020.

3.7 Existing Ground Investigations

A review of existing ground investigation information is contained in the PSSR.

3.8 Consultation with Statutory Bodies and Agencies

To be updated in a further revision.

3.9 Flood Records

Information on flood records is available in the PSSR.

3.10 Contaminated Land

Both former and present industrial land use may have resulted in the presence, along the proposed route corridor, of potentially toxic or other hazardous material, which may pose a threat to human health, controlled waters or other sensitive receptors.

The PSSR collected information on potentially contaminative land use within the route corridor.

Contamination testing was undertaken on Made Ground encountered during the 2020 investigation and consisted of the following:

- Rialta Suite
- Suite E soil samples
- Suite F water samples

3.11 Other Relevant Information

3.11.1 Hydrology

Information on Hydrology is contained in the PSSR.

3.11.2 Groundwater Vulnerability

Information on groundwater vulnerability over the route extents is available in the PSSR.

3.11.3 Hydrogeology

Information on hydrogeology over the route extents is available in the PSSR.

3.11.4 Landslides

According to the Geological Survey of Ireland (GSI) records, there are no recorded landslides along the proposed route.

4. Field and Laboratory Studies

4.1 Walkover Survey

Site walkovers were carried out along the proposed route extents, prior to the undertaking of the Preliminary Ground Investigations. The primary purpose of the site walkover was a review of access and limitations to access for ground investigation plant. The geotechnical constraints of the scheme were also reviewed.

4.2 Geomorphological/Geological Mapping

No mapping has been undertaken.

4.3 Ground Investigation

Two project specific ground investigation have been undertaken to date by Causeway Geotech Ltd:

- Bus Connects Route 9 Tallaght/Clondalkin to City Centre conducted between 29th September and 29th October 2020
- Bus Connects Route 8 Tallaght/Clondalkin to City Centre conducted between 13th and 22nd October 2020

AECOM GIR Drawings in Appendix B show the 'as-built' exploratory hole locations undertaken for the ground investigations referenced above.

4.3.1 Description of Fieldwork

In general, the ground investigations utilised the following exploratory techniques:

- Cable percussion (CP) boring sunk using shell and auger techniques. This technique was used to investigate the superficial ground conditions, undertaking in-situ testing and taking undisturbed and disturbed samples for geotechnical/geochemical laboratory testing. Typically, CP boreholes were terminated on encountering refusal on very dense/stiff soils, boulders or weathered bedrock, or at a predefined depth based on the design and construction requirements for the proposed structure/earthwork.
- Rotary drilling both with and without core recovery. Generally, when using rotary drilling within soils standard penetration tests (SPTs) were taken at regular intervals below the depth attained by the CP boring.
  - Rotary drilling without core recovery (RO) was typically used to identify rockhead level and extend CP boreholes to rockhead when the CP could not advance due to obstructions (i.e. very dense/stiff soils or boulders).
  - Rotary drilling with core recovery (RC) was typically used in soils to extend CP boreholes beyond obstructions (i.e. very dense/stiff soils or boulders), where more soil information was required than would be recovered by RO methods. The use of a geotechnical wireline triple tube core barrel S-size ("Geobor") allowed recovery of good quality (Class 1) samples.

    RC was typically used in rock to provide information on the rock (i.e. lithology, discontinuities, strength, etc.) and recover core samples suitable for laboratory testing.
- Groundwater monitoring standpipes, installed to identify groundwater levels, provide water samples for geochemical testing and monitor groundwater flow.
- Machine excavated trial pits sunk to identify the near surface ground conditions and, at specific locations, to identify whether there was any archaeological significance. Disturbed samples and, where contamination was suspected, environmental samples were recovered from the trial pits to allow for geotechnical and geochemical testing. In-situ hand vane testing was also carried out in suitable cohesive soils. Dynamic Cone Penetrometers (DCPs) were carried out adjacent to trial pits to provide a profile of penetration with depth and to a derive a CBR value.
- Window sampling boreholes at locations, which were unsuitable to access by means of CP rigs, RC rigs or excavators; the window sampling rig was smaller and easier to mobilise to difficult locations. The window sampler was used to identify superficial ground conditions, taking disturbed samples for geotechnical/ geochemical testing and carrying out SPTs. Typically, the window sampling boreholes were terminated on very dense/stiff soils or on possible boulders or bedrock.

4.3.1.1 CBC 09 September 2020 Investigation

Site operations, which were conducted between 29th September and 29th October 2020, comprised:

- Fourteen boreholes (R9CP01-R9CP13) were put down to completion in minimum 200mm diameter using a Dando 2000 light cable percussion boring rig. R9CP13A was terminated due to encountering an old tank and removed to a new position at R9CP13.
- Four boreholes (R9CPGS01-R9CPGS04) were put down by a combination of light cable percussion boring and rotary follow-on drilling techniques using a truck mounted Beretta T44 rotary drilling rig with core recovery in overburden and bedrock.
- One borehole (R9WS01) was put down to completion by light percussion boring techniques using a Dando Terrier dynamic sampling rig.
- Eleven trial pits (R9TP01–R9TP11) were excavated using a 3t tracked excavator or JCB3CX fitted with a 600mm wide bucket, to a maximum depth of 4.20m.
- A groundwater monitoring standpipe was installed in R9CP02, R9CP04, R9CP05, R9CP06, R9CP08, R9CP11, R9CPGS01 and R9CPGS04.

4.3.1.2 CBC 08 October 2020 Investigation

Site operations, which were conducted between 13th and 22nd October 2020, comprised:

- Four boreholes (R8-CPGS01-R8-CPGS04) were put down by a combination of light cable percussion boring using a Dando 2000 rig and rotary follow-on drilling techniques with core recovery in bedrock using a truck mounted Berretta T44 rotary drilling rig.
- A groundwater monitoring standpipe was installed in R8-CPGS02 and R8-CPGS04.

4.3.2 Ground Investigation Factual Reports

The results of the investigation are provided in the following Causeway Geotech Factual Reports: :

- Report No: 20-0399D Bus Connects Route 9 Tallaght/Clondalkin to City Centre – Ground Investigation dated December 2020
- Report No: 20-0399D Bus Connects Route 8 Tallaght/Clondalkin to City Centre – Ground Investigation dated December 2020

4.3.3 Results of in-situ tests

The in-situ testing undertaken during the ground investigation comprised:

- standard penetration testing (SPT);
- hand vane testing to determine in-situ undrained shear strength values; and
- dynamic cone penetrometer (DCP) testing to determine in-situ CBR values;

The results of the in-situ testing are included in the relevant ground investigation factual reports as listed in Section 4.3.2, and summarised in Section 5.0 of this report (where applicable), with relevant charts presented in Appendix C.

4.4 Drainage Studies

Not used

4.5 Geophysical Studies

Not used

4.6 Pile Tests

Not Used

4.7 Other Field Work

Not used

4.8 Summary of Results of Laboratory investigation

A range of geotechnical, geochemical and contamination testing was undertaken on samples of soil, rock, groundwater recovered during the ground investigation. The geotechnical tests were typically carried out in Causeway Geotech UKAS accredited laboratories located in the Ballymoney Co. Antrim. Environmental tests were generally carried out by Eurofins Chemtest Ltd.

A list of the laboratory tests undertaken across the ground investigations is presented in the following subsections, with results presented and discussed in Section 5, and charts provided in Appendix C.

The Ground Investigation Factual Report provides the laboratory test results/reports and details of the testing methods.

4.8.1 Description of tests

4.8.1.1 Soil Testing

Soils tests, undertaken as part of the ground investigation, include the following:

- Classification tests: moisture content, Atterberg Limits, and particle size distribution by wet sieving and sedimentation

- Compaction related tests: MCV and CBR at natural moisture content
- Shear strength (total stress): unconsolidated undrained, single stage triaxial tests on nominal 100mm diameter specimens prepared from U100 and Geobor core samples

4.8.1.2 Rock Testing

Rock tests, undertaken as part of the ground investigations, are detailed below:

- Point load strength tests
- Uniaxial compressive strength (UCS) tests

4.8.1.3 Chemical Testing

The following chemical tests were undertaken:

- pH
- Water soluble sulfate content
- Acid soluble sulfate content
- Total sulfur content

4.8.1.4 Contamination Testing

A suite of contamination testing was scheduled on selected soil and water samples recovered at various locations along the proposed scheme. The full lists of tests and the test results are included in the Ground Investigation Factual Report.

4.8.2 Summary of test results

The results of the test results are described in the Ground Investigation Factual Reports. Where relevant the results of testing are discussed in Section 5 Ground Summary and Material Properties

4.9 Evaluation of geotechnical information

A number of undrained triaxial tests were scheduled in the soil but not undertaken due to unsuitable sample. Similarly, UCS testing of rock core was not possible on all scheduled samples and was replaced with point load testing where applicable.

Laboratory CBR testing of silty boulder clay soils can often provide unexpectedly low results, often attributed to dilatancy, migration of water from granular lenses, or excess pore water pressures within the remoulded specimen following its preparation. Additional in-situ CBR results obtained from Dynamic Cone Penetrometer testing in trial pits and measured Standard Penetration Tests from the boreholes available in the Ground Investigation Factual Reports may provide more realistic predictions of the insitu soil stiffness.

5. Ground Summary and Material Properties

5.1 Ground Conditions

5.1.1 Route summary

Diagrammatic geotechnical long sections have been prepared from the findings of the ground investigations along the route. These sections are presented on the drawings that form Appendix B.

The following lithologies have been assigned to the ground types encountered in the ground investigations:

- Topsoil (TS)
- Made Ground/Highway Fill (MG)
- Glacial Till (GT) deposits –subdivided into brown Dublin boulder Clay (br DBC), and black Dublin boulder clay (bl DBC).
- Sand and Gravel deposits (S&G) – typically glaciofluvial deposits
- Glacial Clay (GC)
- Bedrock (ROCK) – subdivided into Limestone (LMST) and Mudstone (MDST)

Table 3 summarises the ground conditions encountered in Route 09 in approximate lithological order.

Table 3. CBC 09 Summary of soil units encountered

Stratum	Depth to Top of Stratum (m bgl)	Level at Top of Stratum (m AOD)	Thickness (m)
Topsoil	0	101.7 to 64.16	0.10 to 0.6
Made Ground	0	87.89 to 52.22	0.4 to 6.5*
Brown Dublin Boulder Clay	0.3 to 7.5	101.38 to 53.04	0.3 to 4*
Black Dublin Boulder Clay	3 to 7.8	84.89 to 50.37	0.2 to 4*
Sands and Gravels	0.5 to10.5	73 to 50.72	0.55 to 8.05*
Glacial Clay	1.6 to 4.7	55.01 to 52.29	0 to 2*
Mudstone	11.05	62.02	2
Limestone	10.5 to 13.05	57.07 to 54.38	2.95 to 5.50**

**not proven in all testholes*

***not proven*

Table 4 summarises the ground conditions encountered in Route 08 in approximate lithological order.

Table 4. CBC 08 Summary of soil units encountered

Stratum	Depth to Top of Stratum (m bgl)	Level at Top of Stratum (m AOD)	Thickness (m)
Made Ground	0	48.19 to 46.53	0.6 to 1.2
Brown Dublin Boulder Clay	0.6 to 0.7	46.48 to 45.83	1.3 to 1.9
Black Dublin Boulder Clay	1.2 to 2.5	46.99 to 44.53	1.8 to 3.5
Limestone	4.3 to 5.5	43.89 to 41.03	5.35 to 6.5**

**not proven

The strata of each exploratory hole shown on the geotechnical long sections have been assigned to one of the above lithologies by considering:

- strata descriptions and laboratory test results;
- published geology and interpreted geomorphology; and
- topography in the area

The following sections of the report describe the general nature of the identified lithologies and the primary locations where they have been identified in the ground investigations.

5.1.2 Made Ground

Made ground is present in various areas along the length of the route corridor. Highway fill is associated with existing roads or areas of hard standing; it typically comprises general fill of reworked clay/silt/sands and selected fills formed by silty sandy gravels.

Reworked sandy gravelly clay/silt or sandy clayey gravel or gravelly silty sand fill was encountered at all locations except R9CP04, R9CP07, R9CP09, R9CP11, R9CP12, R9CPGS01 and R9TP02 to a maximum depth of 6.50m in R9CPGS02. Varying amounts of red brick, wood, plastic, cloth, glass, rubber, carpet, ceramics and concrete were encountered across the site concentrated in R9CP05, R9TP05 and R9TP06.

The main occurrences encountered in exploratory holes along the route, with approximate chainage are summarised in the following Table 5.

Table 5. CBC 09 occurrences of Made Ground

Approximate Chainage	Testhole	Depth range (m bgl)	Thickness (m)	Description
A 605	R9TP01	0.3 - 2	1.7	MADE GROUND: Stiff greyish brown slightly sandy gravelly CLAY with low cobble content.
A 622	R9TP02	0.3 - 2.4	2.1	Stiff brown slightly sandy slightly gravelly CLAY with low cobble content.
A 2375	R9TP03	0 - 0.9	0.9	0 - 0.1 m bgl : MADE GROUND: Grey rounded coarse GRAVEL. 0.1 - 0.35 m bgl: MADE GROUND: Greyish brown very sandy very silty subangular fine to coarse GRAVEL of mixed lithologies. 0.35 - 0.9 m bgl: MADE GROUND: Dark grey sandy subangular fine to coarse GRAVEL of limestone with high cobble content.
A 2635	R9CP01	0 - 0.4	0.4	MADE GROUND: Soft brown sandy gravelly CLAY. Sand is fine to coarse. Gravel is subangular to subrounded fine to coarse.

Approximate Chainage	Testhole	Depth range (m bgl)	Thickness (m)	Description
A 2882	R9CP02	0.1 - 0.4	0.3	0.1- 0.4 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL. 0.4 – 1.3 m bgl: MADE GROUND: Firm brownish grey sandy gravelly CLAY
A 3055	R9CP03	0.4 - 2	1.6	MADE GROUND: Firm brown sandy gravelly CLAY.
A 3125	R9TP04	0.3 - 1.1	0.8	0.3 – 1.1 m bgl: MADE GROUND: Stiff brown slightly sandy slightly gravelly CLAY with low cobble content and fragments of red brick. 1.1 – 1.7 m bgl: MADE GROUND: Stiff yellowish brown slightly sandy slightly gravelly CLAY with fragments of red brick
A 3355	R9TP05	0 - 1.8	1.8	MADE GROUND: Firm brown slightly sandy slightly gravelly CLAY with medium cobble content and fragments of red brick and wood and pieces of rubber and carpet.
A 3631	R9TP06	0.1 - 0.2	0.95	0.1- 0.2 m bgl: MADE GROUND: Firm orangish brown slightly sandy slightly gravelly CLAY. 0.2- 1.05 m bgl: MADE GROUND: Stiff greyish brown slightly sandy gravelly CLAY with medium cobble and boulder content and fragments of concrete, red brick and pieces of rubber tubes.
A 3680	R9CPGS01	0.3 - 6	5.7	Possible Made Ground: Firm to stiff brown slightly sandy slightly gravelly CLAY with low cobble content.
A 3685	R9CPGS02	0.2 – 6.5	6.3	0.2 – 2.4 m bgl: MADE GROUND: Firm brown sandy gravelly CLAY. 2.4 – 5 m bgl: MADE GROUND: Firm becoming stiff brownish grey sandy gravelly CLAY. 5 - 6.3 m bgl: MADE GROUND: Firm brown sandy gravelly CLAY with fragments of red brick. (Driller's description)
A 3800	R9CPGS04	0.1 - 0.3	1.3	0.1 – 0.3 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL 0.3 – 1.3 m bgl: MADE GROUND: Firm brownish sandy gravelly CLAY.
A 3800	R9CPGS03	0.2 - 2	1.8	MADE GROUND: Firm brown sandy gravelly CLAY. Sand is fine to coarse.
A 3975	R9TP07	0.3 - 1.8	1.5	MADE GROUND: Firm brown slightly sandy slightly gravelly silty CLAY with medium cobble and boulder content and pieces of red brick and concrete.
A 4245	R9CP05	0 - 4.8	4.8	MADE GROUND: Soft becoming firm brown sandy gravelly CLAY with fragments of wood and pieces of cloth and plastic.
A 4340	R9TP08	0 - 0.55	0.55	MADE GROUND: Stiff brown slightly sandy gravelly CLAY.
A 4555	R9WS01	0.6 - 1.2	0.6	MADE GROUND: Soft brown sandy gravelly SILT with concrete fragments.
A 5345	R9CP08	0 – 2.4	2.4	0 - 0.2 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL 0.2 – 2.4 m bgl: MADE GROUND: Soft to firm brown sandy gravelly CLAY.

Approximate Chainage	Testhole	Depth range (m bgl)	Thickness (m)	Description
A 5366	R9TP10	0 - 0.8	0.8	0 – 0.55 m bgl: MADE GROUND: Firm brown slightly sandy slightly gravelly CLAY with fragments of red brick. 0.55 – 0.8 m bgl: MADE GROUND: Soft yellowish brown slightly sandy slightly gravelly CLAY.
A 5402	R9TP11	0 – 1.6	1.6	0 – 0.9 m bgl: MADE GROUND: Stiff brown slightly sandy slightly gravelly CLAY. 0.9 – 1.6 m bgl: MADE GROUND: Stiff yellowish brown slightly sandy slightly gravelly CLAY and fragments of ceramic.
A 5413	R9CP10	0 – 1.4	1.4	0 – 0.2 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL 0.2 - 1.4 m bgl: MADE GROUND: Soft to firm brown sandy gravelly CLAY.
A 5504	R9CP09	0 - 0.4	0.4	0 – 0.2 m bgl: BITMAC 0.2 – 0.4 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL.
A 5617	R9CP12	0 - 0.5	0.5	0 – 0.2 m bgl: BITMAC 0.2 – 0.5 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL
A 5636	R9CP11	0.2 - 0.4	0.2	MADE GROUND: Grey angular fine to coarse GRAVEL
A 5737	R9CP13	0 – 1.2	1.2	0 – 0.1 m bgl: BITMAC 0.1 – 0.3 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL 0.3 – 1.2 MADE GROUND: Soft to firm brown sandy gravelly CLAY
C 425	R9CP06	0 - 4	4	0 – 0.1 m bgl: MADE GROUND: Grey sandy slightly clayey subangular fine to coarse GRAVEL of mixed lithologies. 0.2 – 2 m bgl: MADE GROUND: Firm becoming stiff dark brownish black sandy gravelly CLAY. 2 – 4 m bgl: MADE GROUND: Firm brown sandy gravelly CLAY.
C 475	R9TP09	0 – 2.20	2.20	0 – 0. 15 m bgl: MADE GROUND: Grey sandy very silty subangular fine to coarse GRAVEL of limestone. 0.15 – 0.25 m bgl: MADE GROUND: Light yellowish brown slightly sandy clayey subangular fine to coarse GRAVEL of mudstone. 0.25 - 0.35 m bgl: MADE GROUND: Brown very sandy very clayey subangular to subrounded fine to coarse GRAVEL of mixed lithologies. 0.35 - 0.45 m bgl: MADE GROUND: Dark brown very gravelly very silty fine to coarse SAND 0.45 - 2.2 m bgl: MADE GROUND: Greyish brown slightly sandy gravelly CLAY with high cobble content and fragments of glass and red brick.
C 885	R9CP07	0 - 0.5	0.5	0 – 0.2 m bgl: BITMAC 0.2 – 0.5 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL.

Approximate Chainage	Testhole	Depth range (m bgl)	Thickness (m)	Description
Naas Road Bridge	R8-CPGS01	0 – 1.2	1.2	0 – 0.1 m bgl: MADE GROUND: Paving brick 0.1 – 0.3 m bgl: CONCRETE 0.3 - 0.5 m bgl: BITMAC 0.5 - 0.7 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL 0.7 – 1.2 m bgl: MADE GROUND: Grey sandy silty subangular fine to coarse GRAVEL of mixed lithologies.
Naas Road Bridge	R8-CPGS02	0 - 0.1	0.1	0 - 0.1 m bgl: MADE GROUND: Paving brick 0.1 – 0.4 m bgl: CONCRETE 0.4 – 0.6 m bgl: BITMAC 0.6 – 1 m bgl: CONCRETE 1 – 1.2 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL of mixed lithologies
Naas Road Bridge	R8-CPGS03	0 - 0.6	0.6	0 – 0.1 m bgl MADE GROUND: Paving brick 0.1 – 0.3 m bgl : CONCRETE 0.3 – 0.6 m bgl: MADE GROUND: Grey slightly sandy angular fine to coarse GRAVEL
Naas Road Bridge	R8-CPGS04	0 - 0.7	0.7	0.1 – 0.1 m bgl: MADE GROUND: Paving brick 0.1 – 0.3 m bgl: Concrete 0.3 – 0.7 m bgl: MADE GROUND: Grey angular fine to coarse GRAVEL.

In CBC 08, all boreholes encountered paving brick at ground level. Beneath this were both bitmac and concrete of varying thickness likely representing old road surfaces. Concrete was encountered to a maximum depth of 1.00m in R8-CPGS01 and R8-CPGS02. Sub-base, comprising approximately 200 to 300mm of crushed rock aggregate fill, was encountered beneath the paved surface.

5.1.3 Glacial Clays

In CBC 09, Glacial Clay deposits were found in R9TP10 and R9TP11 near the Greenhills Esker and are described as deposits of stiff brown CLAY with lenses of brown fine to medium SAND of approximate 2 m thickness. It's possible these deposits were also encountered in RPCP12 and R9CP13 based on the similar descriptions and close proximity.

It's possible these layers are the result of deposition from a historical glacial river near the extents of the esker.

This deposit was not encountered in CBC 08.

5.1.4 Sands and Gravels

In CBC 09, glaciofluvial deposits of typically medium dense to dense sands and gravels interspersed with layers of sandy gravelly clay or silt were generally encountered along Greenhills Road from approximately Greenhills Bridge to the extent of the investigation approaching Walkinstown Roundabout.

Greenhill Road is located near the Greenhills Esker, a ridge of sediment deposited by a stream that ran under, over, or within a glacier. Eskers can contain a wide variety of materials, with coarse-grained soils generally prevalent.

Associated sands and gravels along the Greenhills Road, northeast of the esker, are probably part of an associated ice marginal fan. The sands and gravels within the feature are comprised chiefly of limestone clasts.

The area to both side of Greenhills Road was historically mined for Sand and Gravel.

These deposits were not encountered in CBC 08.

5.1.5 Glacial Till

The Glacial Till is typical of the drift cover in much of the Dublin area, comprising boulder clay, a lodgement till deposited during the last ice age, about 10,000 years ago. Farrell et al. (1995) made the distinction between the 'Brown Boulder Clay' and the 'Black Boulder Clay', stating that the Brown Boulder Clay was a weathering product of the Black Boulder Clay, and is broadly similar to it in terms of particle size distribution.

The brown Dublin boulder clay generally consists of sandy gravelly silt/clay with low to medium cobble content; occasionally soft to firm to 0.5 m; typically, firm / firm to stiff to maximum of about 3 m

The black Dublin Boulder clay is found underlying the brown Dublin Boulder Clay and consists of generally stiff / very stiff / sandy gravelly silt/clay; high cobble content and occasional boulders are typical below 2.0m bgl.

For the purposes of interpretation, where a very stiff brown slightly sandy slightly gravelly CLAY was encountered underlying the very stiff black Dublin Boulder clay it was still classified as the black Dublin Boulder Clay for interpretation and presentation purposes.

In CBC 09, Glacial till deposits were typically encountered in the majority of the testholes with Glacial till deposits being more prominent in testholes south of Greenhills Bridge. Soft glacial deposits were encountered in R9CP05, R9CP08, and R9CP10. The upper 0.5 m can be frequently softened (degraded) by weathering or water action. Below the weathered zone, these deposits generally become stiffer with increasing depth, representing unweathers soil. The presence of groundwater within lenses of soil with higher coarse-grained content also leads to softening in the till; consequently zones of degraded till were encountered below unweathered till.

In CBC 08 Glacial Till deposits were encountered in all test holes with the stiffness increasing from firm to stiff/very stiff with increasing depth.

5.1.6 Bedrock

The GSI Bedrock Geology map (scale 1:100,000) indicates both the CBC 08, and CBC 09 route is underlain by the Lucan Formation comprising dark-grey, argillaceous, cherty, spicular micrites and shales, with horizons of graded, skeletal limestones containing ooids and other shallow water grains.

5.1.6.1 CBC 09

Grey weathered LIMESTONE. (Driller's description) was encountered in R9CPGS03 from 10 – 10.5 m bgl.

Medium strong very thinly bedded dark grey argillaceous LIMESTONE was encountered in R9CPGS01-04 to completion depth.

A 2 m thick, medium strong thinly laminated black MUDSTONE was encountered in R9CPGS04 from 11.05 to 13.05 m bgl.

The rock is generally described as partially weathered, leading to closer fracture spacing with probably slightly reduced strength. Full descriptions are available in the borehole logs.

5.1.6.2 CBC 08

Limestone was encountered at depths ranging from 4.50m in R8-CPGS01- R8-CPGS03 to 6.00m in R8-CPGS04. The limestone was typically described as medium strong.

R8-CPGS-03 encountered soft becoming firm brown sandy gravelly Clay infill from 9.65 m bgl to termination depth at 10 m bgl.

Full descriptions are available in the borehole logs

5.1.7 Groundwater

5.1.8 Groundwater Monitoring

The results of groundwater monitoring are as follows:

Table 6. Results of Groundwater Monitoring

Route	Testhole	Standpipe Depth	Slotted Screen Range (m bgl)	Response Zone	Water Level 19-11-2020
CBC 08	R8-CPGS02	4.6	1 - 4.3	Glacial Till	3.29
CBC 08	R8-CPGS04	5.16	1 - 5.5	Glacial Till	2.53
CBC 09	R9-CP02	2.92	1 - 3	1- 1.3 m bgl : Made Ground : reworked boulder clay 1.3 – 3 m bgl: Granular deposits	1.16
CBC 09	R9-CP04	3	1 - 3	Glacial Till	Bung Jammed unable to open
CBC 09	R9-CP05	7.25	4.8 – 7.5	Sand and Gravel deposits	Dry
CBC 09	R9-CP06	5.96	3 - 6	3- 4 m bgl : Made Ground : reworked boulder clay 4 – 6 m bgl: Granular deposits	Dry
CBC 09	R9-CP08	4.45	1 - 4.6	1- 2.4 m bgl : Made Ground : reworked boulder clay 2.4 – 4.6 bgl: Glacial Till	4.1
CBC 09	R9-CP11	4.05	1.3 – 3.8	Granular deposits	3.28
CBC 09	R9-CPGS01	12	6 - 12	6 – 10 m bgl : Glacial Till deposits 10- 12 m bgl : Granular deposits	8
CBC 09	R9-CPGS04	11.04	6 - 11.05	6- 9.4 and 10.5 - 11 m bgl : Granular deposits 9.4 – 10.5 m bgl : Glacial Till deposits	8.92

5.1.9 Groundwater Strikes

The results of groundwater strikes are as follows:

Table 7. Results of Water Strikes

Route	Testhole	Water Strike	Casing to (m)	Time (min)	Rose to (m)	Remarks
CBC 08	R8-CPGS01	4.3	4.3			Strike at 4.30 m
CBC 08	R8-CPGS02	3.4				Strike at 3.40 m
CBC 08	R8-CPGS02	3.6	3.6	20	3.5	Slow seepage at 3.60 m

Route	Testhole	Water Strike	Casing to (m)	Time (min)	Rose to (m)	Remarks
CBC 08	R8-CPGS03	4.2				Strike at 4.20 m
CBC 08	R8-CPGS04	3.5				Strike at 3.5 m
CBC 09	R9CP01	5	5			Slow seepage at 5.00 m
CBC 09	R9CP08	4.1	4.1	20	4	Slow seepage at 4.10 m
CBC 09	R9CP13	2				Seepage at 2 m
CBC 09	R9CPGS01	9	9			Strike at 9.0 m
CBC 09	R9CPGS02	9				Strike at 9.0 m
CBC 09	R9CPGS03	9				Strike at 9.0 m
CBC 09	R9CPGS04	9				Strike at 9.0 m
CBC 09	RPTP05	1.6				Rapid water strike at 1.60 m

5.1.10 Manmade Features

The existing Greenhills Road bridge approach embankments were mainly found to comprise cohesive materials, probable reworked glacial till.

Other man made features encountered along the route corridor include:

- Infilling of probable historical sand and gravel pits along Greenhills Road
- The presence of Made ground comprising reworked cohesive material and construction waste in the majority of trial pits
- paving brick at ground level at Route 08. Beneath this were both bitmac and concrete of varying thickness likely representing old road surfaces. Concrete was encountered to a maximum depth of 1.00m in R8-CPGS01 and R8-CPGS02.

5.2 Material properties

5.2.1 Introduction

The properties of the main soil and rock types are presented as summary tables and charts of material properties.

A series of charts, relating laboratory and in-situ test results for the main materials encountered in the ground investigations, are included in Appendix C. Charts have been divided into soils and rock and are listed in Table 8 below.

Table 8. List of material property charts

Chart Title	Chart Type
Natural moisture content versus depth	Soil
Plasticity Index versus depth	Soil
Plastic Limit versus depth	Soil
Liquid Limit versus depth	Soil
Casagrande (plasticity) chart	Soil
CBR versus natural moisture content	Soil
Moisture Condition Value (MCV) versus natural moisture content	Soil
Undrained shear strength (cu) versus natural moisture content	Soil

Chart Title	Chart Type
Standard Penetration Test N versus depth	Soil
Particle size distribution (PSD) plots	Soil
UCS and point load versus depth below rockhead.	Rock
Fracture index versus depth below rockhead	Rock

Geotechnical parameter tables for material types encountered are summarised below. These tables are intended to be reviewed in conjunction with the parameter summary charts provided in Appendices C.

CBR results are presented for laboratory test data only. Laboratory CBR testing of silty boulder clay soils can often provide unexpectedly low results, often attributed to dilatancy, migration of water from granular lenses, or excess pore water pressures within the remoulded specimen following its preparation. Additional in-situ CBR results obtained from Dynamic Cone Penetrometer testing in trial pits are also available in the Ground Investigation Factual Reports as referenced in Section 4.3.2.

5.2.2 Made Ground

Table 9 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the soil unit in CBC 09.

Table 9. Summary of Geotechnical Laboratory and in-situ results on Made Ground

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Particle Size Distribution						
Clay	%	3	5	7	8	R9.MG.1
Silt			17	18.7	21	
Fines		6	10	24.7	37	
Sand			9	32.25	52.5	
Gravel			18.5	40.9	68	
Cobbles			0	2.16	13	
Atterberg Limits						
Moisture Content	%	27	5.9	15.25	22	R9.MG.2
Liquid Limit (LL)	%	16	21	30.5	44	R9.MG.3, R9.MG.4, R9.MG.5 R9.MG.6
Plastic Limit (PL)			14	19.25	29	
Plasticity Index (PI)			1	11.25	19	
Compaction related						
MCV		2	5.7	8.2	10.6	R9.MG.11
California Bearing Ratio	%	1		0.41		R9.MG.7
Shear strength (total stress)						
In-situ hand vane, peak cu	kPa	24	50	132.5	201	R9.MG.9, R9.MG.10
UU Triaxial test, cu		1		148		
In situ tests						

Standard Penetration Test		17	8	13	23	R9.MG.8
Soil Chemistry						
pH		23	8.2	8.82	11.3	
Water soluble sulfate	g/l	19	<0.010*	NA	1.5	
Acid soluble sulfate	%	7	0.02	0.315	1.9	
Total sulfur	%	7	0.013	0.165	0.77	

** Six samples less than limit of detection*

5.2.3 Glacial Clays

Table 10 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the soil unit in CBC 09.

Table 10. Summary of Geotechnical Laboratory and in-situ results on Glacial Clays

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Particle Size Distribution						
Clay			4	16	39	R9.GC.1
Silt			25	45.7	62	
Sand	%	3	11	27.3	41	
Gravel			1	11.3	30	
Cobbles			0	0	0	
Atterberg Limits						
Moisture Content	%	4	20	24.75	28	R9.GC.2
Liquid Limit (LL)	%		25	31.3	43	R9.GC.3 R9.GC.4 R9.GC.5 R9.GC.6
Plastic Limit (PL)		3	17	19.3	21	
Plasticity Index (PI)			5	12	23	
In-situ tests						
Standard Penetration Test		1	10	10	10	

5.2.3.1 Bulk densities

No specific weight density related tests were carried out for this material type.

Suggested weight density published in Figure 1 and Figure 2 of BS 8004:2015 can be used as a guide.

5.2.3.2 Undrained shear strength

Where appropriate, undrained shear strength (c_u) plots include data from triaxial testing, shear vane tests, and SPT values. For SPT values in Glacial Till, a multiplier has been applied on SPT values to convert to an appropriate c_u value as follows:

$Cu = f_1 \times N_{60}$

Guidance on the value of f_1 is provided by Stroud & Butler (1975) who related the parameter to the soil plasticity index as shown on the Figure 2.

A value of 5 was used for f_1 based on the plasticity encountered; however, only one SPT was available in this strata.

For the purpose of applying the above correlation, a value of E_r = 60% was adopted, resulting in N_{60} = N. This is considered reasonable given the inherent approximation involved in applying the SPT results to estimate c_u. In addition, it is a conservative assumption based on the available hammer energy certificates.

5.2.3.3 Effective stress Parameters

BS8002 (British Standards Institute, 1994) can be used to relate plasticity index to ø'crit, the critical state angle of shearing resistance. Adopting am upper bound plasticity index of 23% for soils at greater than 1 m depth, Table 2 of BS8002 provides a "conservative" value for ø'crit of 25°.

The relationship published by Knappet & Craig (Craig's Soil Mechanics, 8th Edition, 2012) provides a ø'crit of approximately 29°.

5.2.3.4 Stiffness Parameters

Jamiolkowski et al. (1979) have related ratios of Undrained modulus (Eu)/ Undrained shear strength (C_u) to both plasticity and the overconsolidation ratio.

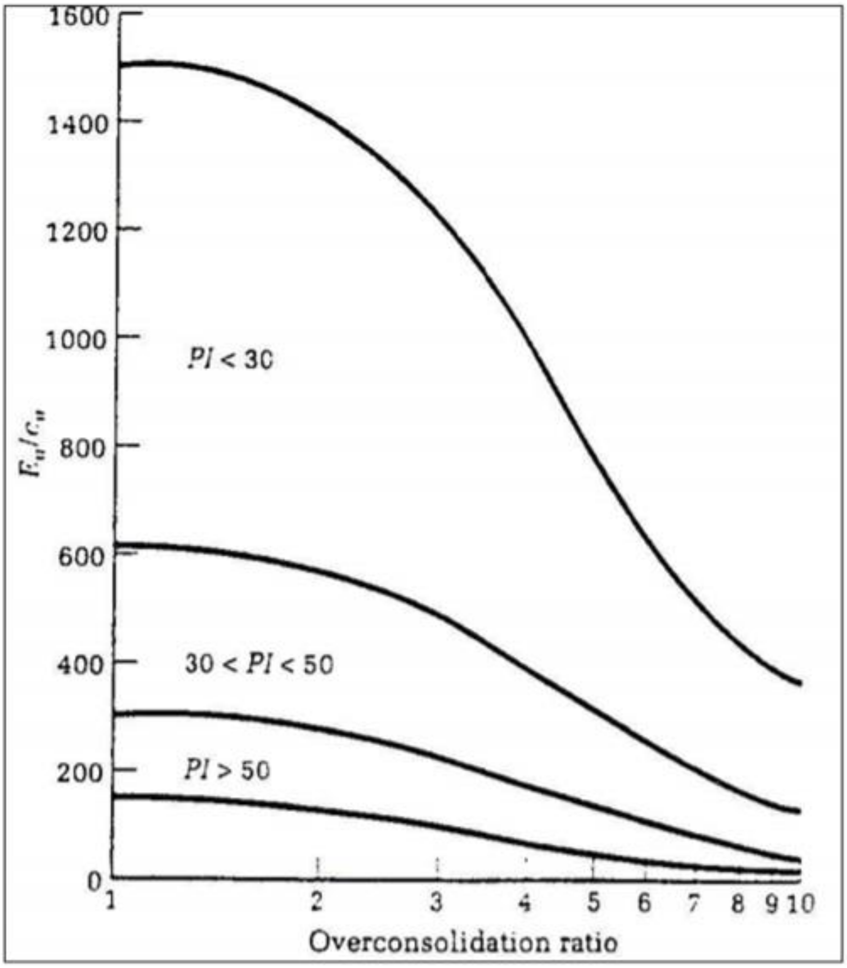

Figure 1. Relationship between Eu / cu Ratio for Clays with Plasticity Index and Degree of Overconsolidation (after Jamiolkowski et al., 1979)

5.2.4 Sands and Gravels

Table 11 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the soil unit in CBC 09.

Table 11. Summary of Geotechnical Laboratory and in-situ results on Sands and Gravels

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Particle Size Distribution						
Clay	%	6	2	3.3	5	R9.SaG.1
Silt			13	22.7	32	
Fines		17	2	15.7	37	
Sand			6	34.5	82	
Gravel			2	46.5	78	
Cobbles			0	3.2	17	
In-situ tests						
Standard Penetration Test	blows per 300 mm	31	10	22	50	R9.SaG.2
Soil Chemistry						
pH		3	8.7	8.83	9	
Water soluble sulfate	g/l	3	< 0.010*	NA	0.09	

**Two samples less than limit of detection*

5.2.4.1 Bulk densities

No weight density related tests were carried out for this material type. However, suggested weight density published in Figure 1 and Figure 2 of BS 8004:2015 can be used as a guide as well as assessing the relative density based on the measured SPT results.

5.2.4.2 Effective stress Parameters

Using the guidance of BS8004 (British Standards Institution, 2015), a characteristic critical state angle of shearing resistance for the sand and gravel deposits can be derived from the combination of the following:

- 30° + “contribution from angularity of the particles (0-4°)” + “contribution the soil’s particle size distribution (0-4°)”

A characteristic peak angle of shearing resistance can be derived by including the contribution from the soil’s relative density (0-9°) to the above equation.

5.2.4.3 Stiffness

The drained Young’s modulus can be derived/correlated by using SPT ‘N’ value $E = N_{60}$ (MPa) and $E' = 2N_{60}$ (MPa) as indicated in CIRIA R143, as based on Stroud (1989) results.

Allowing for anisotropy, 1.5 (or more) times the vertical stiffness may be taken for the prediction of horizontal modulus values.

The Poisson’s ratio υ can be conservatively selected using the range of values quoted in Tomlinson, Foundation Design and Construction 7th Edition (page 74)or CIRIA Report 103 Table 2. Appropriate design value shall be used in the design, depending on the type of analyses, calculations and geotechnical risks. Typical drained values range between 0.1 and 0.3 are considered appropriate.

5.2.5 Glacial Till

Table 12 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the soil unit in CBC 09:

Table 12. Summary of geotechnical laboratory and in-situ results on Glacial Till in CBC 09

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Particle Size Distribution						
Clay	%	4	4	8.75	22	R9.GT.1
Silt			19	25.5	31	
Sand		6	21	37.3	55	
Gravel			16	26.7	41	
Cobbles			0	1	6	
Atterberg Limits						
Moisture Content	%	32	7.5	14	33	R9.GT.2
Liquid Limit (LL)	%	11	23	31.2	43	R9.GT.3, R9.GT.4, R9.GT.5 R9.GT.6
Plastic Limit (PL)		11	17	19.4	24	
Plasticity Index (PI)		11	6	11.8	19	
Compaction						
MCV		1	3	3	3	R9.GT.12
California Bearing Ratio	%	1	0.5	0.5	0.5	R9.GT.7
Shear strength (total stress)						
In-situ hand vane, peak cu	kPa	6	124	171.5	201	R9.GT.10, R9.GT.11
UU Triaxial test, cu		6	59	94.3	129	
Laboratory Vane		2	11	16	21	
SPT, cu (br DBC)		22	36	133.6	300	
SPT, cu (bl DBC)		12	144	255.5	300	
In-situ tests						
Standard Penetration Test (br DBC)	blows per 300 mm	22	6	22.3	50	R9.GT.8
Standard Penetration Test (bl DBC)	blows per 300 mm	12	24	42.5	50	R9.GT.9
Soil Chemistry						
pH		7	8.3	8.85	10.1	
Water soluble sulfate	g/l	5	< 0.010*	NA	0.12	
Acid soluble sulfate	%	1	0.055			
Total sulfur	%	1	0.065			

**Two samples less than limits of detection*

Table 13 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the soil unit in CBC 08:

Table 13. Summary of geotechnical laboratory and in-situ results on Glacial Till in CBC 08

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Particle Size Distribution						
Clay	%	1	7.2	7.2	7.2	R8.GT.1
Silt			16.6	16.6	16.6	
Sand			17.4	17.4	17.4	
Gravel			58.8	58.8	58.8	
Cobbles			0	0	0	
Atterberg Limits						
Moisture Content	%	14	0.79	9.74	21	R8.GT.2
Liquid Limit (LL)	%	3	36	37.33	39	R8.GT.3 R8.GT.4 R8.GT.5 R8.GT.6
Plastic Limit (PL)			19	19	19	
Plasticity Index (PI)			17	18.33	20	
In-situ tests						
Standard Penetration Test	blows per 300 mm	13	13	44	50	R8.GT.7
Shear strength (total stress)						
UU Triaxial test, cu	kPa	1	122			R8.GT.8, R8.GT.9
SPT, cu		13	78	265	300	
Soil Chemistry						
pH		4	8.4	8.825	9.6	NA
Water soluble sulfate	g/l	4	0.01	0.168	0.36	

5.2.5.1 Bulk densities

No specific weight density related tests were carried out for this material type. Bulk densities were recorded as part of the Unconsolidated Undrained Triaxial compression tests and are available in the factual report.

Published literature from the Dublin Port Northern cut-and-cover site measured average bulk densities of 2.228, 2.337, 2.883, and 2.284 Mg/m^3 for the upper brown boulder clay, upper black boulder clay, lower brown boulder clay and lower black boulder clay, respectively.

The specific gravity of DBC is typically 2.70. There is no clear difference in the results from the various formations. Ref: (Long & Menkiti 2007).

Suggested weight density published in Figure 1 and Figure 2 of BS 8004:2015 can be used as a guide.

5.2.5.2 Undrained shear strength

Where appropriate, undrained shear strength (c_u) plots include data from triaxial testing, shear vane tests, and SPT values. For SPT values in Glacial Till, a multiplier has been applied on SPT values to convert to an appropriate c_u value as follows:

$Cu = f_1 \times N_{60}$

Guidance on the value of f1 is provided by Stroud & Butler (1975) who related the parameter to the soil plasticity index as shown on Figure 2.

A value of 6 was used for f_1 which is consistent with the typical plasticity indices of the Glacial Till encountered across the site.

For the purpose of applying the above correlation, a value of E_r = 60% was adopted, resulting in N_{60} = N. This is considered reasonable given the inherent approximation involved in applying the SPT results to estimate c_u. In addition, it is a conservative assumption based on the available hammer energy certificates.

Comparison between undrained shear strength results obtained using SPT 'N' values and results from triaxial testing generally show a reasonably good correlation. Triaxial test results occasionally indicate a trend of slightly lower values of undrained shear strength; however, this may also be linked to the effects of sample disturbance, particularly in Glacial Till deposits.

For the purpose of this report, the values of undrained shear strength derived are considered to provide a good overview of undrained material strengths across the site. Further review and interpretation of these results should be undertaken during the detailed design stage on a localised basis along the route (eg, for a specific structure or earthwork).

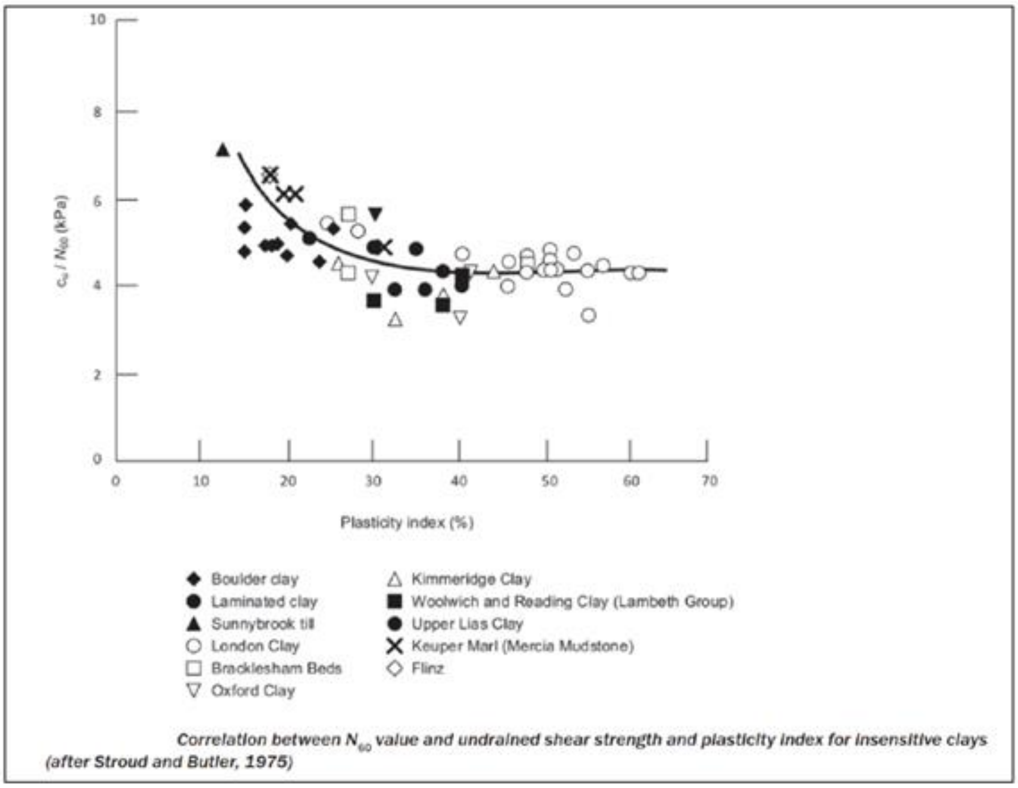

Figure 2. Stroud & Butler (1975)

5.2.5.3 Effective Stress Parameters

Published case studies of construction in Dublin Boulder Clay report peak values of the angle of shearing resistance of 30 - 38°. The gravel content of the soils would provide additional frictional resistance, due to interlock, and there is likely to be some long-term effective cohesion. Long & Menkiti 2007 measured a peak effective friction angle of about 44° at the Dublin Port Tunnel.

BS8002 (British Standards Institute, 1994) can be used to relate plasticity index to $\varnothing'_{crit}$, the critical state angle of shearing resistance. Adopting a plasticity index of 15% for soils at greater than 1 m depth, Table 2 of BS8002 provides a "conservative" value for $\varnothing'_{crit}$ of 30°.

The relationship published by Knappet & Craig (Craig's Soil Mechanics, 8th Edition, 2012) provides a $\varnothing'_{crit}$ of approximately 32°.

Lehane & Faulkner (1998) suggest a critical state friction angle of 34+/- 1° which is similar to the large deformation strength friction angle of 36° measured by Long & Menkiti.

5.2.5.4 Stiffness Parameters

The stiffness of the black Dublin boulder clay (DBC) is complex as it has a non-linear stress/strain relationship which also depends on the effective confining stress, on stress history and whether it is loaded in an undrained or drained condition.

At present in Ireland, practising engineers usually adopt a simple linear elastic perfectly plastic constitutive model. A single 'operational' value of Eu = 100 MPa is used, as derived from field observations by Farrell et al. (1995b). The relationship shown in Figure 2 by Jamiolkowski et al. (1979) relating ratios of Undrained modulus (Eu)/ Undrained shear strength (C_u) to both plasticity and the overconsolidation ratio may also be considered.

Current practice in Dublin (e.g. Dougan et al., 1996; Long, 1997) is to use K_0 values for DBC in the range 1.0–1.5.

For routine foundation design, which is generally carried out assuming a linear elastic E' soil, a value of 80 MPa is generally considered appropriate for the Dublin Boulder Clay for very high compressive stresses.

The stiffness also depends on the loading situation and E'≈ 150MPa more closely models the behaviour of a driven pile (Farrell et al. 1995b).

5.3 Bedrock

Table 13 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the rock units in CBC 09.

Table 14. Summary of geotechnical laboratory and in-situ results on Bedrock in CBC 09

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Rock Strength						
Uniaxial Compressive Strength	MPa	2	39	57.3	75.6	R9.Rock.3
Point Load Index	MPa	43	0.1	1.36	3.60	R9.Rock.2
Discontinuities						
Fracture Index	Nr/m	5	10	16.6	21	R9.Rock.1
Chemistry						
pH		2	9.1	9.15	9.2	NA
Water soluble sulfate	%	2	<0.010			

Rock types encountered in CBC 09 include Mudstone and Limestone.

Table 14 presents a summary of geotechnical and soil/rock chemistry parameters encountered within the rock units in CBC 08.

Table 15. Summary of geotechnical laboratory and in-situ results on Bedrock in CBC 08

Geotechnical Property	Unit	No. Tests	Min Value	Mean Value	Max Value	Figure No.
Rock Strength						
Uniaxial Compressive Strength	MPa	14	72.8	90.1	08	R9.Rock.3
Point Load Index	MPa	20	2.1	3.08	4.40	R9.Rock.2
Discontinuities						
Fracture Index	Nr/m	18	3	10.7	21	R9.Rock.1
Chemistry						

pH	%	4	8.8	8.95	9.2	NA
Water soluble sulfate	%	4	< 0.010*	NA	0.059	

*One sample less than limit of detection

Limestone was encountered in CBC 08.

Rock UCS plots and charts include a correlation with Point Load test results. A multiplication factor of 20 was selected to obtain indicative values of UCS for the rock types encountered across the scheme.

Inspection of the UCS plots in Appendix C, show a reasonable agreement for all rock types between the data derived directly from UCS testing, and data converted to UCS from Point Load testing. On this basis, and for the purpose of this report, the use of a single multiplication factor for the rock types encountered is considered appropriate. Further review and interpretation of these results should be undertaken during the detailed design stage on a localised basis along the route (eg for a specific structure or earthwork).

5.3.1 Bulk densities

The bulk densities of two samples selected for UCS testing ranged from 2.68 to 2.69 Mg/m^3 in CBC 09

The bulk densities of fourteen samples selected for UCS testing ranged from 2.67 to 2.72 Mg/m^3 with an average of 2.69 Mg/m^3 in CBC 08.

5.3.2 Bearing capacity

Suggested values for the presumed design unit bearing resistance of square pad foundations on rock (for settlements not exceeding 0.5% of the foundation width) may be obtained from BS EN 1997-1:2004+A1:2013, Annex G.

CIRIA C760 provides guidance for derivation of rock strength parameters for use in design calculations based on the methodology described by Hoek et al (2002) using unconfined compressive strength data and rock quality information and borehole descriptions.

5.4 Geo-environmental testing results summary

5.4.1 CBC 09

Samples for geo-environmental testing were taken from made ground along the proposed route. Made ground, containing anthropogenic material, was recorded at a number of locations and included varying amounts of red brick, wood, plastic, cloth, glass, rubber, carpet, ceramics and concrete were encountered across the site, and concentrated in R9CP05, R9TP05 and R9TP06.

A list of the main made ground deposits encountered during the ground investigations is provided in Section 5.1.2.

The following samples were tested.

Table 16. Summary of Samples Tested

Testhole	Sample Type	Depth
R9CP01	Soil	0.50
R9CP04	Soil	1.50
R9CP05	Soil	1.50
R9CP06	Soil	1.00
R9CP08	Soil	1.50
R9CPGS02	Soil	2.00
R9TP04	Soil	1.50

R9TP05	Soil	1.00
R9TP06	Soil	0.50
R9TP07	Soil	0.50
R9TP08	Soil	0.50
R9TP09	Soil	1.00
R9TP09	Soil	2.00
R9TP11	Soil	1.00
R9CP02	Water	1.16*
R9CP08	Water	4.1*
R9CP11	Water	3.28*
R9CPGS01	Water	8*
R9CPGS04	Water	8.92*

**water level at time of sampling*

The following table summarise the soil laboratory test results:

Table 17. Summary of Soil Geo-environmental Test Results

Determinand	Unit	No. of samples	Minimum Concentration	Maximum Concentration
Organics		No.	Min	Max
Total Organic Carbon		4	0.51	3.3
Organic Matter	%	8	<0.4	19
Mineral Oil & TPH				
Mineral Oil	mg/kg	8	<10	<10
Total Petroleum Hydrocarbons (by IR)	mg/kg	4	<10	860
Aliphatic TPH >C5-C6	mg/kg	4	< 1.0	0
Aliphatic TPH >C6-C8	mg/kg	4	< 1.0	0
Aliphatic TPH >C8-C10	mg/kg	4	< 1.0	6.2
Aliphatic TPH >C10-C12	mg/kg	4	< 1.0	2.3
Aliphatic TPH >C12-C16	mg/kg	4	< 1.0	1.4
Aliphatic TPH >C16-C21	mg/kg	4	< 1.0	1.2
Aliphatic TPH >C21-C35	mg/kg	4	< 1.0	11
Aliphatic TPH >C35-C44	mg/kg	4	< 1.0	1.9
Total Aliphatic Hydrocarbons	mg/kg	4	< 5.0	24
Aromatic TPH >C5-C7	mg/kg	4	< 1.0	0
Aromatic TPH >C7-C8	mg/kg	4	< 1.0	0

Determinand	Unit	No. of samples	Minimum Concentration	Maximum Concentration
Aromatic TPH >C8-C10	mg/kg	4	< 1.0	1.2
Aromatic TPH >C10-C12	mg/kg	4	< 1.0	1.3
Aromatic TPH >C12-C16	mg/kg	4	< 1.0	2.2
Aromatic TPH >C16-C21	mg/kg	4	< 1.0	5.3
Aromatic TPH >C21-C35	mg/kg	4	< 1.0	57
Aromatic TPH >C35-C44	mg/kg	4	< 1.0	3.7
Total Aromatic Hydrocarbons	mg/kg	4	< 5.0	71
Total Petroleum Hydrocarbons	mg/kg	4	< 10	94
BTEX & MTBE				
Benzene	µg/kg	4	< 1.0	< 1.0
Toluene	µg/kg	4	< 1.0	< 1.0
Ethylbenzene	µg/kg	4	< 1.0	< 1.0
m & p-Xylene	µg/kg	4	< 1.0	< 1.0
o-Xylene	µg/kg	4	< 1.0	< 1.0
Methyl Tert-Butyl Ether	µg/kg	4	< 1.0	< 1.0
PAH				
Naphthalene	mg/kg	12	<0.1	0.32
Acenaphthylene	mg/kg	12	<0.1	0.33
Acenaphthene	mg/kg	12	<0.1	1.3
Fluorene	mg/kg	12	<0.1	1.4
Phenanthrene	mg/kg	12	<0.1	7.7
Anthracene	mg/kg	12	<0.1	2.7
Fluoranthene	mg/kg	12	<0.1	11
Pyrene	mg/kg	12	<0.1	10
Benz(a)anthracene	mg/kg	12	<0.1	4.9
Chrysene	mg/kg	12	<0.1	4.3
Benzo(a) pyrene	mg/kg	12	<0.1	5.3
Indeno(1,2,3-c,d)pyrene	mg/kg	12	<0.1	3.2
Dibenz(a,h)anthracene	mg/kg	12	<0.1	1.9
Benzo(g,h,i)perylene	mg/kg	12	<0.1	3.1
Benzo(b)fluoranthene	mg/kg	8	<0.1	6.2
Benzo(k)fluoranthene	mg/kg	8	<0.1	2.8

Determinand	Unit	No. of samples	Minimum Concentration	Maximum Concentration
PAHs (Sum of total)	mg/kg	12	<2	66
SVOC				
Coronene	mg/kg	12	<0.1	<0.1
PCB				
PCB 28	mg/kg	4	< 0.010	< 0.010
PCB 52	mg/kg	4	< 0.010	< 0.010
PCB 90+101	mg/kg	4	< 0.010	< 0.010
PCB 118	mg/kg	4	< 0.010	< 0.010
PCB 153	mg/kg	4	< 0.010	< 0.010
PCB 138	mg/kg	4	< 0.010	< 0.010
PCB 180	mg/kg	4	< 0.010	< 0.010
Total PCBs (7 Congeners)	mg/kg	4	< 0.10	< 0.10
Phenolics				
nonchlorinated phenols	mg/kg	12	<0.3	<0.3
Metals				
Arsenic	mg/kg	12	15	86
Antimony	mg/kg	4	<2	3.8
Barium	mg/kg	4	53	350
Boron	mg/kg	12	<0.4	1.7
Cadmium	mg/kg	12	<0.1	2.5
Chromium (III+VI)	mg/kg	12	6.8	81
Chromium (Trivalent)	mg/kg	4	15	17
Chromium (Hexavalent)	mg/kg	4	<0.5	<0.5
Copper	mg/kg	12	17	280
Lead	mg/kg	12	19	710
Mercury	mg/kg	12	<0.1	0.51
Molybdenum	mg/kg	4	<0.2	4.6
Nickel	mg/kg	12	27	120
Selenium	mg/kg	4	<0.2	0.54
Zinc	mg/kg	12	49	570
Inorganic				
Cyanide Total	mg/kg	12	<0.5	<0.5

Determinand	Unit	No. of samples	Minimum Concentration	Maximum Concentration
Moisture	%	12	6.5	23
Sulphate (soluble)	g/L	12	<0.01	1.2
pH (Lab)	pH_Units	12	8.2	9.3
Asbestos				
Asbestos		12	NAD	NAD

The following table summarise the water geo-environmental laboratory test results:

Table 18. Summary of Water Geo-environmental Test Results

Determinand	Unit	No. of samples	Minimum Concentration	Maximum Concentration
Organics				
Total Organic Carbon	mg/l	5	85	120
Mineral Oil & TPH				
Mineral Oil	µg/l	5	<10	<10
Total TPH >C6-C40	µg/l	5	<10	<10
PAH				
Naphthalene	µg/l	5	<0.10	<0.10
Acenaphthylene	µg/l	5	<0.10	<0.10
Acenaphthene	µg/l	5	<0.10	<0.10
Fluorene	µg/l	5	<0.10	<0.10
Phenanthrene	µg/l	5	<0.10	<0.10
Anthracene	µg/l	5	<0.10	<0.10
Fluoranthene	µg/l	5	<0.10	<0.10
Pyrene	µg/l	5	<0.10	<0.10
Benzo[a]anthracene	µg/l	5	<0.10	<0.10
Chrysene	µg/l	5	<0.10	<0.10
Benzo[b]fluoranthene	µg/l	5	<0.10	<0.10
Benzo[k]fluoranthene	µg/l	5	<0.10	<0.10
Benzo[a]pyrene	µg/l	5	<0.10	<0.10

Indeno(1,2,3-c,d)Pyrene	µg/l	5	<0.10	<0.10
Dibenz(a,h)Anthracene	µg/l	5	<0.10	<0.10
Benzo[g,h,i]perylene	µg/l	5	<0.10	<0.10
Total Of 16 PAH's	µg/l	5	<2.0	<2.0
Metals				
Arsenic (Dissolved)	µg/l	5	<1.0	<1.0
Boron (Dissolved)	µg/l	5	23	170
Barium (Dissolved)	µg/l	5	61	73
Cadmium (Dissolved)	µg/l	5	<0.080	0.32
Copper (Dissolved)	µg/l	5	<1.0	2.3
Iron (Dissolved)	µg/l	5	290	500
Mercury (Dissolved)	µg/l	5	<0.50	<0.50
Manganese (Dissolved)	µg/l	5	9.4	300
Molybdenum (Dissolved)	µg/l	5	1.1	3.6
Nickel (Dissolved)	µg/l	5	<1.0	14
Lead (Dissolved)	µg/l	5	<1.0	<1.0
Antimony (Dissolved)	µg/l	5	<1.0	<1.0
Selenium (Dissolved)	µg/l	5	<1.0	11
Zinc (Dissolved)	µg/l	5	2.3	8.1
Chromium (Trivalent)	µg/l	5	[B] < 20	[B] < 20
Chromium (Hexavalent)	µg/l	5	[B] < 20	[B] < 20
Inorganic				
pH		5	7.6	8.2
Electrical Conductivity	µS/cm	5	640	1200
Ammonia (Free) as N	mg/l	5	<0.050	<0.050
Nitrite as N	mg/l	5	<0.010	0.3
Nitrate as N	mg/l	5	<0.50	8.3
Phosphorus (Total)	mg/l	5	<0.020	<0.020

Phosphate as P	mg/l	5	<0.050	<0.050
Nitrogen (Total)	mg/l	5	<5.0	16
Calcium	mg/l	5	73	160
Magnesium	mg/l	5	7.7	29
Sodium	mg/l	5	25	56
Total Hardness as CaCO3	mg/l	5	250	520

5.4.2 CBC 08

No Contamination testing was undertaken at CBC 08.

6. Geotechnical Risk Register

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
EWK	Potential for ULS failure (global instability, local instability, bearing resistance failure, extrusion of foundation soils) of embankments due to the presence of loose / very soft / soft soils and/or made ground	4	5	20	Embankment failure along carriageway could result road traffic accident if loss of road pavement / road edge support occurs. Services and drainage infrastructure could be damaged requiring repair or replacement.	Scheme Designer to design and supervise solutions to prevent ULS failure of embankments in accordance with National Standards and good practice.	1-2	5	5-10
EWK	Potential for unacceptable magnitudes of differential settlement along embankment long/cross sections due to variations in compressible soil thickness and/or soil compressibility characteristics.	4	5	20	Differential road pavement deformations may result in road traffic operations that could result in impar to road users. Services or infrastructure may be damaged requiring repair or replacement as a result of differential settlement.	The Scheme Designer to identify areas where differential settlement potential may exist because of variable compressible soil thickness during the detailed design phase and design construction measures to reduce expected differential settlement to tolerable magnitudes.	1-2	5	5-10
EWK	Potential for differential settlement in cross section where widening existing earthworks.	4	5	20	Differential road pavement deformations may result in road traffic operations that could result in impar to road users. Services or infrastructure may be damaged requiring repair or replacement as a result of differential settlement.	The Scheme Designer to identify areas where differential settlement potential may exist because of variable compressible soil thickness during the detailed design phase and design construction measures to reduce expected differential settlement to tolerable magnitudes.	1-2	5	5-10
EWK	Unstable widened / new cutting Slopes including temporary works	4	5	20	Cutting failure that is costly to repair. Potential for under cutting carriageway, which could lead to a road traffic accident or partial/full road blockage/closure. Road traffic accident could lead to injury/death to road users.	The Scheme Designer to design a solution that prevents ULS failure of cut slopes. Where uncertainty in ground or groundwater conditions is identified during ground model development, further GI to be implemented prior to commencing construction activities to verify the design ground model.	1-2	5	5-10

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
EWK	Encountering soils of unexpectedly low CBR value, at road pavement subgrade level.	4	5	20	Pavement design requires adjustment resulting in construction delays. Pavement design is not adjusted leading to poor pavement performance in pavement design life that requires costly repair or reconstruction.	Scheme Designer to design pavement foundation solutions for the range of CBRs expected site wide and inspect formations regularly to verify pavement is being construction in accordance with the design/design philosophy. Where uncertainty in the nature of subgrade soils is identified during ground model development, further GI to be implemented prior to commencing construction activities to verify the design ground model.	1-2	5	5-10
EWK	The volumes of organic and/or very soft soils and/or made ground, to be excavated and replaced below embankments are greater than anticipated based on the available ground investigation data.	4	5	20	Greater volume of excavated material to be disposed of, and an increase in the required volume of replacement fill. Construction delays. Increased construction costs.	Where uncertainty in the nature of subgrade soils is identified during ground model development, further GI to be implemented prior to commencing construction activities to verify the design ground model.	1-2	5	5-10
EWK	Higher cobble and boulder content in Glacial Till than anticipated	4	5	20	Increased requirement to separate and sort excavated material to allow placement and compaction as fill.	Utilisation of appropriate plant to allow sorting before placement in fill areas.	1-2	5	5-10
EWK	Absence of adequate locations, on or close to the site, for disposal of of unacceptable soils.	4	5	20	Absence of adequate locations, on or close to the site, for disposal of unacceptable soils.	Early in the works programme, the Contractor to source locations of possible local disposal areas and obtain necessary landowner and statutory approvals.	1-2	5	5-10
EWK	Absence of adequate locations, on or close to the site, for storage of of reusable soils.	4	5	20	Absence of adequate locations, on or close to the site, for disposal of suitable soils.	Early in the works programme, the Contractor to source locations of possible local storage areas and obtain necessary landowner and statutory approvals.	1-2	5	5-10

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
STR	Potential for bearing resistance failure / unacceptable total or differential settlement magnitudes where spread foundations are underlain by soil of inadequate bearing resistance or piles have inadequate load bearing capacity.	4	5	20	Significant structure damage requiring costly extensive repairs or replacement.	Scheme Designer to design solutions to prevent ULS failure of foundations, or unacceptable settlements.. Spread foundation formation to be inspected to verify ground conditions, and piles to be adequately tested. Where uncertainty in the nature of subgrade soils is identified during ground model development, further GI to be implemented prior to commencing construction activities to verify the design ground model.	1-2	5	5-10
STR	Potential for inducing negative skin friction / lateral loads onto existing and new piled foundations resulting in increased pile loads and potential pile failure and/or piled foundation settlement.	4	5	20	Significant structure settlement / damage requiring costly extensive repairs or replacement.	Scheme Designer to identify areas where compressible soils exist adjacent to existing or new piled foundations and inform Contractor of such locations. Scheme Designer to design adjacent new/widened earthworks to prevent lateral loading /inducing negative skin friction on existing piles. New piles to be designed to allow for expected lateral / negative skin friction loads. Where working platforms are required for new piled structures, negative skin friction induced by settlement of the working platform after pile construction, to be allowed for in the design. Where increased lateral and/or negative skin friction loads on existing piled foundations cannot be avoided, the impact of such increases to be investigated to demonstrate that there will not be any detrimental impact on the existing piles.	1-2	5	5-10
STR	Potential for foundation construction difficulties/delays where depth to competent founding strata is unconfirmed or increased thickness of made ground	4	5	20	Construction delays where competent founding strata is situated at a significantly greater depth than envisaged in the detailed design ground model.	Where uncertainty in the nature of subgrade soils is identified during ground model development, further GI to be implemented prior to commencing construction activities to verify the design ground model.	1-2	5	5-10

Risk Reference	Description of Risk	Initial Risk Rating (See matrix below)			Consequence	Control Measures to Reduce Risk	Residual Risk Rating (See matrix below)		
		P	I	R			P	I	R
STR	Encountering higher than interpreted groundwater levels and unexpected groundwater during excavation or piling that requires groundwater control measures / design modifications during excavation.	4	5	20	Construction delays / unstable excavations. Risk of construction plant/personnel falling into excavations if they collapse.	Scheme Designer to determine expected groundwater levels at all proposed areas of temporary excavation / piling and to inform Contractor. Contractor to plan for groundwater control measures at locations identified by the Scheme Designer. Contractor to design all temporary excavation works to account for groundwater where expected. Water head to be balanced during construction of bored piles.	1-2	5	5-10
STR	Potential for ground subsidence related damage to existing nearby structures, buildings or other sensitive infrastructure due to consolidation settlement induced by temporary groundwater lowering whilst excavating.	4	5	20	Subsidence may result in foundation / structure damage where existing structures are situated in area where groundwater lowering is expected to induce subsidence. Structures may require costly repairs or reconstruction depending on degree of damage.	Where groundwater control measures are required during construction, the Contractor to undertake site-specific assessments to establish if there is a risk of groundwater extraction induced subsidence and the presence of any potential receptors such as existing spread or piled foundations.	1-2	5	5-10
	Encountering unexpected contamination on the site including potential areas of “fly-tipping”, or infilled former surface depressions / gravel pits.	4	5	20	Health and safety impact on construction workers and third parties. Potential impact on environmental receptors, including watercourses. Increase in cost of treatment of contaminated ground if encountered	The ground investigation data includes exploratory holes, lab testing and monitoring in positions of known/potential contamination. Site clearance and excavations on site to be monitored for the presence of potential contaminants. Contractor to undertake additional ground investigation, including geotechnical environmental laboratory testing, if additional areas of suspected contamination are encountered and, if necessary, devise remedial works.	2	5	10
	Encountering ground gases generated in organic alluvium or Made Ground.	4	5	20	Health and safety impact (asphyxiation/fire/explosion) on construction workers and third parties, particularly where gases accumulate in confined spaces.	Adopt appropriate precautions including gas monitoring during construction and minimise creation of confined spaces within the temporary works	1-2	5	5-10

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Appendix A Geological Longitudinal Sections K ey Plans

KEY PLAN NOTES

SHEET XX (red)	PROPOSED BOREHOLE/TRIAL PIT LOCATIONS
SHEET XX (black)	NO SIGNIFICANT BOREHOLE/TRIAL PIT PROPOSED

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Rev	Date	Drn	Chk'd	App'd	Description
L01.1	17/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM, MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS KEY PLAN

Date	Scale	Drawn	Checked	Approved
17/12/20	1:12500 @ A1 1:25000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_KP-0009_XX_00-DR-CE-0001	01 of 01		L01.1

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Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	17/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC08
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS
KEY PLAN

Date	Scale	Drawn	Checked	Approved
17/12/20	1:10000 @ A1 1:20000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_KP-0008_XX_00-DR-CE-0001	01 of 01	S0	L01.1

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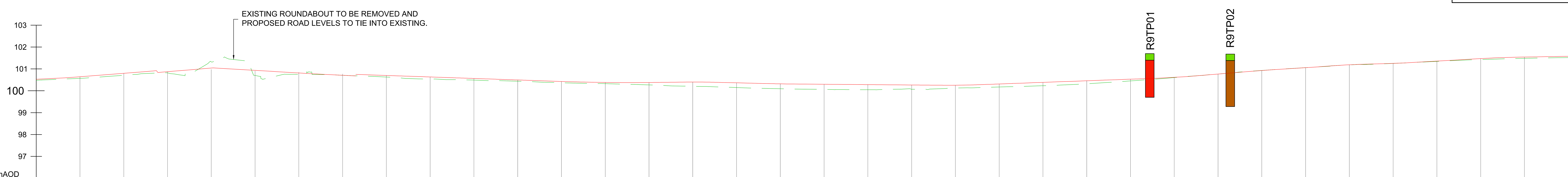
Appendix B Combined Ground Investigation Plan and Geological Longitudinal Sections

LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



PROPOSED LEVELS	100.5	100.6	100.8	100.9	101.0	100.9	100.8	100.7	100.7	100.6	100.6	100.5	100.4	100.4	100.4	100.4	100.4	100.3	100.3	100.3	100.3	100.3	100.3	100.4	100.5	100.5	100.6	100.8	100.9	101.1	101.2	101.3	101.4	101.5	101.5	101.6
EXISTING LEVELS	100.5	100.6	100.7	100.8	101.3	100.7	100.7	100.7	100.6	100.5	100.5	100.4	100.4	100.3	100.3	100.2	100.1	100.1	100.1	100.0	100.1	100.1	100.2	100.2	100.3	100.5	100.6	100.8	100.9	101.1	101.2	101.2	101.3	101.4	101.5	101.5
GLOBAL CHAINAGE	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0003	02 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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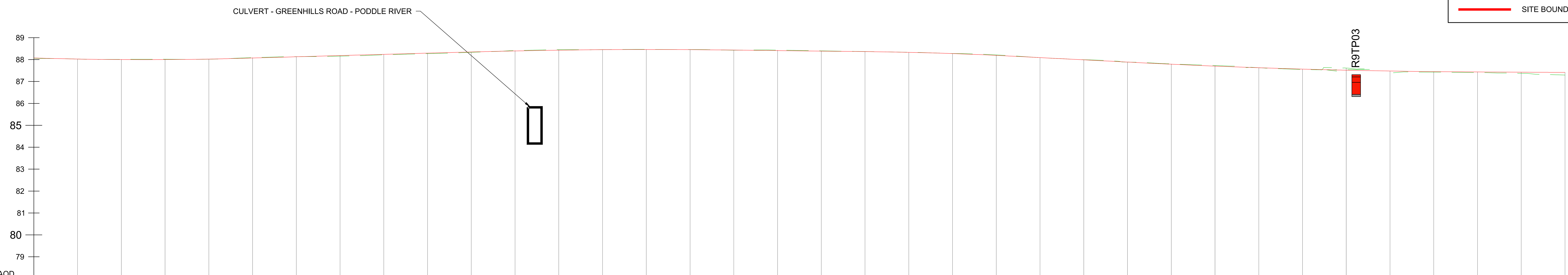
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



GLOBAL CHAINAGE	PROPOSED LEVELS	EXISTING LEVELS
2100	88.1	88.1
2110	88.0	88.0
2120	88.0	88.0
2130	88.0	88.0
2140	88.0	88.0
2150	88.1	88.1
2160	88.1	88.1
2170	88.2	88.2
2180	88.2	88.2
2190	88.3	88.3
2200	88.3	88.3
2210	88.4	88.4
2220	88.4	88.5
2230	88.5	88.5
2240	88.5	88.5
2250	88.5	88.5
2260	88.4	88.4
2270	88.4	88.4
2280	88.4	88.4
2290	88.4	88.4
2300	88.3	88.3
2310	88.3	88.3
2320	88.2	88.2
2330	88.1	88.1
2340	88.0	88.0
2350	87.9	87.9
2360	87.8	87.8
2370	87.7	87.7
2380	87.6	87.6
2390	87.6	87.5
2400	87.5	87.6
2410	87.5	87.5
2420	87.5	87.4
2430	87.4	87.4
2440	87.4	87.4
2450	87.4	87.3

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1; 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0007	07 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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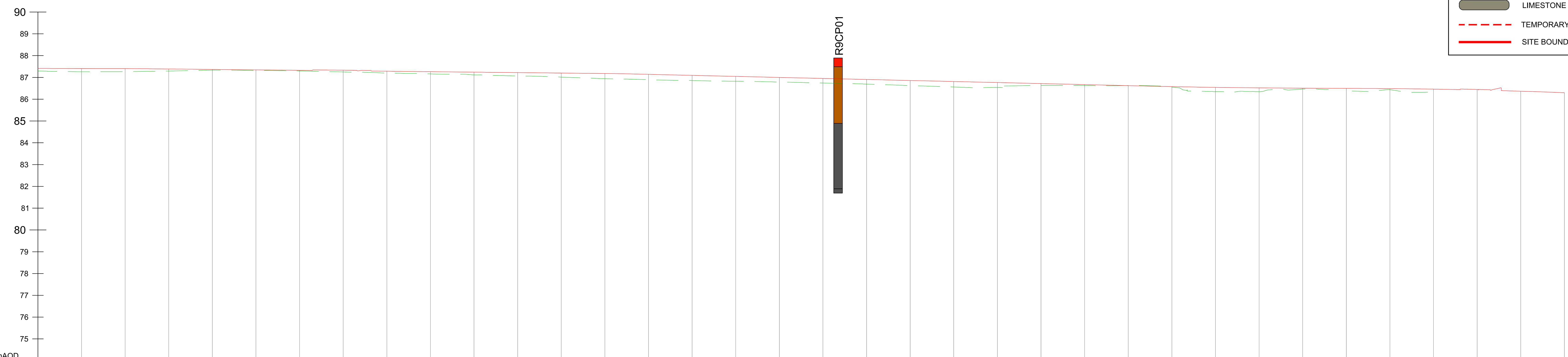
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



Datum: 74.00 mAOD

GLOBAL CHAINAGE	2450	2460	2470	2480	2490	2500	2510	2520	2530	2540	2550	2560	2570	2580	2590	2600	2610	2620
PROPOSED LEVELS	87.4	87.4	87.4	87.4	87.4	87.3	87.3	87.3	87.3	87.3	87.2	87.2	87.2	87.2	87.1	87.1	87.0	87.0
EXISTING LEVELS	87.3	87.3	87.3	87.3	87.3	87.3	87.3	87.3	87.2	87.2	87.1	87.1	87.0	86.9	86.9	86.9	86.8	86.8

GLOBAL CHAINAGE	2630	2640	2650	2660	2670	2680	2690	2700	2710	2720	2730	2740	2750	2760	2770	2780	2790	2800
PROPOSED LEVELS	87.0	86.9	86.9	86.8	86.8	86.7	86.7	86.6	86.6	86.5	86.5	86.5	86.5	86.5	86.5	86.4	86.4	86.3
EXISTING LEVELS	86.7	86.7	86.6	86.6	86.5	86.6	86.6	86.6	86.6	86.3	86.3	86.5		86.4				

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

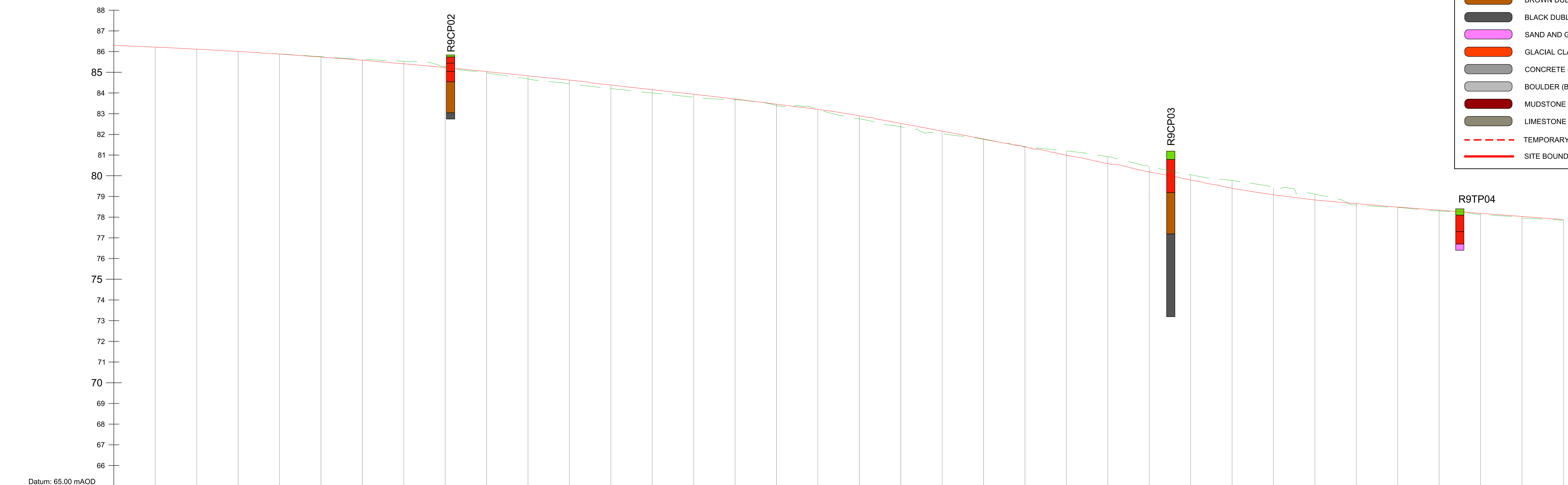
Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC09
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0008	08 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE

GLOBAL CHAINAGE	PROPOSED LEVELS	EXISTING LEVELS
2800	86.3	
2810	86.2	
2820	86.1	
2830	86.0	
2840	85.9	85.9
2850	85.7	85.8
2860	85.6	85.6
2870	85.4	85.5
2880	85.2	85.3
2890	85.0	85.0
2900	84.8	84.7
2910	84.6	84.4
2920	84.4	84.2
2930	84.2	84.0
2940	83.9	83.8
2950	83.7	83.7
2960	83.5	83.4
2970	83.2	83.2
2980	82.9	82.8
2990	82.5	82.4
3000	82.2	82.0
3010	81.8	81.8
3020	81.4	81.4
3030	81.0	81.2
3040	80.6	80.9
3050	80.2	80.5
3060	79.8	80.0
3070	79.4	79.8
3080	79.1	79.4
3090	78.8	79.1
3100	78.7	78.6
3110	78.5	78.5
3120	78.3	78.3
3130	78.2	78.1
3140	78.0	78.0
3150	77.9	77.8

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Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA — Údarás Náisiúnta Iompair — National Transport Authority

Engineering Designer: AECOM — MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN — CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 — TALLAGHT/CLONDALKIN TO CITY CENTRE — GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

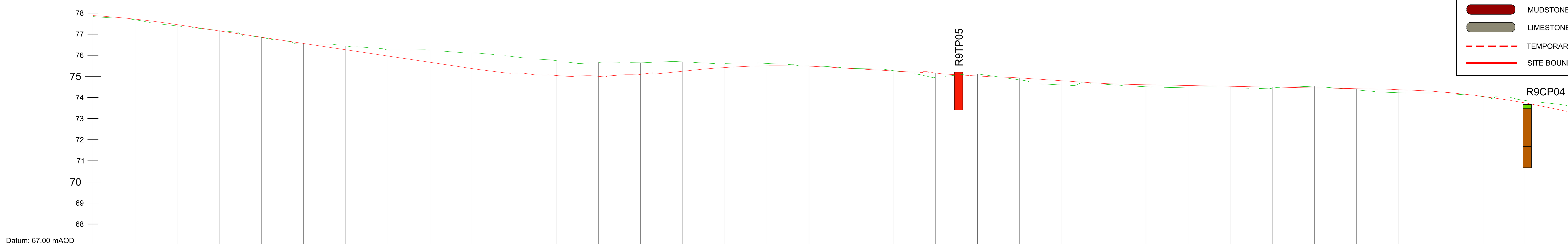
Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1; 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0009	09 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



GLOBAL CHAINAGE	3150	3160	3170	3180	3190	3200	3210	3220	3230	3240	3250	3260	3270	3280	3290	3300	3310	3320
PROPOSED LEVELS	77.9	77.7	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.4	75.2	75.0	75.0	75.1	75.2	75.4	75.5	75.5
EXISTING LEVELS	77.8	77.7	77.4	77.2	76.9	76.5	76.4	76.3	76.2	76.1	75.9	75.7	75.7	75.6	75.7	75.6	75.6	75.5

GLOBAL CHAINAGE	3330	3340	3350	3360	3370	3380	3390	3400	3410	3420	3430	3440	3450	3460	3470	3480	3490	3500
PROPOSED LEVELS	75.4	75.3	75.2	75.0	74.9	74.8	74.7	74.6	74.6	74.5	74.5	74.5	74.4	74.4	74.3	74.0	73.7	73.3
EXISTING LEVELS	75.4	75.3	74.9	75.1	74.8	74.6	74.6	74.5	74.5	74.5	74.4	74.5	74.4	74.2	74.2	74.0	73.9	73.6

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0010	10 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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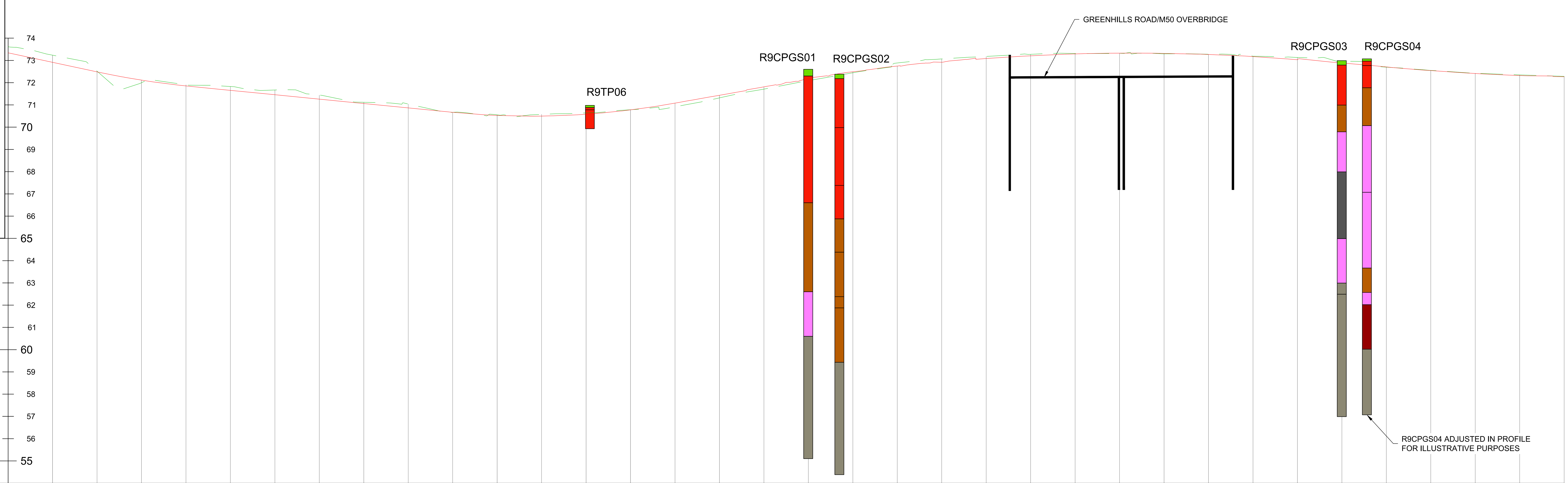
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



Datum: 54.00 mAOD

GLOBAL CHAINAGE	3500	3510	3520	3530	3540	3550	3560	3570	3580	3590	3600	3610	3620	3630	3640	3650	3660	3670
PROPOSED LEVELS	73.3	72.9	72.5	72.1	71.9	71.7	71.5	71.3	71.1	70.9	70.7	70.5	70.5	70.6	70.8	71.1	71.4	71.8
EXISTING LEVELS	73.6	73.2	72.5	72.0	71.9	71.8	71.7	71.4	71.1	71.0	70.7	70.6	70.6	70.6	70.8	70.9	71.3	71.7

GLOBAL CHAINAGE	3680	3690	3700	3710	3720	3730	3740	3750	3760	3770	3780	3790	3800	3810	3820	3830	3840	3850
PROPOSED LEVELS	72.2	72.5	72.7	72.9	73.1	73.2	73.3	73.3	73.3	73.3	73.2	73.0	72.9	72.7	72.5	72.4	72.3	72.3
EXISTING LEVELS	72.1	72.4	72.9	73.1	73.2	73.3	73.3	73.3	73.3	73.3	73.2	73.1	72.9	72.7	72.6	72.4	72.3	72.3

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1; 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0011	11 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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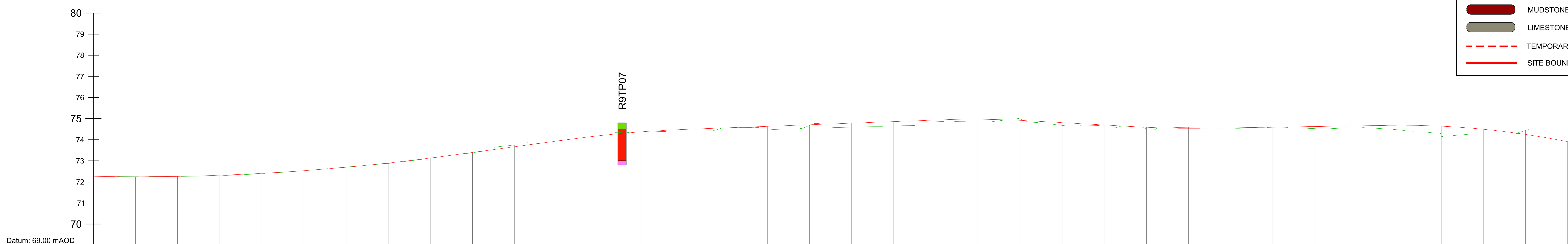
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



PROPOSED LEVELS	72.3	72.2	72.3	72.3	72.4	72.5	72.7	72.9	73.1	73.4	73.7	73.9	74.2	74.4	74.5	74.6	74.6	74.7	74.8	74.9	74.9	75.0	74.9	74.8	74.7	74.6	74.5	74.6	74.6	74.6	74.7	74.7	74.6	74.5	74.3	73.9
EXISTING LEVELS	72.3	72.3	72.3	72.3	72.4	72.5	72.7	72.9	73.1	73.4	73.7	73.9	74.1	74.3	74.4	74.6	74.5	74.7	74.6	74.6	74.9	74.8	75.0	74.7	74.6	74.5	74.6	74.5	74.6	74.5	74.6	74.5	74.1	74.3	74.4	
GLOBAL CHAINAGE	3850	3860	3870	3880	3890	3900	3910	3920	3930	3940	3950	3960	3970	3980	3990	4000	4010	4020	4030	4040	4050	4060	4070	4080	4090	4100	4110	4120	4130	4140	4150	4160	4170	4180	4190	4200

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

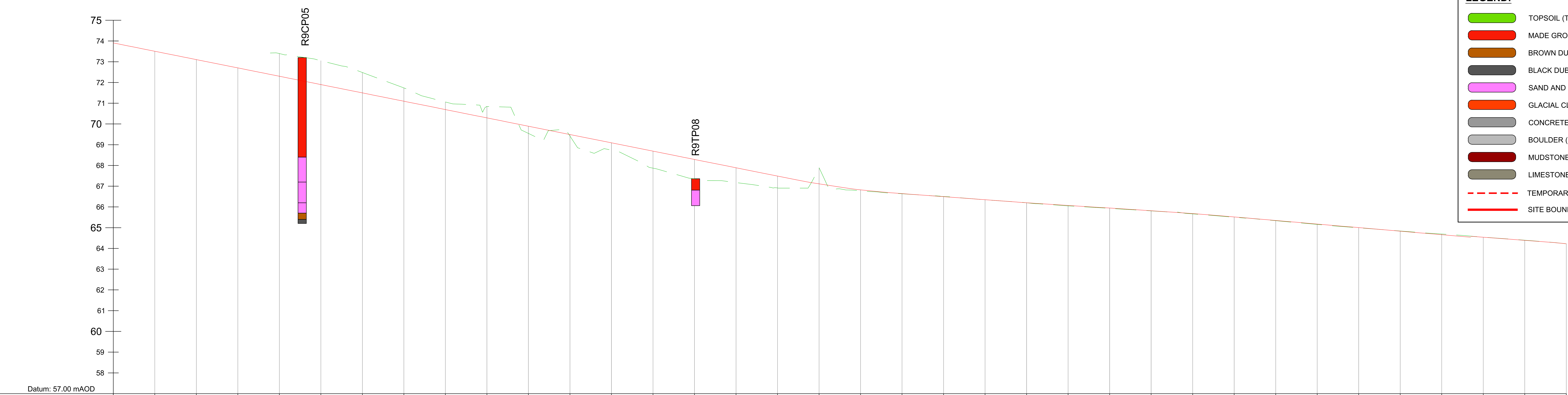
Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC09
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0012	12 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY



LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
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- LIMESTONE (LST)
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- SITE BOUNDARY LINE

GLOBAL CHAINAGE	4200	4210	4220	4230	4240	4250	4260	4270	4280	4290	4300	4310	4320	4330	4340	4350	4360	4370
PROPOSED LEVELS	73.9	73.5	73.1	72.7	72.3	71.9	71.5	71.1	70.7	70.3	69.9	69.5	69.1	68.7	68.3	67.9	67.5	67.1
EXISTING LEVELS					73.4	73.1	72.5	71.7	71.1	70.8	69.5	69.4	68.7	67.9	67.4	67.2	66.9	67.9

GLOBAL CHAINAGE	4380	4390	4400	4410	4420	4430	4440	4450	4460	4470	4480	4490	4500	4510	4520	4530	4540	4550
PROPOSED LEVELS	66.8	66.6	66.5	66.3	66.2	66.1	65.9	65.8	65.7	65.5	65.3	65.2	65.0	64.8	64.7	64.5	64.4	64.2
EXISTING LEVELS	66.8	66.6	66.5	66.3	66.2	66.1	65.9	65.8	65.7	65.5	65.3	65.2	65.0	64.8	64.7	64.5	64.4	64.2

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC09
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0013	13 of 33		L01.1

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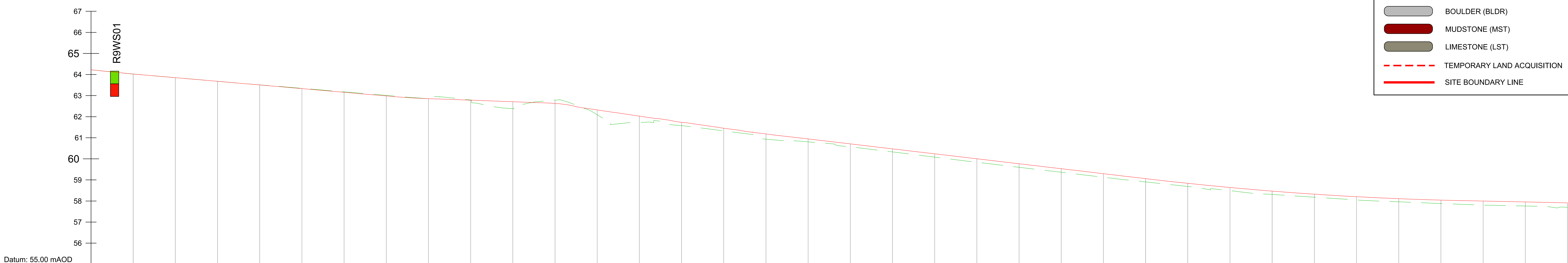
DO NOT SCALE USE FIGURED DIMENSIONS ONLY

LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



GLOBAL CHAINAGE	PROPOSED LEVELS	EXISTING LEVELS
4550	64.2	64.2
4560	64.0	64.0
4570	63.9	63.9
4580	63.7	63.7
4590	63.5	63.5
4600	63.3	63.3
4610	63.2	63.2
4620	63.0	63.0
4630	62.9	62.9
4640	62.8	62.8
4650	62.7	62.4
4660	62.6	62.8
4670	62.3	62.1
4680	62.0	61.7
4690	61.7	61.6
4700	61.5	61.3
4710	61.2	60.9
4720	60.9	60.8
4730	60.7	60.6
4740	60.5	60.3
4750	60.2	60.1
4760	60.0	59.8
4770	59.8	59.6
4780	59.5	59.4
4790	59.3	59.1
4800	59.1	58.9
4810	58.8	58.7
4820	58.6	58.5
4830	58.5	58.3
4840	58.3	58.2
4850	58.2	58.0
4860	58.1	58.0
4870	58.0	57.9
4880	58.0	57.8
4890	58.0	57.8
4900	57.9	57.7

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA — Údarás Náisiúnta Iompair — National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC09
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0014	14 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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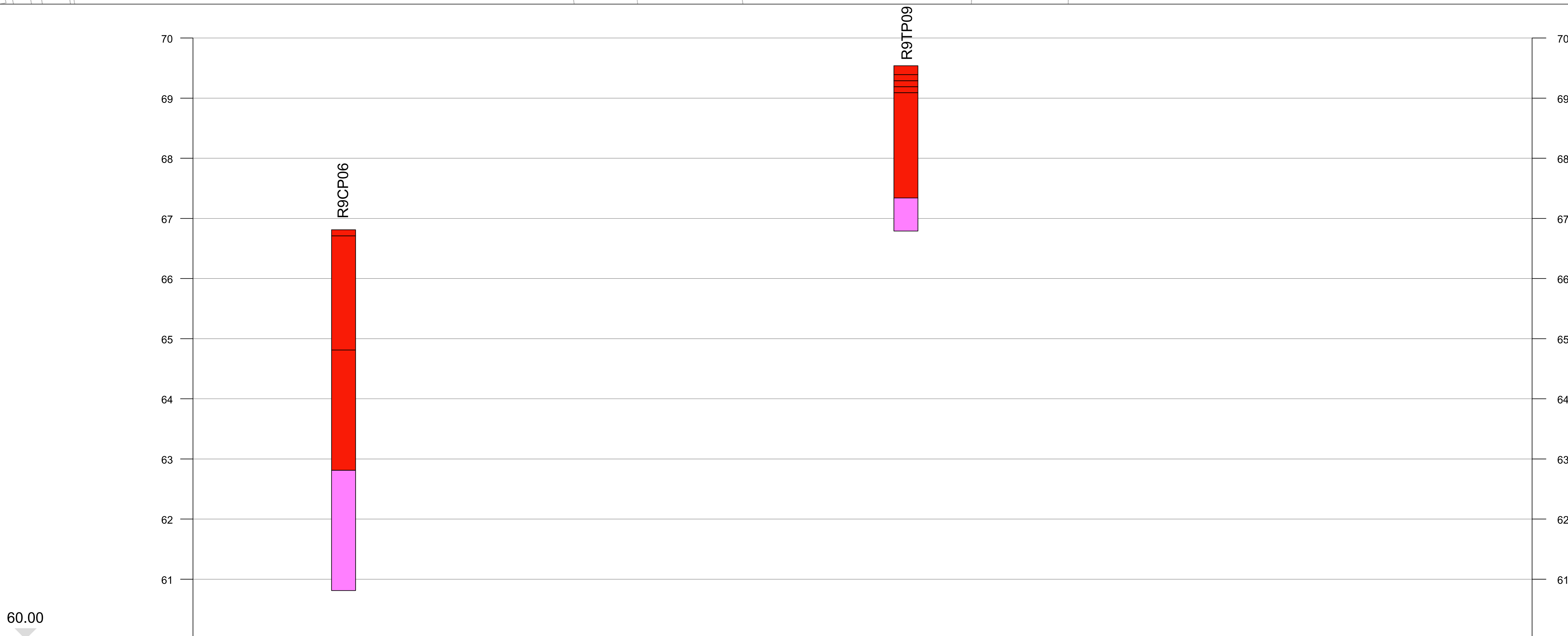

CHAINAGE (M)	437.00	478.77
OFFSET (M)		
ELEVATION (mAOD)	66.81	69.54

LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE

Project Ireland 2040
Building Ireland's Future

Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0015	15 of 33		L01.1

DO NOT SCALE USE FIGURED DIMENSIONS ONLY

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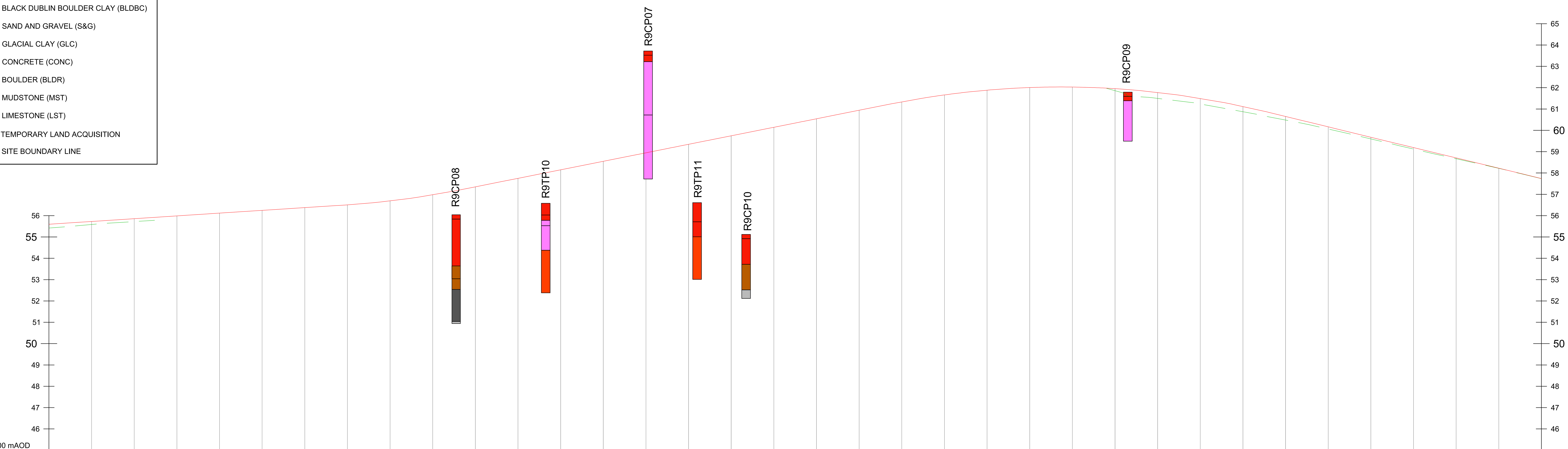
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE

0 5.0 10.0 20.0 30.0 40.0 50.0m

SCALE 1:500 @ A1; 1:1000 @ A3



GLOBAL CHAINAGE	5250	5260	5270	5280	5290	5300	5310	5320	5330	5340	5350	5360
PROPOSED LEVELS	55.6	55.7	55.9	56.0	56.1	56.2	56.4	56.5	56.7	57.0	57.4	57.7
EXISTING LEVELS	55.4	55.6	55.7									

GLOBAL CHAINAGE	5370	5380	5390	5400	5410	5420	5430	5440	5450	5460	5470	5480
PROPOSED LEVELS	58.1	58.5	58.9	59.3	59.7	60.1	60.5	60.9	61.3	61.7	61.9	62.0
EXISTING LEVELS								54.8	55.3			

GLOBAL CHAINAGE	5490	5500	5510	5520	5530	5540	5550	5560	5570	5580	5590	5600
PROPOSED LEVELS	62.0	62.0	61.8	61.5	61.1	60.7	60.2	59.7	59.2	58.7	58.2	57.7
EXISTING LEVELS		61.9	61.5	61.2	60.9	60.5	60.1	59.6	59.1	58.7	58.2	57.7

Project Ireland 2040
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Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: BUSCONNECTS DUBLIN
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC09
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0016	16 of 33		L01.1

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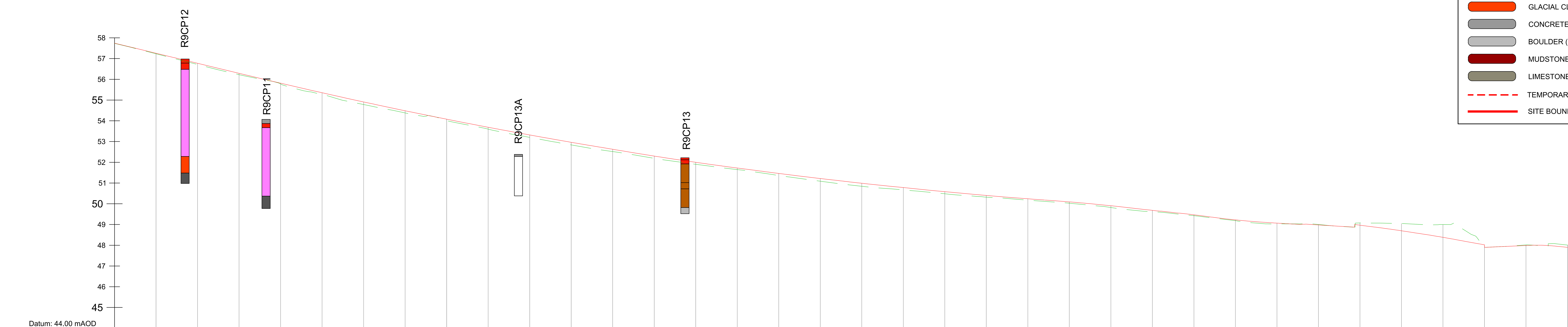
LEGEND:

- TOPSOIL (TS)
- MADE GROUND (MG)
- BROWN DUBLIN BOULDER CLAY (BRDBC)
- BLACK DUBLIN BOULDER CLAY (BLDBC)
- SAND AND GRAVEL (S&G)
- GLACIAL CLAY (GLC)
- CONCRETE (CONC)
- BOULDER (BLDR)
- MUDSTONE (MST)
- LIMESTONE (LST)
- TEMPORARY LAND ACQUISITION
- SITE BOUNDARY LINE



GLOBAL CHAINAGE	5600	5610	5620	5630	5640	5650	5660	5670	5680	5690	5700	5710	5720	5730	5740	5750	5760	5770
PROPOSED LEVELS	57.7	57.3	56.8	56.3	55.8	55.4	54.9	54.5	54.1	53.7	53.3	53.0	52.6	52.3	52.0	51.7	51.5	51.2
EXISTING LEVELS	57.7	57.2	56.7	56.2	55.8	55.3	54.8	54.4	54.0	53.6	53.2	52.8	52.5	52.2	51.9	51.7	51.4	51.1

GLOBAL CHAINAGE	5780	5790	5800	5810	5820	5830	5840	5850	5860	5870	5880	5890	5900	5910	5920	5930	5940	5950
PROPOSED LEVELS	51.0	50.8	50.6	50.4	50.2	50.1	49.9	49.7	49.5	49.2	49.1	49.0	49.0	48.7	48.4	48.0	48.0	47.9
EXISTING LEVELS	50.8	50.7	50.5	50.3	50.2	50.0	49.8	49.6	49.4	49.2	49.0	49.0	49.1	49.0	49.0	47.9	48.0	48.0

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Project Ireland 2040
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Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN CORE BUS CORRIDORS INFRASTRUCTURE WORKS**

Drawing Title: CBC09 TALLAGHT/CLONDALKIN TO CITY CENTRE GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1; 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0009_XX_00-DR-CE-0017	17 of 33		L01.1

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PROPOSED LEVELS	47.7	47.7	47.7	47.8	47.8	47.8	47.8	47.8	47.7	47.8	47.9							
EXISTING LEVELS	47.7	47.7	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.8	47.9	48.0	48.1	48.2	48.2	48.2	47.9	47.7
GLOBAL CHAINAGE	2050	2060	2070	2080	2090	2100	2110	2120	2130	2140	2150	2160	2170	2180	2190	2200	2210	2220

PROPOSED LEVELS																		
EXISTING LEVELS	47.5	47.3	47.3	47.2	47.0	46.9	46.6	46.4	46.2	46.1	45.9	45.8	45.6	45.4	45.2	45.0	44.9	44.7
GLOBAL CHAINAGE	2230	2240	2250	2260	2270	2280	2290	2300	2310	2320	2330	2340	2350	2360	2370	2380	2390	2400

GEO_HV-0008_ML_XX-M3-CR-0001 - A01 - LONGITUDINAL SECTION
SCALE: H 1:500,V 1:100

Project Ireland 2040
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Rev	Date	Drn	Chk'd	App'd	Description
L01.1	16/12/20				

W.I.P.

Client: NTA Údarás Náisiúnta Iompair National Transport Authority

Engineering Designer: AECOM / MOTT MACDONALD

Programme Title: **BUSCONNECTS DUBLIN**
CORE BUS CORRIDORS INFRASTRUCTURE WORKS

Drawing Title: CBC08
TALLAGHT/CLONDALKIN TO CITY CENTRE
GROUND INVESTIGATION GEOLOGICAL LONGITUDINAL SECTIONS

Date	Scale	Drawn	Checked	Approved
16/12/20	1:500 @ A1; 1:1000 @ A3			

Project Code	Originator Code	QMS Code	Drawing File Name	Sheet Number	Status	Rev
BCIDA	ACM		BCIDA-ACM-ERW_GI-0008_XX_00-DR-CE-0007	07 of 12	S0	L01.1

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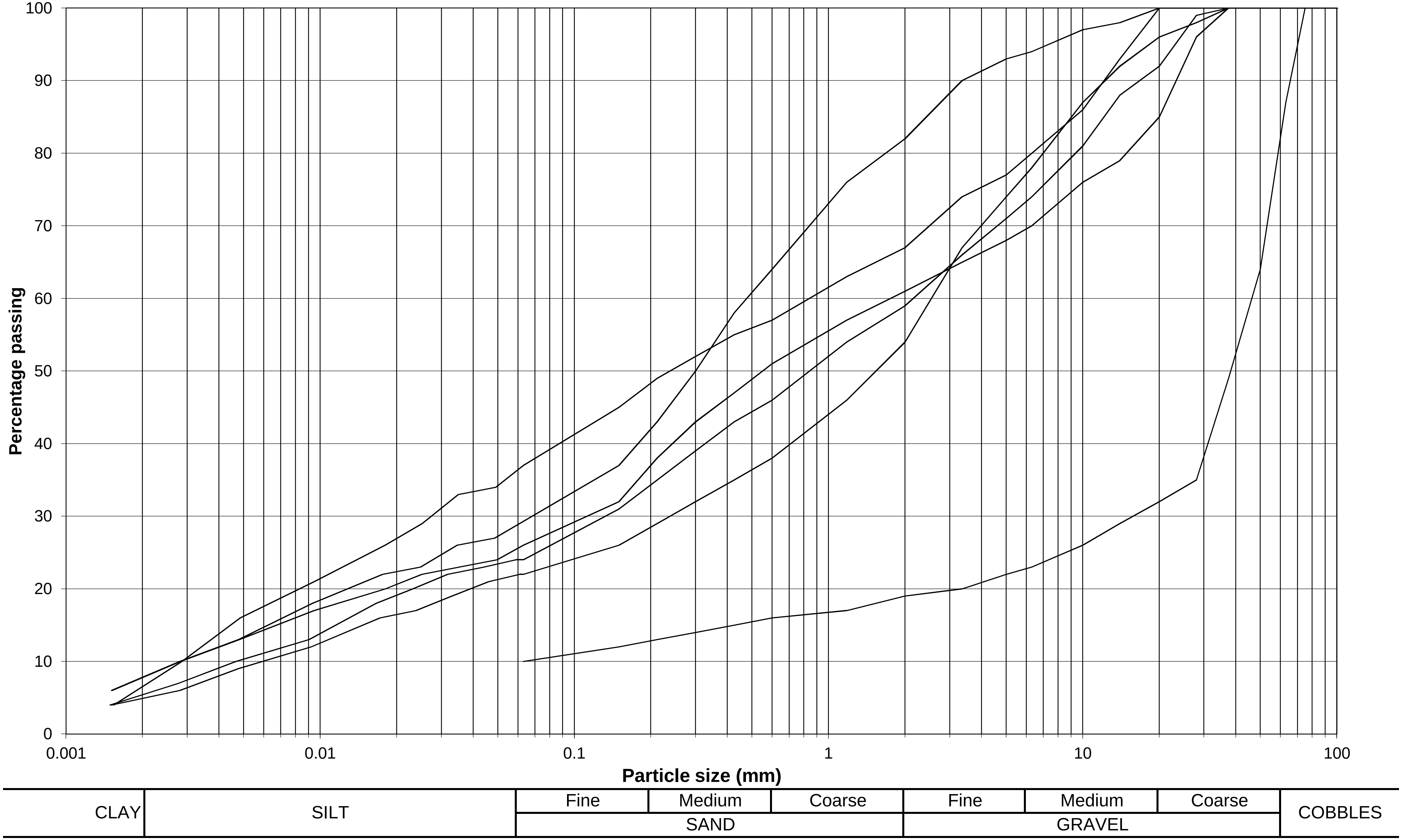
Appendix C Laboratory Test Summary Charts



Made Ground- particle size distribution

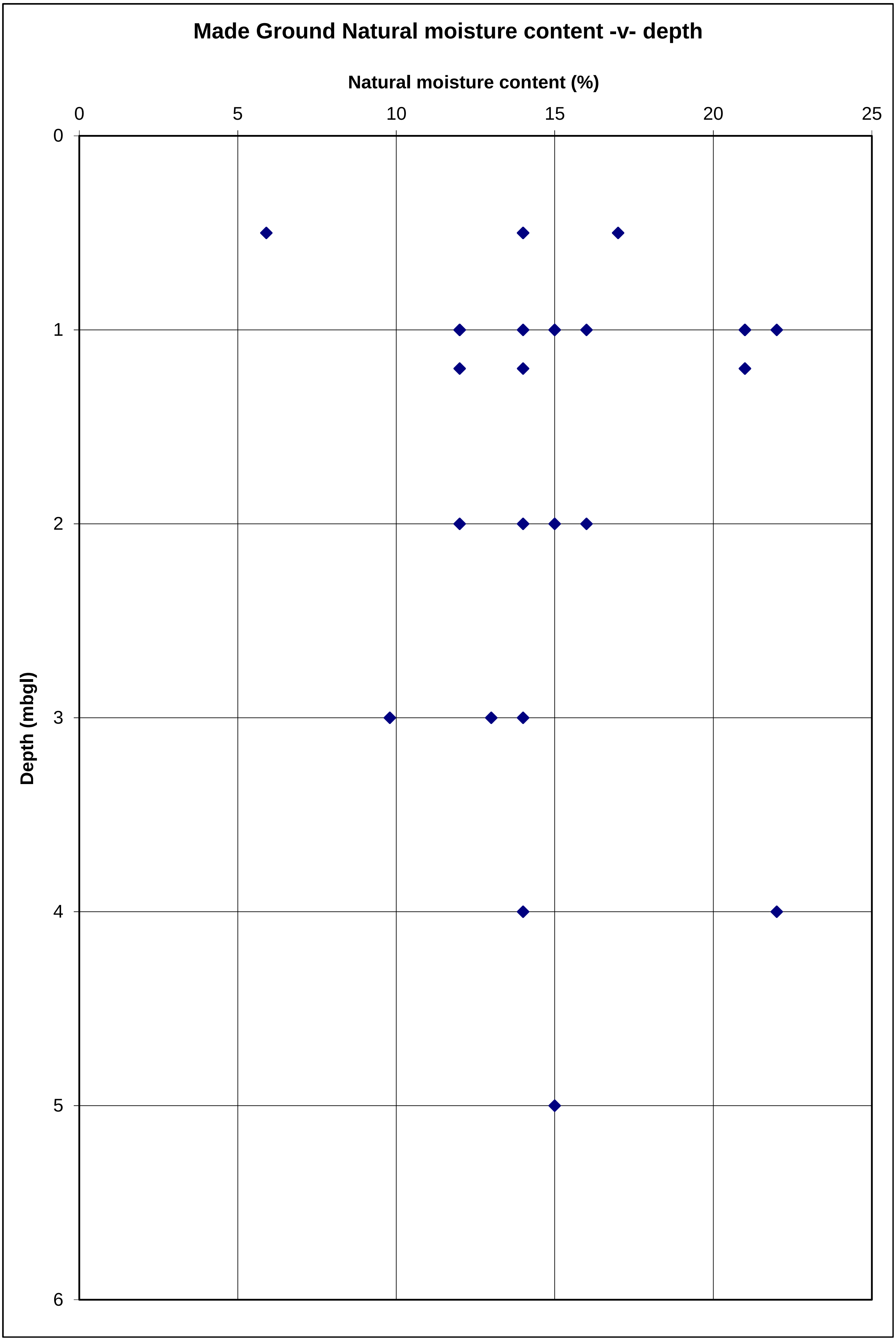
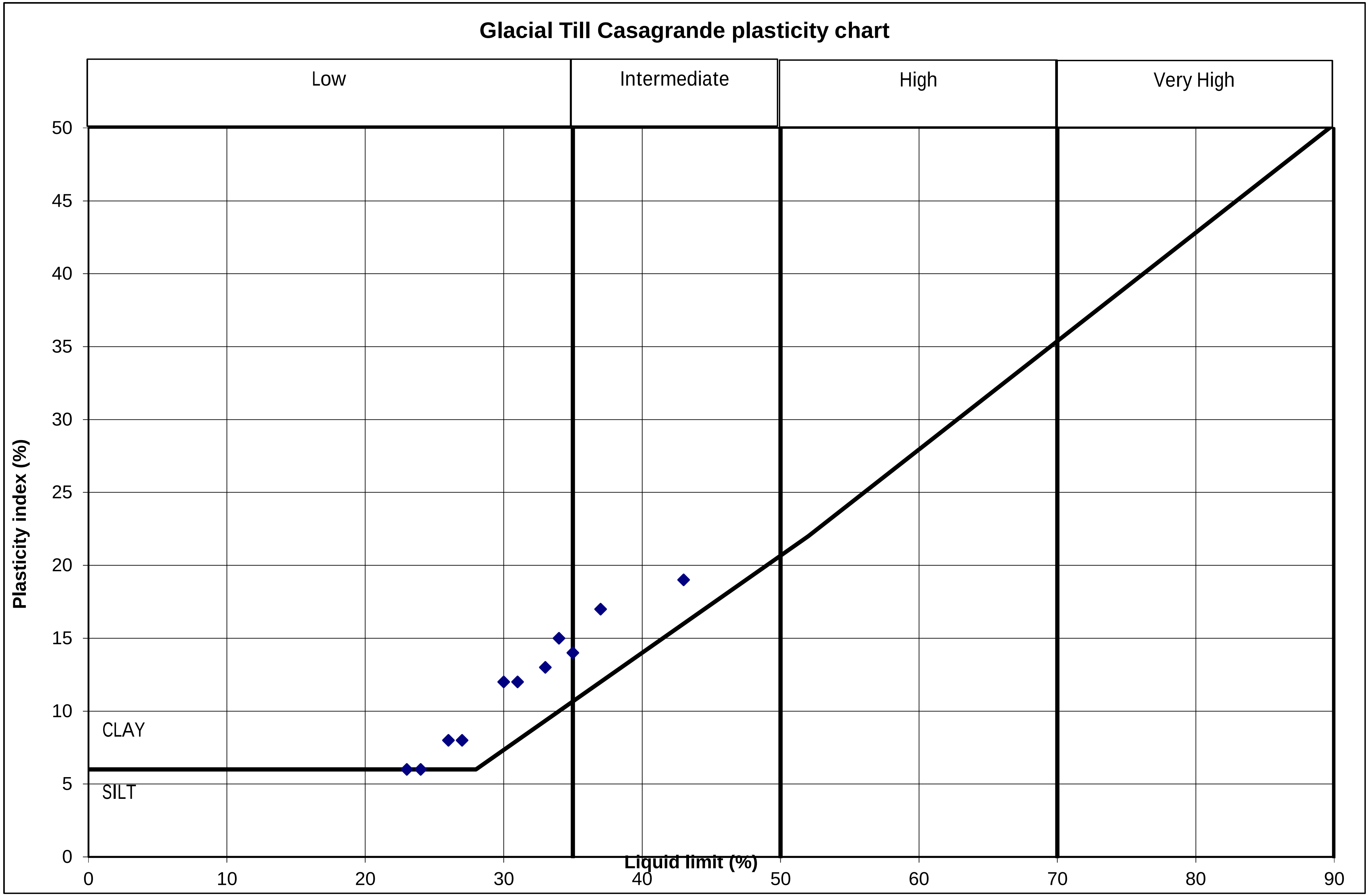
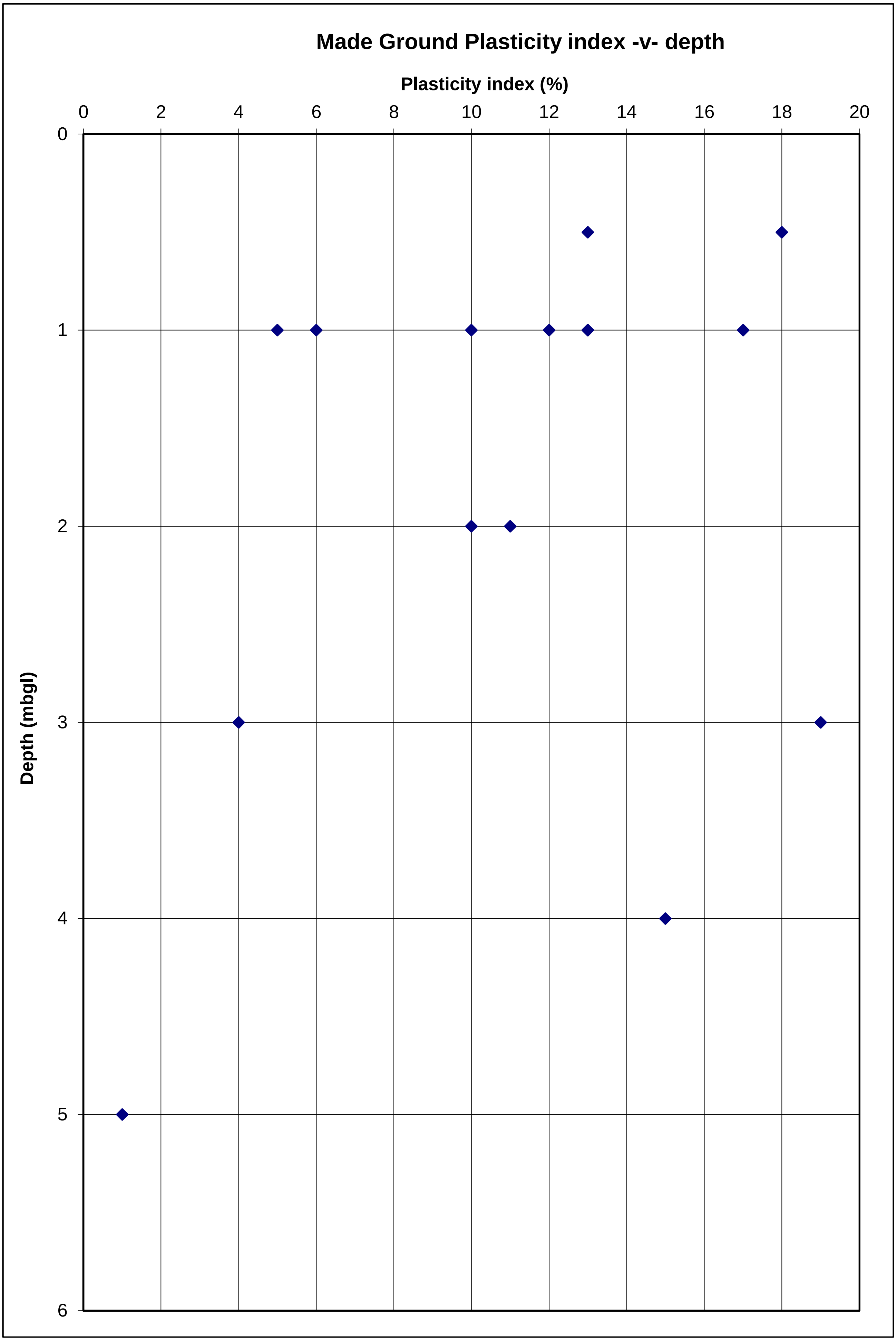
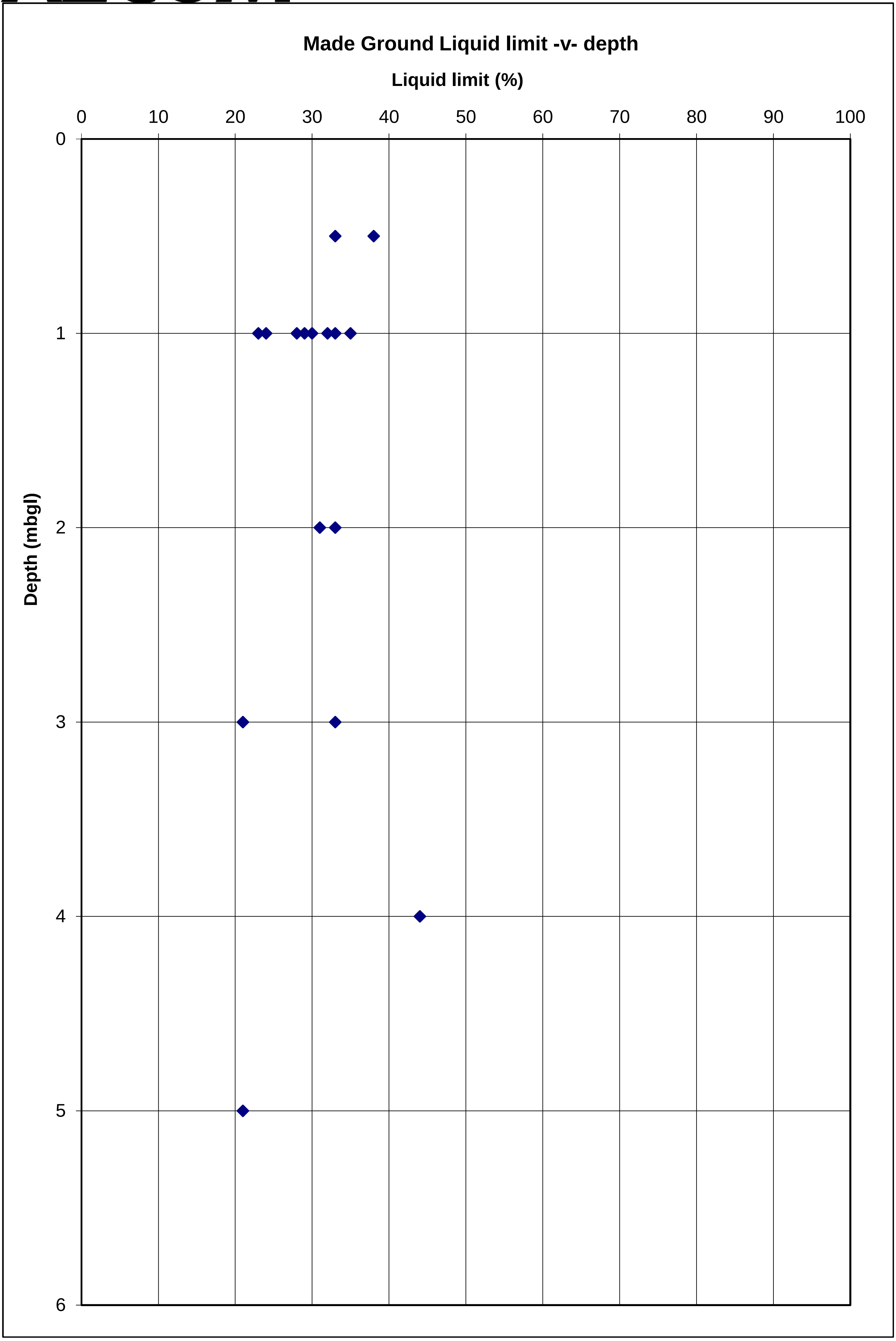
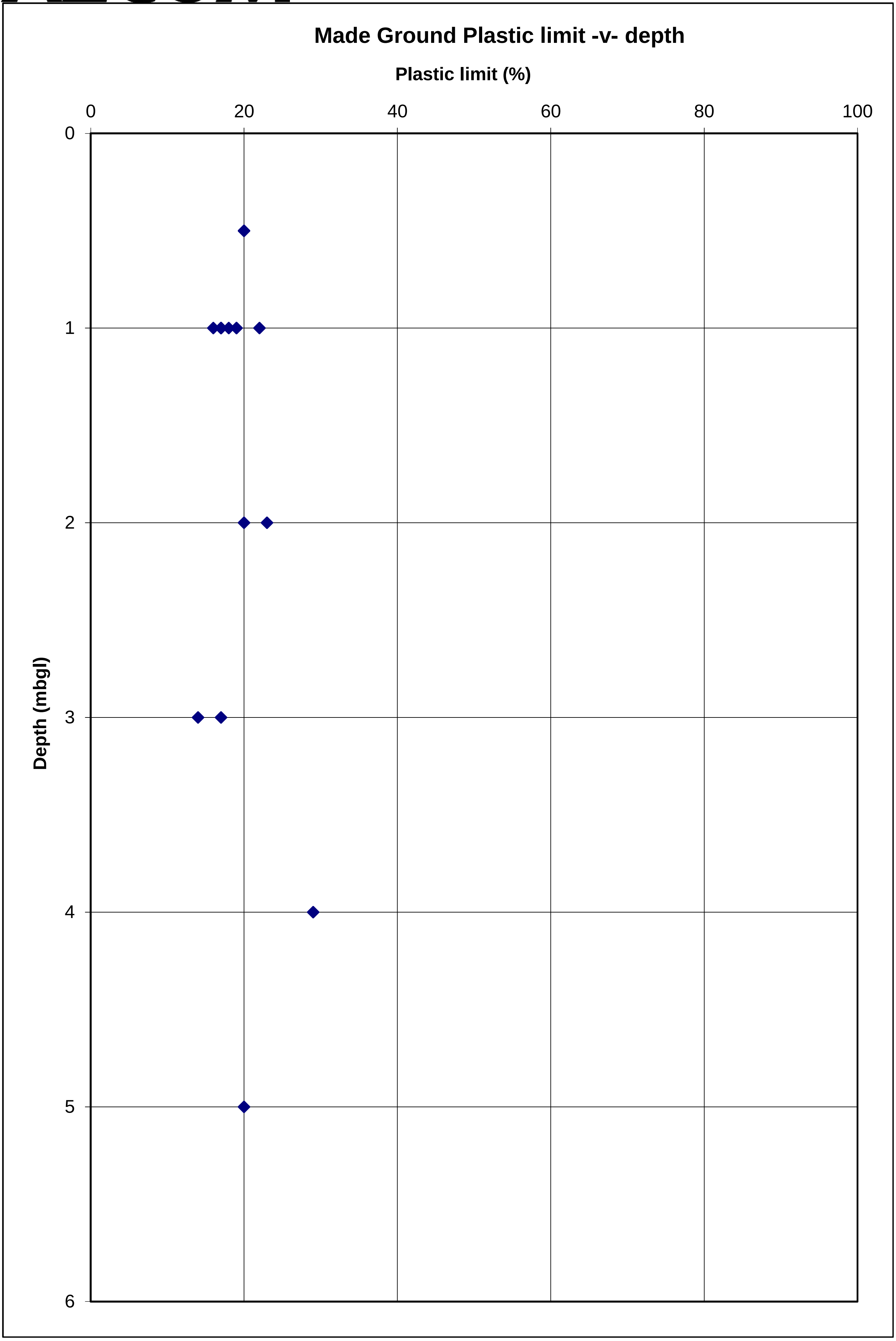


Figure R9.MG.2


Glacial Till Casagrande plasticity chart
Low
Intermediate
High
Very High
Plasticity index (%)
Liquid limit (%)
CLAY
SILT
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90


Made Ground Plasticity index -v- depth
Plasticity index (%)
0
2
4
6
8
10
12
14
16
18
20
Depth (mbgl)
0
1
2
3
4
5
6


Made Ground Liquid limit -v- depth
Liquid limit (%)
0
10
20
30
40
50
60
70
80
90
100
Depth (mbgl)
0
1
2
3
4
5
6


Made Ground Plastic limit -v- depth
Plastic limit (%)
0
20
40
60
80
100
Depth (mbgl)
0
1
2
3
4
5
6

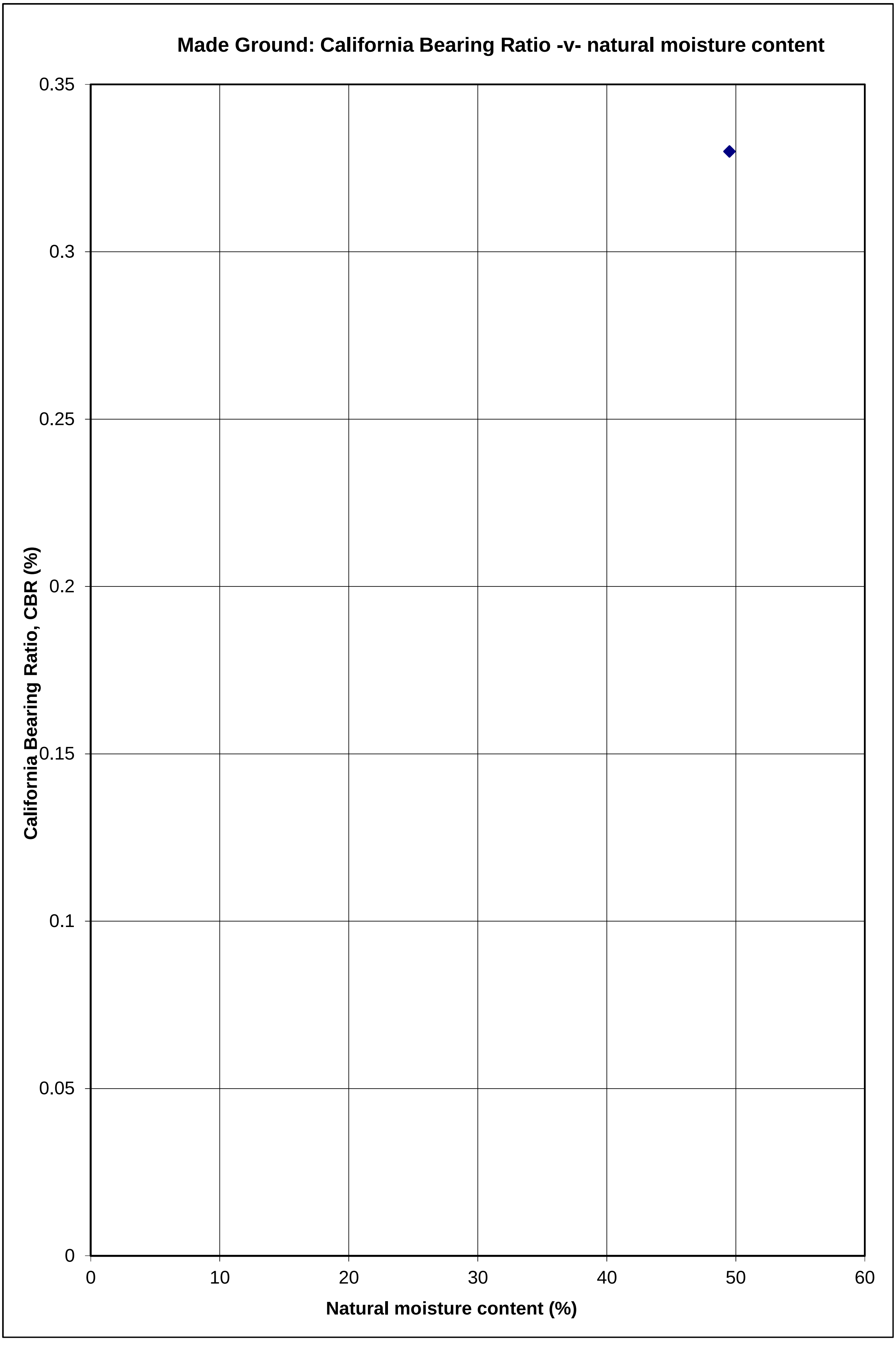
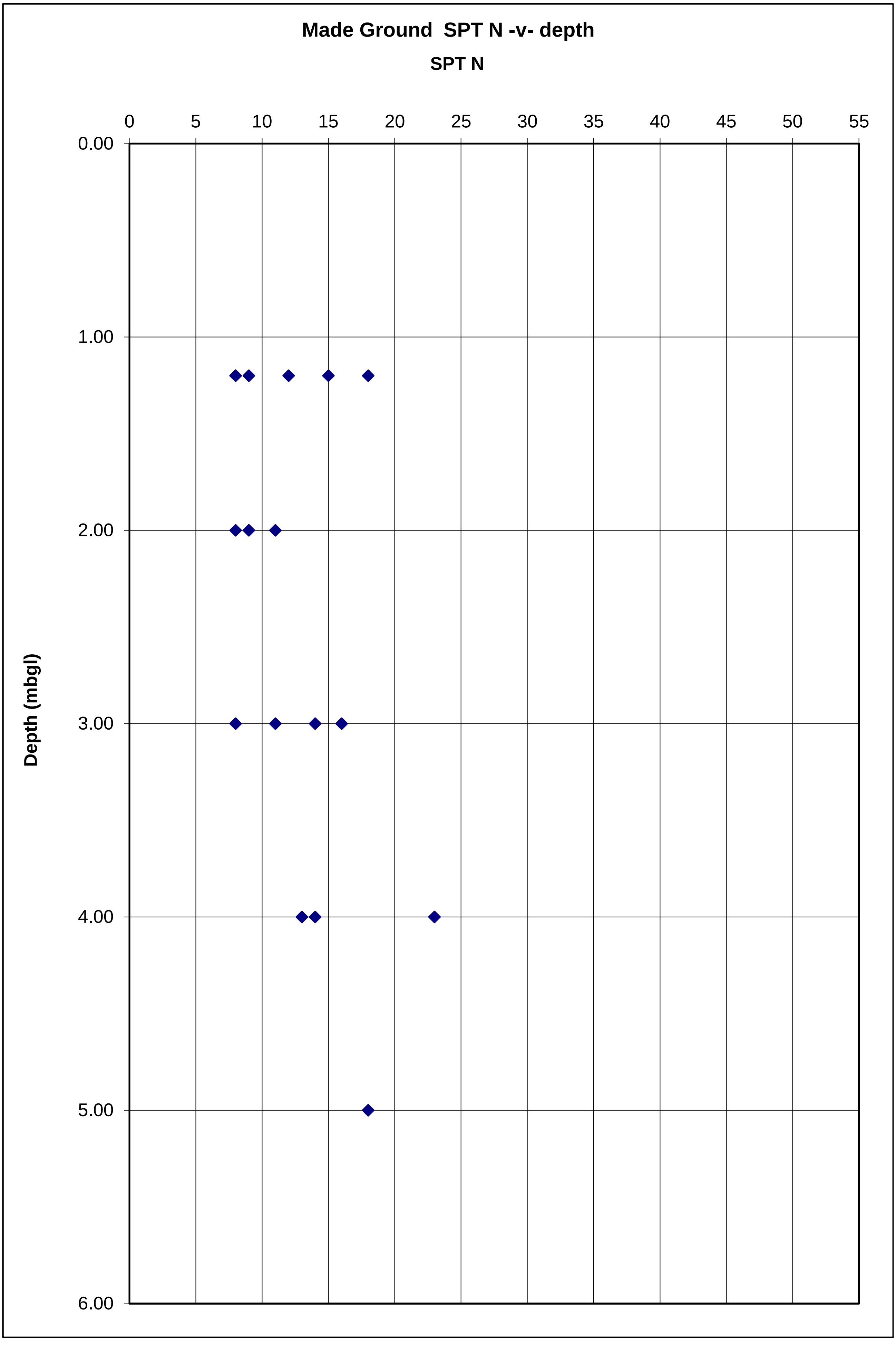
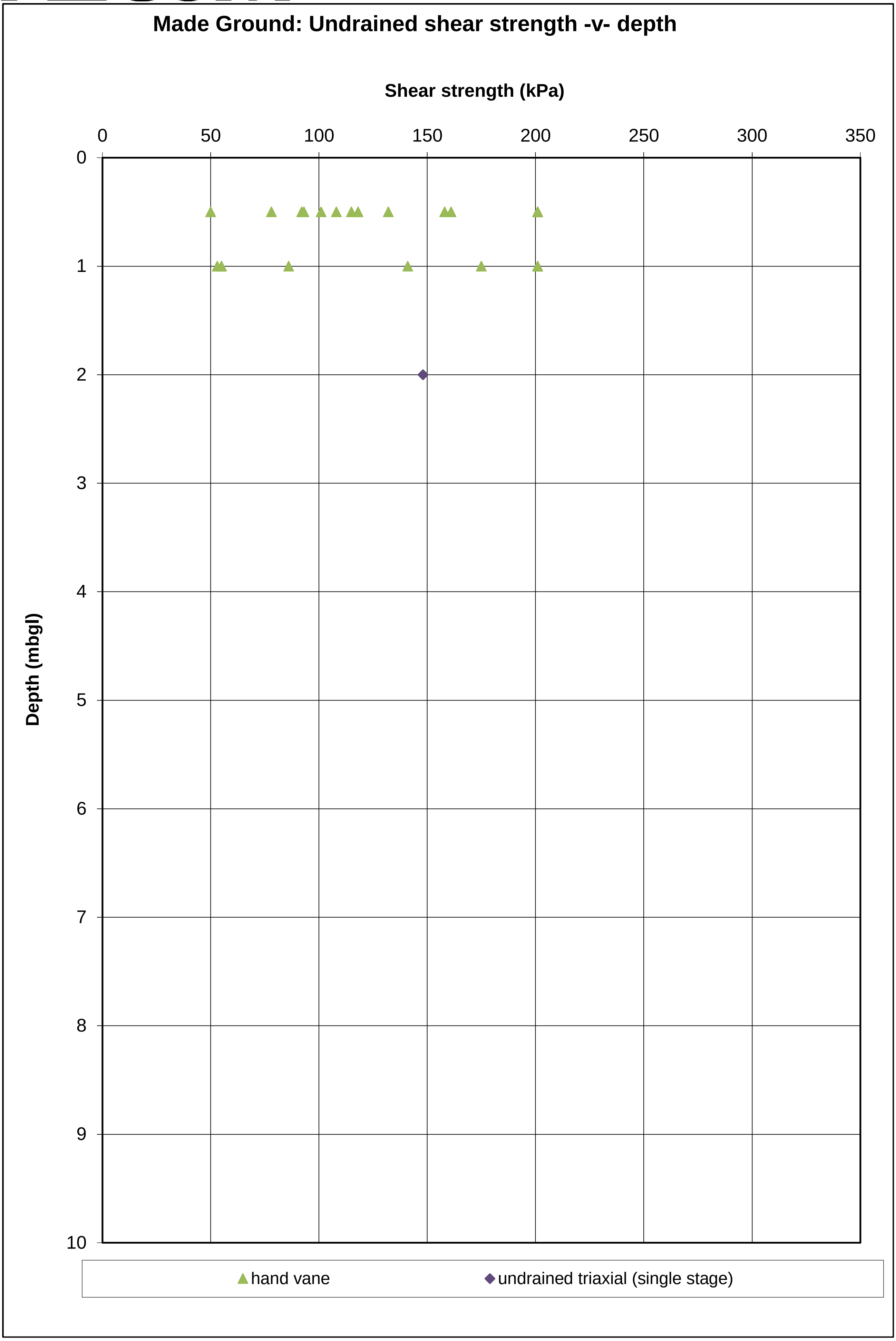
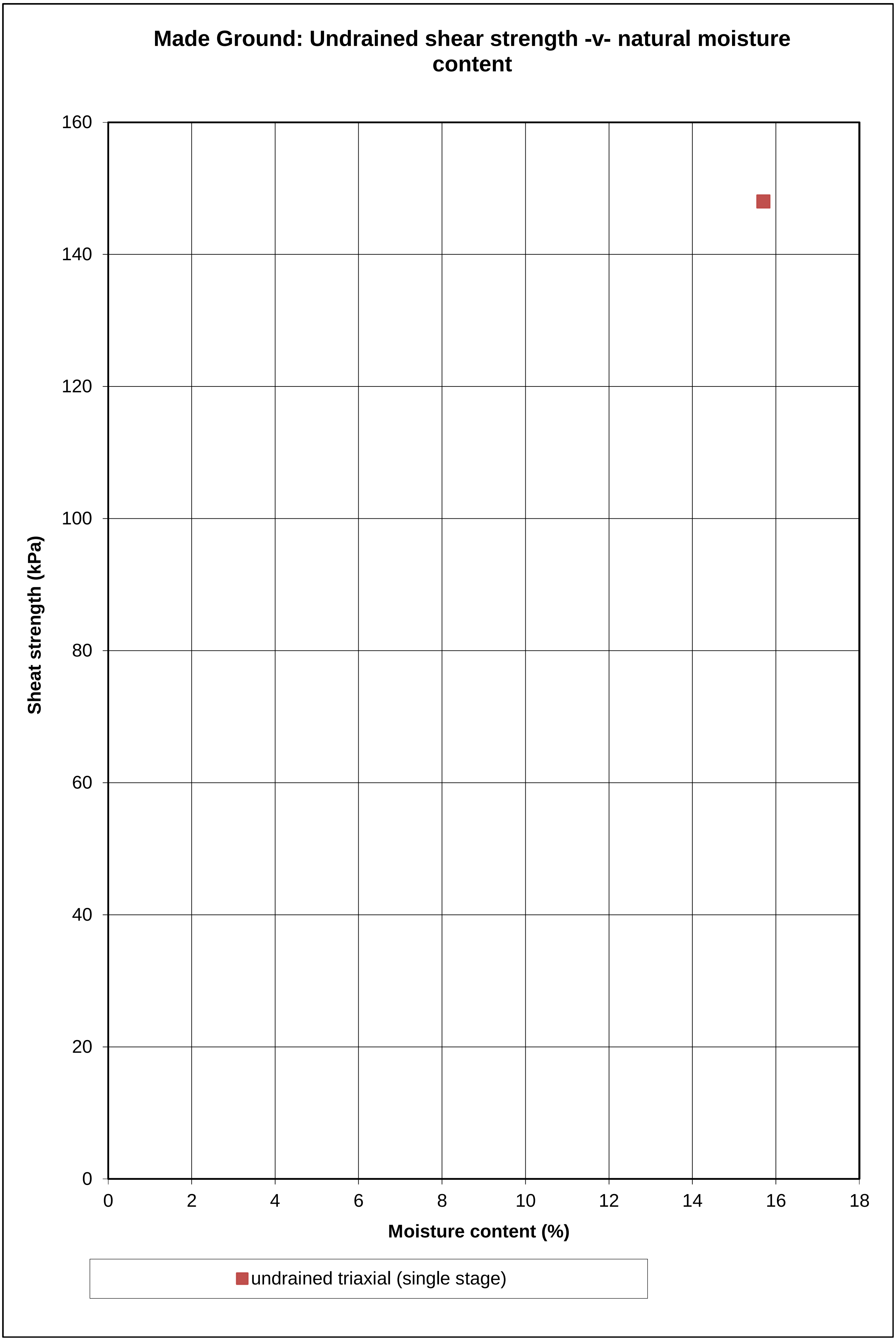
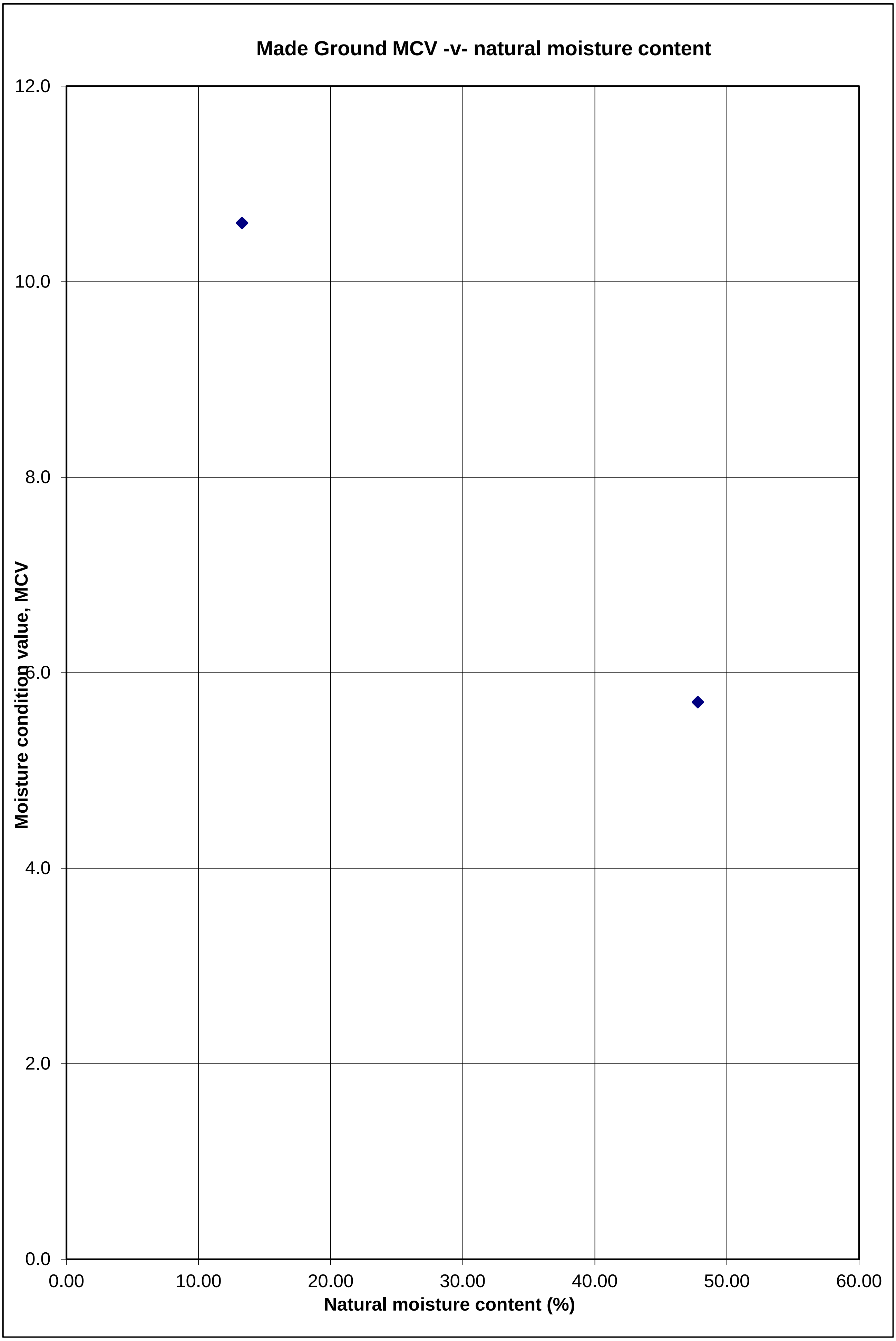


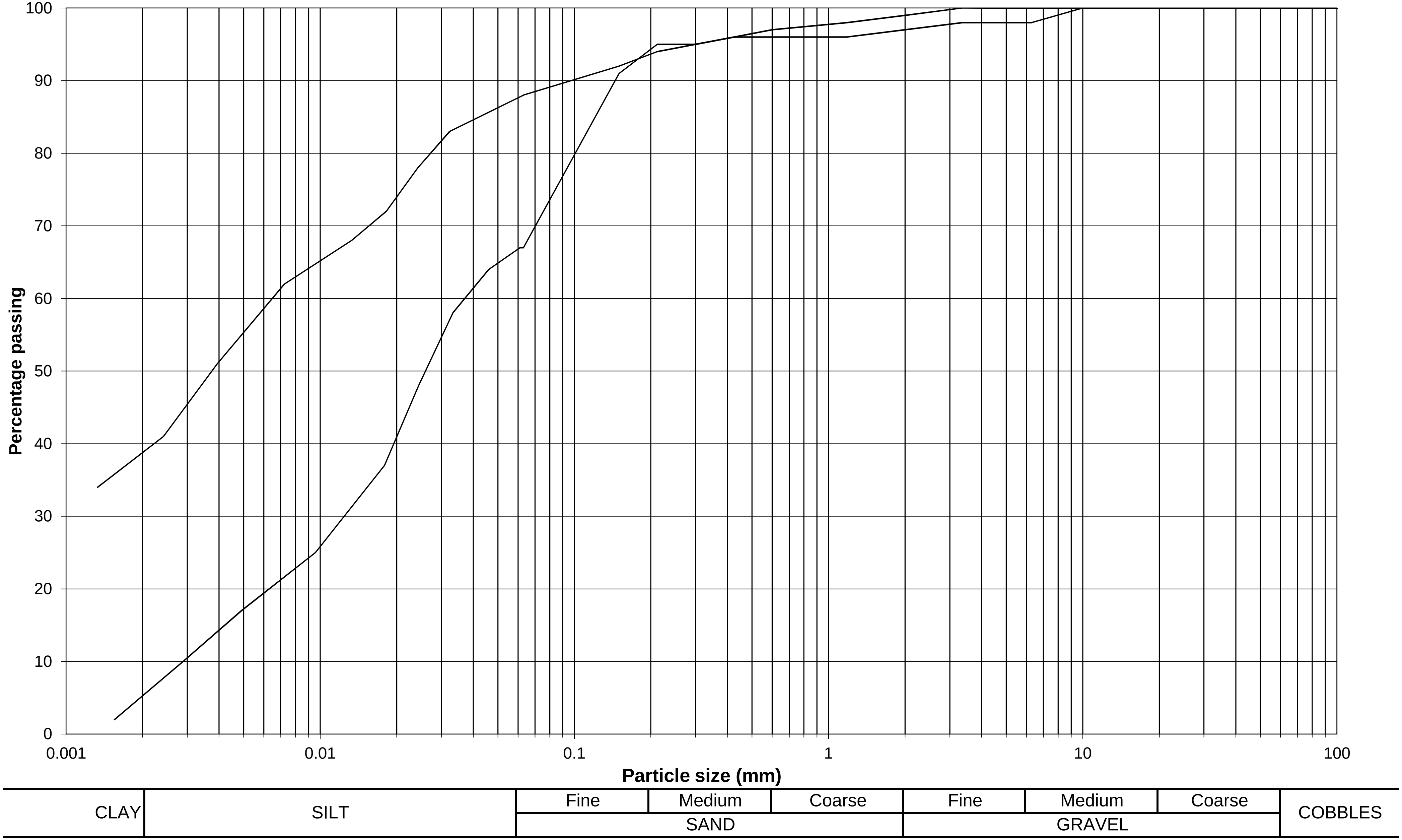
Figure R9.MG.7


Made Ground SPT N -v- depth
SPT N
0
5
10
15
20
25
30
35
40
45
50
55
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Depth (mbgl)

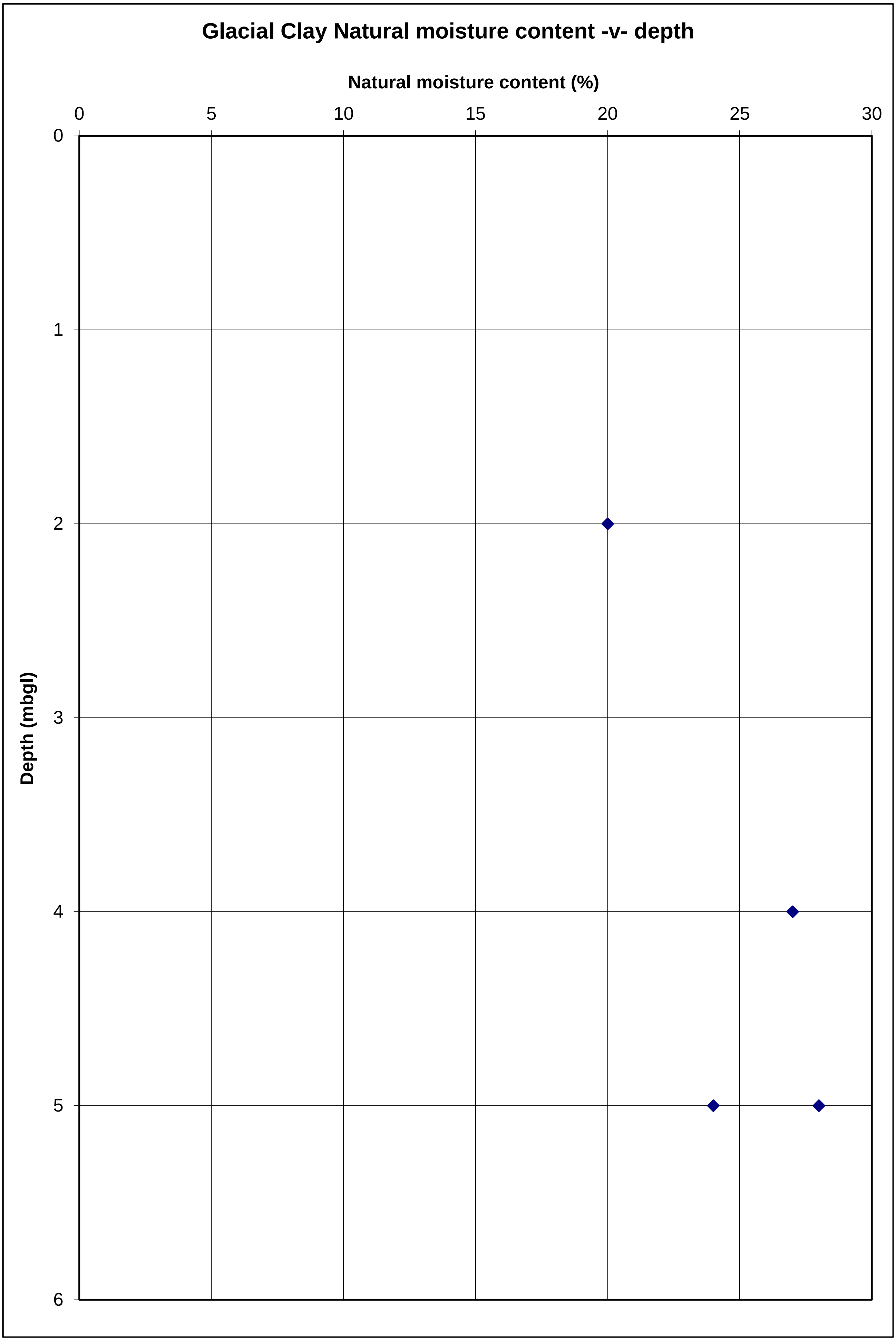

Made Ground: Undrained shear strength -v- depth
Shear strength (kPa)
0
50
100
150
200
250
300
350
Depth (mbgl)
0
1
2
3
4
5
6
7
8
9
10
hand vane
undrained triaxial (single stage)

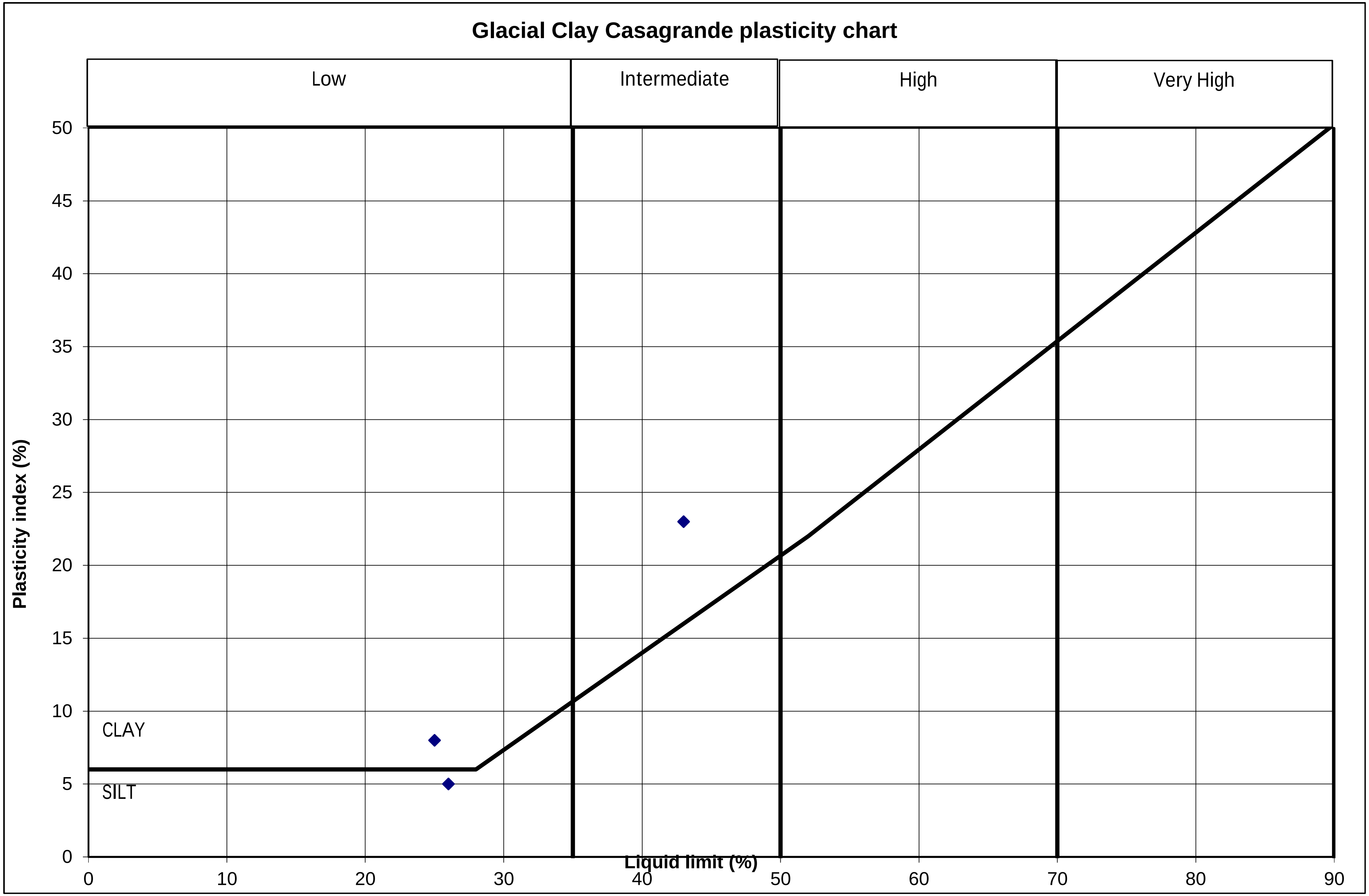

Made Ground: Undrained shear strength -v- natural moisture content
Sheat strength (kPa)
0
20
40
60
80
100
120
140
160
0
2
4
6
8
10
12
14
16
18
Moisture content (%)
undrained triaxial (single stage)

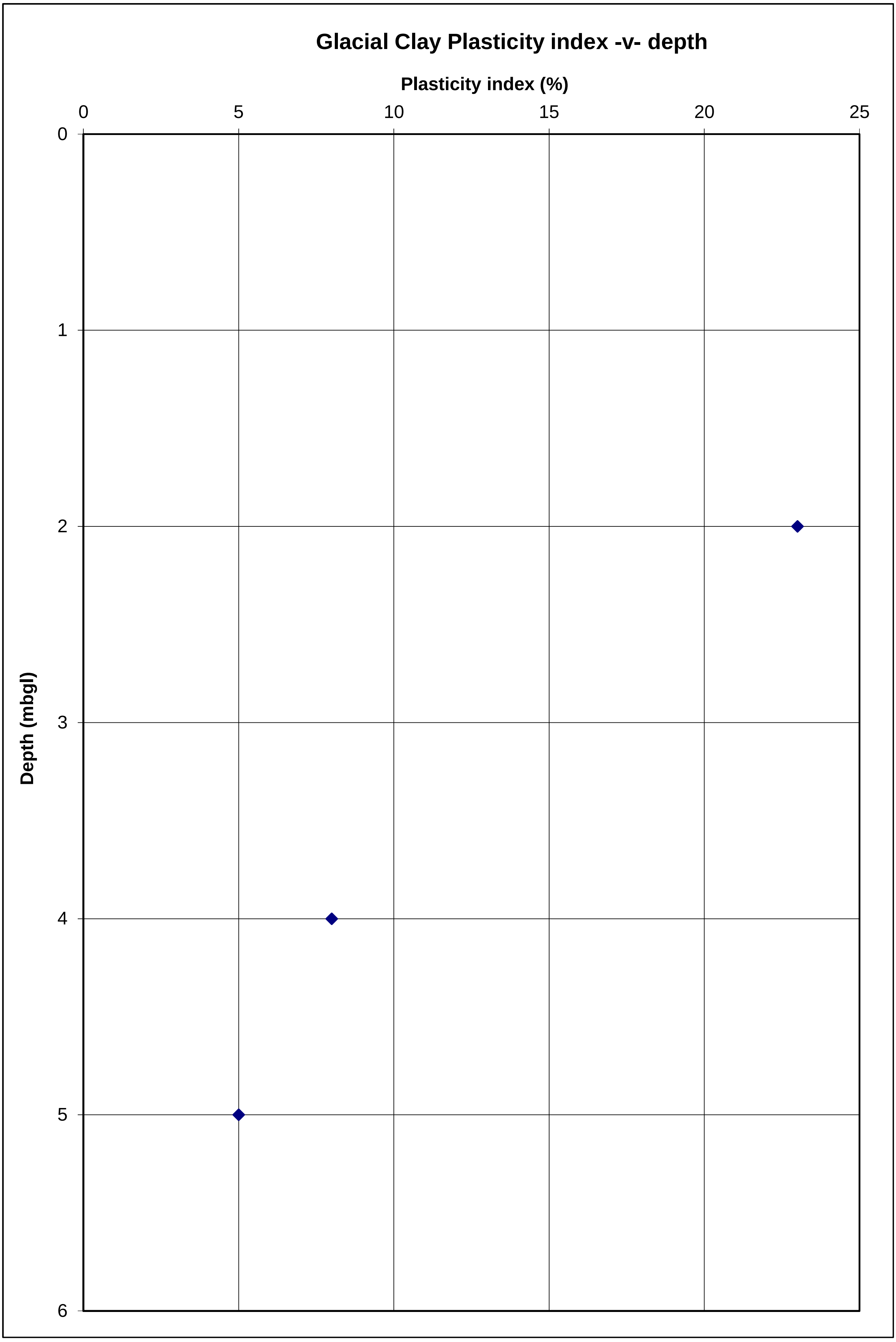

Made Ground MCV -v- natural moisture content
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Natural moisture content (%)
Moisture condition value, MCV

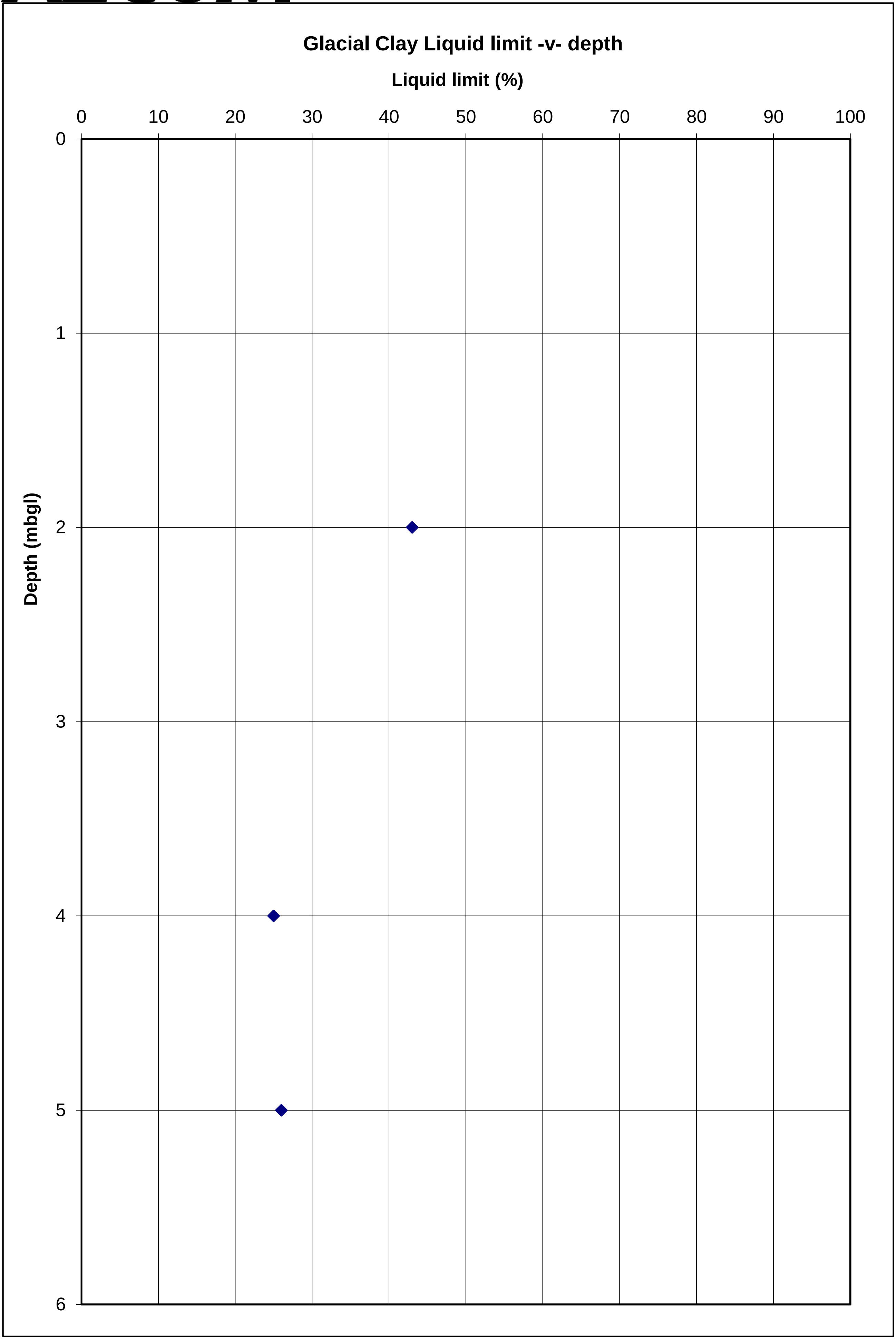


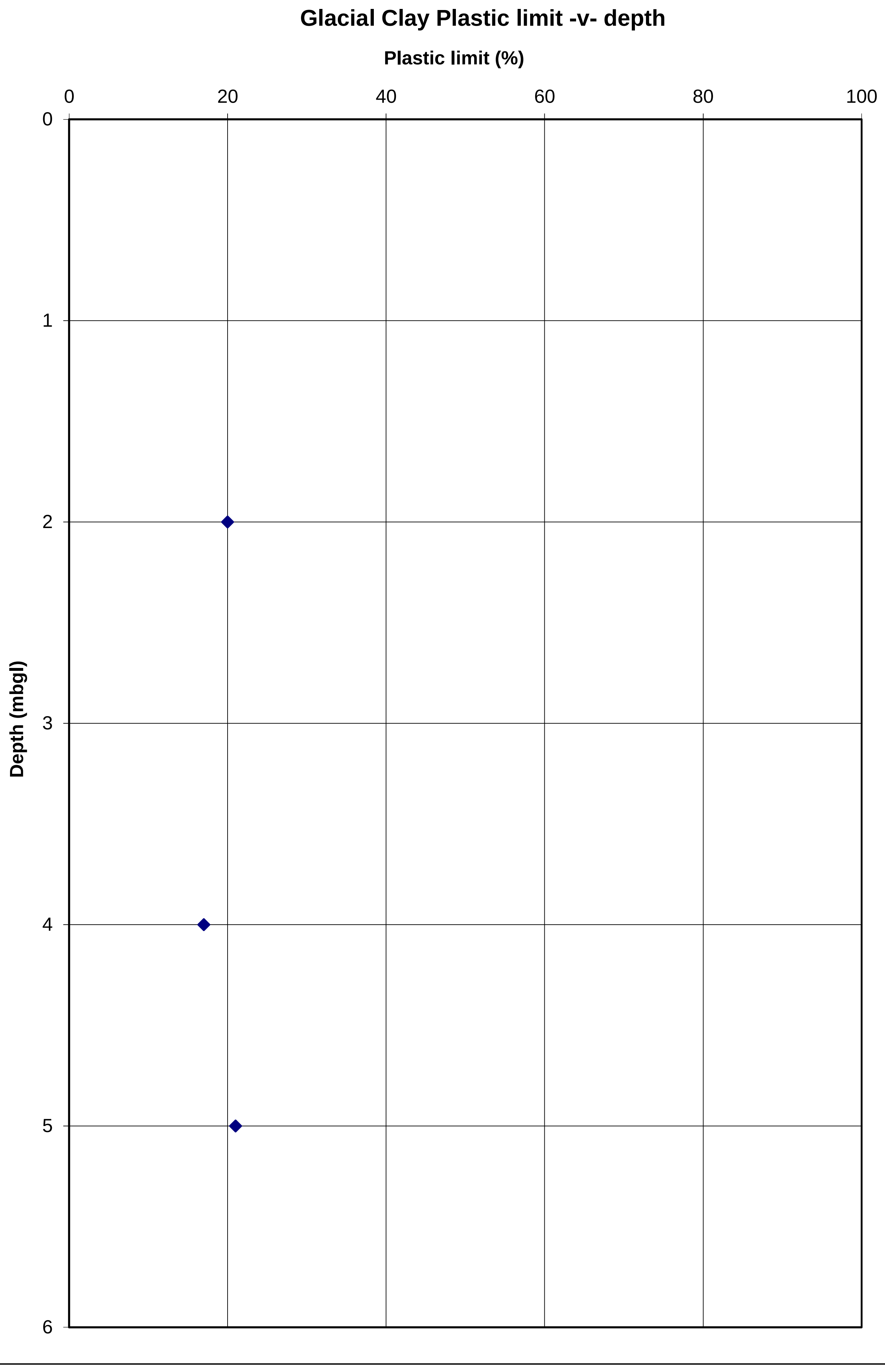
Glacial Clay- particle size distribution

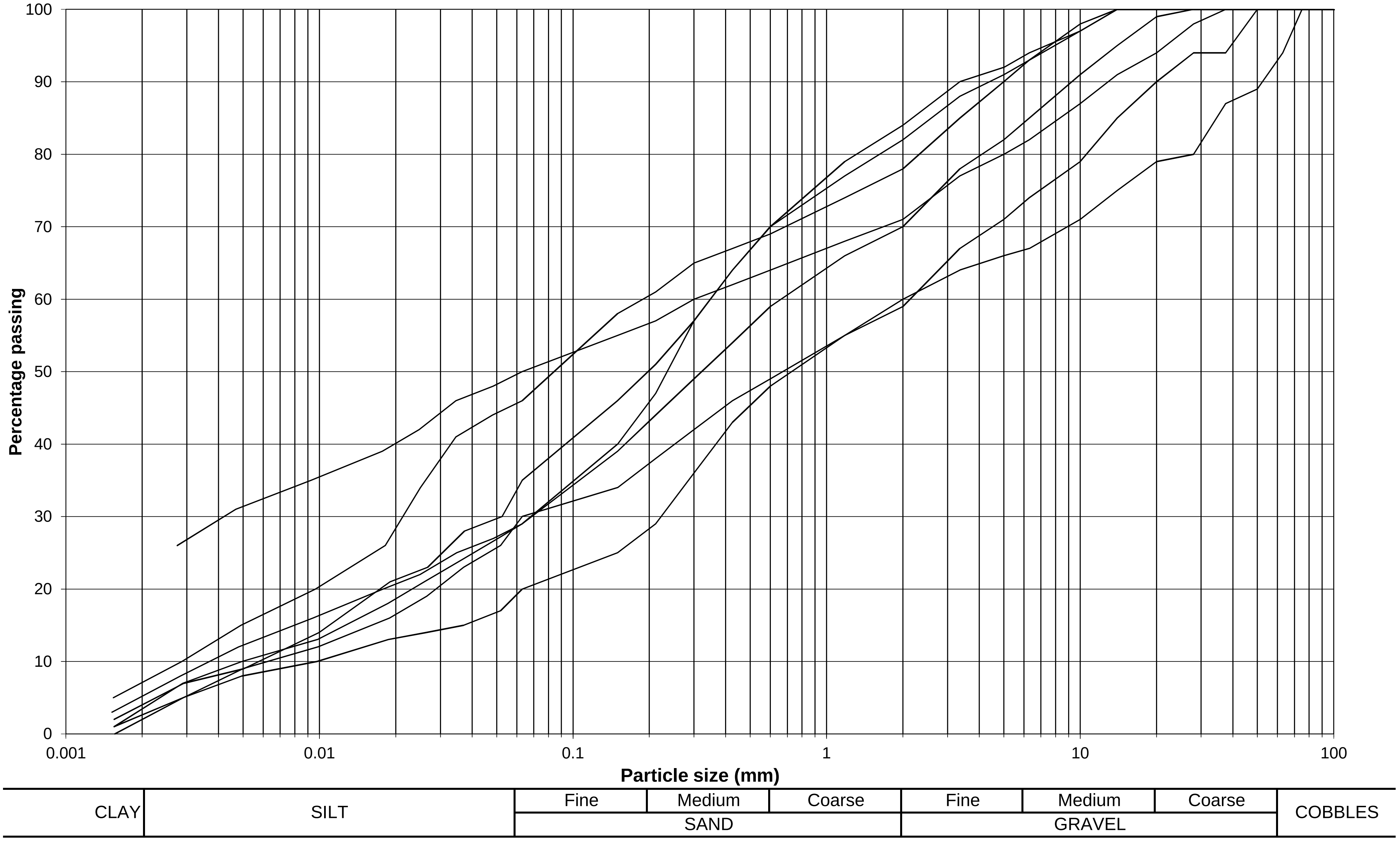

Glacial Clay Natural moisture content -v- depth
Natural moisture content (%)
0
5
10
15
20
25
30
Depth (mbgl)
0
1
2
3
4
5
6


Glacial Clay Casagrande plasticity chart
Low
Intermediate
High
Very High
Plasticity index (%)
Liquid limit (%)
CLAY
SILT
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90

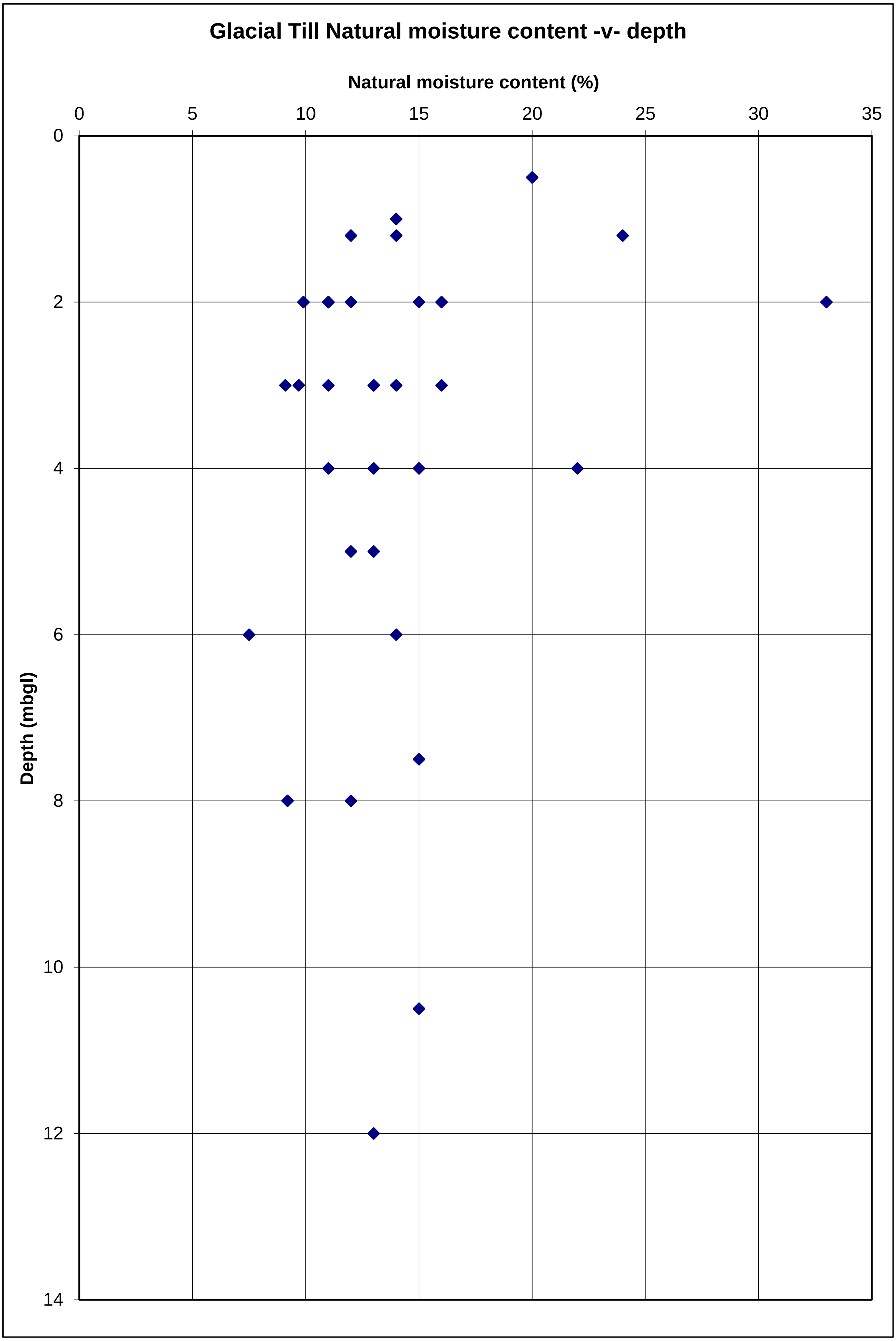

Glacial Clay Plasticity index -v- depth
Plasticity index (%)
0
5
10
15
20
25
0
1
2
3
4
5
6
Depth (mbgl)

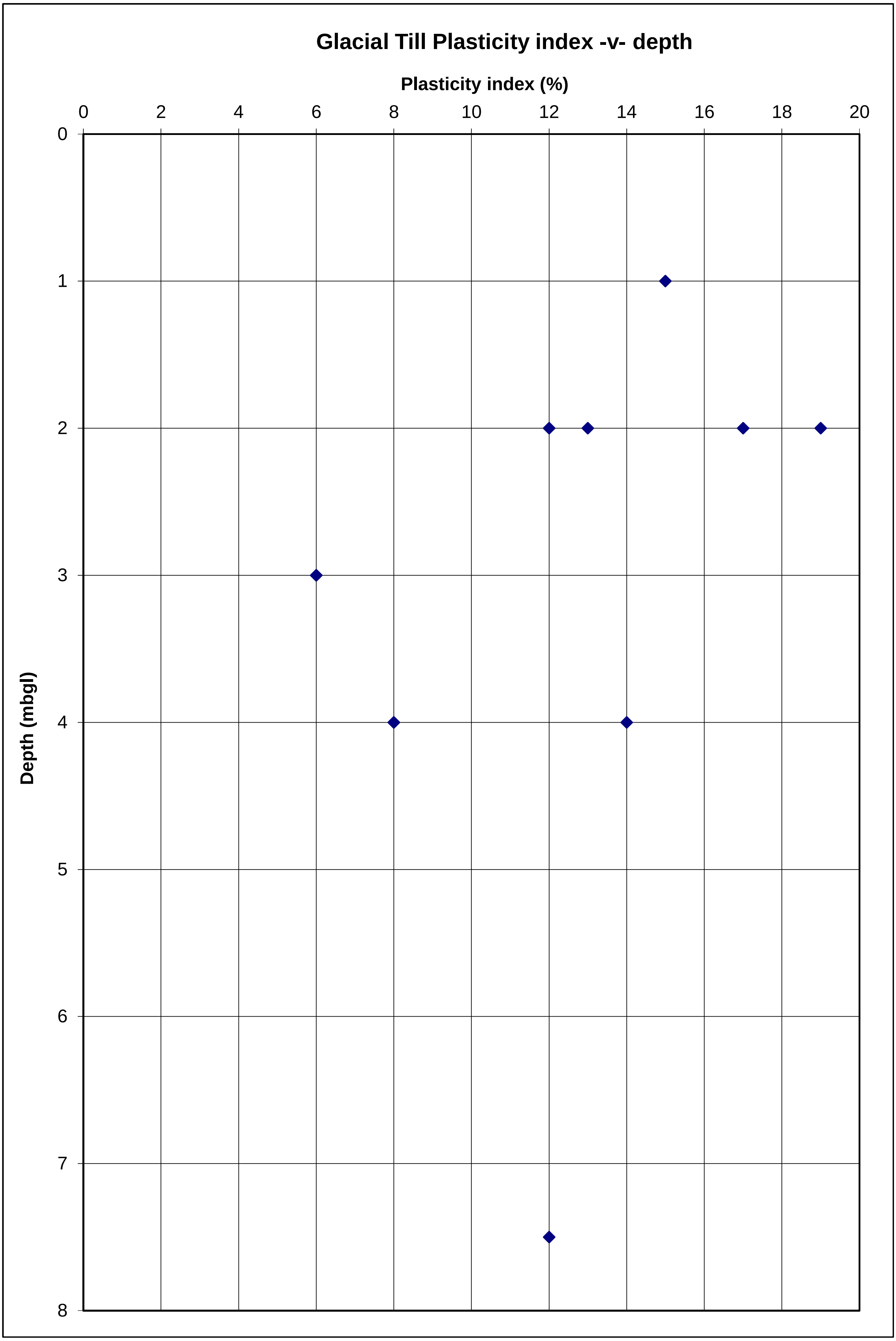

Glacial Clay Liquid limit -v- depth
Liquid limit (%)
0
10
20
30
40
50
60
70
80
90
100
Depth (mbgl)
0
1
2
3
4
5
6


Glacial Clay Plastic limit -v- depth
Plastic limit (%)
0
20
40
60
80
100
Depth (mbgl)
0
1
2
3
4
5
6



Glacial Till- particle size distribution


Glacial Till Natural moisture content -v- depth
Natural moisture content (%)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
Depth (mbgl)


Glacial Till Plasticity index -v- depth
Plasticity index (%)
0 2 4 6 8 10 12 14 16 18 20
Depth (mbgl)
0 1 2 3 4 5 6 7 8

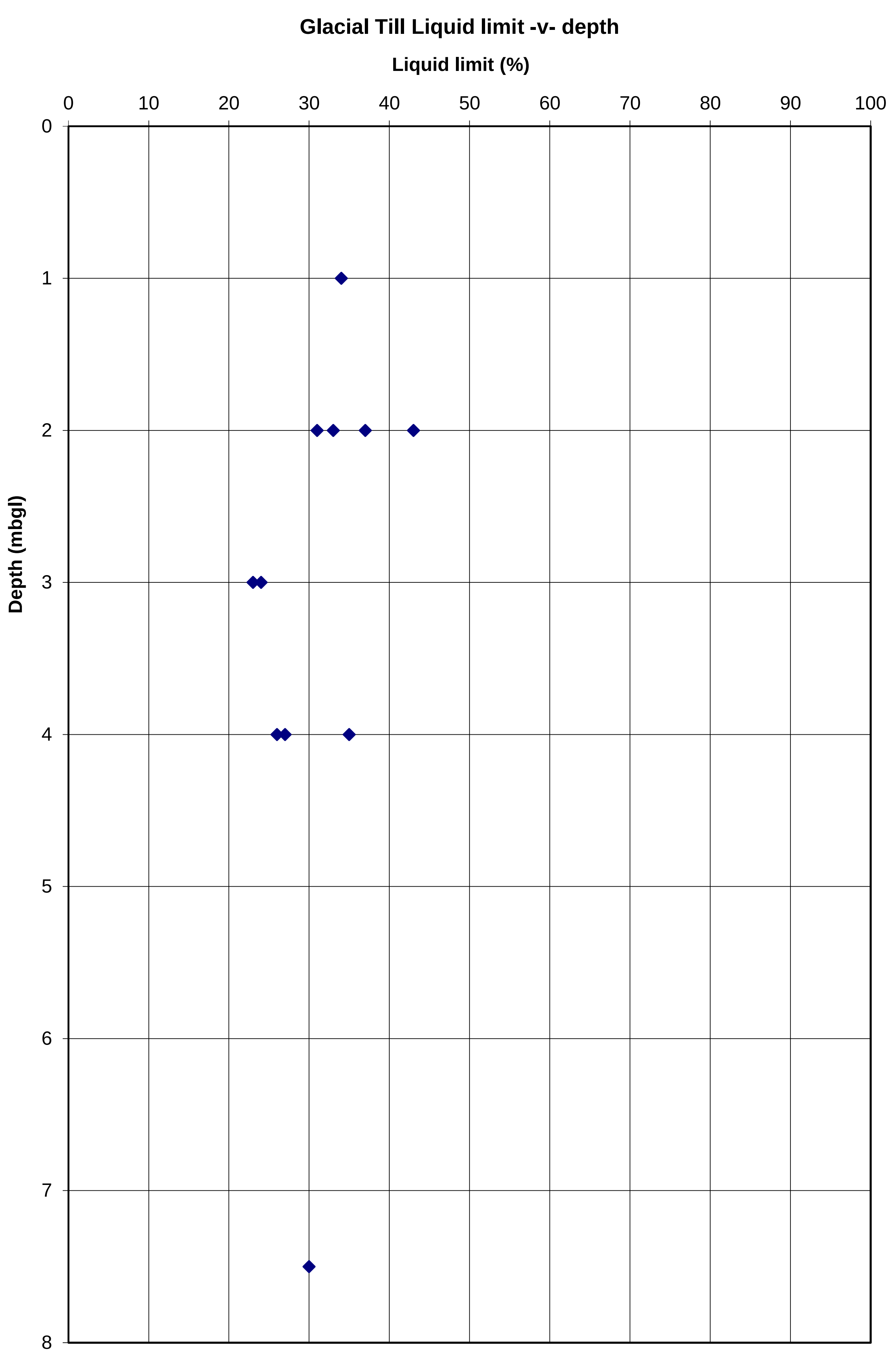
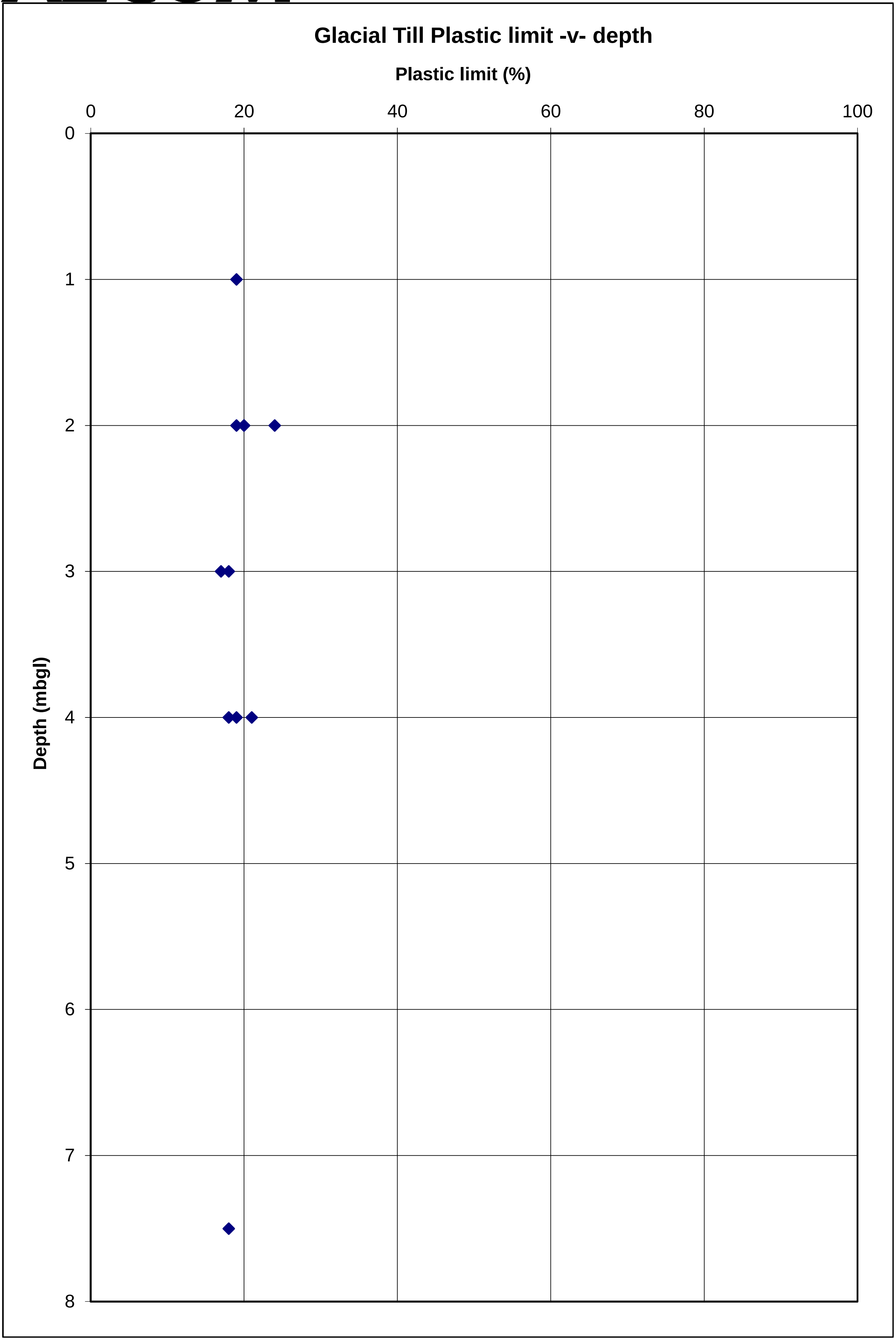


Figure R9.GT.5


Glacial Till Plastic limit -v- depth
Plastic limit (%)
0
20
40
60
80
100
Depth (mbgl)
0
1
2
3
4
5
6
7
8

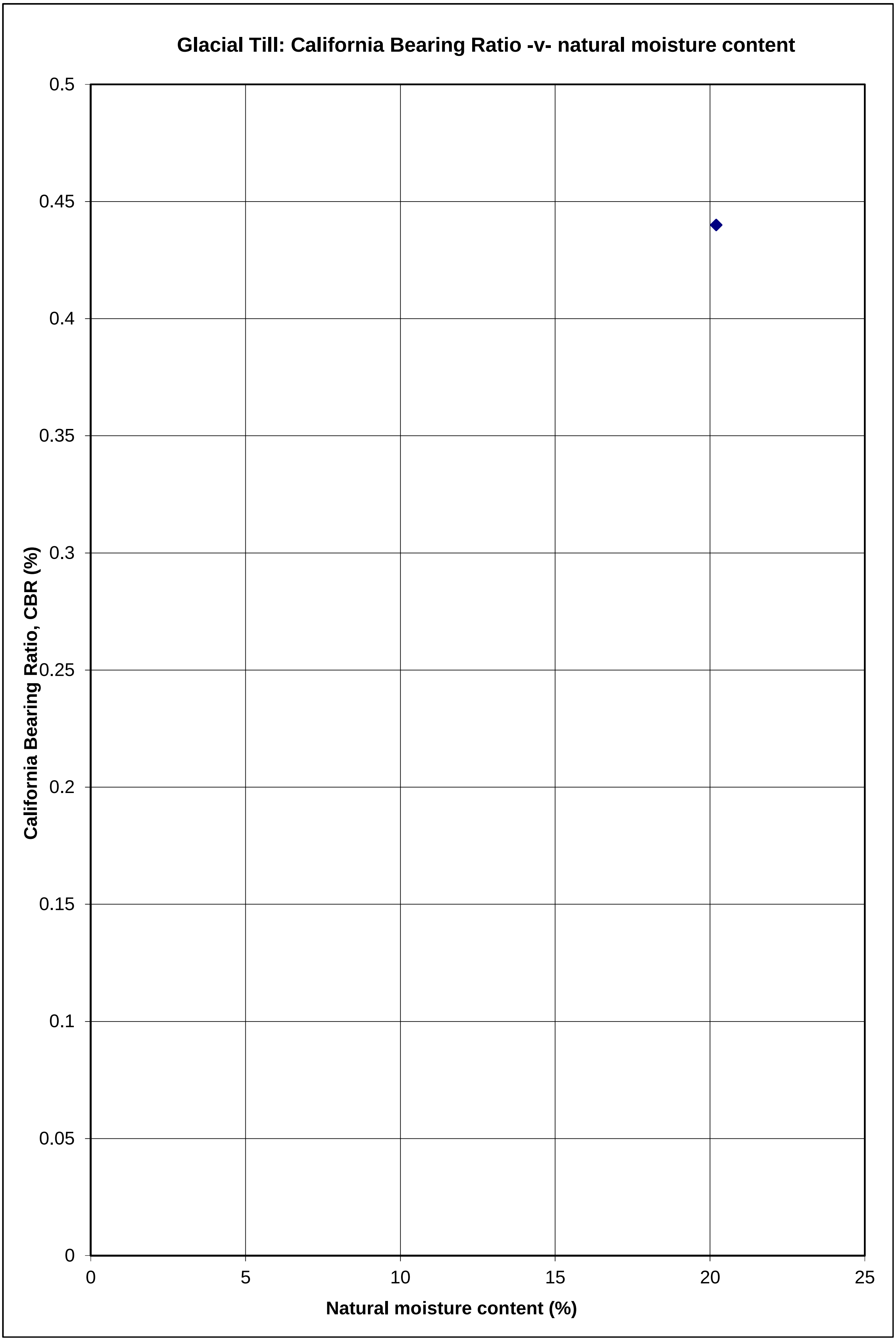
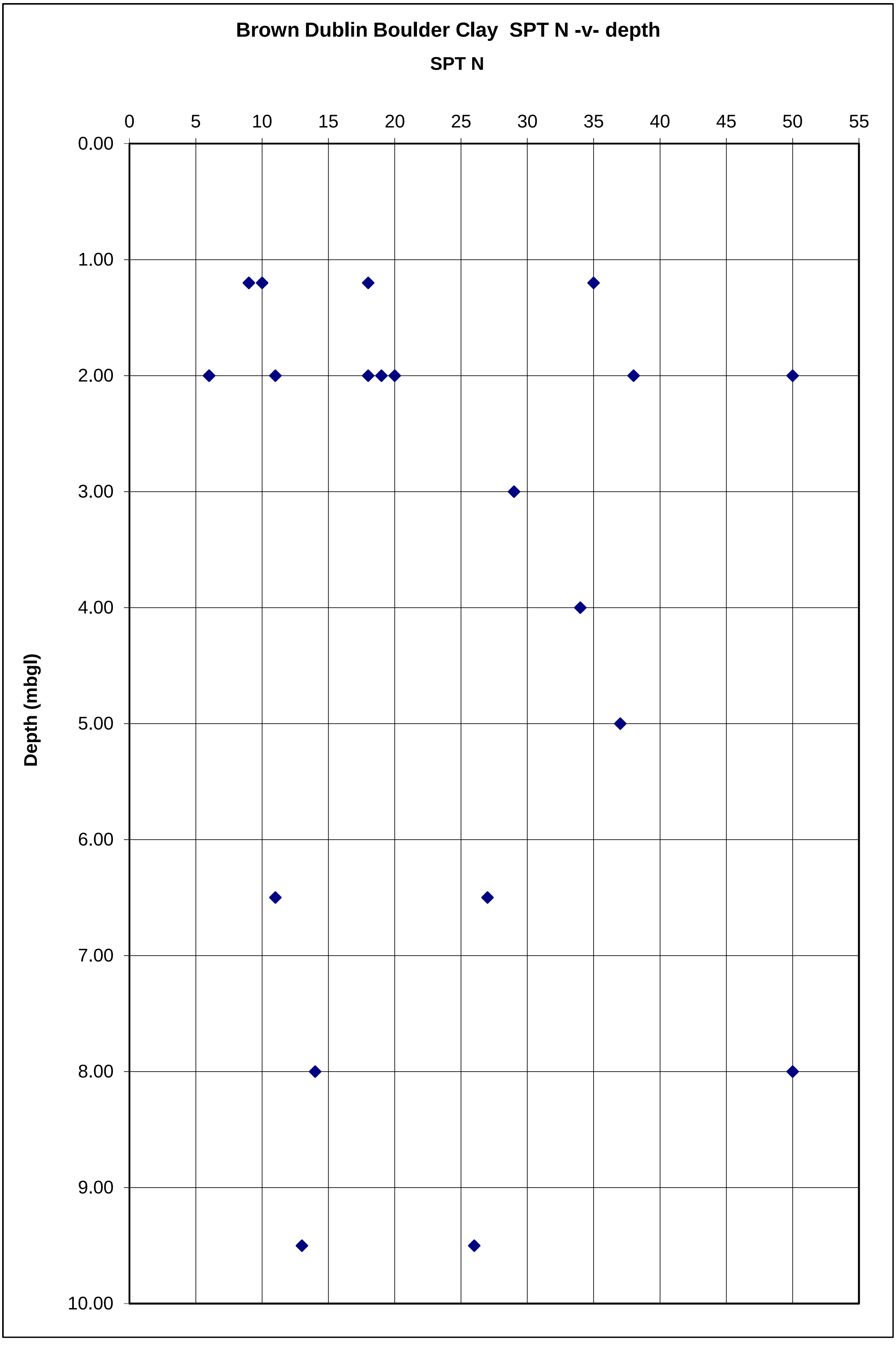
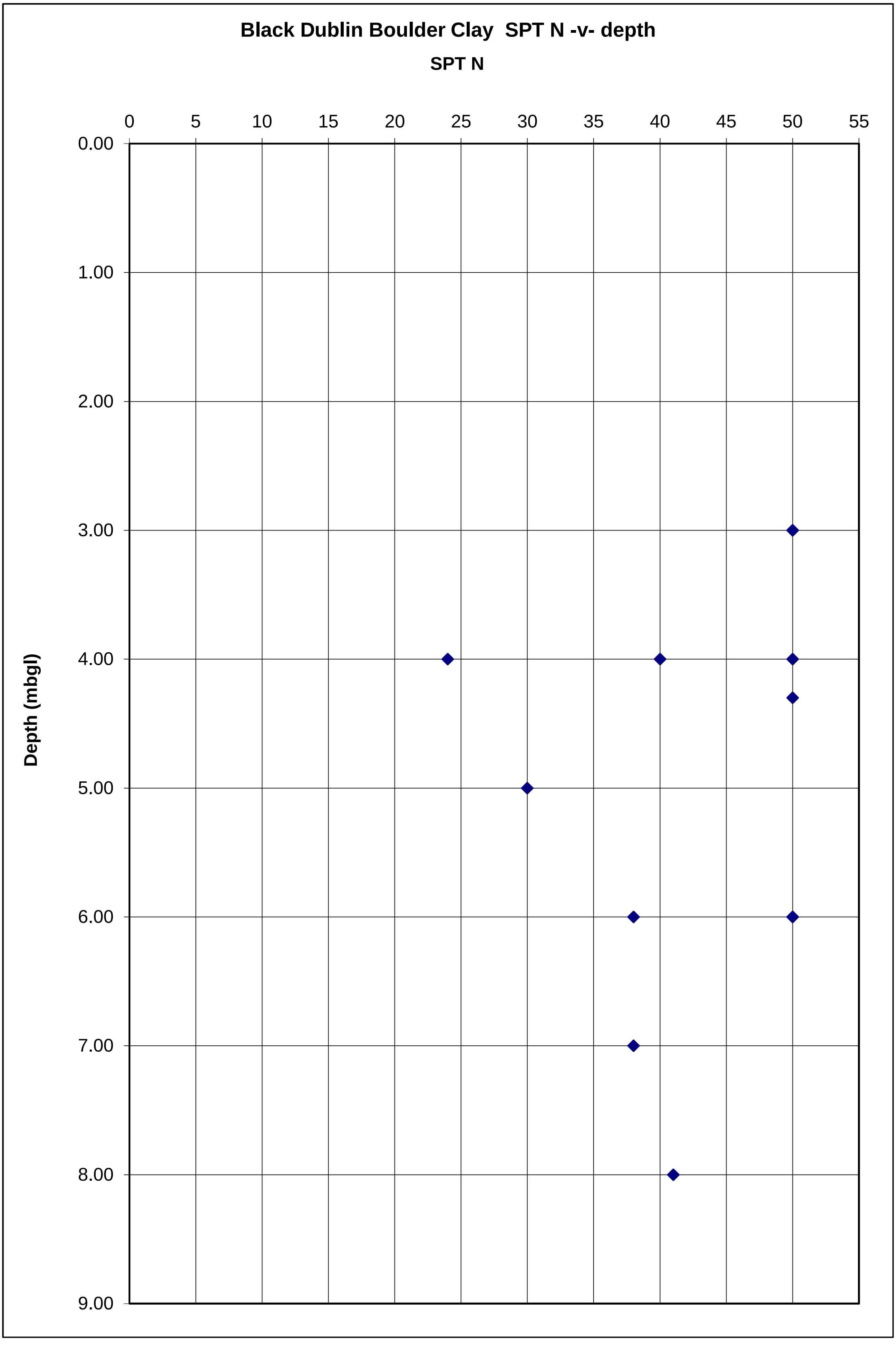
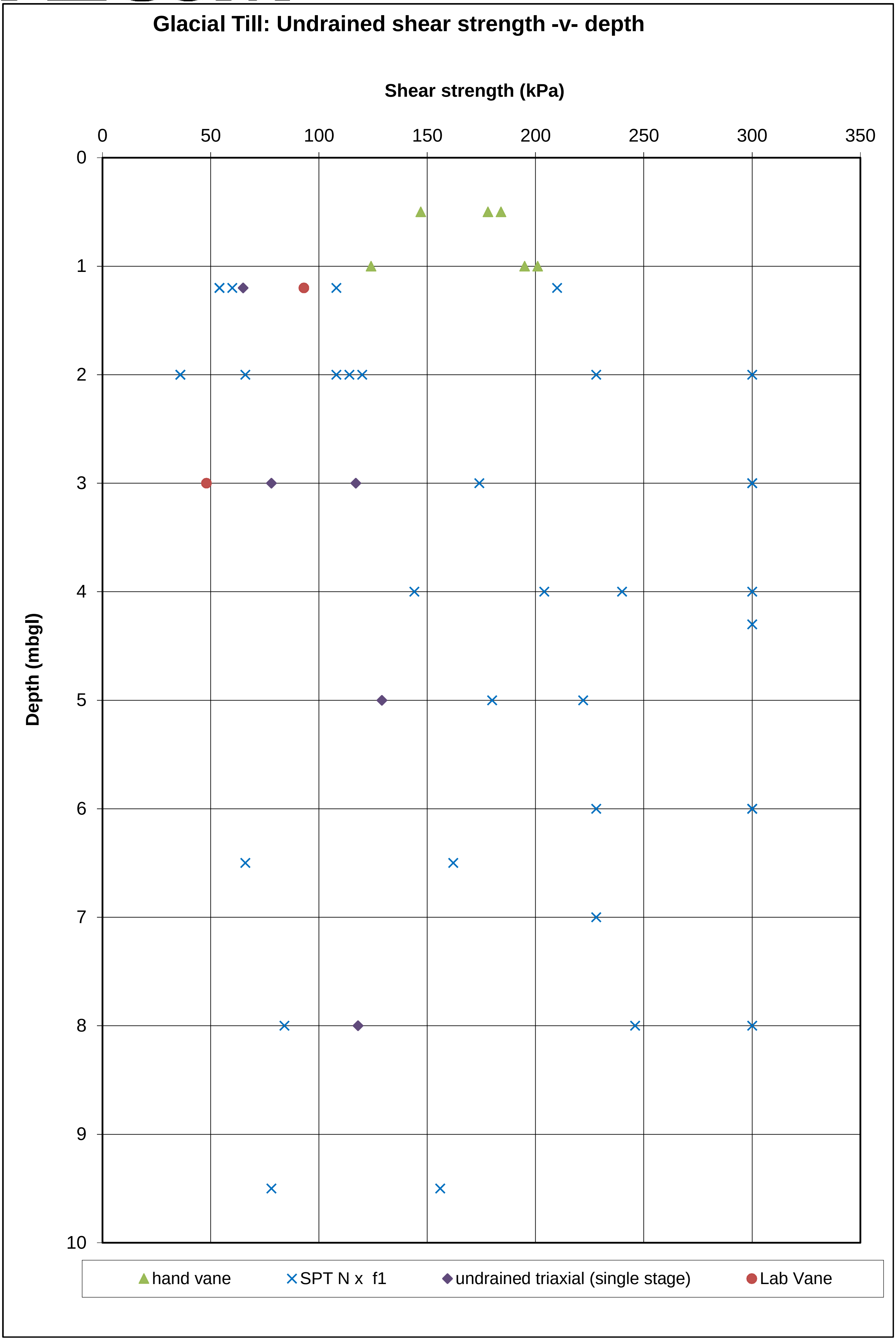
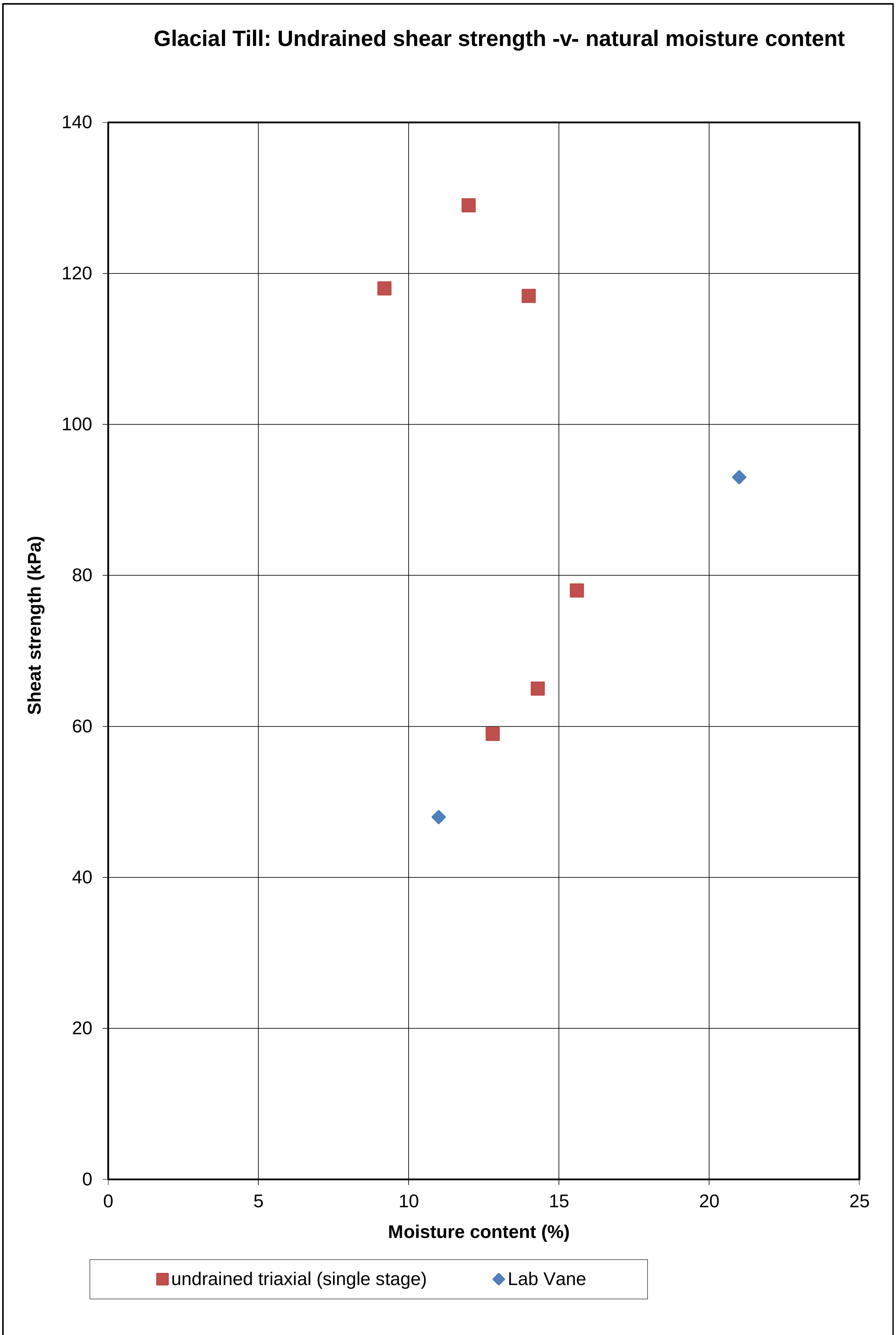


Figure R9.GT.7


Brown Dublin Boulder Clay SPT N -v- depth
SPT N
0
5
10
15
20
25
30
35
40
45
50
55
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Depth (mbgl)


Black Dublin Boulder Clay SPT N -v- depth
SPT N
0
5
10
15
20
25
30
35
40
45
50
55
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
Depth (mbgl)


Glacial Till: Undrained shear strength -v- depth
Shear strength (kPa)
0
50
100
150
200
250
300
350
Depth (mbgl)
0
1
2
3
4
5
6
7
8
9
10
hand vane
SPT N x f1
undrained triaxial (single stage)
Lab Vane


Glacial Till: Undrained shear strength -v- natural moisture content
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Sheat strength (kPa)
Moisture content (%)
undrained triaxial (single stage)
Lab Vane

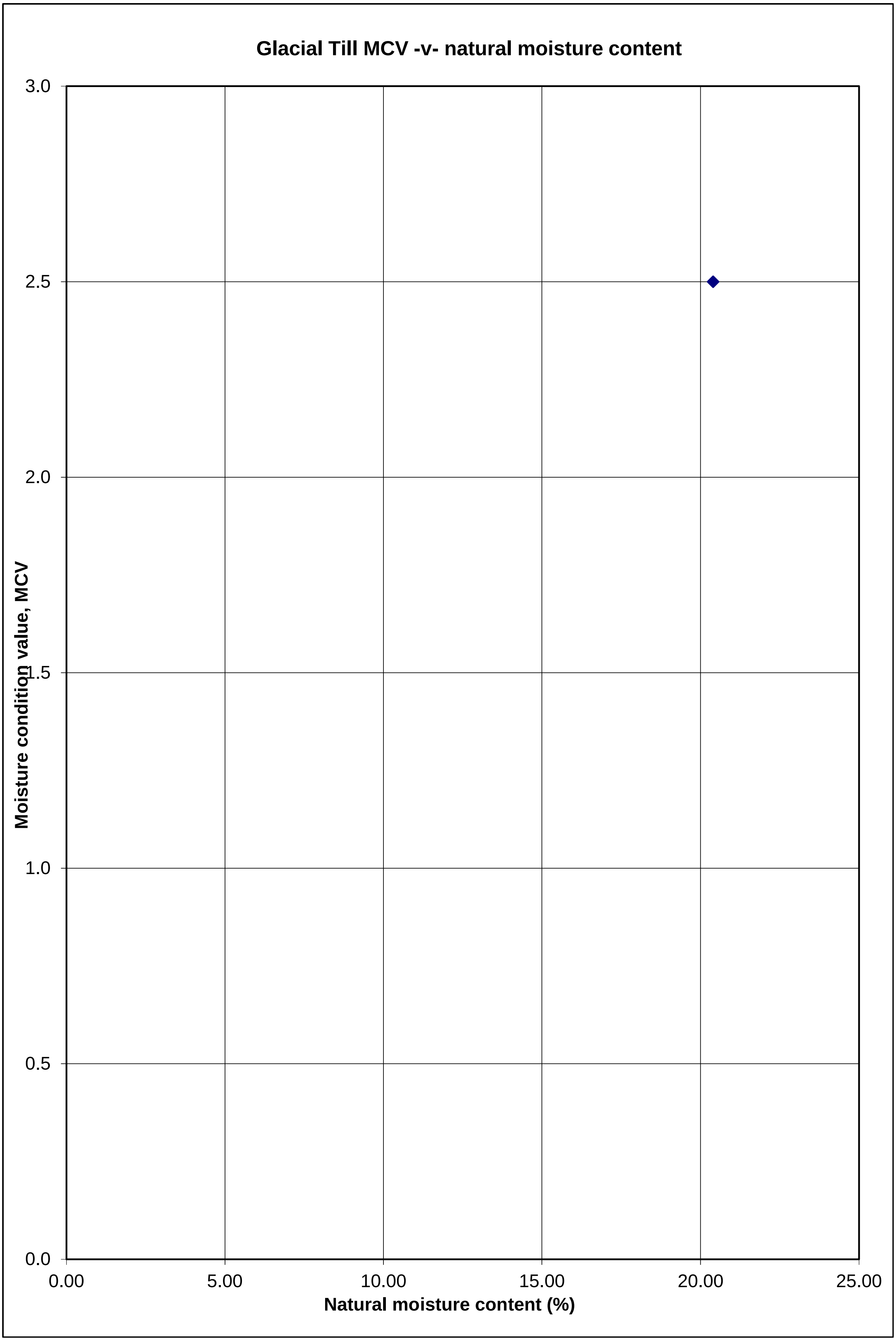
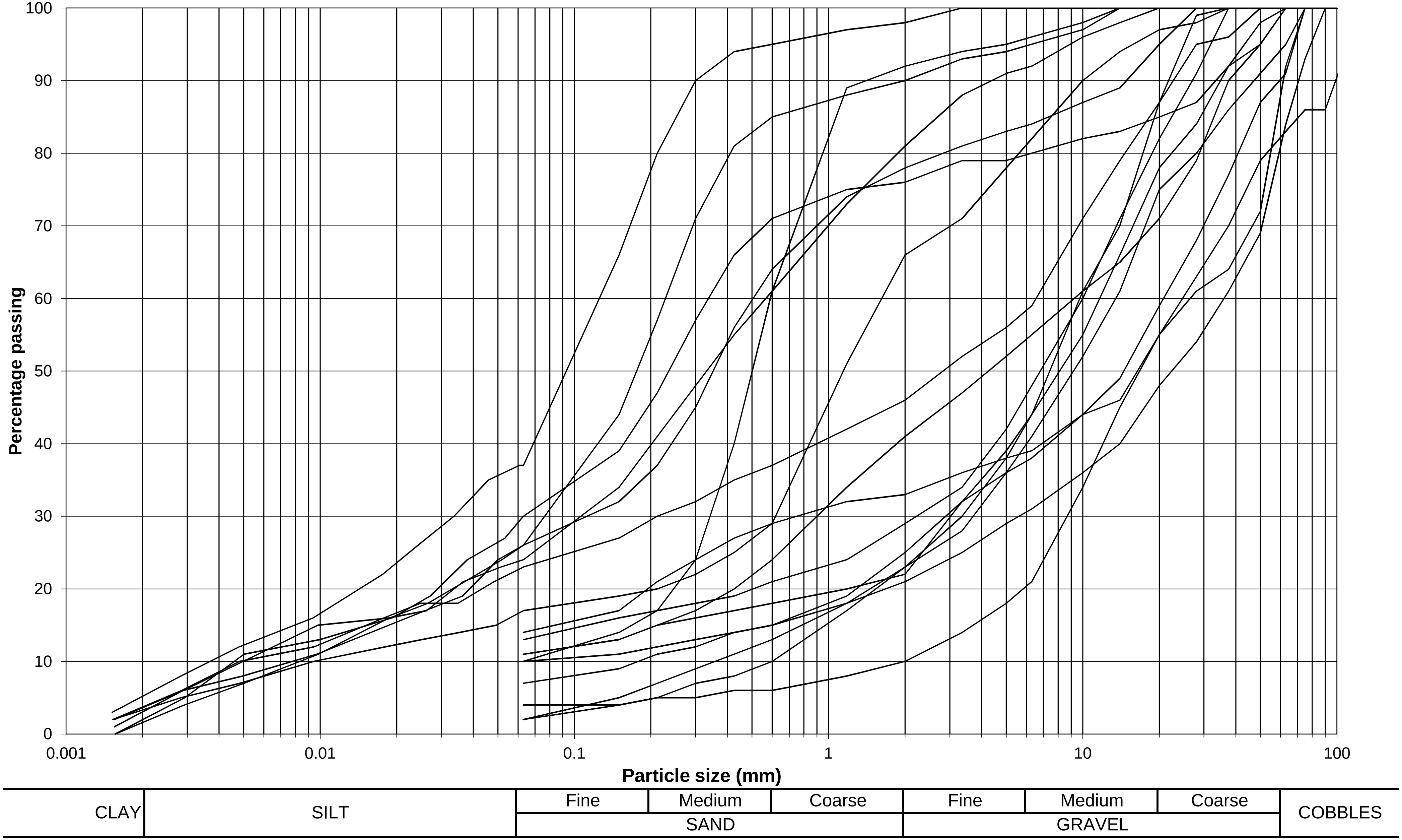
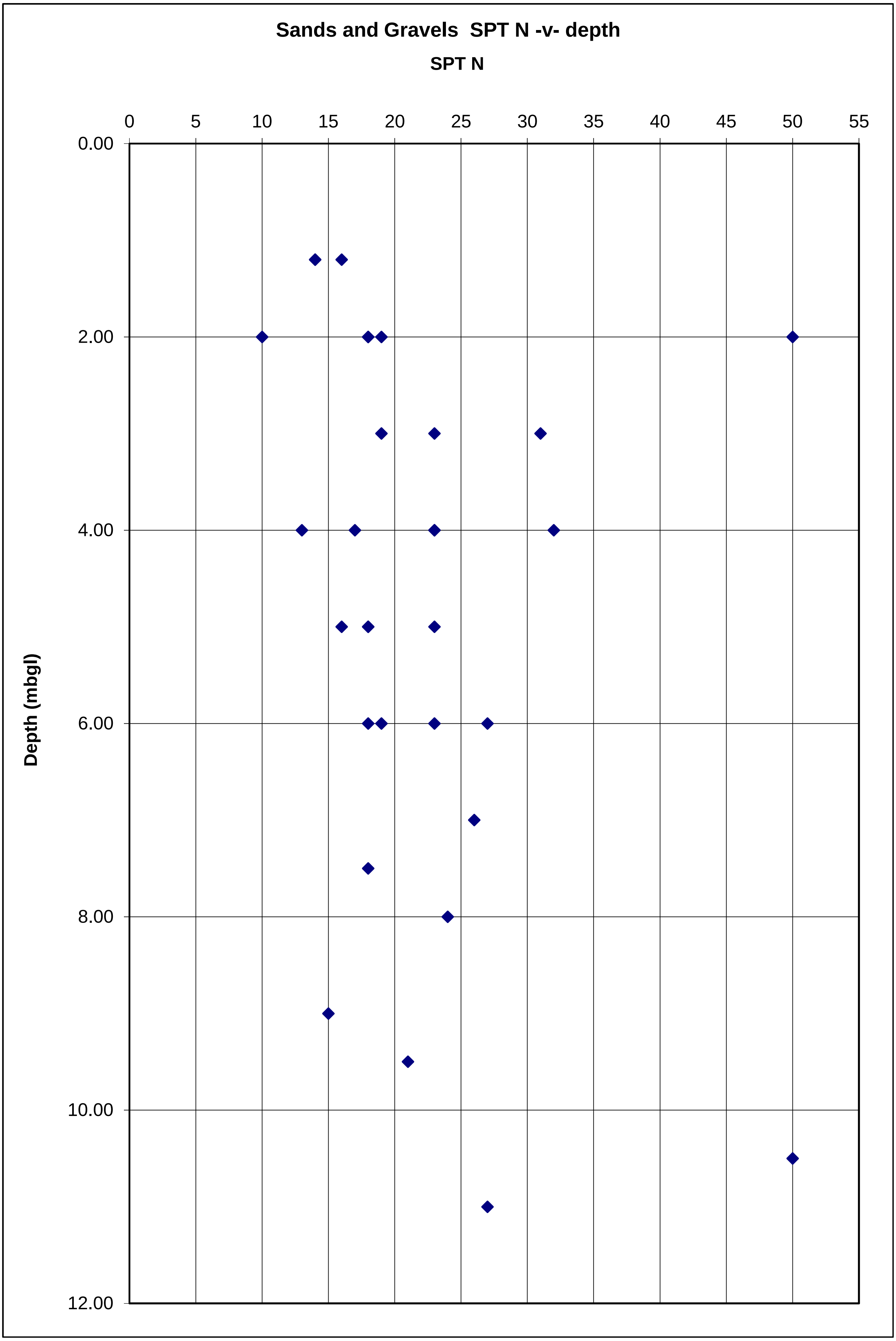
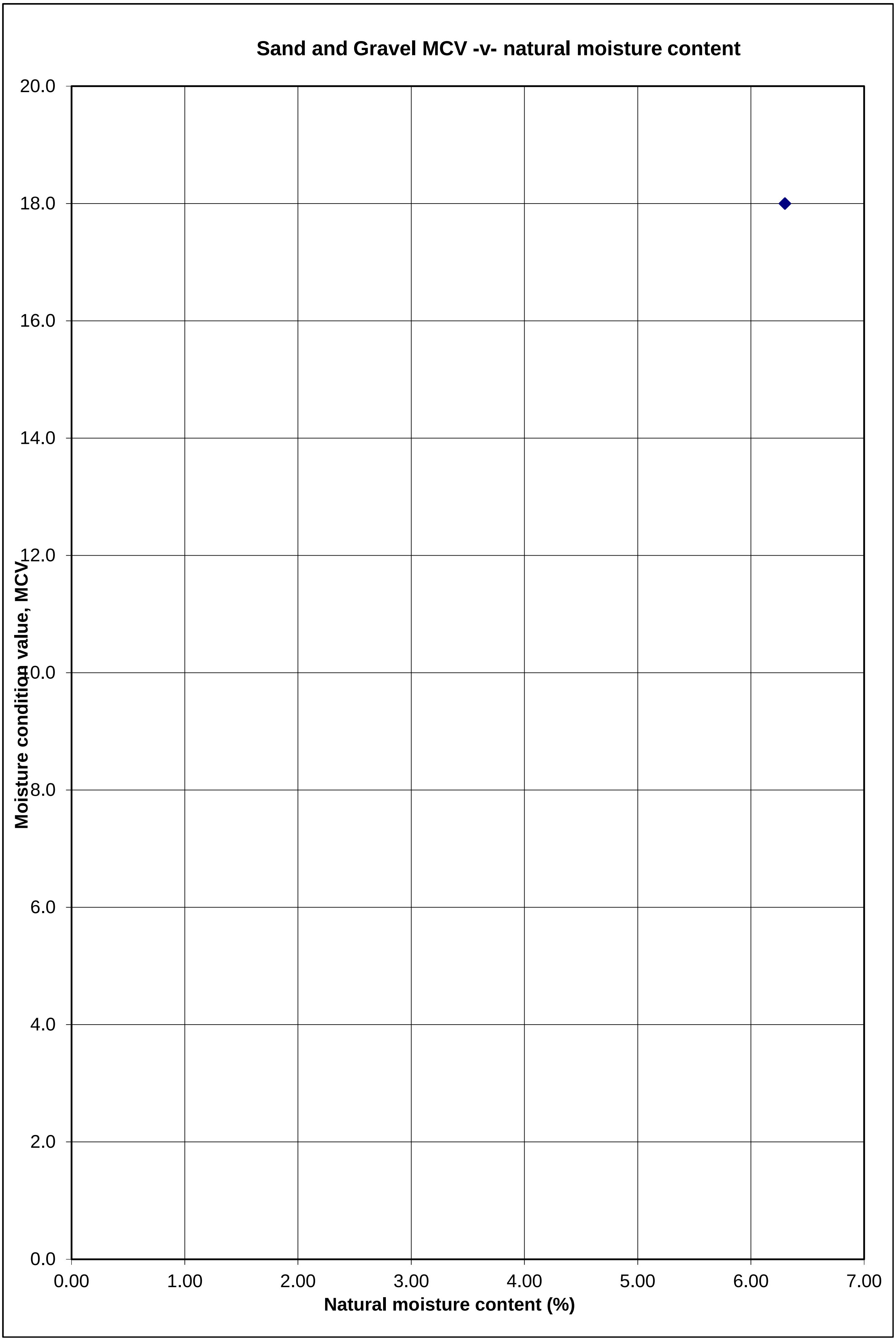


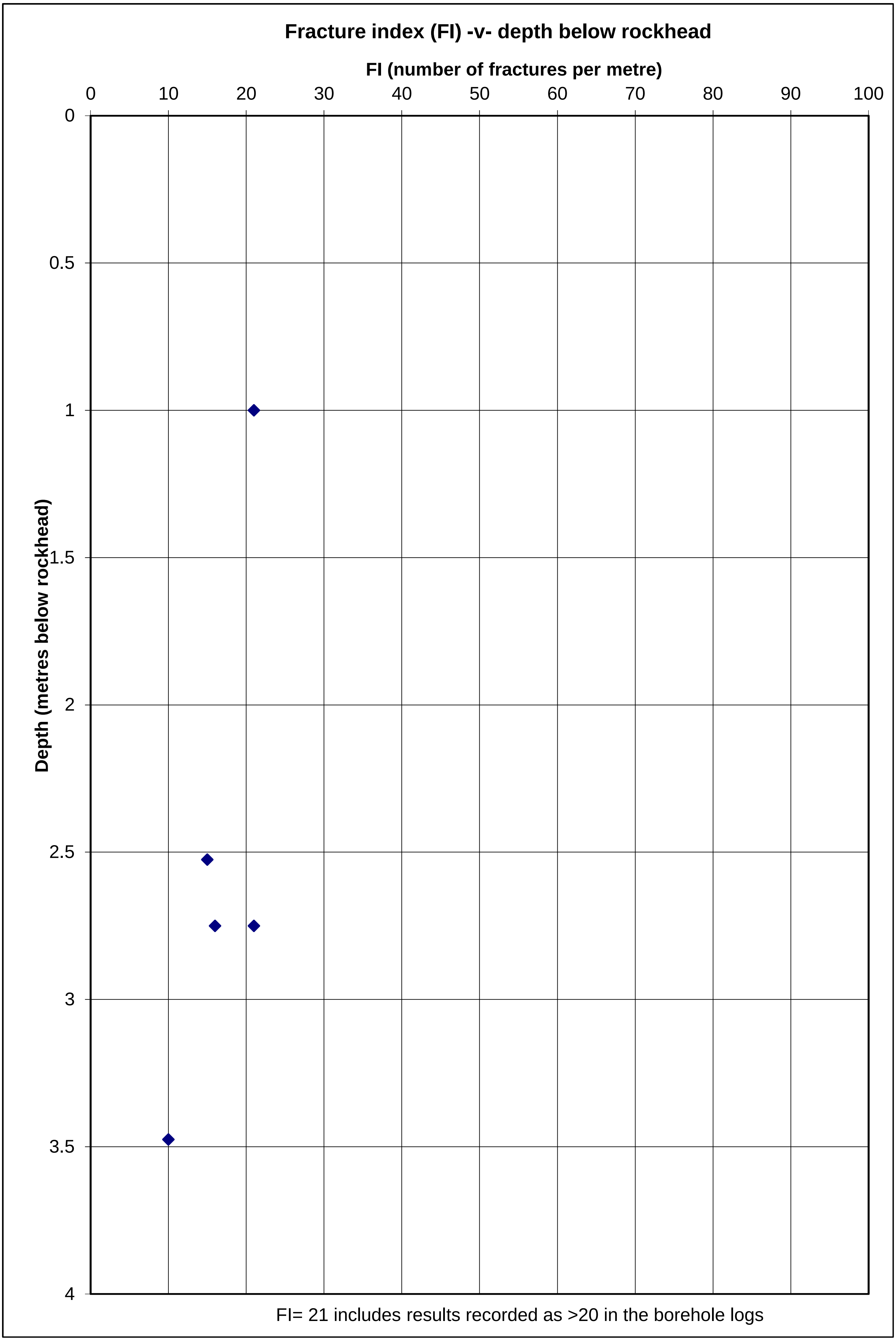
Figure R9.GT.12

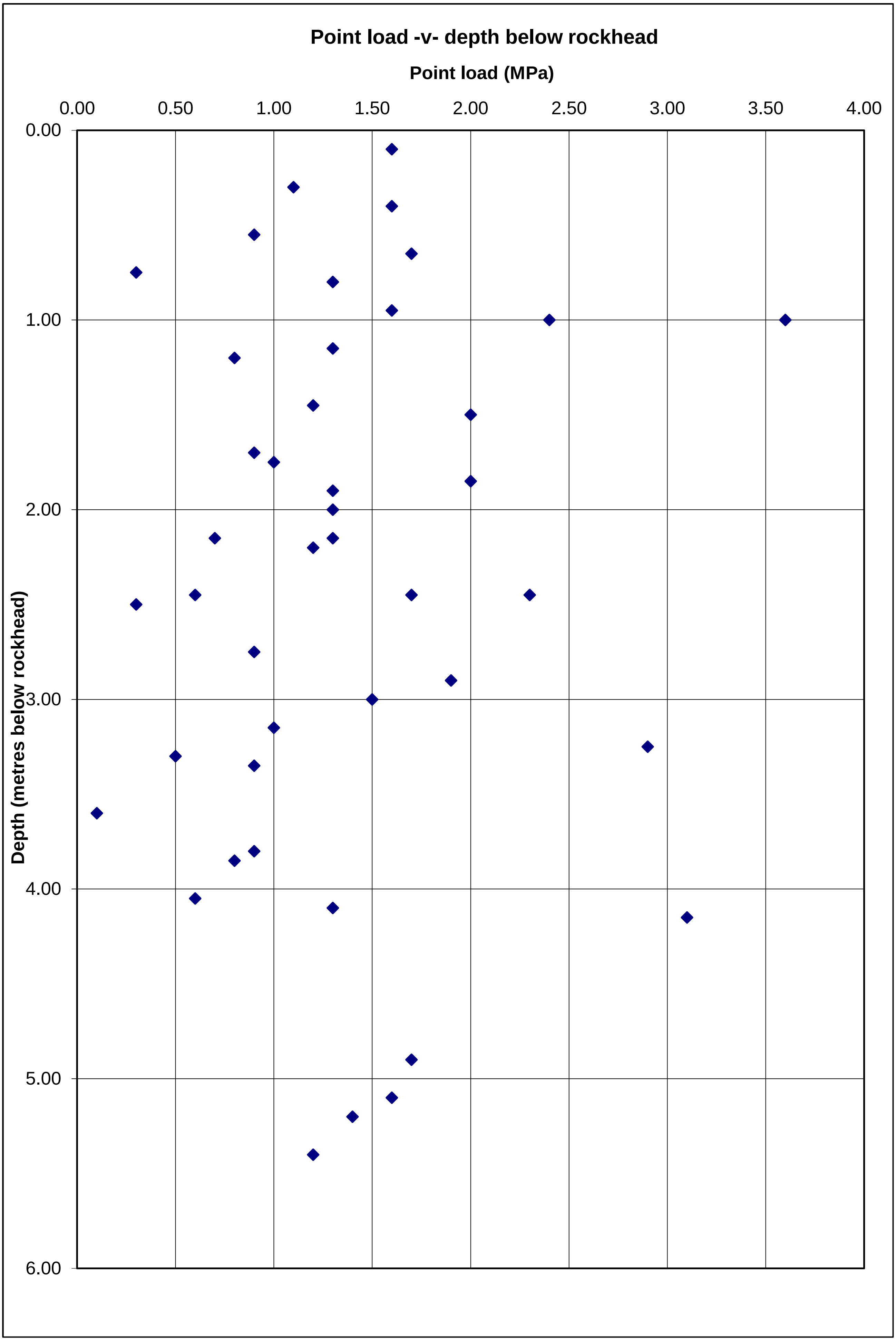


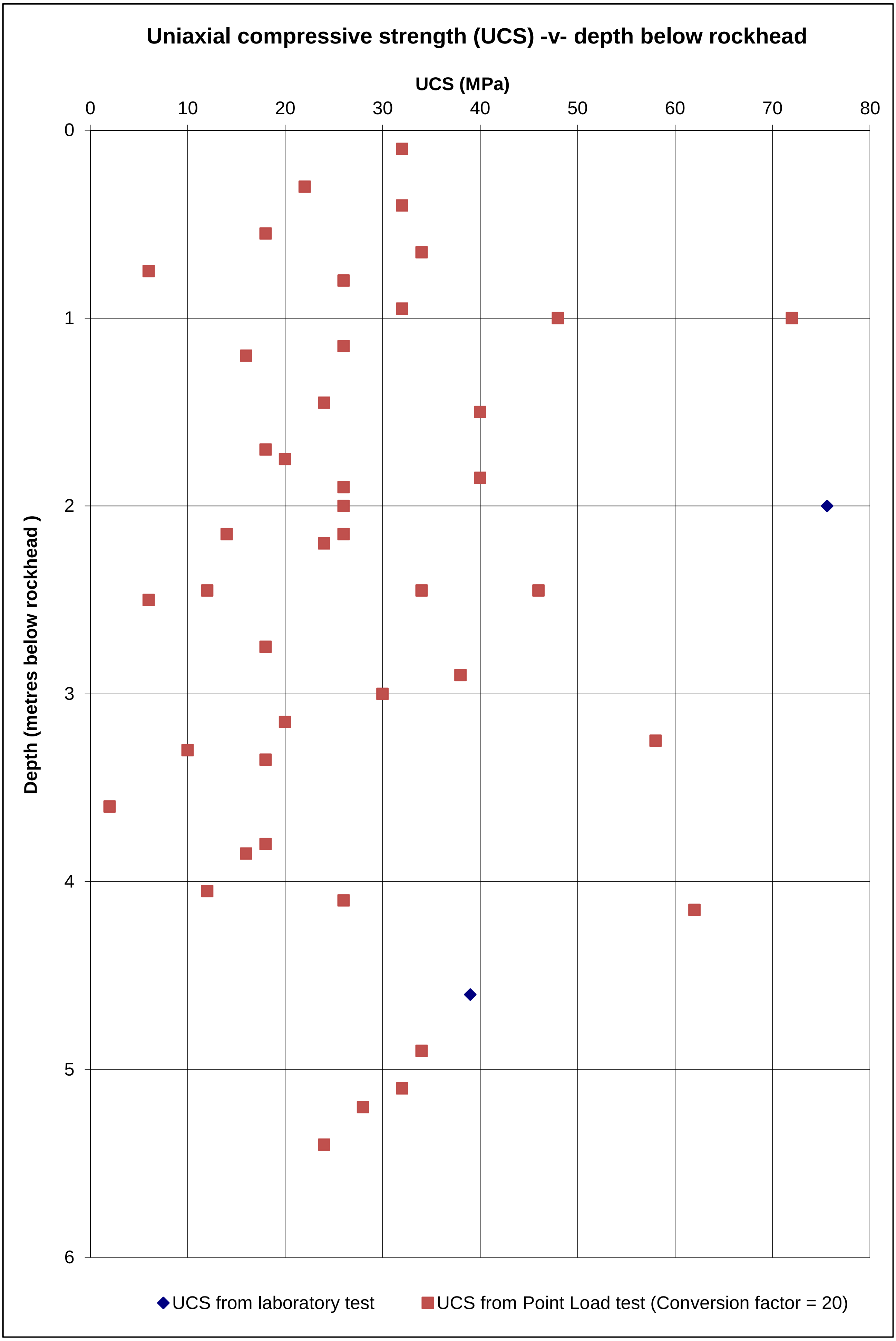
Sand and Gravel - particle size distribution

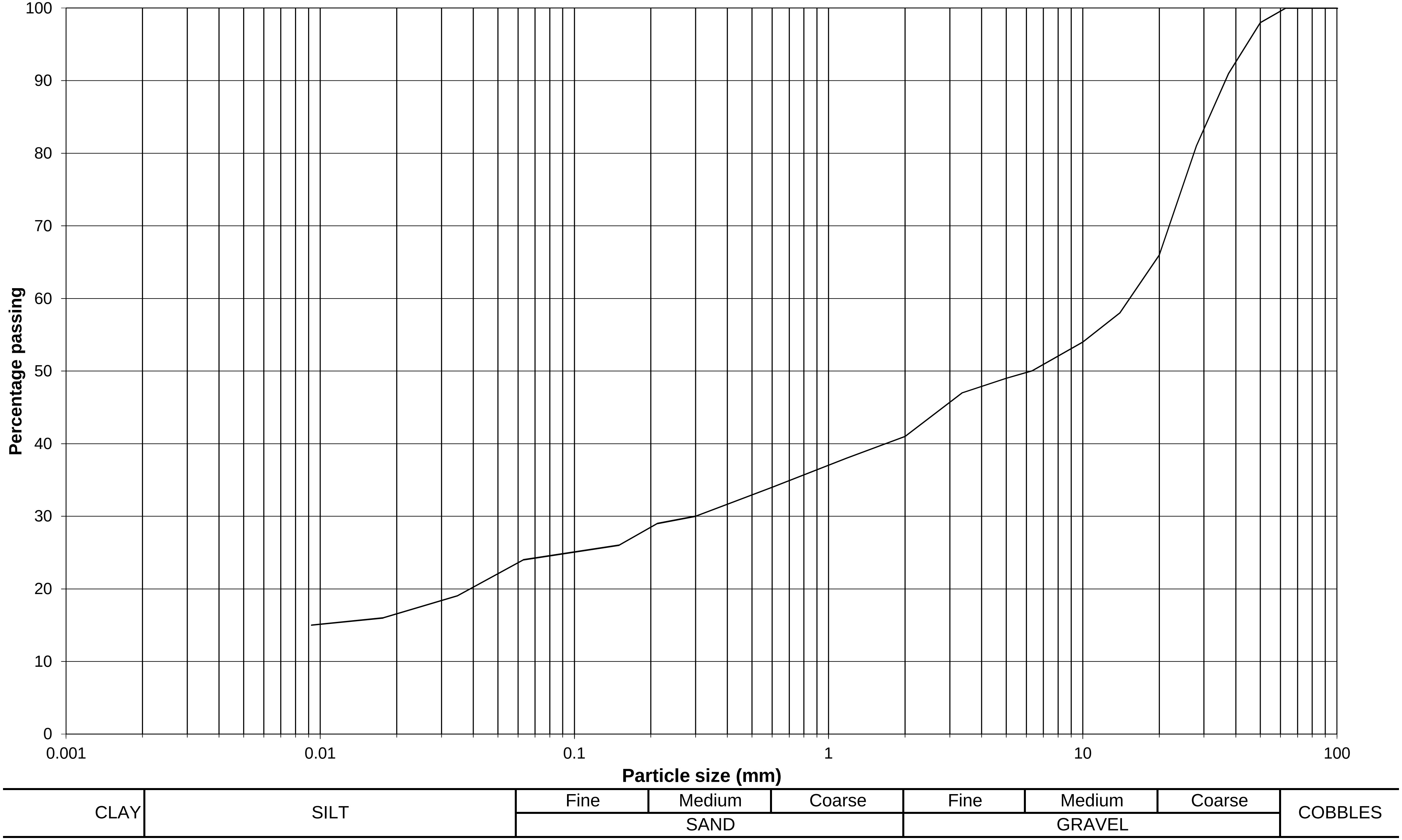

Sands and Gravels SPT N -v- depth
SPT N
0
5
10
15
20
25
30
35
40
45
50
55
0.00
2.00
4.00
6.00
8.00
10.00
12.00
Depth (mbgl)


Sand and Gravel MCV -v- natural moisture content
Moisture condition value, MCV
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Natural moisture content (%)


Fracture index (FI) -v- depth below rockhead
FI (number of fractures per metre)
0
10
20
30
40
50
60
70
80
90
100
Depth (metres below rockhead)
0
0.5
1
1.5
2
2.5
3
3.5
4
FI= 21 includes results recorded as >20 in the borehole logs


Point load -v- depth below rockhead
Point load (MPa)
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Depth (metres below rockhead)
0.00
1.00
2.00
3.00
4.00
5.00
6.00


Uniaxial compressive strength (UCS) -v- depth below rockhead
UCS (MPa)
0
10
20
30
40
50
60
70
80
Depth (metres below rockhead)
0
1
2
3
4
5
6
UCS from laboratory test
UCS from Point Load test (Conversion factor = 20)



Glacial Till- particle size distribution

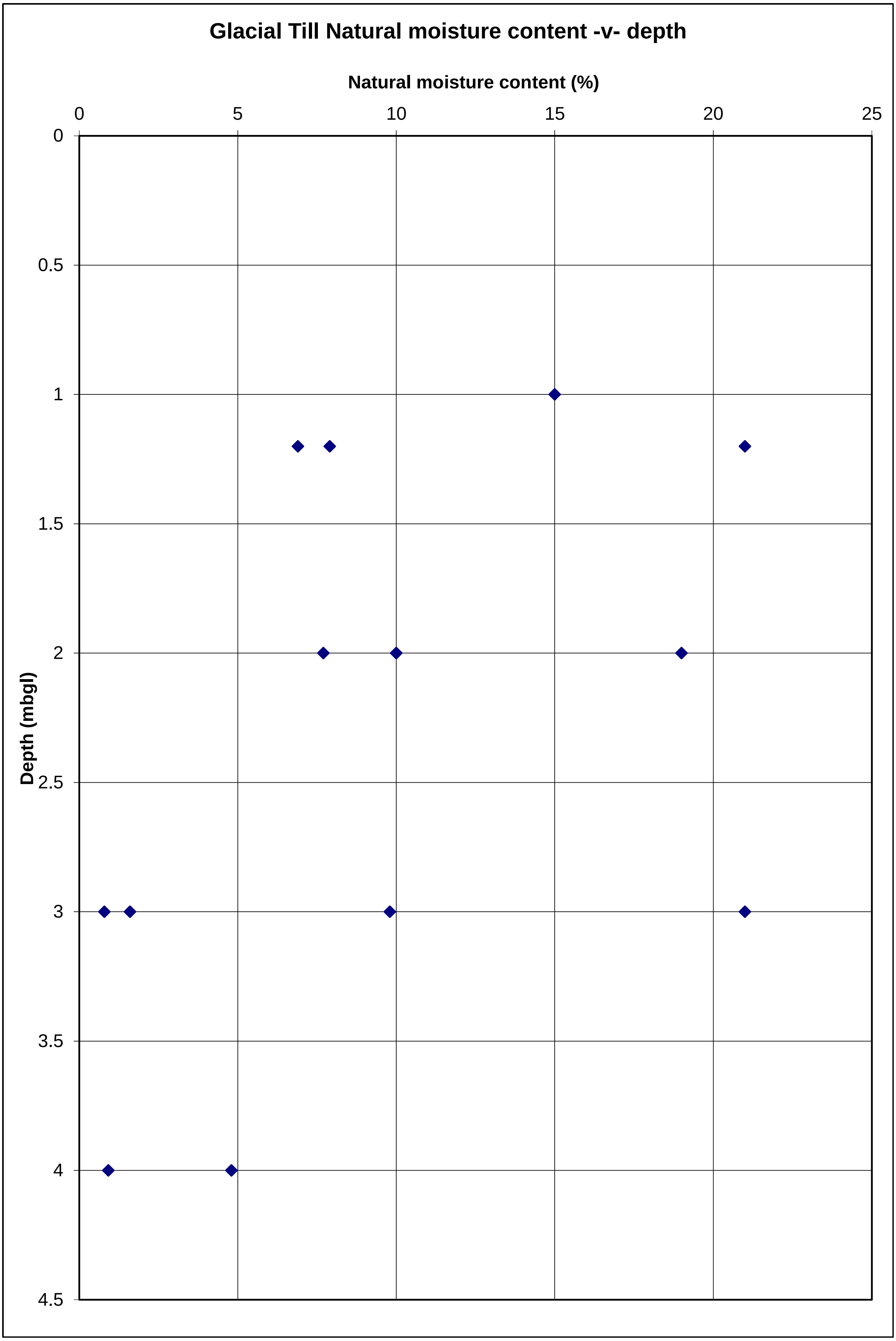
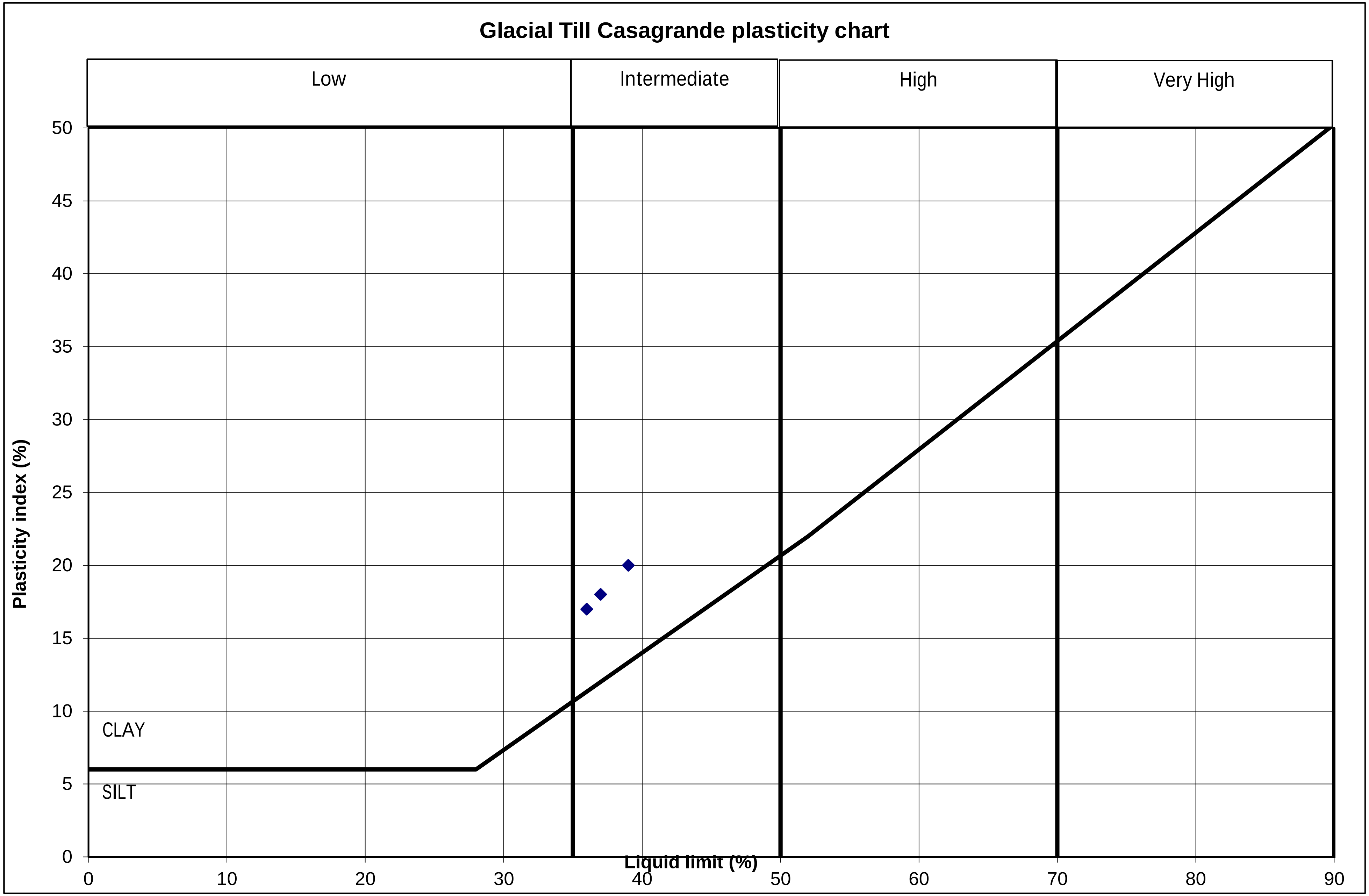
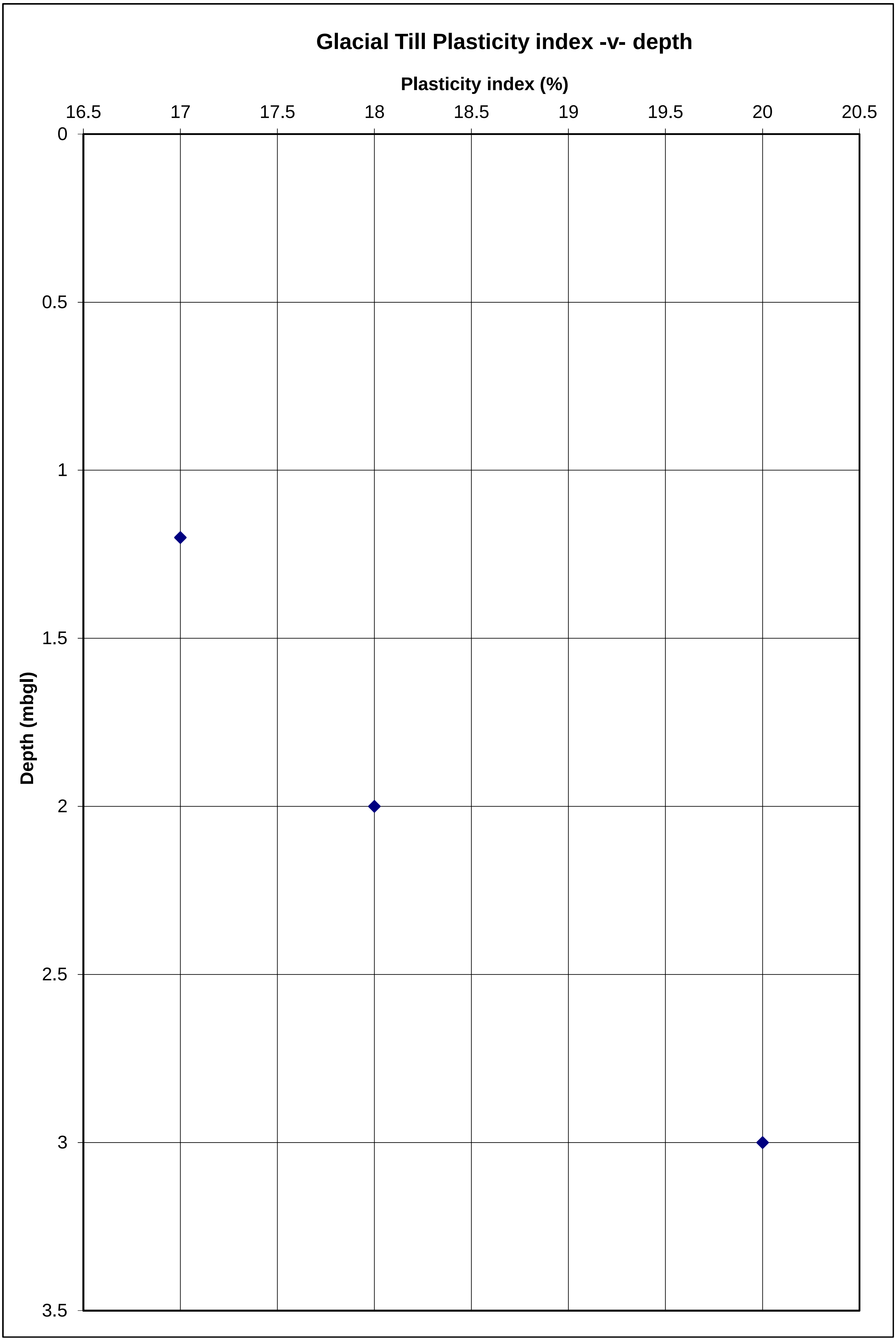
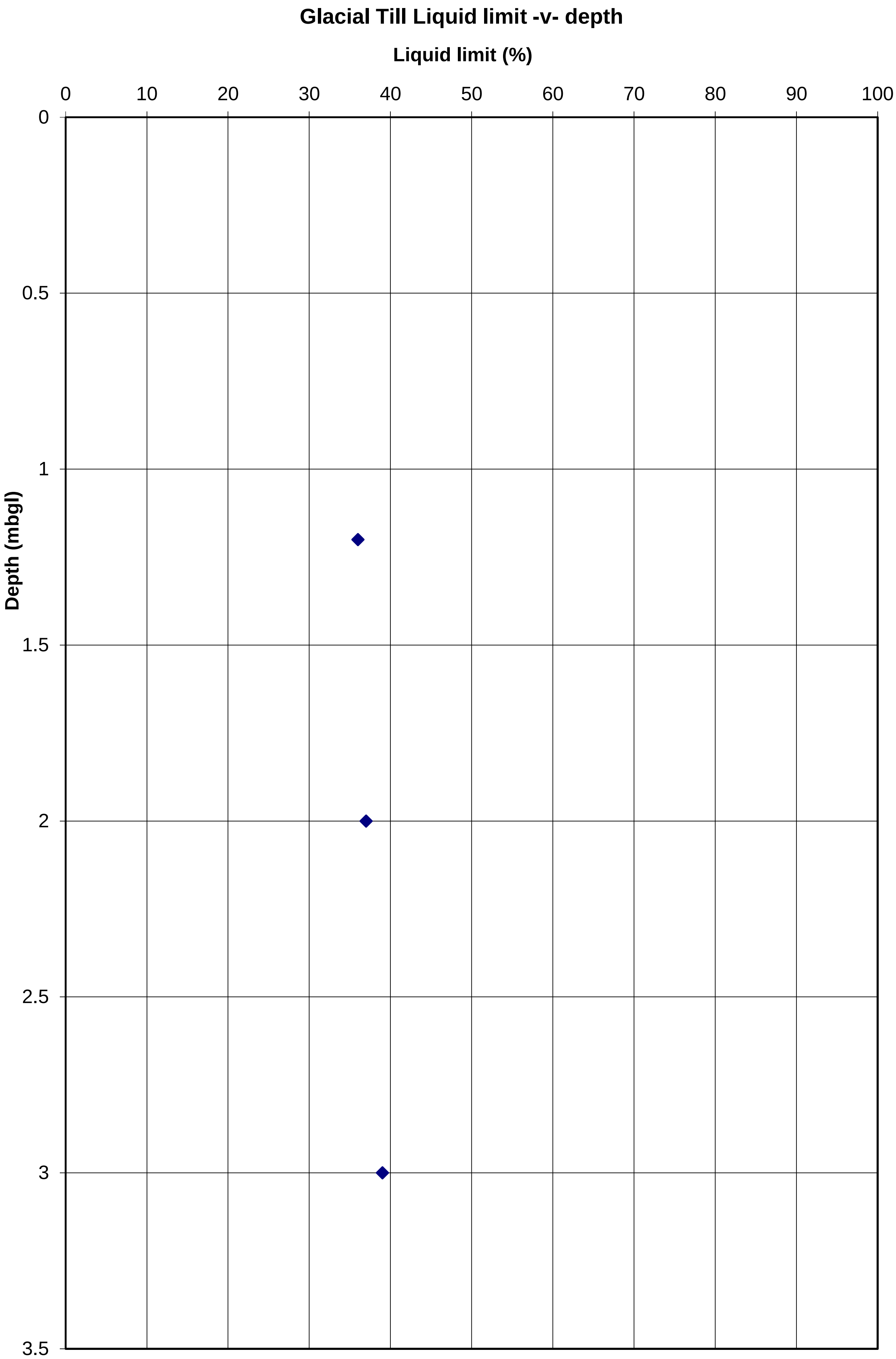
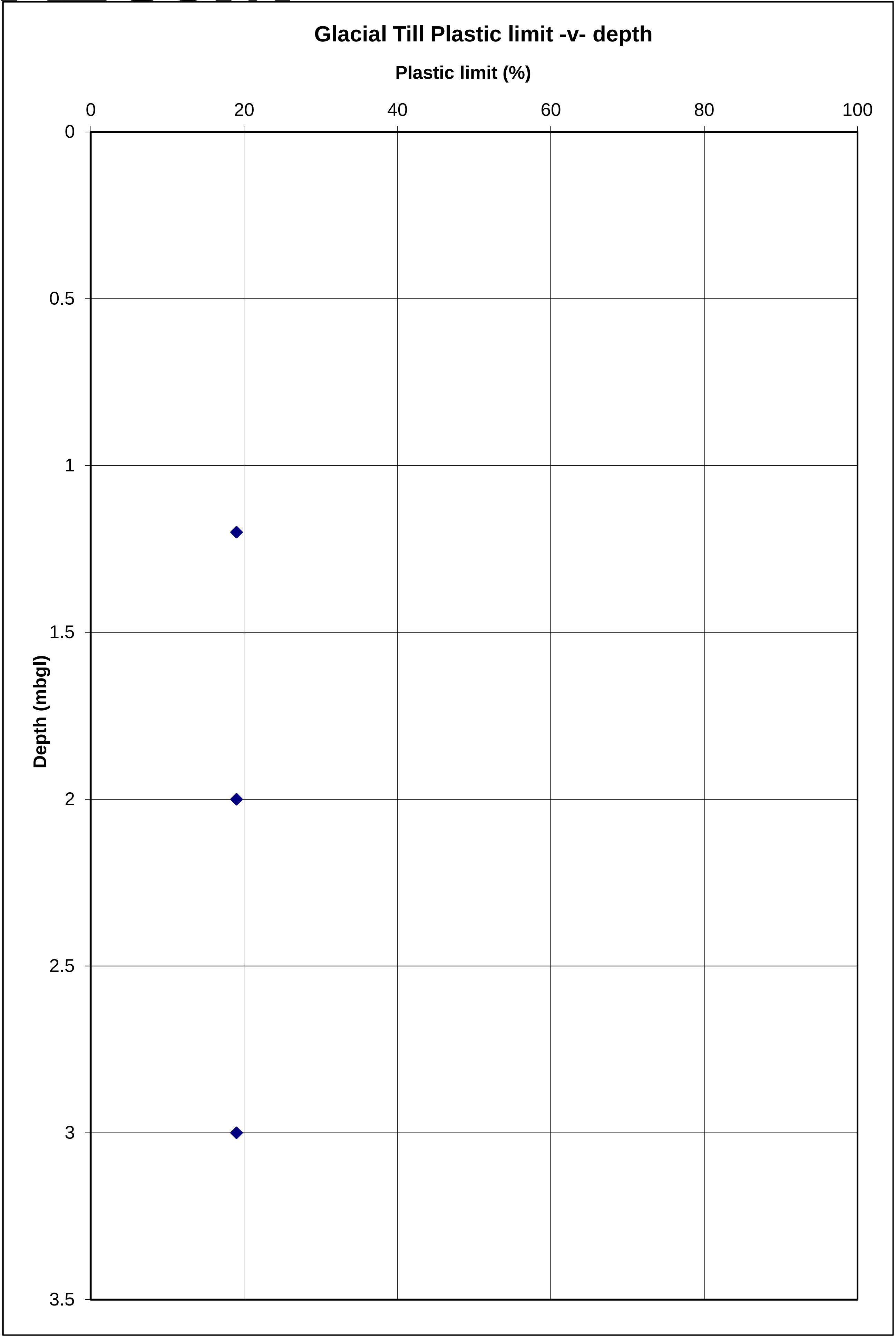


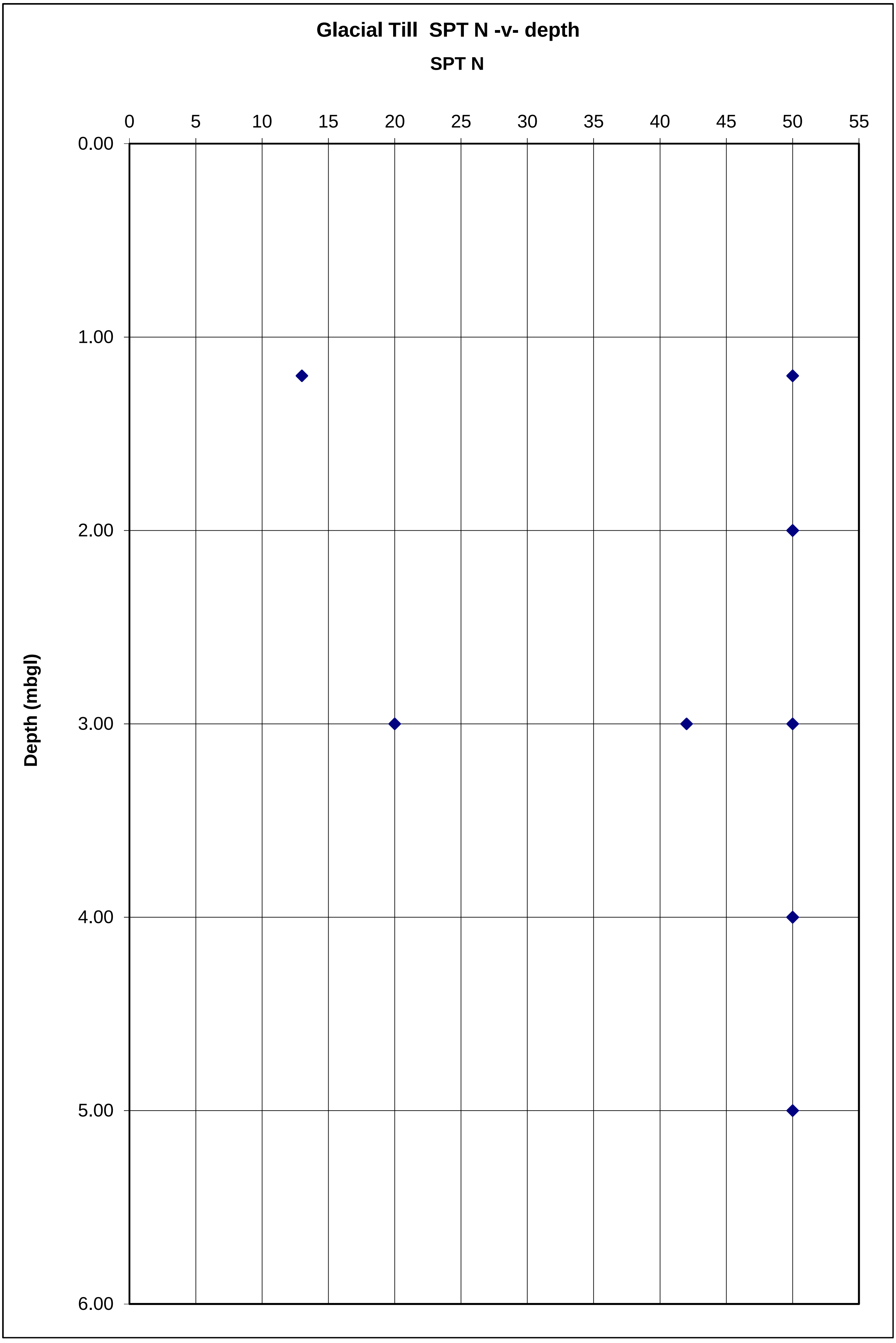
Figure R8.GT.2

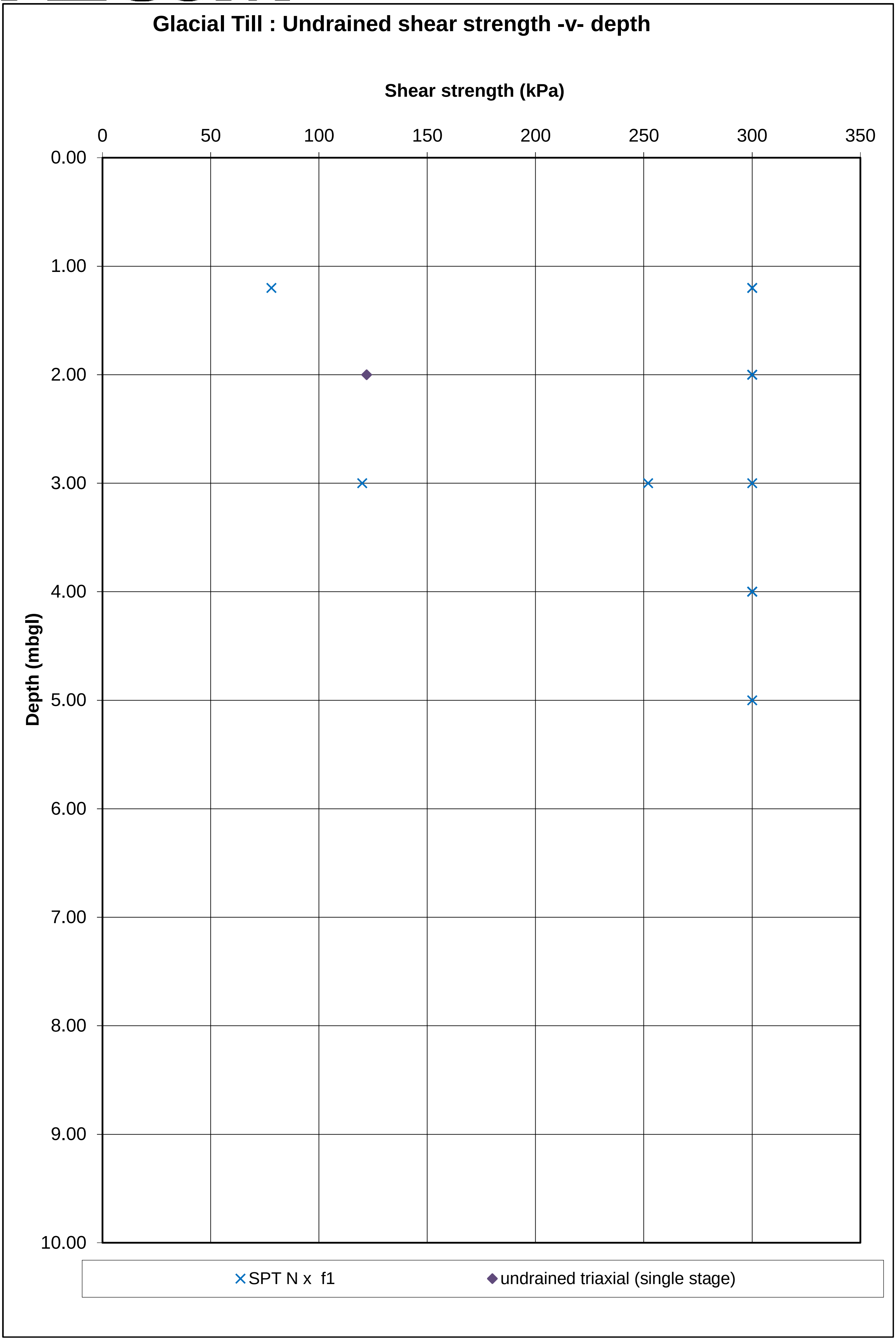

Glacial Till Casagrande plasticity chart
Low
Intermediate
High
Very High
Plasticity index (%)
Liquid limit (%)
CLAY
SILT
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80
90


Glacial Till Plasticity index -v- depth
Plasticity index (%)
16.5
17
17.5
18
18.5
19
19.5
20
20.5
Depth (mbgl)
0
0.5
1
1.5
2
2.5
3
3.5


Glacial Till Liquid limit -v- depth
Liquid limit (%)
0
10
20
30
40
50
60
70
80
90
100
Depth (mbgl)
0
0.5
1
1.5
2
2.5
3
3.5


Glacial Till Plastic limit -v- depth
Plastic limit (%)
0
20
40
60
80
100
Depth (mbgl)
0
0.5
1
1.5
2
2.5
3
3.5


Glacial Till SPT N -v- depth
SPT N
0
5
10
15
20
25
30
35
40
45
50
55
0.00
1.00
2.00
3.00
4.00
5.00
6.00
Depth (mbgl)


Glacial Till : Undrained shear strength -v- depth
Shear strength (kPa)
0
50
100
150
200
250
300
350
Depth (mbgl)
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
SPT N x f1
undrained triaxial (single stage)

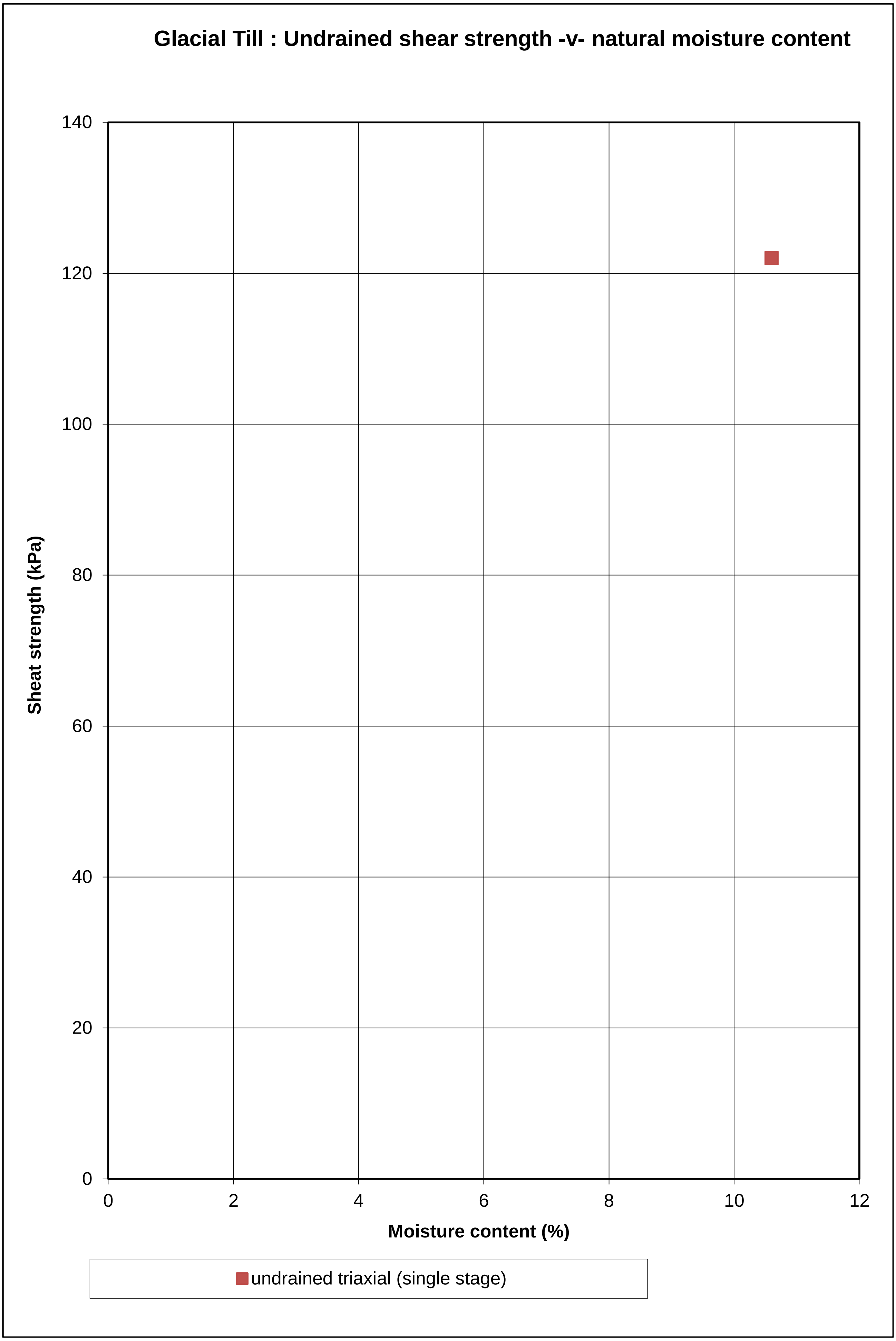
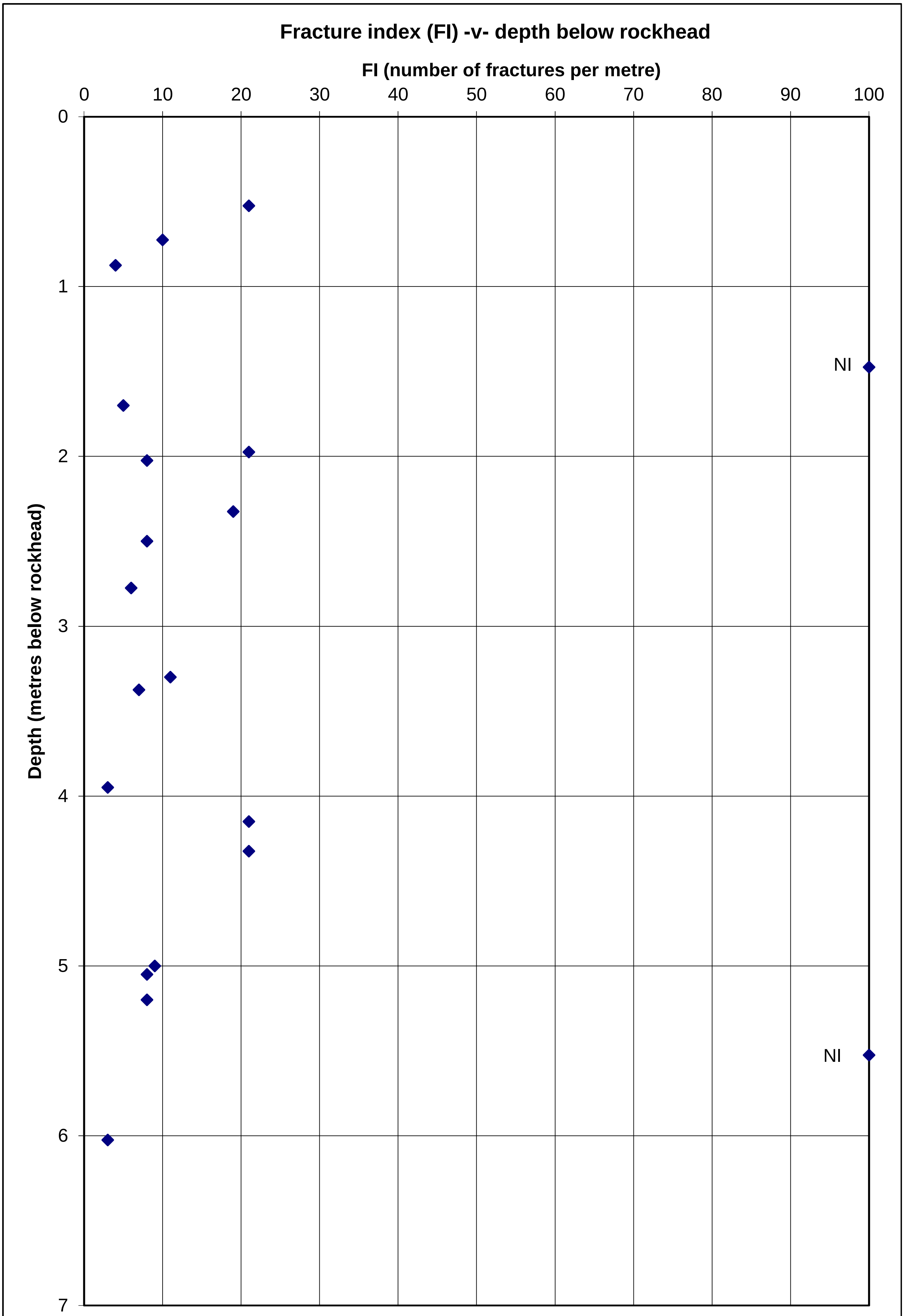


Figure R8.GT.9



FI= 21 includes results recorded as >20 in the borehole logs

FI= 100 includes results recorded as Non - Intact in the borehole logs

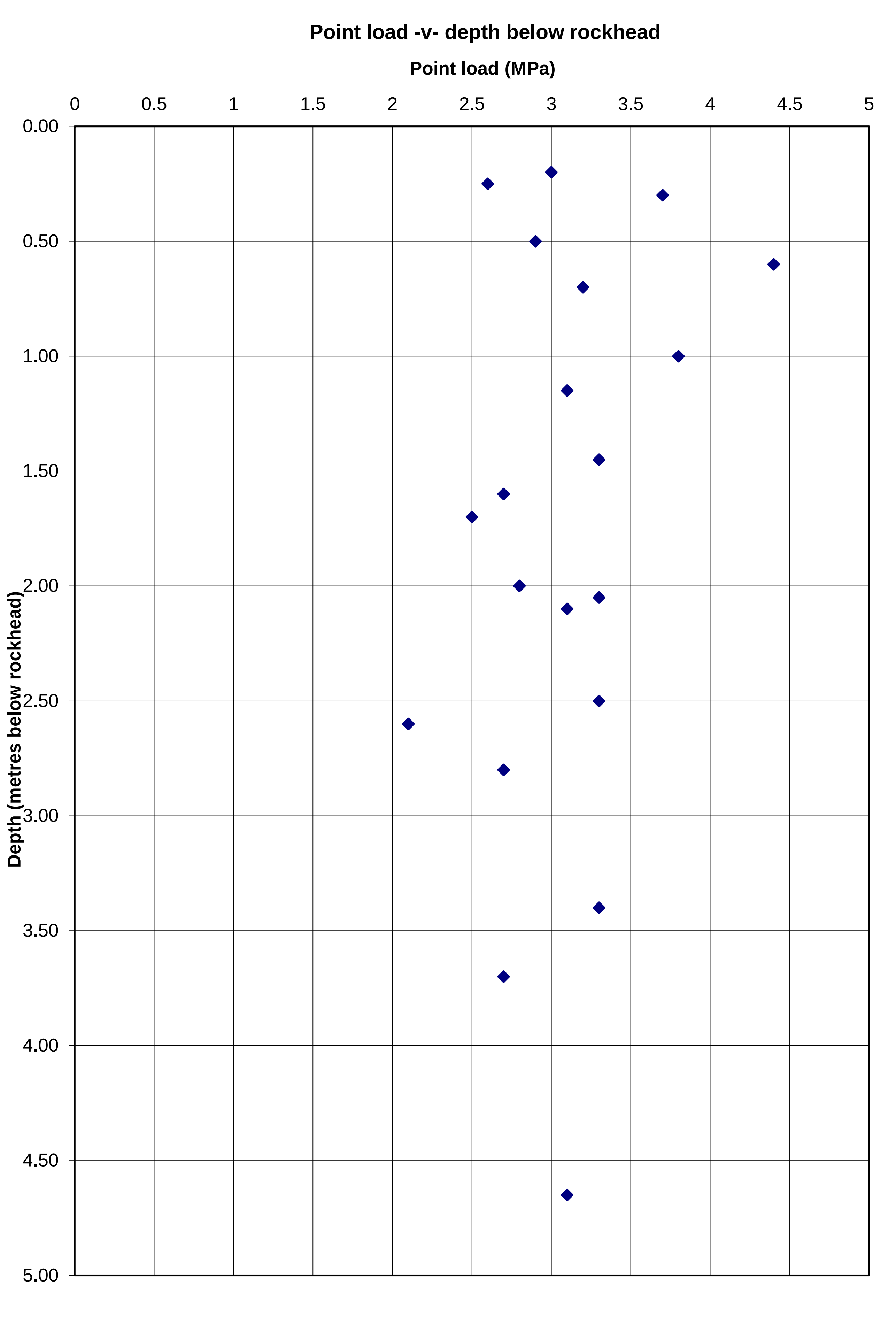


Figure R8.ROCK.2

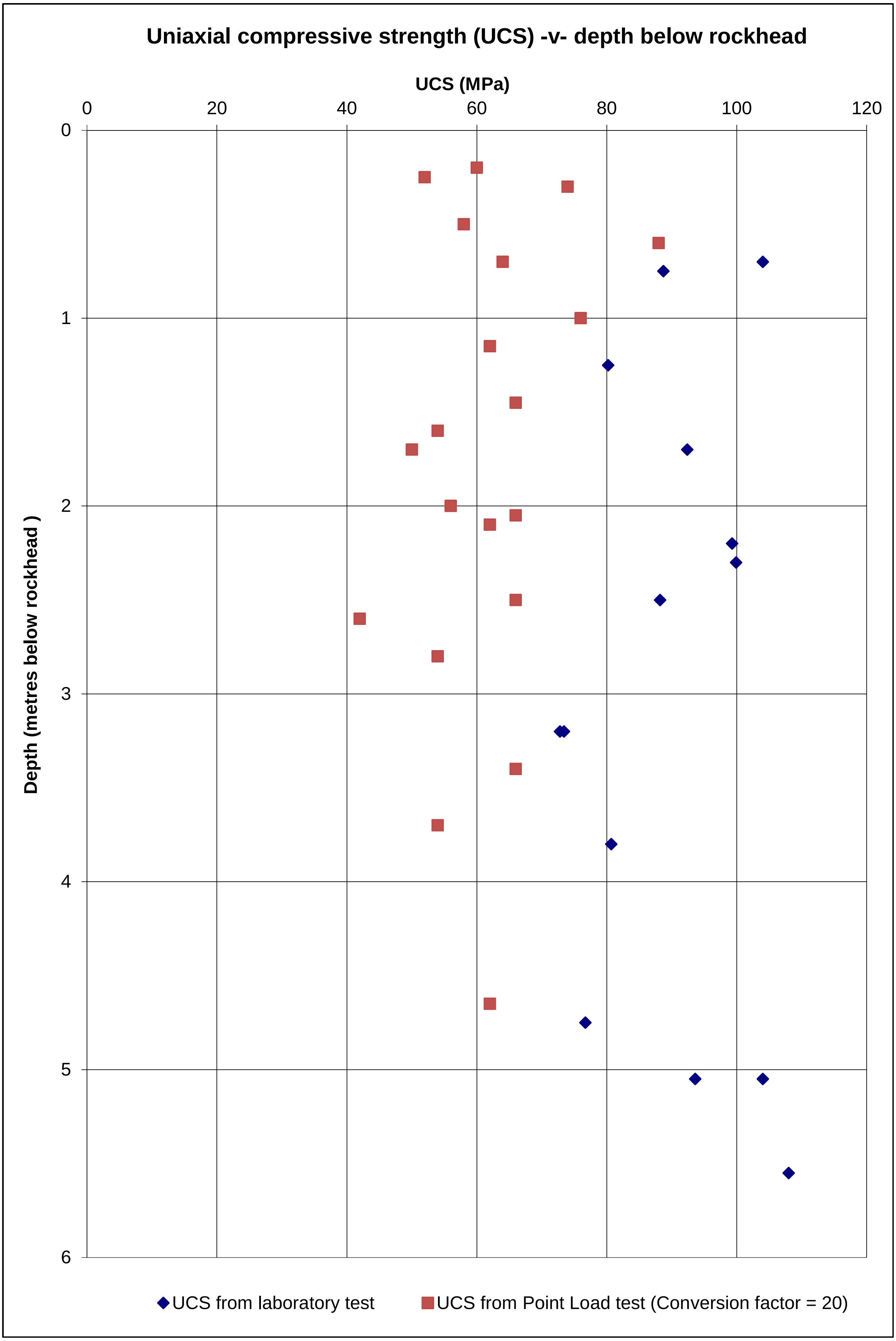


Figure R8.ROCK.3