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Rosemerryn Subdivision, Lincoln

Stages 19 to 24 Geotechnical Investigation Report

Fulton Hogan Land Development Limited

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Appendices

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1 Executive Summary

Introduction

Fulton Hogan Land Development Limited is proposing to subdivide approximately 23ha area of rural land in Lincoln, for Stages 19 to 24 of the Rosemerryn residential subdivision. The site is located on the eastern side of the wider Rosemerryn Subdivision that is currently being developed and will comprise approximately 240 residential lots with reserves and roading.

Fulton Hogan Land Development Limited (FHLD) has engaged Aurecon New Zealand Ltd (Aurecon) to undertake a geotechnical investigation and assessment for Stages 19 to 24 of the Rosemerryn Subdivision, which is continuation of our work on the wider site since 2005. The purpose of the investigation is to assess the suitability of the land for residential development to characterise the risk of liquefaction and lateral spreading to the development and to provide a report to support the resource consent application.

Geotechnical Investigations

The geotechnical investigations comprised a review of Environment Canterbury (ECan) well logs and previous geotechnical investigations undertaken across the site since 2011, Cone Penetration Tests (CPTs), piezometer installations and Multi-channel Analysis of Surface Waves (MASW) soundings.

Based on the results of our geotechnical investigations, the ground conditions across the site can separated into three different ground profiles based on the depth to the underlying gravel. To the north, gravel is at relatively shallow depths of 2m or less, with the depth to gravel deepening towards the south. At the southern corner of the site the gravels are approximately 7m below ground level. The gravel is overlain by interbedded loose to medium dense Sands and Silty Sands, and firm to stiff Sandy Silts and Silts.

Piezometer readings indicate groundwater levels in the order of 1.4m to 1.5m depth, with the exception of BH203 adjacent to the stream, which indicated water at 1m depth. It is noted that groundwater levels will vary seasonally or following prolonged rainfall.

Liquefaction Assessment

A liquefaction assessment has been carried out at the site and the results indicate the following:

- Based on the O'Rourke et. al. (2012) PGA model the site has been "sufficiently tested" (MBIE Guidelines (2012)) as the median value for the PGA for the 4 September 2010 event exceeded 170% of the SLS PGA (i.e. 1.7 x 0.13g = 0.22g). Therefore, we have used the lack of ground damage observed at the site after the 4 September 2010 earthquake event to help calibrate our liquefaction assessment.
- The GNS Science report on liquefaction (GNS, 2012), a review of aerial photography, and site observations made by Aurecon and Fulton Hogan staff confirms that there was no evidence of liquefaction observed at the site after the 4 September 2010 Darfield earthquake, or any subsequent earthquakes part of the Canterbury Earthquake Sequence.
- In the northern part of the site, liquefaction induced settlements and damage are likely to be minimal and consistent with a TC1 classification while elsewhere the calculated liquefaction induced settlements and assessed ground damage are consistent with TC2 and TC3 classifications. However, when compared to actual site performance, the level of calculated damage is well overstated, as the back analysis indicates that moderate to major ground damage should have occurred when only limited to minor damage was observed at and around the site.

- The liquefaction induced lateral spreading potential is considered to be minor.
- Based on our liquefaction assessment, and the limited evidence of ground damage, we infer that only minor to moderate land damage from liquefaction is possible in future large earthquakes at parts of the site.

Technical Category Classification

Based on our liquefaction assessment we consider that the northern part of Stage 19 to 24 is consistent with the classifications of **Technical Category 1 (TC1)** and the remainder of the site is consistent with the classification of **Technical Category 2 (TC2)**. Across Stages 19 to 24 future land damage from liquefaction is unlikely in the Technical Category 1 area, and possible in the Technical Category 2 area in future large earthquakes. The locations of the Technical Category zones are shown on see Figure 11 in Appendix A.

Bearing Capacity

Based on the available investigation logs it is unlikely that shallow bearing for a typical house foundation of 300kPa ultimate bearing capacity will be achieved. Therefore "good ground" as per New Zealand Standards Timber Framed Buildings (NZS3604:2011) and Concrete Masonry Buildings Not Requiring Specific Engineering Design (NZS4229:1999) will not be met at this site and specifically designed foundations will be required based on the building consent investigations.

Therefore, irrespective of any potential liquefaction risk at the site, typical light weight timber framed or masonry houses (which would generally be designed within the guidelines of NZS3604:2011 or NZS4229:1999) will require specific foundation investigation and design (which are outside the scope of this report). We believe, that TC2 enhanced slab foundations will be suitable for soils with bearing capacities of 200kPa or more. Where lower bearing capacities are encountered shallow foundations can be specifically designed to ensure deformations are within acceptable limits. Based on our experience we believe that TC2-type enhanced slab foundations or robust rib rafts will be suitable for the lower bearing capacity soils. These foundation types will also mitigate the impact from shallow liquefaction induced land damage.

Site specific testing (including hand augers and DCPs) will be required on all lots to confirm the actual ground conditions and to determine available bearing capacities.

RMA Section 106 Assessment

A risk assessment approach has been undertaken on the significant geotechnical hazards that may affect the site (see Appendix I). Based on this assessment we consider that there are no significant geotechnical hazards at the site other than the potential for earthquake induced soil liquefaction. However, provided that the geotechnical recommendations provided within this report are followed, and the appropriate engineering measures are implemented, then we consider that the development is unlikely to be affected by significant geotechnical hazards nor will the development worsen, accelerate or result in material damage. **Therefore, from a geotechnical perspective we consider that the residential subdivision development will comply with the requirements of RMA Clause 106.**

The geotechnical investigations were aimed at assessing the site for geotechnical suitability for subdivision into residential lots with associated access roads and rights-of-way. Detailed design of house foundations is not part of this report and will need to be undertaken by the individual lot owner. This report shall be read as a whole and our limitations are provided in Section 8.

2 Introduction

Fulton Hogan Land Development Limited is proposing to subdivide approximately 23ha area of rural land in Lincoln, for Stages 19 to 24 of the Rosemerryn residential subdivision. The site is located on the eastern side of the wider Rosemerryn Subdivision that is currently being developed and will comprise approximately 240 residential lots with reserves and roading.

Fulton Hogan Land Development Limited (FHLD) has engaged Aurecon New Zealand Ltd (Aurecon) to undertake a geotechnical investigation and assessment for Stages 19 to 24 of the Rosemerryn Subdivision, which is continuation of our work on the wider site since 2005. The purpose of the investigation is to assess the suitability of the land for residential development, and to characterise the risk of liquefaction and lateral spreading to the development. The scope of the works undertaken was as follows:

- A detailed desk study of readily available geological and geotechnical information available for this site.
- A site walkover by a Senior Engineering Geologist.
- Review the existing geotechnical work carried out in the area by Aurecon.
- Undertake further geotechnical investigations comprising of fifteen cone penetration tests, installation of five piezometers and MASW soundings.
- A liquefaction analysis using latest MBIE and NZGS Guidelines to identify the liquefaction potential of the underlying natural soils and to confirm the technical categories across the site based on the liquefaction assessment.
- Provide recommendations on potential liquefaction remediation options for the site.
- Provide recommendations for further testing (if required).
- Assess the site against Section 106 of the Resource Management Act (RMA).
- Prepare a geotechnical investigation report for Rosemerryn Subdivision Stages 19 to 24.

This geotechnical report presents the results of our geotechnical investigations and assessment, confirms the suitability of the land for residential development, as well providing recommendations for site development.

Our work has been carried out under the existing ACENZ/IPENZ Short Form Agreement between FHLD and Aurecon, as per Aurecon's fee proposals dated 24 April 2018. Approval to proceed was given by Greg Dewe on 25 April 2018.

Our limitations are provided in as Section 8 of this report and this report shall be read as a whole.

3 Site Conditions

3.1 Site Description

The site is located on the eastern side of the wider Rosemerryn subdivision (See Figures 1 and 2 in Appendix A and the Davie Lovell Smith drawing in Appendix B). The main site features are:

- The site has an approximate area of 23ha and has an irregular rectangular shape.
- The site topography is relatively flat with less than 1.5m height change across the area.
- The site is bound to the north by rural land, to the west by previous stages of the Rosemerryn Subdivision, to the south by Edward Street and to the east by Ellesmere Road.
- There is a small stream which runs through the Rosemerryn subdivision and divides the northern section from the southern section. The stream is approximately 0.5m deep and 2m to 3m wide with no significant bank.
- The site is currently being used for pastoral and crop farming and is covered in grass with localised shelter belts along the fence lines.
- Current drainage is inferred to be via direct soakage to the ground or via runoff to the small stream.

3.2 Regional Geology

The geology of the site is shown on the Geological and Nuclear Sciences Map 16, Geology of Christchurch area, scale 1:25,000 (compiled by Forsyth, Barrell and Jongens, 2008). The map indicates that the site is underlain by *grey river alluvium beneath plains of low-level terraces (Q1a).*

3.3 Seismicity

The GNS Science Active Fault System database (GNS, 2012a and 2012b) indicates that the site is within an area of recent seismic activity known as the Canterbury Earthquake Sequence (CES) and is approximately:

- 12km south-east of the eastern extension of the Greendale Fault, which was responsible for the Magnitude M_w7.1 Darfield (Canterbury) Earthquake on 4 September 2010.
- 16km south-west of the epicentre of the Magnitude M_w6.2 Christchurch Earthquake on 22 February 2011 (GNS, 2011b);
- 21km south-west of the epicentre of the Magnitude M_w6.0 major aftershock on 13 June 2011 (GNS, 2011b); and
- 23km south-west of the epicentre of the Magnitude M_w5.9 major aftershock on 23 December 2011 (GNS, 2011b).

Based on the O'Rourke et. al. (2012), as shown on the New Zealand Geotechnical Database, peak ground accelerations of approximately 0.33g were experienced at the site during the 4 September 2010 Darfield Earthquake.

3.4 Recorded Earthquake Damage

Based on the GNS report "*Review of liquefaction hazard information in eastern Canterbury, including Christchurch City and parts of Selwyn, Waimakariri and Hurunui*" (GNS, 2012), there was no observed liquefaction induced ground damage after the 4 September 2010 or 22 February 2011 earthquakes. Minor surface expression of liquefaction was observed in areas 500m southeast of the site. The locations of observed damage are shown in Figures 3 and 4 in Appendix A.

Based on reviews of aerial photography, discussions with Fulton Hogan staff who are familiar with the site, and Aurecon site walk overs in 2011, 2012, 2013, 2015 and 2018, no surface expression, of liquefaction or land cracking occurred within the proposed subdivision. The lack of observations of liquefaction induced ground damage is consistent with the GNS report.

3.5 MBIE Land Classification

The current land classification for the site, according to the Ministry of Business Innovation and Employment (MBIE) Technical Categories map, is "*N/A – Rural & Unmapped*". To the east of the site on the eastern side of Ellesmere Road it is classified as "*Technical Category 2*" and to the west of the site it is classified as "*Technical Category 1*".

"*N/A – Rural & Unmapped*" means that normal consenting procedures apply in these areas. "*Technical Category 1*" means that future land damage from liquefaction is unlikely, and ground settlements are expected to be within normally accepted tolerances. Standard foundations (NZS 3604) are acceptable in TC 1 areas subject to shallow geotechnical investigation. "*Technical Category 2*" means that minor to moderate land damage from liquefaction is possible in future large earthquakes. Lightweight construction or enhanced foundations are likely to be required such as enhanced concrete raft foundations (i.e. stiffer floor slabs that tie the structure together).

4 Geotechnical Investigations

4.1 General

The objective of the geotechnical review and site investigation was to determine the ground and groundwater conditions across the site in order to assess the suitability of the site for subdividing into residential sections.

Geotechnical investigations have been carried out across the site at various stages since August 2011 with more recent investigations in Stages 19 to 24 carried out in May 2018. As part of our assessment for the site we have reviewed previous investigations on and around Stages 19 to 24, as well as the results from the recent investigations.

The geotechnical review and investigation included the following information:

- Readily available Environment Canterbury well logs from Canterbury Maps.
- Previous geotechnical investigations, which comprised geotechnical boreholes, test pits, cone penetration tests (CPT) and Multi-channel Analysis of Surface Waves (MASW).
- Additional investigations which comprised
  - Fifteen CPTs to target depths of 10m or refusal.
  - Four piezometers installed to depths ranging from 3m to 5m.
  - One geotechnical borehole to 12m with standard penetration tests (SPT) at 1.5m centres and piezometer installation.
  - 1,125m of MASW lines.

Details of the geotechnical investigations is presented in the following sections.

4.2 Environment Canterbury Well Logs

A review of the Canterbury Maps and Environment Canterbury GIS Database (ECan, 2015) indicates five Environment Canterbury boreholes with logs on the site. The borehole logs, locations, and depths are summarised in Table 1 below.

Table 1: Summary of ECan borehole logs

Borehole	Location	Depth	Groundwater Depth	Summary of Stratigraphy
M36/8674	South western corner of the site	6.0m	1.1m	• 0 to 0.2m – Topsoil • 0.2 to 6.0m – Silty Clay
M36/8675	On the eastern side of the site	5.8m	1.5m	• 0 to 0.2m – Topsoil • 0.2 to 3.6m – Silty Clay • 3.6 to 5.8m – Silty Sandy Gravel
M36/8676	On the west side of the site, north of the stream	5.2m	1.6m	• 0 to 0.2m – Topsoil • 0.2 to 3.6m – Sandy Silt, Silt and Silty Clay • 3.6 to 5.2m – Gravel
M36/8679	On the western side of the northern part of the site	5.8m	1.1m	• 0 to 0.2m – Topsoil • 0.2 to 4.2m – Sandy Silt and Silty Clay • 4.2 to 5.8m – Gravel

Borehole	Location	Depth	Groundwater Depth	Summary of Stratigraphy
M36/8680	North western corner of the site	6.7m	1.4m	• 0 to 0.2m – Topsoil • 0.2 to 3.2m – Silty Sand and Silty Clay • 3.2 to 6.7m – Gravel

The locations of the ECan borehole logs are presented in Figure 5 in Appendix A and the borehole logs are presented in Appendix C.

4.3 Previous Geotechnical Investigations

Previous investigations carried on and around Stages 19 to 24 have comprised of geotechnical boreholes, test pits, cone penetration tests (CPT) and Multi-channel Analysis of Surface Waves (MASW). A summary of the previous investigations is presented in Table 2.

Table 2: Summary of relevant previous investigations

Year	Testing Type	Relevant Test
2011	Boreholes	BH3 and BH4
2011	CPTs	CPT18 to CPT27
2011	Test Pits	TP33 to TP47
2012	CPTs	CPT1, CPT2, CPT4 and CPT27
2012	Test Pits	TP1
2013	CPTs	CPT19, CPT, 21 and CPT22
2015	Boreholes	BH102 and BH103
2015	MASW	3.1km of MASW line carried out of which approximately 1.1km is in Stage 19 to 24.

The location of these investigations is presented in Figures 6 and 7 in Appendix A and the logs are presented in Appendix D.

4.4 Recent (2018) Investigations

4.4.1 Cone Penetration Testing

An additional 15 Cone Penetration Tests (CPT) were undertaken within Stages 19 to 24 between 18 and 22 May 2018. The CPTs were undertaken by McMillan Drilling using a track mounted CPT rig and the tests were undertaken to effective refusal (tip pressure reaching 40MPa) of the rig at 2m to 7m depth. The CPT locations are shown in Figure 6 in Appendix A and the logs are presented in Appendix E.

4.4.2 Boreholes and Piezometers

Five machine boreholes were drilled to install piezometers between 17 and 18 May 2018 to allow the ongoing measurement of groundwater levels. The piezometers were drilled and installed by McMillan Drilling using a track mounted dual tube rig. As the purpose of the boreholes was to install the piezometers, Boreholes BH201 to BH204 in Stages 19 to 24 were blind driven to the required depths (3m to 5m) with no soil recovered for logging. Borehole BH205, located to the west in a previous stage, was carried out at a new sewer proposed pump station location. This borehole was drilled to a target depth of 12m with Standard Penetration Tests (SPT) at 1.5m centres and a piezometer installed with the response zone at 7m depth. Soil recovered from the borehole was logged by a Geotechnical Engineer from Aurecon, in accordance with NZ Geotechnical Society's *Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes* (NZGS, 2005).

Although Borehole BH205 is not located in Stages 19 to 24, it has been included in this report to provided information on groundwater levels. The piezometer installations comprised of 32mm pipe with 1m slotted section at the base of the hole. The locations of the boreholes are shown in Figure 6 in Appendix A and the driller's logs are presented in Appendix F.

Previous work at Rosemerryn has found relatively complex groundwater conditions across the site with a phreatic surface at shallow depths and sub-artesian pressures within the underlying gravels. The depth to groundwater has been critical in the determining the likely site performance and hence piezometers were installed at varying depths across the site. The depth of the piezometers installation is presented in Table 3.

Table 3: Piezometer installation summary

Borehole	Depth of Installation	Comments
BH201	5m	Installed in the underlying gravel to monitor sub-artesian pressures
BH202	3m	Installed in the overlying silts and sands to measure the phreatic surface.
BH203	3m	Installed in the overlying silts and sands to measure the phreatic surface.
BH204	4m	Installed in the overlying silts and sands to measure the phreatic surface.
BH205	7m	Installed in the underlying gravel to monitor to sub-artesian pressures

In addition to the piezometers, groundwater level observations were taken in tests holes carried out at the various investigation stages. These groundwater levels are likely to be less accurate than those measured in the piezometers but they can provide indicative values to correlate between piezometers.

4.4.3 MASW Soundings

Five Multi-channel Analysis of Surface Waves (MASW) profile lines were undertaken by Southern Geophysical Limited in May 2018. These profile lines had a total length of 1,125m and comprised individual MASW soundings at approximately 10m centres.

From the MASW soundings, shear wave velocity profile sections have been produced for the upper 25m of the soil profile. The MASW soundings were undertaken to obtain information between the physical control points (CPT, borehole and test pits). MASW provided information on the depths of the gravel layer as well as the presence of sand lenses within the gravel layer. The locations of the profile lines are shown in Figure 7 in Appendix A and the velocity profiles are presented in Appendix G.

The shear wave velocity (V_s) profiles when calibrated to the CPT, test pit and borehole logs indicate:

- Upper Sands and Silts – $V_s < 180$m/s
- Gravels (Upper 10m) – 180m/s $< V_s <$ 350 m/s
- Sand Lenses – 180m/s $< V_s <$ 220 m/s (only apparent in northern part of site)
- Gravels (Deeper) – 350m/s $< V_s$

5 Engineering Considerations

5.1 General

Fulton Hogan Land Development Limited is proposing to subdivide 23ha of rural land in Lincoln into Rosemerryn Stages 19 to 24. The subdivision will comprise approximately 240 residential lots as well as reserve areas and road. The Ministry of Business, Innovation and Employment (MBIE, 2012) guidelines on residential development, requires that ground conditions and geotechnical hazards, including liquefaction, are assessed and, based on the result of this assessment, mitigation measures (if required) can be developed.

This section of the report presents the:

- Geotechnical ground model for the site.
- Potential for seismically induced liquefaction.
- Implications for building foundations.
- Assessment against the Resource Management Act (RMA) Section 106.

5.2 Geotechnical Ground Model

5.2.1 Ground Conditions

Based on the results of our geotechnical site investigation results, including calibration on the MASW soundings with intrusive investigations, the ground conditions across the site can be separated into three ground profiles. These ground profile areas are presented in Figure 8 in Appendix A and are summarised in Tables 4, 5 and 6.

Table 4: Inferred Ground Profile 1 (Northern section of site)

Unit	Depth to Start of Layer	Depth to End of Layer	Material
1	Surface	0.2 to 0.3m	Topsoil
2	0.2 to 0.3m	0.6 to 2.1m	Loose to medium dense Sands and Silty Sands interbedded with layers of stiff Sandy Silts and Silts
3	0.6 to 2.1m	10m onwards	Predominately medium dense to very dense Sandy Gravels and Gravel with occasional sand lenses up to 1.5m thick

Table 5: Inferred Ground Profile 2 (Middle section of site)

Unit	Depth to Start of Layer	Depth to End of Layer	Material
1	Surface	0.2 to 0.7m	Topsoil
2	0.2 to 0.7m	2.5 to 4.2m	Loose to medium dense Sands and Silty Sands interbedded with layers of firm to stiff Sandy Silts, Silts and Clayey Silts
3	2.5 to 4.2m	15m onwards	Medium dense to very dense Sandy Gravels and Gravels

Table 6: Inferred Ground Profile 3 (Southern section of site)

Unit	Depth to Start of Layer	Depth to End of Layer	Material
1	Surface	0.2 to 0.4m	Topsoil
2	0.2 to 0.4m	5.1m to 7.1m	Loose to medium dense Sands and Silty Sands interbedded with layers of soft to firm to stiff Sandy Silts, Silts and Clayey Silts
3	5.1m to 7.1m	15m onwards	Medium dense to very dense Sandy Gravels and Gravels

The main difference between the above soil profiles lies in the depth to the gravel layer. The gravel is at relatively shallow depths in the north part of the site and deepens to the south. Aspects of note are as follows:

- Sand lenses are present within the gravel in the northern section of the site (Ground Profile 1), as noted in Borehole BH102 at 4.56m depth, MASW Line 4 Chainage 20m, and MASW Line 10 Chainage 217m. The sand lenses appear to be limited in extent, with one lens logged as approximately 1.5m thick.
- The top of the gravel in the middle section of the site (Ground Profile 2) is not a consistent surface but appears to be undulating, which likely reflects the deposition environment where the undulation represents old eroded channels that are now infilled.
- Similar to Ground Profile 2, the top of the gravel in the southern section of the site (Ground Profile 3) varies, with areas of deeper gravel such as on the western side next to Stage 18. As above the variable depth to gravel is likely to reflect the deposition environment of old eroded channels within the gravel that are now infilled.
- In the upper soil profile in the southern section of the site there are soft silt layers interbedded with firm and stiff silt layers. Generally, these soft layers are limited in thickness ranging from 0.2m to 0.5m thick and are typically below 2.5m depth.

The ground conditions encountered in Stage 19 to 24 are consistent with those of the previous subdivision stages to the west.

5.2.2 Groundwater

The depth to groundwater is considered critical in the determining the likely site performance and therefore our assessment of the groundwater level has been carried out based on the ECan groundwater model, piezometer readings and groundwater levels encountered during the investigations.

ECan groundwater models available on Canterbury Maps, provide a depth to groundwater for wells installed at depth, presumably measuring piezometric pressures in the underlying gravel formations. A review of shallow wells located nearby monitored by ECan since 1980's indicates variable groundwater levels over the year with deeper groundwater levels from late November to early May and higher levels from late May to early November. The groundwater variability over the course of the year ranges from 0.8m to 1.2m. So, groundwater levels are expected to vary seasonally or with period of high or low precipitation.

Shallow piezometer readings indicate groundwater levels in the order of 1.4m to 1.5m depth, with the exception of BH203 adjacent to the stream, which indicates groundwater at 1m depth. The relative levels (RL) based on these depths are presented in Table 7.

Table 7: Groundwater levels and relative levels

Borehole	Groundwater Depth (m)	Groundwater RL (m)
BH201	1.4	8.6
BH202	1.5	7.8
BH203	1.0	8
BH204	1.5	6.6
BH205	1.5	8.7

Boreholes BH201 and BH205, installed in the underlying gravels, have consistent groundwater levels and RL, which is likely to represent the sub-artesian groundwater levels within the gravel. It is anticipated that this groundwater level will vary depending on the time of year and the recharge of the gravel layer. Given that this artesian pressure is within the gravel layer, it is not anticipated to govern the shallow groundwater level in the overlying soils, or influence the site liquefication potential.

Boreholes BH202 to BH204, installed at shallower depths, are likely to represent the phreatic groundwater surface across the site. Based on a review of the groundwater depth, the depth to groundwater appears to be consistent across the site at 1.5m depth but is a 1m depth near the stream running through the centre of the site. The shallower depth may be influence by the presence of ponded water in the stream channel, or possibly there is a zone of elevated groundwater levels due to the interaction of the stream and groundwater levels in the underlying soil profile. Reviewing the groundwater level RLs indicates a general fall in water level towards the south, with an elevated RL around the stream.

The levels in Table 7 above were taken in late May, and based on water levels in the ECan wells are likely to be above median groundwater levels and hence, are considered to be suitable for assessing the site future land performance. The groundwater levels across the site are presented in Figure 9 in Appendix A.

The groundwater levels in Table 7 have been compared to groundwater levels encountered during the course of the various investigation, from observations within test pits and boreholes, and from dipping CPT holes. Although observations during investigations may not be accurate as measured groundwater levels, there does appear to be a reasonable level of correlation between groundwater levels in the test holes and the piezometric information on Table 7 discussed above.

It is noted that the groundwater levels in the northern part of the site are higher than those measured in the adjacent previous stages (Stage 10 to 18), but the site topography in Stage 19 to 24 is slightly lower, which will account for the relatively higher groundwater level. Further to the south a higher groundwater level of 1m has been used in the past on the previous stages, but given that the above groundwater levels have been measured from piezometers we consider the levels in Table 7 to be more accurate.

5.3 Site Flexibility

We have assessed the site flexibility based on the following:

- Site stratigraphy comprises approximately sands and silts underlain by gravels to at least 15m depth (maximum depth investigated at the site).
- Clause 3.1.3 and Table 3.2 of NZS 1170.5:2004.

We consider that the site subsoil category in terms of NZS 1170.5:2004 Clause 3.1.3 is Class D (Deep soil site).

5.4 Liquefaction Assessment

5.4.1 General

Under cyclic loading (i.e. during an earthquake) loose, non-cohesive materials such as gravels, sands, silty-sands, tend to decrease in volume. This tendency to decrease in volume is much greater in loose than in dense soils. When loose non-cohesive soils are saturated and rapid loading occurs under undrained conditions, the soils densification causes pore water pressure to increase. The increase in pore water pressure results in a loss of soil strength due to a decrease in effective stress and eventually liquefaction occurs when the effective stress drops to zero. Liquefaction can lead to large displacements of foundations, flow failures of slopes and ground surface settlement, sand boils, and post-earthquake stability failures.

In determining the liquefaction potential at the site, the main factors to be considered are:

- How has the site performed during the major seismic events of the Canterbury earthquake sequence?
- Which layers have liquefied?
- What is the likelihood of further liquefaction in the future?
- How the potential liquefaction affects the development?

Each of these is considered below.

Observations after Previous Major Earthquake Events

As outlined in Section 3.4 there is no evidence of liquefaction observed at the site after the 4 September 2010 Darfield Earthquake or any subsequent earthquakes during the Canterbury Earthquake Sequence. This suggests limited potential for soil liquefaction at the site for shaking levels close to a ULS design event.

Potential for Liquefaction

Three primary factors contribute to liquefaction potential:

- Soil grading and density.
- Groundwater.
- Earthquake intensity and level of ground shaking.

Each of these is discussed below.

Soil Grading and Density

The CPT logs show layers of loose to medium dense sands, silty sands and sandy silts. These layers are considered to be potentially susceptible to liquefaction from a soil grading and density perspective.

Groundwater

We have adopted a groundwater level of 1.5m below ground level for most of the site with an elevated groundwater level at 1m around the stream. Therefore, soils are potentially liquefiable from a depth of 1m to 1.5m from a saturation criterion. It should be noted that groundwater levels are subject to seasonal changes.

Earthquake Intensity and Level of Shaking

The level of ground shaking is one of the key factors in determining whether liquefaction will or will not occur. For this analysis, we have assessed three design levels of shaking. The residential structures to be constructed on site will likely be classified as Importance Level 2 (IL2) structures in accordance with Table 3.2 of the New Zealand structural loadings standard (NZS 1170.0.2004) and the building will have a nominal 50 year design life. To determine the design level for earthquake shaking we have adopted the MBIE/NZGS (2016) recommendations, which correspond to design level earthquake events as follows:

- ULS shaking a M_w7.5 earthquake with 0.35g peak ground acceleration (PGA)
- SLS-a shaking a M_w7.5 earthquake with 0.13g PGA
- SLS-b shaking a M_w6.0 earthquake with 0.19g PGA

For an Ultimate Limit State (ULS) earthquake, buildings are expected to retain their structural integrity and form and not endanger life. Some plastic deformation of structural elements within the structure is expected to occur but ideally the damage can be repaired and the structure can be returned to service after the event, although repair may be uneconomical.

For a Serviceability Limit State (SLS) earthquake, buildings are expected to perform well for the SLS event and be returned to service after limited repair.

In addition, we have assessed two peak ground acceleration cases of the 4 September 2010 earthquake event as a back analysis of past event to calibrate the liquefaction assessment. We have considered the 4 September 2010 Darfield earthquake as there is PGA data available from the O'Rourke et al (2012) model that extended into Lincoln area. The model indicates PGAs of 0.33g.

Based on this PGA model and the MBIE Guidelines (2012) the site has been 'sufficiently tested' as the PGA for the 4 September 2010 event exceeded 170% of the SLS PGA (i.e. 1.7 x 0.13g = 0.22g). For the assessment we have used a PGA of 0.33g as well as a lower bound PGA of 0.19g (i.e. 0.33g/1.7) to account for any uncertainty in the model. The levels of shaking used for our analysis are presented in Table 8.

The 4 September 2010 event shaking parameters are similar to ULS design event, while the lower bound 4 September 2010 event shaking parameters are similar to SLS-b design event. Given these comparable ground shaking parameters and that the site has been sufficiently tested, we consider the ground damage observations at the site after the 4 September 2010 earthquake event can be used to calibrate our liquefaction assessment.

Table 8: Earthquake design level events for liquefaction analysis

Earthquake Event	Magnitude	Peak Ground Acceleration
4 September 2010-a	M_w7.1(1)	0.33g(1)
4 September 2010-b	M_w7.1(1)	0.19g(2)
ULS	M_w7.5	0.35g
SLS-a	M_w7.5	0.13g
SLS-b	M_w6.0	0.19g

(1) Magnitude and peak ground acceleration from O'Rourke et. al. (2012) (as shown on the NZGD 2018)

(2) Approximately 60% (1/170%) of the peak ground acceleration of the O'Rourke et. al. (2012) to account for uncertainty of PGA model

5.4.2 Liquefaction Potential Assessment

The ground investigations show that the site is directly underlain by sandy and silty soils which in turn is underlain by predominately gravels with some sand lenses. Based on the geotechnical investigations the gravels have been assessed to be non-liquefiable in design level events due to the recorded relative densities and grain size distribution. Therefore, to define the liquefaction hazard at the site we need to assess the liquefaction potential of the upper soils as well as the sand lenses within the gravel layers.

To assess the liquefaction potential of the sand lenses we have considered the relative density of the sandy layers from the SPT and shear wave velocity data, and to assess the liquefaction potential of the upper soils we have used a cone penetration test (CPT) results.

Liquefaction in the Deeper Soil Layers

Sand lenses within the underlying gravels were encountered in Borehole BH102 (2015) and are inferred from the MASW soundings, where there are shear wave velocities between 180m/s and 220m/s. The sand lenses appear to be localised in the northern part of the site.

To assess liquefaction of these sand lenses we have considered:

- SPT testing undertaken in this layer
- Shear wave velocity profiles obtained from the MASW soundings
- Consideration of past land performance including the mechanism of liquefaction triggering and the likely damage from it occurring and the previous observed lack of damage.

Using the single SPT (BH102 at 4.56m depth) from a sand lenses we have assessed the liquefaction potential of this layer based on the Boulanger and Idriss (2014) SPT based liquefaction assessment method assuming a clean sand. The calculated factors of safety are shown in Table 9.

Table 9: Summary of SPT based liquefaction analysis for sand lenses

Earthquake Event	Calculated Factor of Safety Against Liquefaction
4 September 2010-a	0.4
4 September 2010-b	0.7
SLS-a	1.0
SLS-b	0.8
ULS	0.4

From this SPT based liquefaction assessment, the sand lenses are assessed as being liquefiable even at relatively low levels of shaking. The calculated factor of safety against liquefaction for 4 September 2010 event lies between the factors of safety for a SLS and ULS design event.

To supplement this SPT result we have also considered the shear wave velocity obtained from the MASW soundings. The sand lenses have a shear wave velocity of less than 215m/s which, based on Idriss and Boulanger (2008), is the maximum shear wave velocity for liquefiable soils. The liquefaction analysis considered shear wave velocity from the MASW investigation using the method of Kayen et al (2013). We have taken the shear wave velocity profiles of MASW Line 4 Chainage 20m and MASW Line 10 Chainage 217m, which both had a low velocity pocket at depth inferred to be sand lenses in the gravel. This analysis indicates that the sand layers have a factor of safety as summarised in Table 10.

Table 10: Summary of V_s based liquefaction analysis for sand lenses

Earthquake Event	Calculated Factor of Safety Against Liquefaction
4 September 2010-a	0.5 to 0.6
4 September 2010-b	0.9 to 1.0
SLS-a	>1.0
SLS-b	>1.0
ULS	0.4 to 0.5

The shear wave velocity method indicates that there is the potential for liquefaction of the sand lenses. However, in MASW Line 4 Chainage 20m the liquefiable layer is at 6.5m depth and in MASW Line 10 Chainage 217m the liquefiable layer is at 7m depth. In both case these are overlain by medium dense to dense gravel from ground level.

In addition, we have considered the mechanism of the liquefaction process. When loose non-cohesive soils are saturated and rapid loading occurs under undrained conditions, the soils densification causes pore water pressure to increase. The increase in pore water pressure results in a loss of soil strength due to a decrease in effective stress and eventually liquefaction occurs when the effective stress drops to zero. However, as these sand lenses as surrounded by gravel, drainage is likely to occur, limiting and reducing the build-up of excess pore water pressure, and thus reducing the liquefaction potential of these sand lenses.

The effects of these sand lenses liquefying also required needs to be considered. The log of Borehole BH102 indicates 4.5m of medium to very dense gravels overlying the potentially liquefiable sand lenses, while the MASW profiles indicate 6.5m to 7m of medium to very dense gravels overlying the potentially liquefiable sand lenses. This depth of gravel will form a thick non-liquefiable crust, which based on observations in Christchurch during the CES is likely to supress liquefaction induced ground damage on shallow founded structures, even if these sand layers were to liquefy.

Lastly, no significant ground damage, including settlement or land cracking, was observed across areas with and without sand lenses, which suggests that either theses layers did not liquefy, or the upper gravel layer has supressed the surface expression of liquefaction induced damage in these areas.

Based on this assessment we consider the that liquefaction effects occurring in these deeper localised sand lenses will have minimal effect on shallow founded domestic structures and therefore we have not considered it further in our assessment. Instead we have focussed on liquefaction in the upper soils as the main mechanism that could drive land damage in Stages 19 to 24.

Liquefaction in the Upper Soil Layers

Methodology

The ability for the subsoils to resist the effect of ground shaking associated with the design level events has been assessed from the upper subsoil information obtained from the CPTs. The liquefaction assessment was carried out using the methods outlined in MBIE Guidelines (2014) and are summarised in Table 11.

Table 11: Liquefaction Assessment Methodology Summary

Test	Liquefaction Assessment(1)	Fines Content	Liquefaction Cut Off	Liquefaction Settlement Method(2)
CPT	Boulanger and Idriss (2014)	Based on a soil Character Index (I_c) with a Co-efficient for Fines Content (C_{fc}) =0	Based on a 2.6 I_c cut off	Zhang et al (2002)

(1) A 15% probability of liquefaction (PL) has been considered with all methods.

(2) We note that there is an inherent uncertainty when identifying liquefiable layers in CPT analysis, due to this inherent uncertainty, calculated settlements will likely differ from actual settlements experienced on site.

The fines content fitting parameter has been set as 0 as no laboratory testing has been undertaken on the soils at the site. Layers within the upper soils were inferred to be clayey silts to organic silts (I_c greater than 2.6). As limited laboratory testing has been carried out to aid in determining a liquefaction cut off on the soils underlying the site, soils have been assumed to be non-liquefiable where the CPT Soil Character Index, I_c, is greater than 2.6.

Liquefaction Effects

Liquefaction can have a number of effects on buildings and land. In this assessment we have considered the following effects:

- Liquefiable layers.
- Liquefaction induced reconsolidation settlement.
- Liquefaction induced ground damage.

These are discussed in the following sections:

Liquefiable Layers

The layers which may liquefy in a design level event are critical in regards to the foundation performance. The Boulanger and Idriss (2014) method has been used in this assessment and it has been assumed that soils are liquefiable when the factor of safety is below one.

Liquefaction Induced Settlement

The method of Zhang et. al. (2004) was used for calculating the potential liquefaction induced reconsolidation settlements in the CPT analysis. Due to the presence of dense gravel from the CPT refusal depth to at least 10m below ground level, index settlements have been calculated from the CPT data.

Liquefaction Induced Ground Damage

We have used two methods to assess the potential for liquefaction induced ground damage as outlined below:

a) Published information (after Ishihara, 1985) can be used to assess the potential for surface expression of liquefaction and hence the likelihood of inducing damage. Ishihara's method is for a single non-liquefiable layer overlying a single liquefiable layer only. The liquefaction analysis indicates multiple liquefiable layers within the CPT profiles and to account for this we have taken the thickness of the non-liquefied crust as the thickness from the ground surface to the top of the uppermost critical liquefiable layer, and the thickness of the critical liquefied layer as the sum of the thicknesses of all critical liquefiable layers.

   Ishihara's plots do not explicitly indicate ground damage curves for specific PGAs such as 0.13g which is the SLS level PGA. To simplify the analysis, we have used following curves to assess the ground damage:

   - The 0.20g curve when assessing damage under SLS design levels of ground shaking and the lower bound 4 September 2010 Darfield Earthquake.
   - The 0.40g curve when assessing damage under ULS design level of ground shaking and the 4 September 2010 Darfield Earthquake.

b) Tonkin & Taylor (T&T) developed the Liquefaction Severity Number (LSN) (Tonkin & Taylor 2013) based on investigation data and observations made following major earthquake events in Christchurch. The LSN uses the settlements calculated from the Idriss and Boulanger (2008) method with the Robertson and Wride (1998) fines content method and the Zhang et. al. (2004) settlement method to assess the expected ground damage that could be caused by liquefaction in future earthquakes. The level of ground damage associated with LSN numbers is summarised in Table 12.

Table 12: LSN descriptions

LSN Range	Predominate Performance
0-10	Little to no expression of liquefaction, minor effects
10-20	Minor expression of liquefaction, some sand boils
20-30	Moderate expression of liquefaction, with sand boils and some structural damage
30-40	Moderate to severe expression of liquefaction, settlement can cause structural damage
40-50	Major expression of liquefaction, undulations and damage to ground surface, severe total and differential settlement of structures
>50	Severe damage, extensive evidence of liquefaction at surface, severe total and differential settlement affecting structures, damage to services

Upper Liquefaction Results

The result of the liquefaction assessment for the 4 September 2010 event are summarised in Table 13 and the results of the design level events are summarised in Table 14. The liquefaction outputs are presented in Appendix H.

Table 13: Summary of liquefaction analysis for the 4 September 2010 Darfield Earthquake

Earthquake Event	Earthquake Effects	Ground Profile 1 Northern Section	Ground Profile 2 Middle Section	Ground Profile 3 Southern Section
4 September 2010 Darfield Earthquake (M_w7.1, 0.33g)	Liquefiable Layers(1)	Limited layers in Unit 2 below the water level	Unit 2 below the water level	Unit 2 below the water level
	Settlement(2)	0 to 10mm	10 to 55mm	40 to 135mm
	Ground Damage(3)	No	Yes	Yes
	LSN	0 to 7	6 to 26	12 to 35
	Comments	Little to minor damage	Minor to Moderate damage	Moderate to major damage
4 September 2010 Darfield Earthquake (M_w7.1, 0.19g)	Liquefiable Layers(1)	Limited layers in Unit 2 below the water level	Some of the sandy layers of Unit 2 below the water table	Some of the sandy layers of Unit 2 below the water table
	Settlement(2)	<10mm	0 to 45mm	35 to 105mm
	Ground Damage(3)	No	Yes in parts of the site	Yes over half of the site
	LSN	0 to 4	1 to 20	10 to 25
	Comments	Little to minor damage	Minor damage	Moderate damage

(1) Due to the inherent uncertainty in calculating liquefiable layers, the calculated layers are indicative only. Actual positions and thickness of liquefiable layers could vary from those above.
(2) Settlements are calculated over the full CPT profile. Settlements are presented to the nearest 5mm. Due to the inherent uncertainty in calculating liquefaction induced settlements, the calculated settlements are indicative only and actual settlements will vary from those above.
(3) Ground damage based upon published information after Ishihara (1985).

Table 14: Summary of liquefaction analysis for the design level events

Earthquake Event	Earthquake Effects	Ground Profile 1 Northern Section	Ground Profile 2 Middle Section	Ground Profile 3 Southern Section
ULS (1 in 500 year event) (M_w7.5, 0.35g)	Liquefiable Layers(1)	Limited layers in Unit 2 below the water level	Unit 2 below the water level	Unit 2 below the water level
	Settlement(2)	0 to 10mm	15 to 60mm	40 to 135mm
	Ground Damage(3)	No	Yes	Yes
	LSN	0 to 7	7 to 26	12 to 35
	Comments	Little to minor damage	Minor to Moderate damage.	Moderate to major damage

Earthquake Event	Earthquake Effects	Ground Profile 1 Northern Section	Ground Profile 2 Middle Section	Ground Profile 3 Southern Section
SLS-a (1 in 25 year event) (M_w7.5, 0.13g)	Liquefiable Layers(1)	Limited layers	Limited layers	Limited layers
	Settlement(2)	<5mm	0 to 15mm	10 to 60mm
	Ground Damage(3)	No	No	No
	LSN	0	0 to 6	3 to 12
	Comments	No damage	Little to no damage	Little to minor damage
SLS-b (1 in 25 year event) (M_w6.0, 0.19g)	Liquefiable Layers(1)	Limited layers	Some of the sandy layers of Unit 2 below the water table	Some of the sandy layers of Unit 2 below the water table
	Settlement(2)	<5mm	0 to 40mm	30 to 90mm
	Ground Damage(3)	No	No	Yes in parts of the site
	LSN	0 to 3	0 to 17	8 to 23
	Comments	Little to no damage	Little to minor damage	Minor to Moderate damage.

(1) Due to the inherent uncertainty in calculating liquefiable layers, the calculated layers are indicative only. Actual positions and thickness of liquefiable layers could vary from those above.
(2) Settlements are calculated over the full CPT profile. Settlements are presented to the nearest 5mm. Due to the inherent uncertainty in calculating liquefaction induced settlements, the calculated settlements are indicative only and actual settlements will vary from those above.
(3) Ground damage based upon published information after Ishihara (1985).

Lateral Spreading

Lateral spreading is a co-seismic effect where surface soils move on a layer, or layers, of liquefied soil downslope or towards a free edge, such as a river or basin. Lateral spreading can occur during an earthquake under seismic loading and following the earthquake until the excess pore water pressure caused by ground shaking dissipate and the soil regains strength.

When assessing liquefaction induced lateral spreading we considered the following:

- There is a small stream which runs through the site which is approximately 0.5m deep and 2m to 3m wide with no significant bank.
- In the south east corner of the site is a stormwater basin that has been installed as part of the overall Rosemerryn Subdivision development, which is in the order of 0.5m deep.
- No other significant rivers or significant changes in height are in close proximity to the site.
- The site is relatively level and we understand that there will be no significant change in the site levels once the development is undertaken.
- We understand that no additional stormwater basins or open channels will be built as part of this development.

Based on the site topography, the depth of the stream and stormwater basin, and the depth to groundwater across the site we consider that the global lateral movement and lateral stretch potentials across the site is considered to be minor or less and will not govern the MBIE Technical Category assessment. It is noted that TC2 type foundations have the ability to sustain minor levels of lateral movement and lateral stretch. As such no further assessment of lateral spreading has been undertaken.

Technical Classification

We have assessed the risk of future liquefaction in terms of the technical category classification system as per the MBIE Guidelines (2012 and 2014). This classification system is divided into three technical categories that reflect both the liquefaction experience to date and future performance expectations. The categories and corresponding criteria are summarised as follows:

- **Technical Category 1 (TC1)** – Future land damage from liquefaction is unlikely, and ground settlements are expected to be within normally accepted tolerances.
- **Technical Category 2 (TC2)** – Minor to moderate land damage form liquefaction is possible in future large earthquakes.
- **Technical Category 3 (TC3)** – Moderate to significant land damage from liquefaction is possible in future large earthquakes.

MBIE has indicated the following liquefaction and lateral spreading deformation limits for house foundations as summarised in Table 15.

Table 15: Liquefaction deformation limits and house foundation implications

Technical Category	Index Liquefaction Deformation Limits				Likely Implication for House Foundations (subject to individual assessment)
	Vertical		Lateral Spread		
	SLS	ULS	SLS	ULS	
TC1	15mm	25mm	Nil	Nil	Standard NZS3604 type foundations with tied slabs
TC2	50mm	100mm	50mm	100mm	MBIE enhanced foundation solutions
TC3	>50mm	>100mm	>50mm	>100mm	Site specific foundation solution

Discussion

As the Bradley and Hughes (2012a, b) does not extend into Lincoln so we have considered the O'Rourke et. al. (2012) PGA model which indicates a PGA of 0.33g for the 4 September 2010 Darfield Earthquake event. Based on the MBIE Guidelines (2012) the site has been 'sufficiently tested' as the median value for the PGA for the 4 September 2010 earthquake event exceeded 170% of the SLS PGA (i.e. 1.7 x 0.13g = 0.22g).

No damage was observed on the site due to liquefaction after the 4 September 2010 earthquake event. Based upon this actual site response we infer that the liquefaction assessment method over estimates likely settlement and damage under future large earthquakes. Therefore, we have calibrated the liquefaction assessment based on observations from the previous 4 September 2010 earthquake event.

It is not possible to compare the calculated and actual settlements for the 4 September 2010 Darfield earthquake event at the site because there is no quality information on actual ground settlements. We can however make the following comments based on observations of ground performance, and calculated settlements and ground damage for the three design earthquakes:

- Based on the GNS (2012) report on liquefaction in eastern Canterbury, discussions with Fulton Hogan staff and the original farm owner who are familiar with the site, review of aerial photography, and Aurecon site walkovers in 2011, 2012, 2013 and 2015, no liquefaction induced damage was noted on the site and its direct surroundings.
- The back analysis of the 4 September 2010 earthquake indicates that moderate to major ground damage should have occurred when assessing against the measured and lower bound PGA. However, this calculated level of damage is not supported by field observations

- For the northern part of the site (Ground Profile 1) where gravel is at shallow depths, the calculated ULS settlements are less than 10mm and the calculated SLS-b settlements are less than 5mm which is consistent with a MBIE TC1 classification.
- To the north of the stream (Ground Profile 2), where the gravel layer is deeper, the calculated ULS settlements are between 15mm and 60mm and the calculated SLS-b settlements are between 0mm and 40mm which is consistent with a MBIE TC2 classification.
- South of the stream (Ground Profile 3), the calculated ULS settlements are between 40mm and 135mm and the calculated SLS-b settlements are between 30mm and 90mm which is consistent with MBIE TC2 and TC3 classifications respectively. These calculated settlements are similar to the 4 September 2010 earthquake back analysis.

  The back analysis also indicates that in a ULS event moderate to major damage is likely which is similar those calculated in the 4 September 2010 earthquake event, and in a SLS-b event minor to moderate damage is likely, which is less than that calculated for the 4 September 2010 earthquake event lower bound PGA.

  The assessment also calculated that lower levels of vertical settlement and ground damage will occur in a SLS-a earthquake event than the 4 September 2010 Darfield Earthquake.

In summary, south of the stream, the liquefaction assessment overstates the liquefaction potential when compared to actual site performance as only limited to minor damage was observed at and around the site after the 4 September 2010 earthquake event but the back analysis indicates that moderate to major ground damage should have occurred.

Hence, based on our liquefaction assessment, and the observed ground damage we infer that minor to moderate land damage from liquefaction is possible in future large earthquakes at parts of the site. Therefore, we conclude:

- The northern part of the site underlain by shallow gravel is consistent with a **Technical Category 1 (TC1)** classification.
- The remainder of Stage 19 to 24 is consistent with a **Technical Category 2 (TC2)** classification.

The areas of TC1 and TC2 classified land are shown in Figure 11 in Appendix A.

5.4.3 Summary of MBIE Technical Category Liquefaction Assessment

The liquefaction analysis indicates the following:

- Based on the O'Rourke et. al. (2012) PGA model the site has been "sufficiently tested" (MBIE Guidelines (2012)) as the median value for the PGA for the 4 September 2010 event exceeded 170% of the SLS PGA (i.e. 1.7 x 0.13g = 0.22g). Therefore, we have used the lack of ground damage observed at the site after the 4 September 2010 earthquake event to calibrate our liquefaction assessment.
- The GNS report on liquefaction (GNS, 2012), a review of aerial photography, and site observations made by Aurecon and Fulton Hogan staff confirms there was no evidence of liquefaction observed at the site after the 4 September 2010 Darfield earthquake, or any subsequent earthquakes in the Canterbury Earthquake Sequence.
- In the northern part of the site liquefaction induced settlements and damage are likely to be minimal and are consistent with a TC1 classification while elsewhere the calculated liquefaction induced settlements and assessed ground damage are consistent with a TC2 or TC3 classification. However, when compared to actual site performance, the level of calculated damage is overstated, as the back analysis indicates that moderate to major ground damage should have occurred, when only limited to minor damage was observed at and around the site.
- The liquefaction induced lateral spreading potential is considered to be minor.
- Based on our liquefaction assessment and observed ground damage we infer that minor to moderate land damage from liquefaction is possible in future large earthquakes at parts of the site.

- Therefore, based on our liquefaction assessment, we consider that the northern part of Stage 19 to 24 is consistent with a **Technical Category 1 (TC1)** classification and the remainder of the site is consistent a **Technical Category 2 (TC2)** classification, see Figure 11 in Appendix A.

5.5 Liquefaction Mitigation

5.5.1 General

We consider that parts of the site in its current assessed state are susceptible to varying degrees of seismically induced liquefaction in a future major seismic event. In terms of liquefaction hazard mitigation at this site, and considering the proposed site layout and development, there are two basic approaches available as follows:

Building Strengthening

Structurally design the building to accommodate the effects of liquefaction. Examples of this include using raft or piled foundations. These methods do not remove the liquefaction hazard but reinforce the structure in such a way that it maintains stability during a liquefaction event. This approach is recommended in the TC2 equivalent area.

Ground Improvement

Improve the soil at the site so that it is less susceptible to seismically induced liquefaction. This general approach can be divided into three categories:

1. Densify the soil so that soil grain skeleton will not collapse under earthquake loading. Examples of this include compaction and replacement (refilling with material which will not liquefy).
2. Soil reinforcement. Examples include stone columns, driven piles to densify and stiffen the soil, deep soil mixing, soil cement columns etc.
3. Allow dissipation of excess pore water pressure so that liquefaction is reduced. Examples of this include installation of drains, drainage blankets, and or stone columns.

The recommended approach for liquefaction mitigation in each Technical Category classification zone is discussed below.

5.5.2 Technical Category 1

As per the MBIE (2012) Guidelines with TC1 sites *"Future land damage from liquefaction is unlikely, and ground settlements from liquefaction effects are expected to be within normal accepted tolerances"*. For Technical Category 1 areas the MBIE Guidelines has recommended Standard NZS3604:2011 type foundations with tied slabs provided there is suitable bearing.

MBIE Guidelines recommend that a site specific geotechnical assessment be carried out by suitability qualified chartered engineer with experience in residential house development at the detailed house design stage.

5.5.3 Technical Category 2

This section provides generic foundation advice for the wider subdivision development. It ***does not*** constitute a detailed design of house foundations. Additional investigations will be required at the building consent stage for each house to determine the appropriate foundations and to support a building consent application.

It is considered that parts of the site in its current assessed state is consistent with a MBIE TC2 classification. Land with the deformation characteristics of TC2 does not meet the definition of "good ground" as per the New Zealand Standards (NZS3604 *'Timber Framed Buildings'* and NZS4229 '*Concrete Masonry Buildings not requiring Specific Engineering Design*') without modification to the standard foundation system as described below. The generic foundation types in these documents are not appropriate due to their potential for damage in liquefaction events.

The risk of building damage due to liquefaction in TC2 land can be mitigated by providing strengthened foundations, which reduce the differential settlement of the building and are designed to be readily re-levellable following a major earthquake. There are a range of standard foundation types available for TC2 land which are presented in the MBIE Guidelines and include enhanced raft or rib raft foundations.

Although it is not an explicit consent requirement, we recommend that lightweight cladding and roofing materials are used on all dwellings in TC2 areas, as reducing the dwelling mass will lead to reduced foundation movements and less building damage in future large earthquakes.

As part of the detailed foundation design, particular attention should be paid to detailing the connection joints of buried services (water and sewer pipes, power conduits, etc.) between the house foundation and the insitu ground. The design should allow sufficient movement and ductility to account for seismic shaking and liquefaction induced movement, and to allow for easy reinstatement if they were to be damaged during a future seismic event.

Other foundation solutions are available (i.e. ground improvement to achieve TC1 site characteristics etc.). However, these options are unlikely to be economic relative to the options below.

It should be noted that this report provides guidance only on residential foundation design and should not be taken as detailed design. MBIE Guidelines require that for detailed house design, a site specific geotechnical assessment shall be carried out by suitability qualified chartered engineer with experience in residential house development.

5.6 Bearing Capacity

The criteria for determining whether suitable founding is available follows that outlined in Section 3 of NZS 3604: 2011 'Timber-framed Buildings'. NZS 3604 requires:

Clause 3.4.1

All foundations shall bear on a solid bottom in undisturbed good ground material or upon firm fill where a certificate of suitability has been issued under NZS 4431.

Where good ground is at a depth greater than 0.6m, the excavation between the good ground and the foundation base may be filled with mass concrete having a minimum strength of 10MPa at 28 days.

Clause 3.3.7.1

The soil below the underside of the foundations shall be assumed to have a bearing pressure of not less than 300kPa when:

- *a) None of the following is encountered below the depth of the underside of the proposed footing at any test site:*
  - *i) Organic Topsoil;*
  - ii) *Soft or very soft peat;*
  - iii) *Soft or very soft clay;*
  - iv) *Fill material except where a certificate of suitability has been issued in terms of NZS 4431;*
- *b) Scala Penetrometer tests conducted in accordance with 3.3.2(a) where the number of blows per 100mm depth of penetration below the underside of the proposed footing at each test sites exceeds:*
- *i) Five down to a depth equal to the width of the widest footing below the underside of the proposed footing;*
- *ii) Three at greater depths; and*
- *iii) Providing the set blow is relatively uniform, the number of blows per 100mm may be obtained by averaging the number of blows for depths not exceeding 300mm; and*
- *c) Comparison of results at all test sites show that soil conditions are closely similar at each test site.*

We interpret Clause 3.4.1 as meaning that if "good ground" is found at less than 600mm depth, the foundations will comply with the requirements of NZS 3604. Otherwise, specific engineering design is required.

Based on the available investigation logs it is unlikely that shallow bearing for a typical house foundation of 300kPa ultimate bearing capacity could be achieved in these areas. Therefore "good ground" as per New Zealand Standards Timber Framed Buildings (NZS3604:2011) and Concrete Masonry Buildings Not Requiring Specific Engineering Design (NZS4229:1999) will not be met and specific ground investigations and foundation design will be required based at the building consent stage.

Therefore, irrespective of any potential liquefaction risk at the site, typical light weight timber framed or masonry houses (which would generally be designed within the guidelines of NZS3604:2011 or NZS4229:1999) will require specific foundation investigation and design. TC2 enhanced slab foundations are suitable for bearing capacities of 200kPa and can be modified for lower bearing capacities, so it is likely that TC2 enhanced slab foundations will be suitable for the lower bearing soil as well as mitigation against liquefaction induced land damage.

It is noted that earthworks across Stages 19 to 24 is likely to include placement of fill. Depending on the depth of the fill, and provided it is placed to a suitable level of compaction, the earthworks may render the site compliant with the definition of "good ground", however this will need to be assessed on a lot by lot basis as part of the building consent investigations.

It is noted that soft layers are present south of the stream ranging from 0.2m to 0.5m thick and typically below 2.5m depth. At these depths, settlement of the soft layer is anticipated to be negligible under additional surcharge. TC2 enhanced foundation systems are suitable solutions as raft foundations can distribute the loads and induced deformations to acceptable limits.

In any case, site specific testing (including hand augers and DCPs) will be required on the individual lots to determine ground conditions and provide bearing capacities of residential building design.

6 Assessment Against the RMA

Section 106 of the Resource Management Act (RMA) (2017) states *inter alia*

Consent authority may refuse subdivision consent in certain circumstances

1) A consent authority may refuse to grant a subdivision consent, or may grant a subdivision consent subject to conditions, if it considers that—

- *a) there is a significant risk from natural hazards; or*
- *b) Repealed*
- *c) sufficient provision has not been made for legal and physical access to each allotment to be created by the subdivision.*

1A) For the purpose of subsection (1) (a), an assessment of the risk from natural hazards requires a combined assessment of—

- *a) the likelihood of natural hazards occurring (whether individually or in combination); and*
- *b) the material damage to land in respect of which the consent is sought, other land, or structures that would result from natural hazards; and*
- *c) any likely subsequent use of the land in respect of which the consent is sought that would accelerate, worsen, or result in material damage of the kind referred to in paragraph (b).*

2) Conditions under subsection (1) must be—

- *a) for the purposes of avoiding, remedying, or mitigating the effects referred to in subsection (1); and*
- b) *of a type that could be imposed under section 108.*

A risk assessment approach has been undertaken on the significant geotechnical hazards that may affect the site, which is presented in Appendix I.

Based on this assessment we consider that at the site there are no significant geotechnical hazards other than the potential for earthquake induced soil liquefaction of varying degrees. However, provided that the geotechnical recommendations provided within this report are followed, and the appropriate engineering measures are implemented, then we consider that the development is unlikely to be significant affected by geotechnical hazards nor will the development worsen, accelerate or result in material damage. Therefore, from a geotechnical perspective we consider that Stage 19 to 24 of the Rosemerryn residential subdivision development can proceed.

7 References

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8 Limitations

We have prepared this report in accordance with the brief as provided. The contents of the report are for the sole use of the Client and no responsibility or liability will be accepted to any third party. Data or opinions contained within the report may not be used in other contexts or for any other purposes without our prior review and agreement.

The recommendations in this report are based on data collected at specific locations and by using appropriate investigation methods with limited site coverage. Only a finite amount of information has been collected to meet the specific financial and technical requirements of the Client's brief and this report does not purport to completely describe all the site characteristics and properties. The nature and continuity of the ground between test locations has been inferred using experience and judgment and it must be appreciated that actual conditions could vary from the assumed model.

Subsurface conditions relevant to construction works should be assessed by contractors who can make their own interpretation of the factual data provided. They should perform any additional tests as necessary for their own purposes.

Subsurface conditions, such as groundwater levels, can change over time. This should be borne in mind, particularly if the report is used after a protracted delay.

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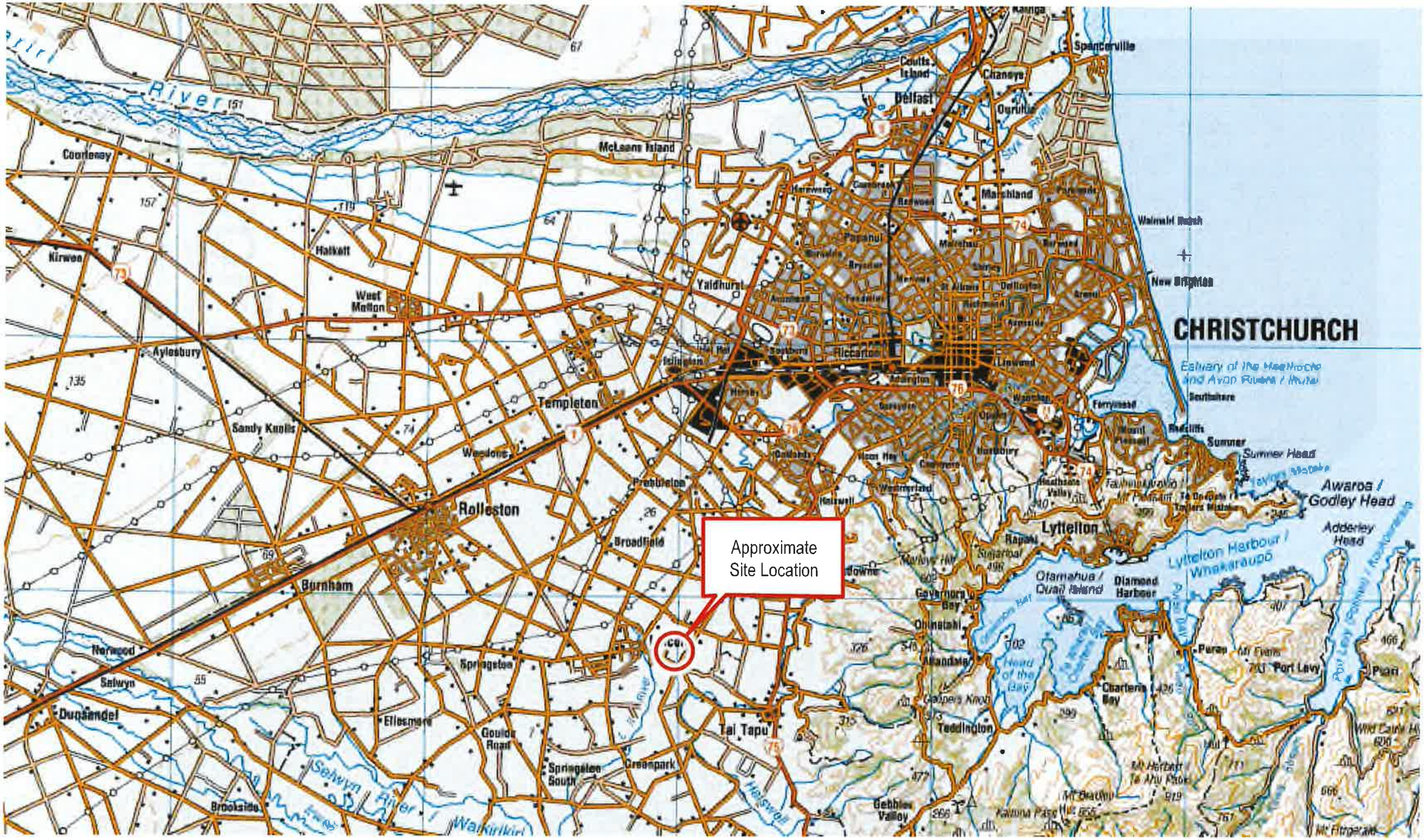
A

Figures



CLIENT	PRELIMINARY NOT FOR CONSTRUCTION	ALL DIMENSIONS APPROXIMATE ONLY	SCALE	SIZE	TITLE	REGIONAL LOCATION PLAN
			NTS	A4		
FIGURE	FIGURE 1		BY		REFERENCE	BACKGROUND SOURCED FROM LINZ CROWN COPYRIGHT RESERVED
			J. MUIRSON			
PROJECT	ROSEMERRYN SUBDIVISION		APPROVED			
			J. KUPEC			
			DATE		PROJECT | WBS | TYPE | DISC | NUMBER	

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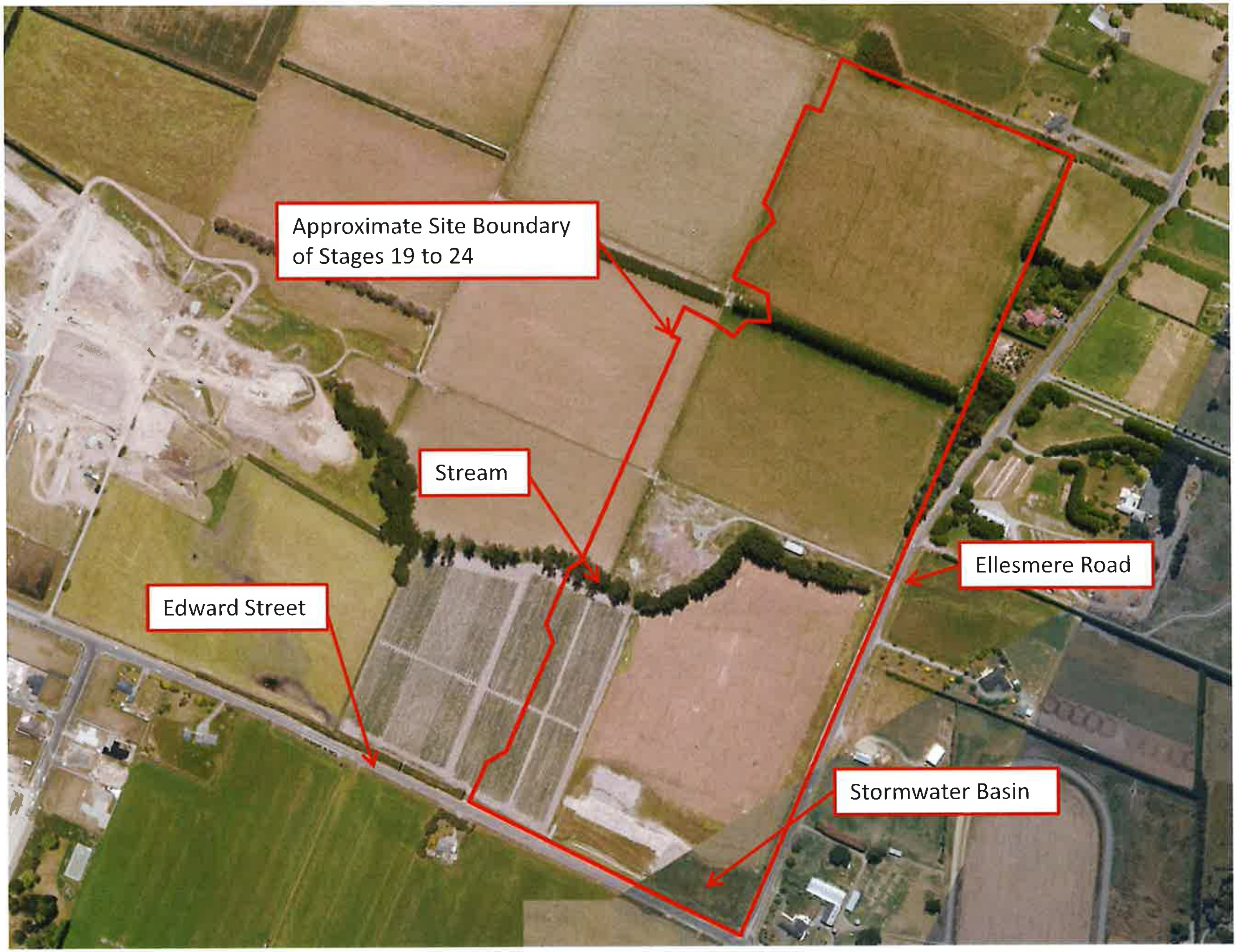

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			NTS	A4		
	FIGURE	FIGURE 2	BY		REFERENCE	BACKGROUND IMAGINE SOURCED FROM CANTERBURY MA
			J. MUIRSON			
	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED			PROJECT WBS TYPE DISC NUMBER
			J. KUPEC			
			DATE			

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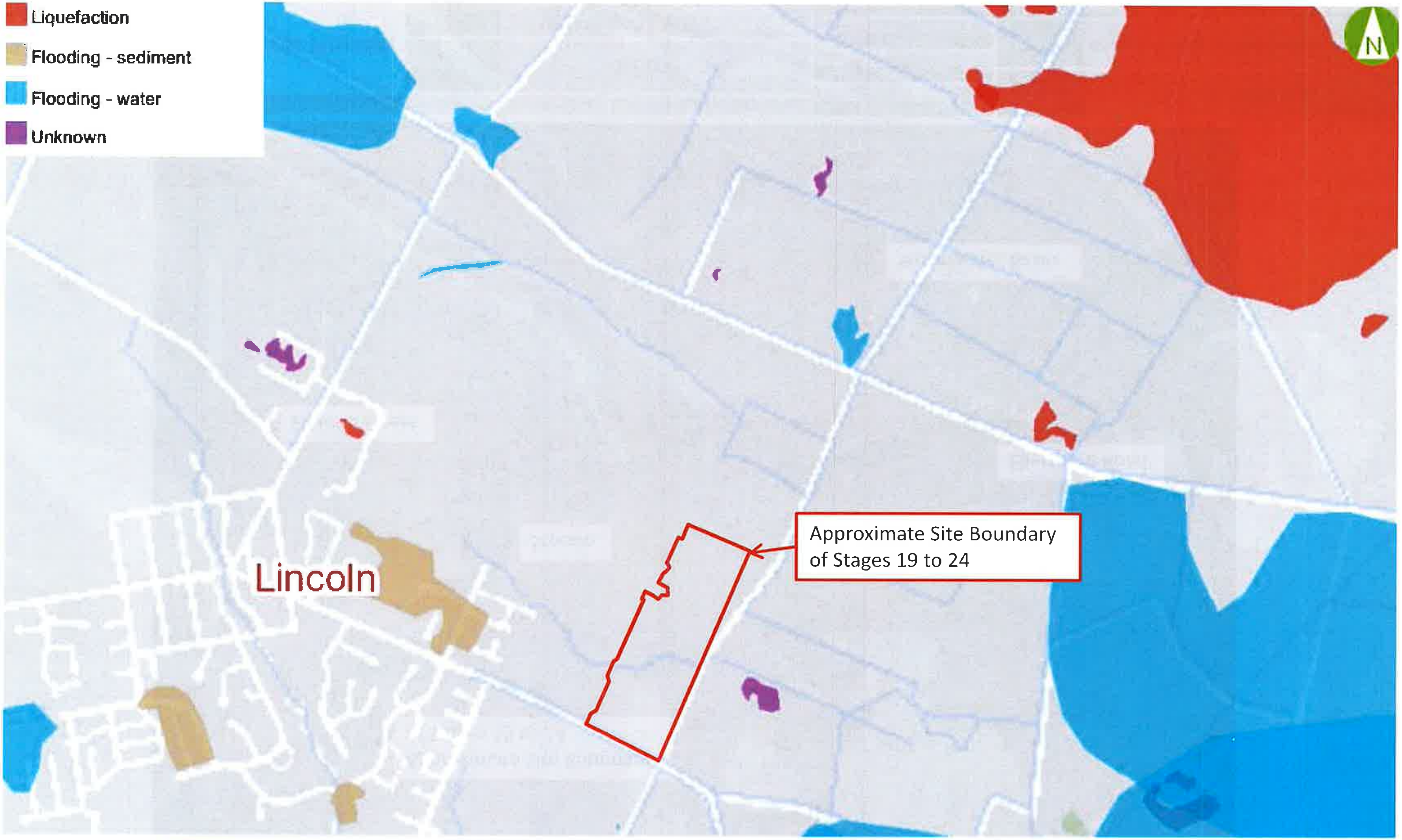

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aurecon / Fulton Hogan			NTS	A4	GNS (2012) RECORDED LIQUEFACTION AFTE[R] THE 4 SEPTEMBER 2010 EARTHQUAKE
FIGURE	FIGURE 3		BY J. MUIRSON		
PROJECT	ROSEMERRYN SUBDIVISION		APPROVED J. KUPEC		REFERENCE: BACKGROUND IMAGINE SOURCED FROM CANTERBURY MA[PS] COPYRIGHT RESERVED
			DATE		PROJECT / WBS / TYPE / DISC / NUMBER

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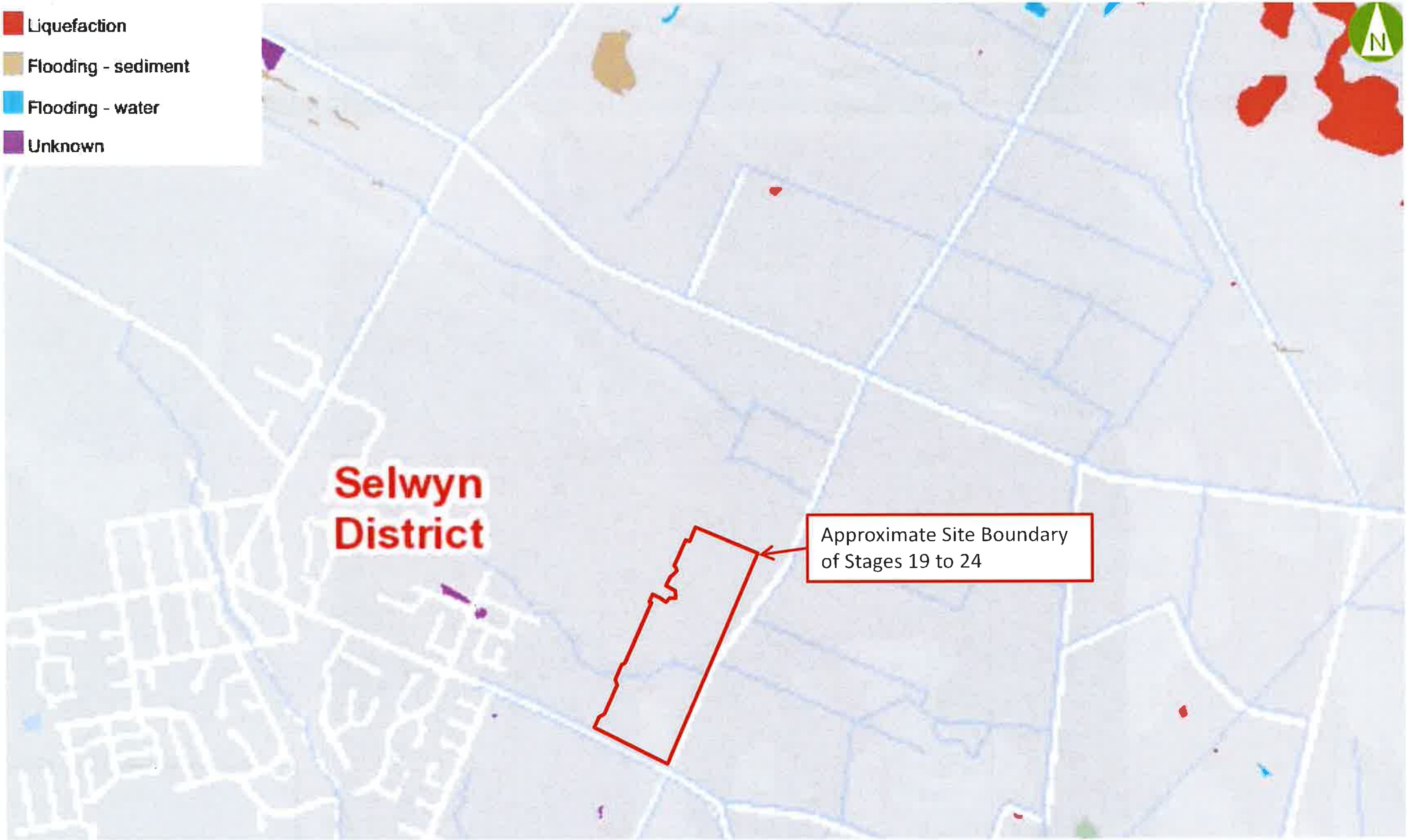
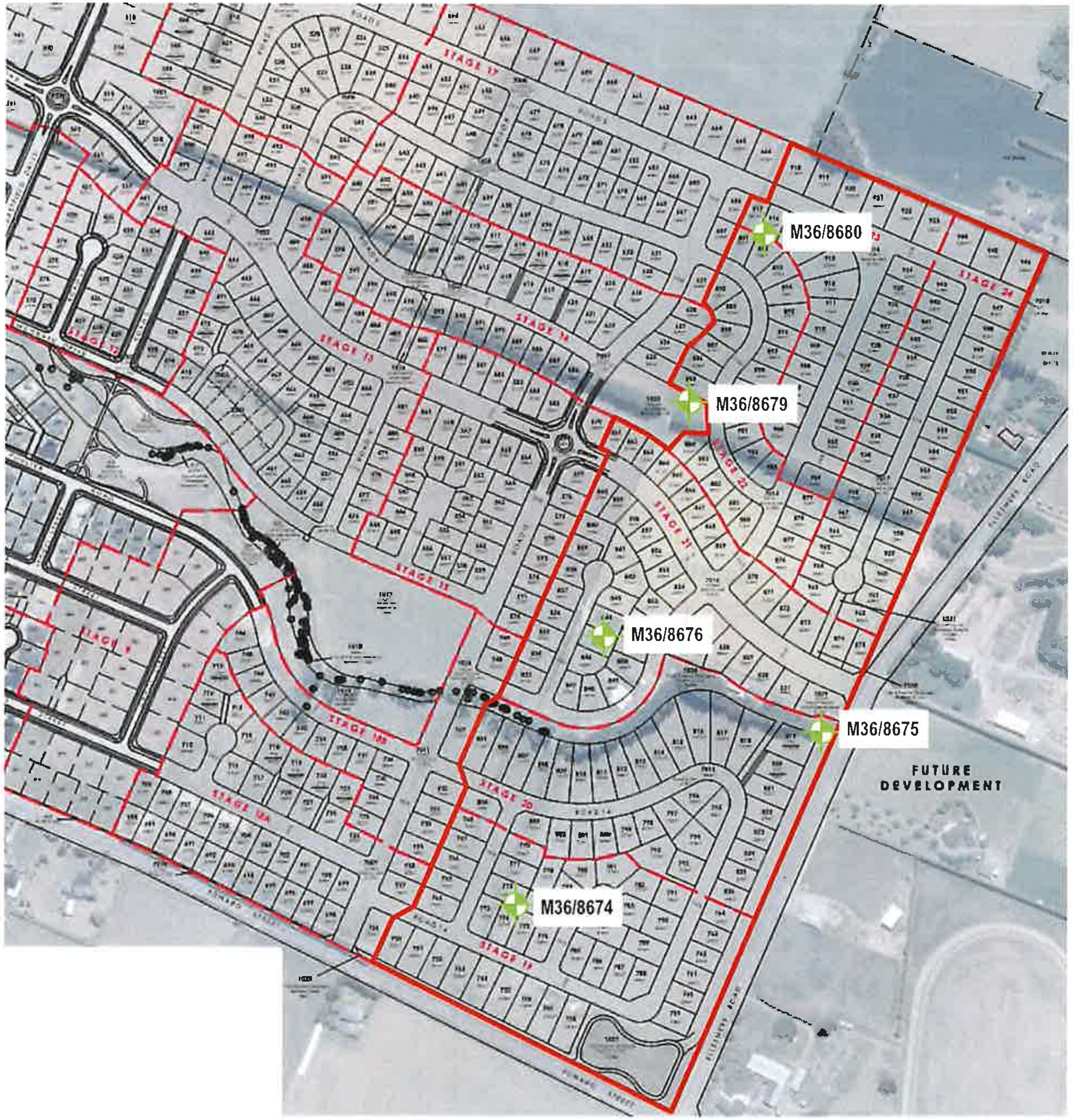


CLIENT	PRELIMINARY NOT FOR CONSTRUCTION	ALL DIMENSIONS APPROXIMATE ONLY	SCALE: NTS	SIZE: A4	TITLE: GNS (2012) RECORDED LIQUEFACTION AFTE[R] THE 22 FEBRUARY 2011 EARTHQUAKE
aurecon / Fulton Hogan	FIGURE	FIGURE 4	BY: J. MUIRSON		REFERENCE: BACKGROUND IMAGINE SOURCED FROM CANTERBURY MA[…] COPYRIGHT RESERVED
ww.aurecongroup.com	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED: J. KUPEC		
			DATE		PROJECT · WBS · TYPE · DISC · NUMBER

Legend

- Site Boundary
- ECan Borehole



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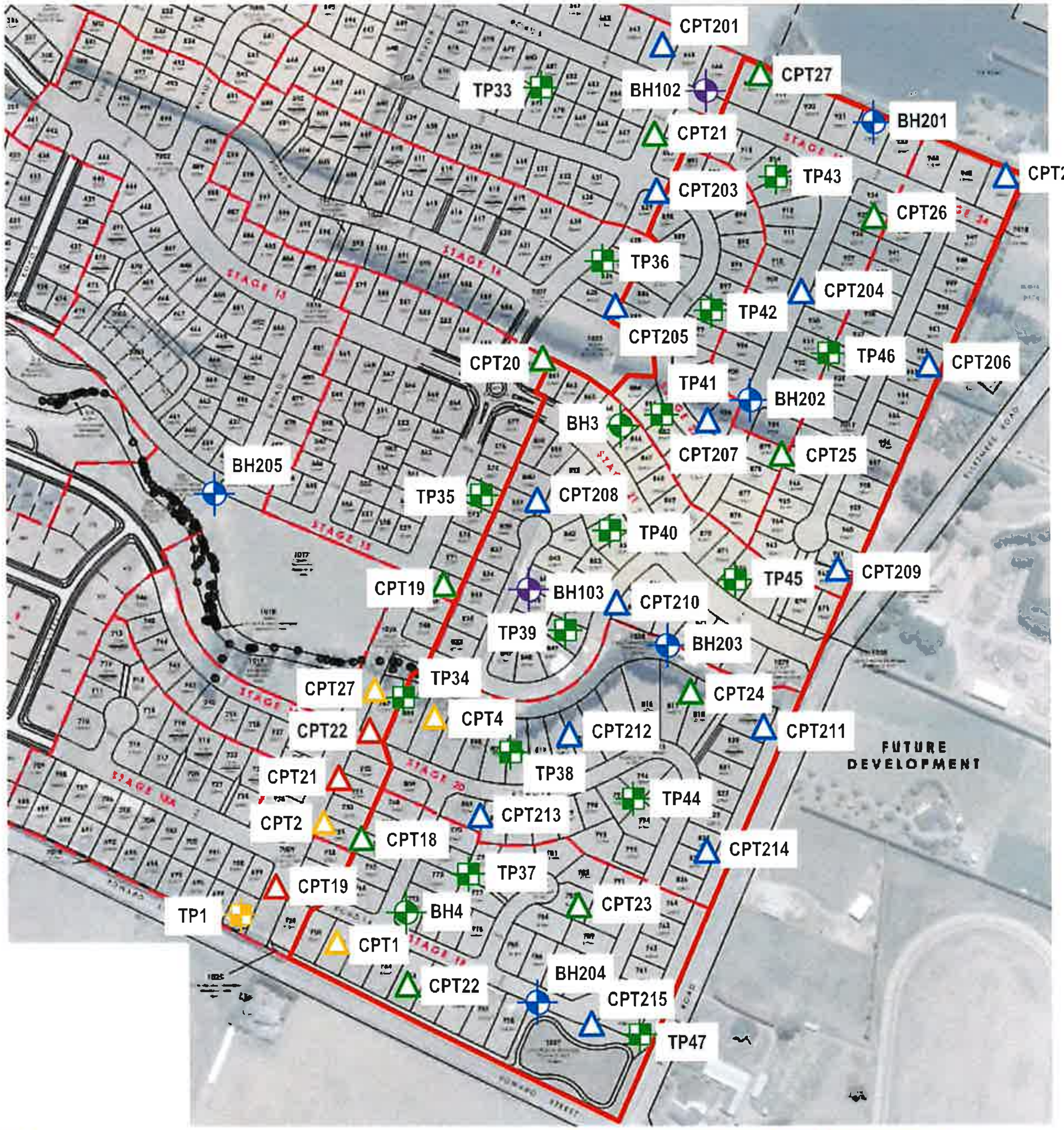
aurecon / Fulton Hogan	FIGURE: FIGURE 5		BY: J. MUIRSON	TITLE: ECAN WELL LOCATION PLAN
www.aurecongroup.com	PROJECT: ROSEMERRYN SUBDIVISION		APPROVED: J. KUPEC	REFERENCE: BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM
			DATE	PROJECT / WBS / TYPE / DISC / NUMBER

Legend

(red outline)	Site Boundary
(green borehole symbol)	2011 Borehole
(green triangle)	2011 CPT
(green test pit symbol)	2011 Test Pit
(yellow triangle)	2012 CPT
(yellow test pit symbol)	2012 Test Pit
(red triangle)	2013 CPT
(purple borehole symbol)	2015 Borehole
(purple triangle)	2015 CPT
(blue piezometer symbol)	2018 Piezometer
(blue triangle)	2018 CPT



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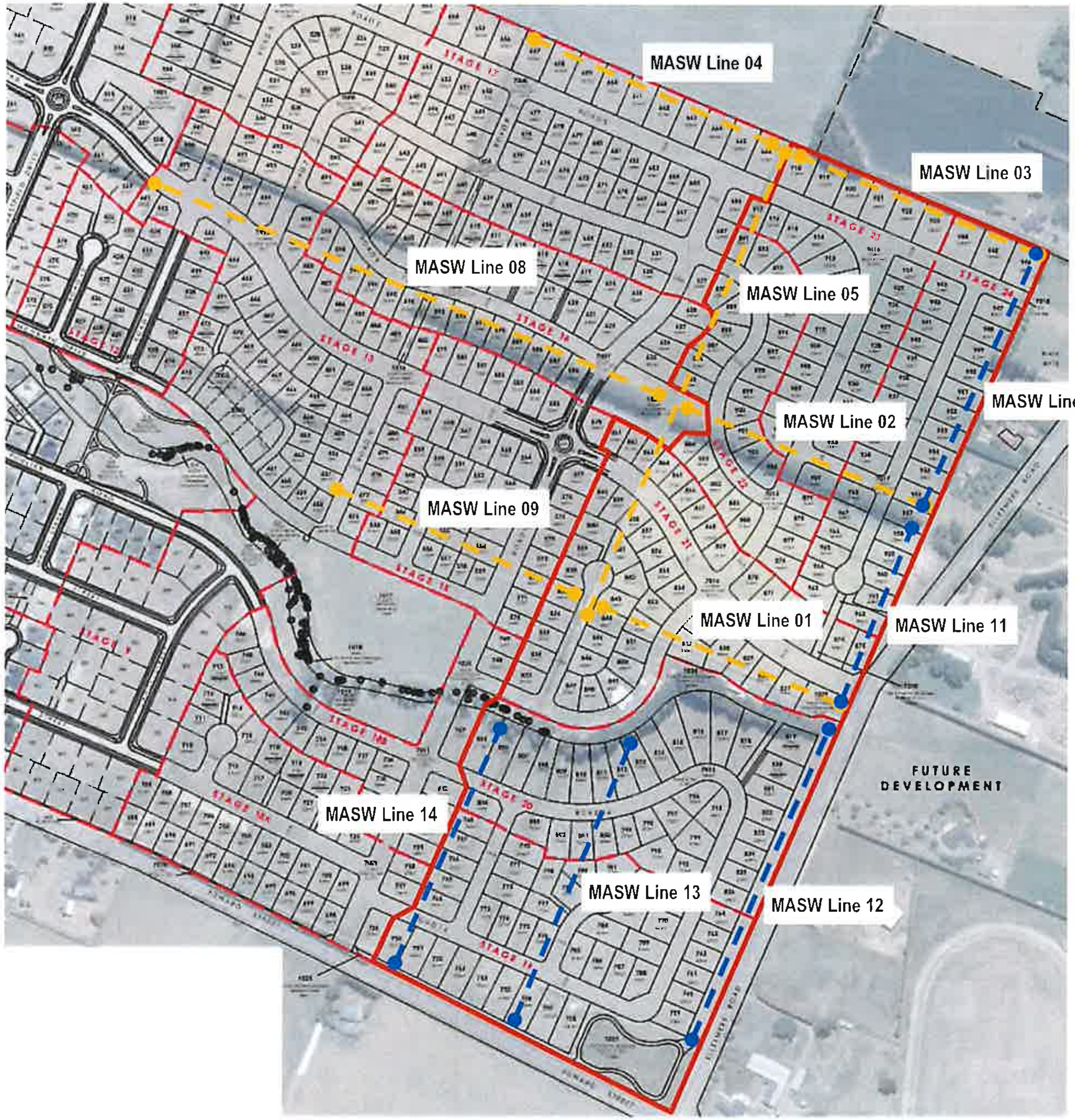
aurecon www.aurecongroup.com / Fulton Hogan	FIGURE	FIGURE 6	NTS	A4		
			BY: J. MUIRSON		REFERENCE	BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM
	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED: J. KUPEC			
			DATE		PROJECT / WBS / TYPE / DISC / NUMBER	



Legend

Site Boundary

2015 MASW Line

2018 MASW Lines

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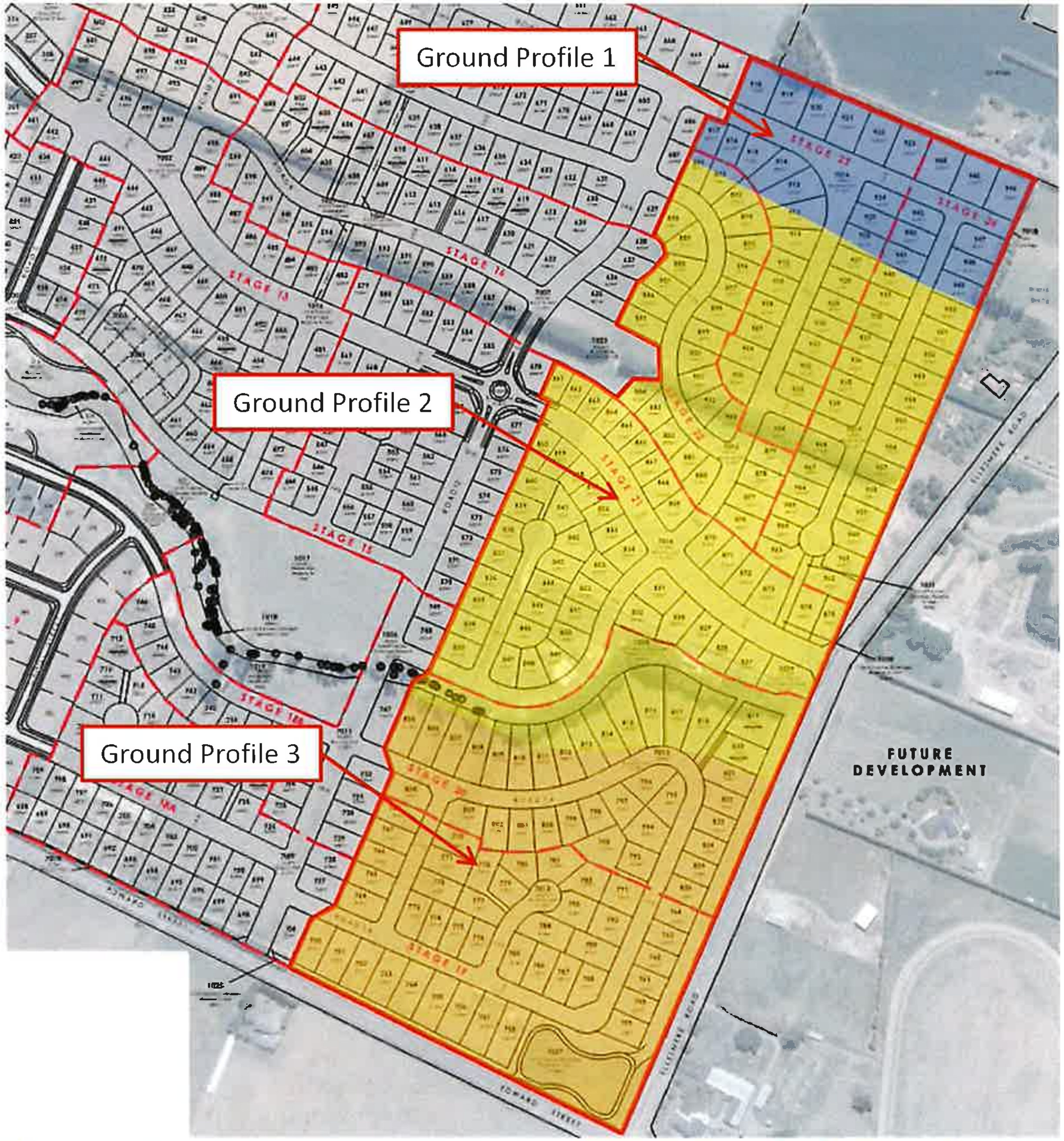
CLIENT	PRELIMINARY NOT FOR CONSTRUCTION	ALL DIMENSIONS APPROXIMATE ONLY	
FIGURE	FIGURE 7		
PROJECT	ROSEMERRYN SUBDIVISION		
SCALE	NTS	SIZE	A4
BY	J. MUIRSON		
APPROVED	J. KUPEC		
DATE			
TITLE	MASW SECTIONS		
REFERENCE	BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM		
PROJECT	WBS	TYPE	DISC
NUMBER			

Legend

Site Boundary



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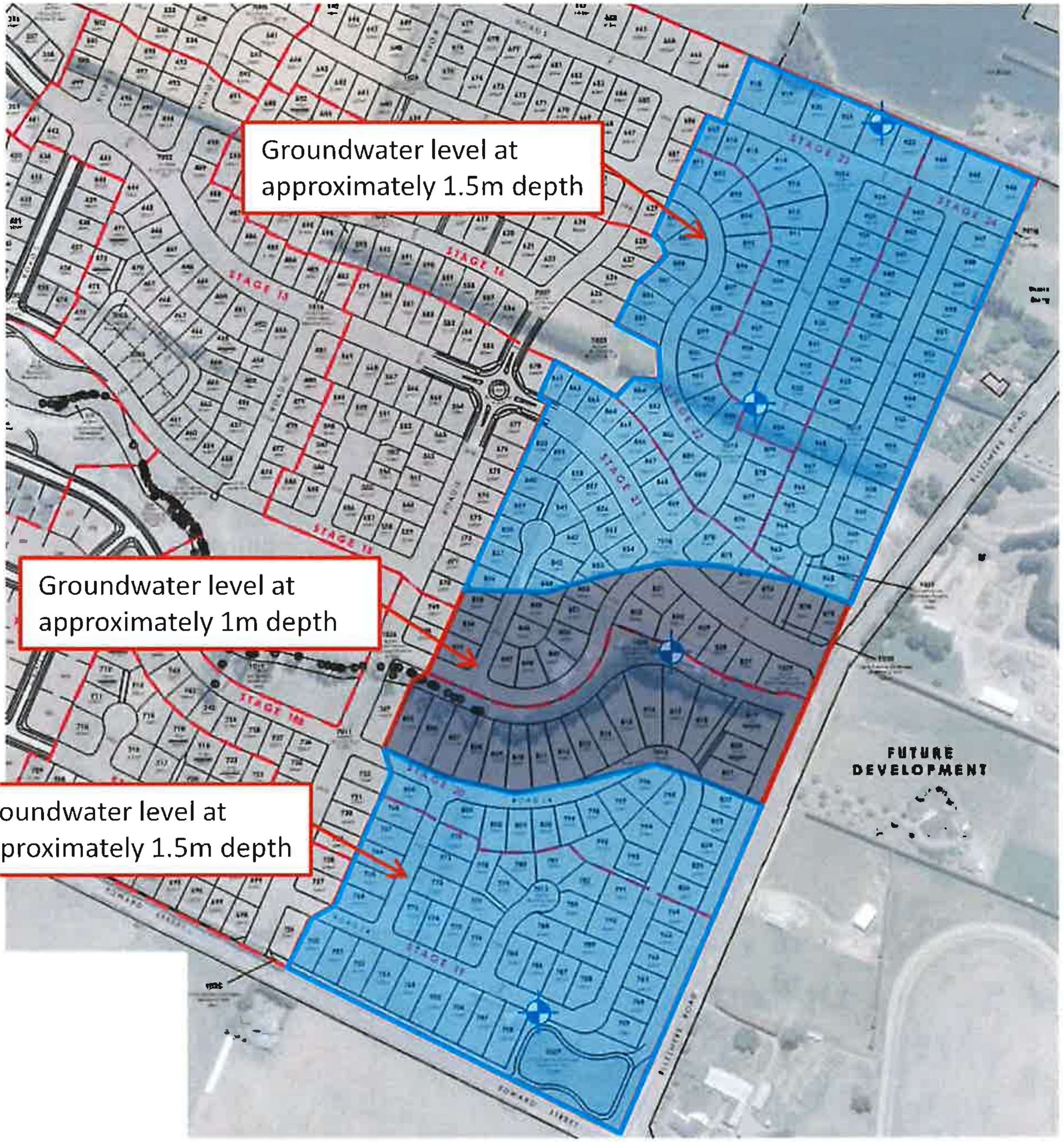
aurecon / Fulton Hogan	FIGURE	FIGURE 8	BY: J. MUIRSON		REFERENCE: BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM
ww.aurecongroup.com	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED: J. KUPEC		PROJECT / WBS / TYPE / DISC / NUMBER
			DATE		

Legend

Site Boundary



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aurecon (www.aurecongroup.com) · Fulton Hogan	FIGURE	FIGURE 9	BY: J. MUIRSON		REFERENCE: BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM
	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED: J. KUPEC		

Legend

- Site Boundary
- TC1
- TC2
- TC3

Note: Equivalent technical categories are based on index settlements only.

CLIENT	PRELIMINARY NOT FOR CONSTRUCTION	ALL DIMENSIONS APPROXIMATE ONLY	SCALE	SIZE	TITLE	TECHNICAL CLASSIFICATION MAP FOR EA… CPT BASED ON INDEX SETTLEMENTS
aurecon / Fulton Hogan / ww.aurecongroup.com	FIGURE	FIGURE 10	NTS	A4		
			BY	J. MUIRSON	REFERENCE	BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM…
	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED	J. KUPEC	PROJECT	WBS / TYPE / DISC / NUMBER
			DATE			

Legend

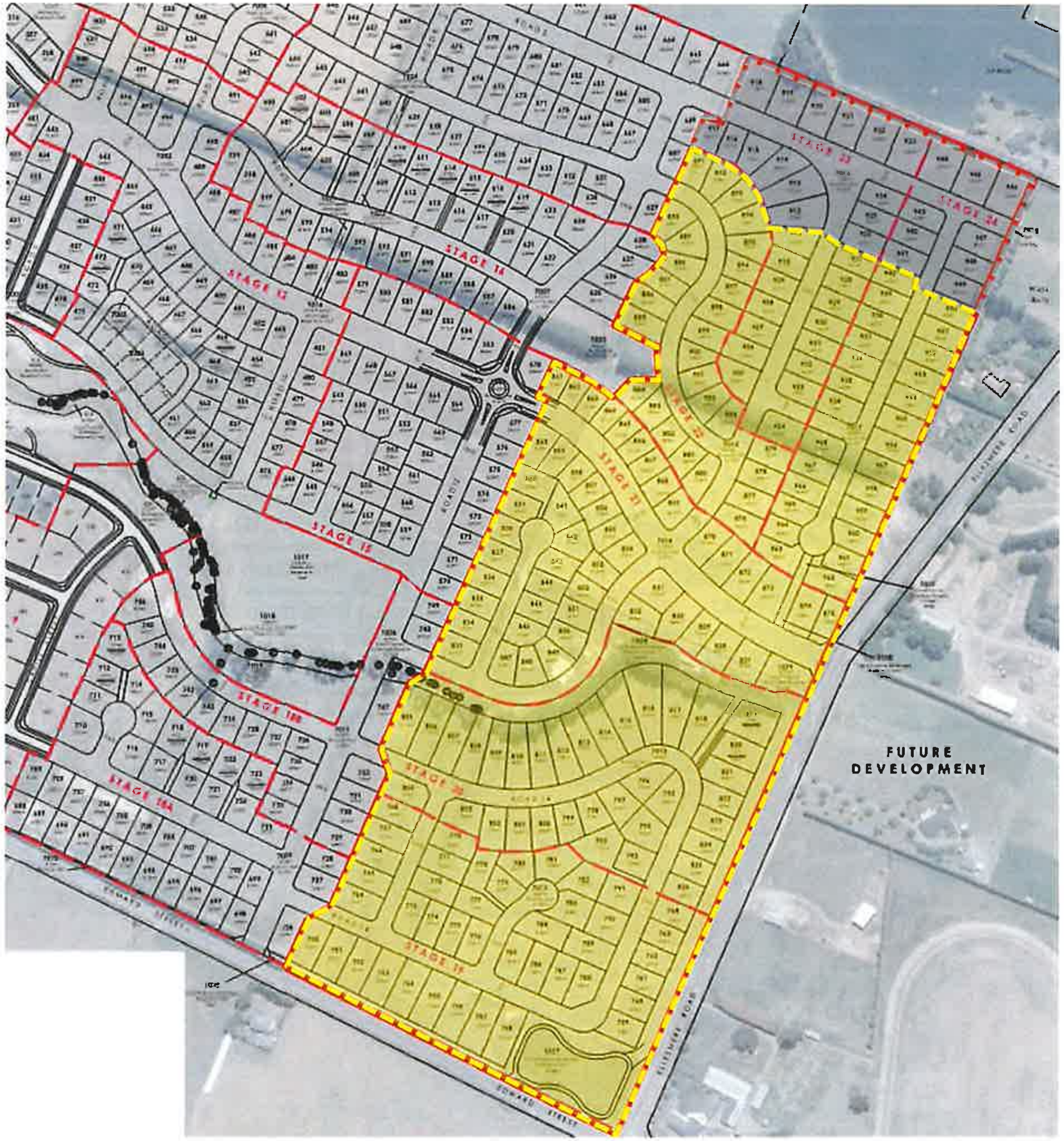
TC1 Equivalent behaviour

TC2 Equivalent behaviour

Note:
Equivalent technical categories are based on CPT based liquefaction analysis only, assuming a CFC of 0.0 and PL of 15%.

Map boundaries are indicative only and are only be used as a visual tool.

Note: Equivalent technical categories are based the liquefaction assessment calibrated with site performance.



CLIENT	PRELIMINARY NOT FOR CONSTRUCTION	ALL DIMENSIONS APPROXIMATE ONLY	SCALE	SIZE	TITLE	TECHNICAL CLASSIFICATION MAP (BASED ON LIQUEFACTION ASSESSMENT
aurecon / Fulton Hogan	FIGURE	FIGURE 11	NTS	A4		
			BY: J. MUIRSON		REFERENCE	BACKGROUND IMAGINE PROVIDED BY DAVIE LOVELL-SM
	PROJECT	ROSEMERRYN SUBDIVISION	APPROVED: J. KUPEC			

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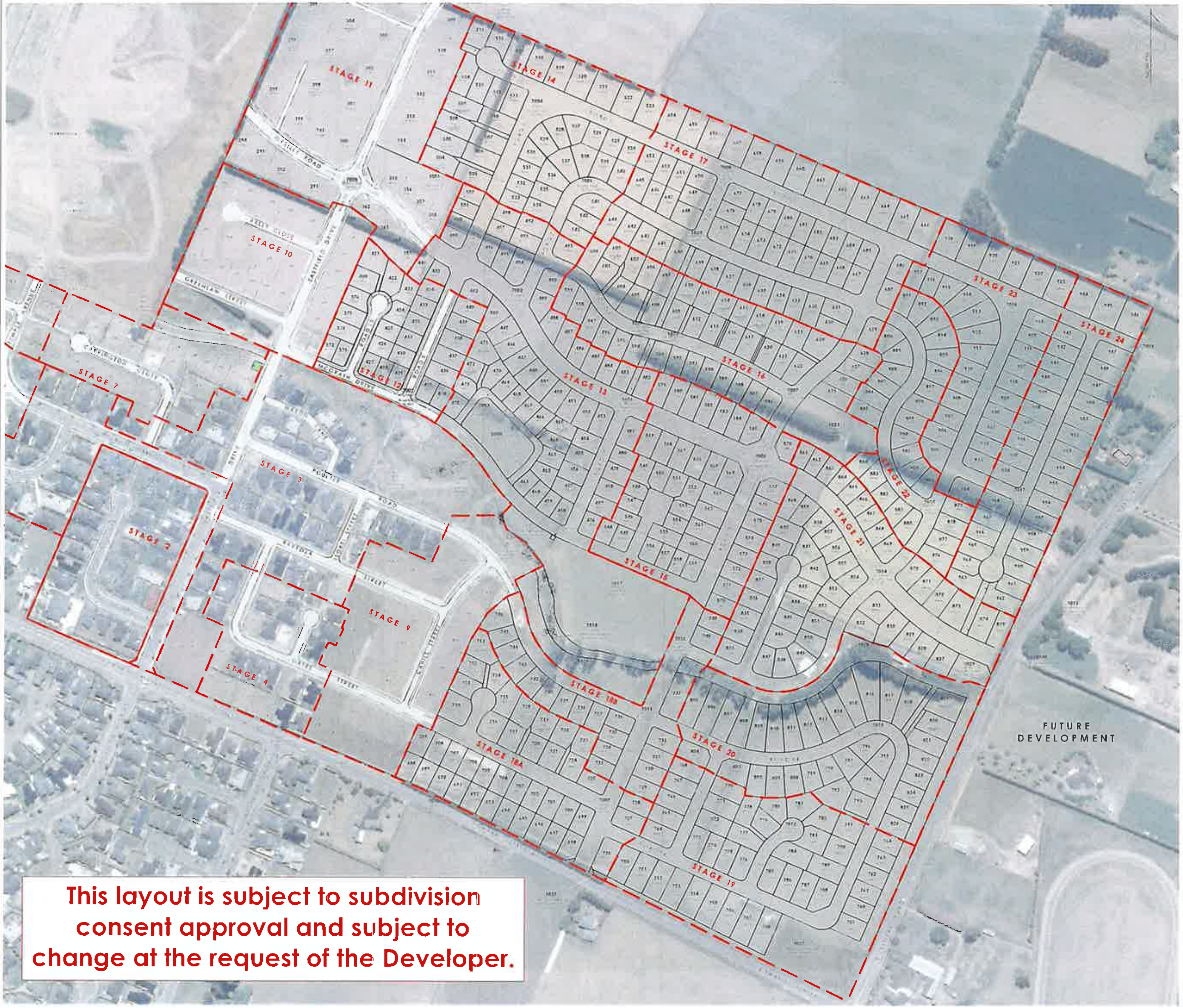
B

DLS Plans



This layout is subject to subdivision consent approval and subject to change at the request of the Developer.

NOTES:

1) Areas and dimensions are approximate only and are subject to final survey and deposit of plans.
2) Service easements to be created as required.
3) This plan has been prepared for subdivision consent purposes only. No liability is accepted if the plan is used for any other purposes.

DRAFT

Rosemerryn

DAVIE LOVELL-SMITH

PLANNING SURVEYING ENGINEERING

JOB TITLE: Rosemerryn

SHEET TITLE: Proposed Subdivision Stages 11 - 24

DRAWING STATUS: For Information

SCALE	1:2000@A1 1:4000@A3	DATE	April 2018
DRAWING No.	19458	SHEET No.	1 OF 1
REVISION	R1		

C

ECan Logs

Borelog for well M36/8674

Grid Reference (NZTM): 1559985 mE, 5167473 mN
Location Accuracy: 2 - 15m
Ground Level Altitude: 8.5 m +MSD Accuracy: < 2.5 m
Driller: not known
Drill Method: Rotary/Percussion
Borelog Depth: 6.0 m Drill Date: 09-Oct-2008

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		0.20m	Dark grey loamy topsoil	
1		2.00m	Very soft light grey, mottled with orange, silty clay, minor patches of rusty brown sand	
2		2.40m	Very soft blue grey silty clay (pug)	
3, 4, 5		6.00m	Very soft blue grey silty clay with patches of rusty brown silty clay and occasional pieces of timber	

Borelog for well M36/8675

Grid Reference (NZTM): 1560265 mE, 5167627 mN
Location Accuracy: 2 - 15m
Ground Level Altitude: 8.0 m +MSD Accuracy: < 2.5 m
Driller: not known
Drill Method: Rotary/Percussion
Borelog Depth: 5.8 m Drill Date: 09-Oct-2008

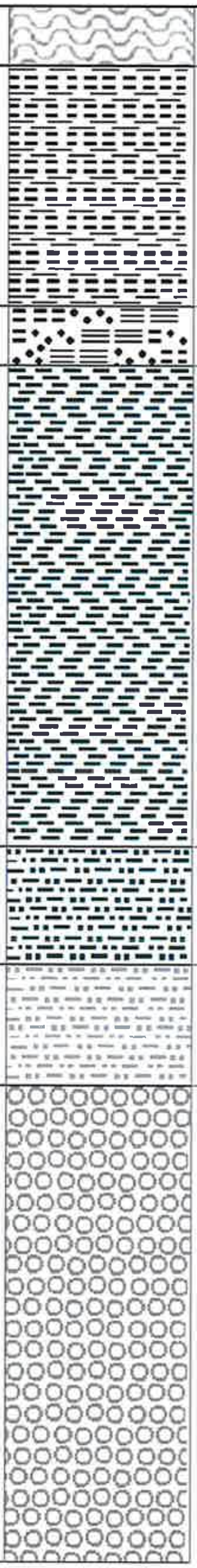
Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		0.20m	Dark grey loamy topsoil	
1		1.20m	Soft grey intermixed with brown silty clay. Speckled with patches of orange and some timber	
2, 3		3.20m	Soft blue grey silty clay with pieces of timber	
		3.60m	Grey brown sand mixed with soft grey brown silty clay	
4, 5		5.80m	Grey silty sandy gravel	

Borelog for well M36/8676

Grid Reference (NZTM): 1560062 mE, 5167719 mN
Location Accuracy: 2 - 15m
Ground Level Altitude: 9.3 m +MSD Accuracy: < 2.5 m
Driller: not known
Drill Method: Rotary/Percussion
Borelog Depth: 5.2 m Drill Date: 09-Oct-2008

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

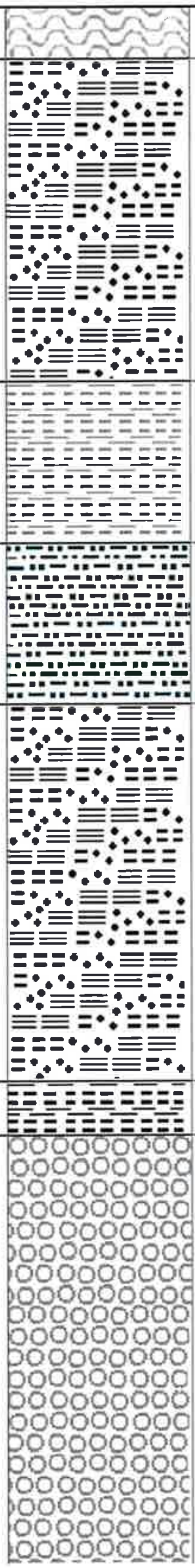


Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		0.20m	Dark grey loamy topsoil	
1		1.00m	Firm grey silty clay speckled with orange	
		1.20m	Grey silty clay speckled with orange sandy silt	
2		2.80m	Soft blue grey silt with pieces of timber	
3		3.20m	Blue grey silt with patches of grey sandy silt	
		3.60m	Grey sandy silt	
4, 5		5.20m	Grey gravel	

Borelog for well M36/8679

Grid Reference (NZTM): 1560150 mE, 5167922 mN
Location Accuracy: 2 - 15m
Ground Level Altitude: 10.1 m +MSD Accuracy: < 2.5 m
Driller: not known
Drill Method: Rotary/Percussion
Borelog Depth: 5.8 m Drill Date: 09-Oct-2008

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

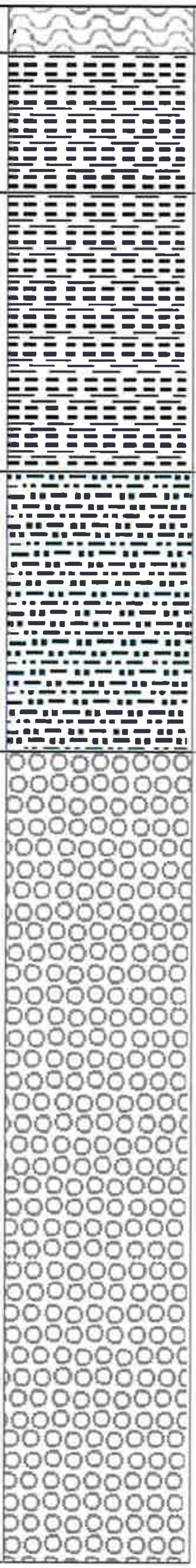


Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		0.20m	Dark grey loamy topsoil	
1		1.40m	Soft light grey & yellow silty clay with minor patches of rusty orange sandy silt	
2		2.00m	Soft grey silty clay	
		2.60m	Soft blue grey sandy silt with pieces of timber	
3, 4		4.00m	Soft blue grey silty clay with patches of brown sand	
		4.20m	Firm brown yellow silty clay	
5		5.80m	Grey gravel	

Borelog for well M36/8680

Grid Reference (NZTM): 1560211 mE, 5168084 mN
Location Accuracy: 2 - 15m
Ground Level Altitude: 10.1 m +MSD Accuracy: < 2.5 m
Driller: not known
Drill Method: Rotary/Percussion
Borelog Depth: 6.7 m   Drill Date: 09-Oct-2008

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha



Scale(m)	Water Level	Depth(m)	Full Drillers Description	Formation Code
		0.20m	Dark grey loamy topsoil	
		0.80m	Firm light grey silty clay mixed with yellow orange silty clay	
1, 2		2.00m	Soft blue grey silty clay with minor patches of light yellow.	
3		3.20m	Grey & light yellow silty sand. Sand faction increasing with depth	
4, 5, 6		6.70m	Grey gravel. 2-20mm diameter in size. Stone size increasing with depth	

D

Previous Investigations

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www.aurecongroup.com
Email: christchurch@ap.aurecongroup.com

Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN FARM SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

BH03

BOREHOLE INFORMATION	CO-ORDINATES N/A		
Drilling Method: CAT 312 Track Rig	Easting: N/A	Date Started: 16/09/2011	Logged by: JSM
Diameter Core: 100mm	Northing: N/A	Date Completed: 16/09/2011	Input by: JSM
Contractor: McMillan Drilling	Ground Level: N/A	Inclination: 90	Checked by: JSM
		Orientation:	Verified by: JK

Method/Casing	Core Recovery (%)	Water Loss (%)	Groundwater Level (m)	R.L (m)	Depth (m)	Graphic Log	Material Description	USC Description	Consistency/Density	Moisture	Sample	In-Situ Testing	Laboratory Testing	Notes	Backfill	Geological Unit
WASH					0	Topsoil	TOPSOIL SILT with trace sand and occaisional rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	OL					NO LABORATORY TESTING			
						Sandy SILT	Sandy SILT; Yellow brown. Low plasticity. Firm. Moist.	ML								
			▼ (approx. 1m)		1	Sandy SILT	Sandy SILT; Dark grey. Low plasticity. Firm. Moist.	ML				SPT at 1.6m N = 7 1, 1/1, 1, 2, 3 450mm (SC)				
					3		Borehole Terminated at 3m (Target Depth)									

Depth scale (m): 1, 2, 3, 4, 5, 6, 7, 8, 9

Method
CC concrete core
OB open barrel
SSA solid stem auger
HSA hollow stem auger
WASH wash drill
PQ3 PQ Triple Tube
HQ3 HQ Triple Tube
NQ3 NQ Triple Tube
NMLC NMLC Triple Tube
DP Direct Push
DT Dual Tube (70mm)
Casing

USC Classification
CH Inorganic CLAYS high plasticity
CI Inorganic CLAYS medium plasticity
CL Inorganic CLAYS low plasticity
GC Clayey GRAVEL
GM Silty GRAVEL
GP Poorly Graded GRAVEL
GW Well Graded GRAVEL
MH Inorganic SILT high plasticity
ML Inorganic SILT low plasticity
OH ORGANIC CLAY medium to high plasticity
OL ORGANIC SILT low plasticity
PT PEAT and highly organic soils
SC Clayey SAND
SM Silty SAND
SP Poorly graded SAND
SW Well graded SAND

Consistency
VS very soft
S soft
F firm
S stiff
VS very stiff
H hard

Density
VL very loose
L loose
MD medium dense
D dense
VD very dense

Soil Samples
B bulk
U undisturbed
D disturbed

Water
at end of excavation
at time of excavation
at time of closure

In Situ Testing
PP pen penetrometer
VS vane shear
SPT std. pen. test
SS split spoon
SC solid cone
HB hammer bouncing
SH sinks under own weight

Moisture
D dry
M moist
W wet
S saturated

Graphic Log
Topsoil
Sandy SILT

Backfill
Cement Seal: 1 pipe group, 1 pipe
Bentonite Seal: 1 pipe group, 1 pipe
Filter Pack: 1 pipe group, 1 pipe
Slotted Pipe: 1 pipe group, 1 pipe

Last Generated: 19/10/2011 12:50:53 p.m.

Database File: TEST PITS.GPJ, Library: COPY OF CHCH LIBRARY MARCH 2011.GLB, Data template: CHCH DATA TEMPLATE NOV 2010.GDT, Last Generated: 19/10/2011.

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Telephone: +64 3 [illegible]
Facsimile: +64 3 379 [illegible]

Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN FARM SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

BH04

BOREHOLE INFORMATION	CO-ORDINATES N/A		
Drilling Method: CAT 312 Track Rig	Easting: N/A	Date Started: 15/09/2011	Logged by: JSM
Diameter Core: 100mm	Northing: N/A	Date Completed: 15/09/2011	Input by: JSM
Contractor: McMillan Drilling	Ground Level: N/A	Inclination: 90	Checked by: JSM
		Orientation:	Verified by: JK

Method/Casing	Core Recovery (%)	Water Loss (%)	Groundwater Level (m)	R.L. (m)	Depth (m)	Graphic Log	Material Description	USC Description	Consistency/Density	Moisture	Sample	In-Situ Testing	Laboratory Testing	Notes	Backfill	Geological Unit
WASH			▼ (approx. 1.1)		0–0.4	Topsoil	TOPSOIL SILT with trace sand and occaisional rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	OL					NO LABORATORY TESTING			
					0.4–1.4	Silt	SILT with minor sand; Yellow brown. Low plasticity. Firm. Moist. Sand fine to medium grained.	ML								
					1.4–4.2	Silty SAND	Silty SAND; Dark blue grey. Loose to medium dense. Moist to wet. Sand fine to medium grained.	SM				SPT at 3m N = 12 2, 2/3, 3, 3, 3 450mm (SC)				
					4.2–6.8	Silt	SILT: Dark blue grey. Low plasticity. Firm to stiff. Moist.	ML								
					6.8–	Sandy GRAVEL	Sandy GRAVEL: Dark grey with orange brown mottling. Dense. Wet to saturated. Gravel fine to coarse grained and rounded. Sand fine to medium grained.	GW								

Method
CC concrete core
OB open barrel
SSA solid stem auger
HSA hollow stem auger
WASH wash drill
PQ3 PQ Triple Tube
HQ3 HQ Triple Tube
NQ3 NQ Triple Tube
NMLC NMLC Triple Tube
DP Direct Push
DT Dual Tube (70mm)
Casing

USC Classification
CH Inorganic CLAYS high plasticity
CI Inorganic CLAYS medium plasticity
CL Inorganic CLAYS low plasticity
GC Clayey GRAVEL
GM Silty GRAVEL
GP Poorly Graded GRAVEL
GW Well Graded GRAVEL
MH Inorganic SILT high plasticity
ML Inorganic SILT low plasticity
OH ORGANIC CLAY medium to high plasticity
OL ORGANIC SILT low plasticity
PT PEAT and highly organic soils
SC Clayey SAND
SM Silty SAND
SP Poorly graded SAND
SW Well graded SAND

Consistency
VS very soft
S soft
F firm
S stiff
VS very stiff
H hard

Density
VL very loose
L loose
MD medium dense
D dense
VD very dense

Soil Samples
B bulk
U undisturbed
D disturbed

Water
at end of excavation
at time of excavation
at time of closure

In Situ Testing
PP pen penetrometer
VS vane shear
SPT std. pen. test
SS split spoon
SC solid cone
HB hammer bouncing
SH sinks under own weight

Moisture
D dry
M moist
W wet
S saturated

Graphic Log
Topsoil
SILT
Silty SAND
Sandy GRAVEL

Backfill
Cement Seal: 1 pipe group, 1 pipe
Bentonite Seal: 1 pipe group, 1 pipe
Slough Backfill: 1 pipe group, 1 pipe
Slotted Pipe: 1 pipe group, 1 pipe

Database File: TEST PITS.GPJ, Library: COPY OF CHCH LIBRARY MARCH 2011.GLB, Data template: CHCH DATA TEMPLATE NOV 2010.GDT, Last Generated: 19/10/2011.

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Client: FULTON HOGAN LAND DEVELOPMENT
Project Name: ROSEMERRYN FARM SUBDIVISION
Location: SEE PLAN
Project Reference: 224464

BH04

BOREHOLE INFORMATION	CO-ORDINATES N/A		
Drilling Method: CAT 312 Track Rig	Easting: N/A	Date Started: 15/09/2011	Logged by: JSM
Diameter Core: 100mm	Northing: N/A	Date Completed: 15/09/2011	Input by: JSM
Contractor: McMillan Drilling	Ground Level: N/A	Inclination: 90	Checked by: JSM
		Orientation:	Verified by: JK

Method/Casing	Core Recovery (%)	Water Loss (%)	Groundwater Level (m)	R.L. (m)	Depth (m)	Graphic Log	Material Description	USC Description	Consistency/Density	Moisture	Sample	In-Situ Testing	Laboratory Testing	Notes	Backfill	Geological Unit
WASH					10–15 (11, 12, 13, 14)		Sandy GRAVEL: Dark grey with orange brown mottling. Dense. Wet to saturated. Gravel fine to coarse grained and rounded. Sand fine to medium grained. *(Layer Continued from previous page)*	GW				SPT at 10m N = 49 8, 6/10, 16, 9, 16 460mm (SC)	NO LABORATORY TESTING			
					15		Borehole Terminated at 15m (Target Depth)									
					16, 17, 18, 19											

Method
CC concrete core
OB open barrel
SSA solid stem auger
HSA hollow stem auger
WASH wash drill
PQ3 PQ Triple Tube
HQ3 HQ Triple Tube
NQ3 NQ Triple Tube
NMLC NMLC Triple Tube
DP Direct Push
DT Dual Tube (70mm)
Casing

USC Classification
CH Inorganic CLAYS high plasticity
CI Inorganic CLAYS medium plasticity
CL Inorganic CLAYS low plasticity
GC Clayey GRAVEL
GM Silty GRAVEL
GP Poorly Graded GRAVEL
GW Well Graded GRAVEL
MH Inorganic SILT high plasticity
ML Inorganic SILT low plasticity
OH ORGANIC CLAY medium to high plasticity
OL ORGANIC SILT low plasticity
PT PEAT and highly organic soils
SC Clayey SAND
SM Silty SAND
SP Poorly graded SAND
SW Well graded SAND

Consistency
VS very soft
S soft
F firm
S stiff
VS very stiff
H hard

Density
VL very loose
L loose
MD medium dense
D dense
VD very dense

Soil Samples
B bulk
U undisturbed
D disturbed

Water
at end of excavation
at time of excavation
at time of closure

In Situ Testing
PP pen penetrometer
VS vane shear
SPT std. pen. test
SS split spoon
SC solid cone
HB hammer bouncing
SH sinks under own weight

Moisture
D dry
M moist
W wet
S saturated

Graphic Log
Topsoil
SILT
Silty SAND
Sandy GRAVEL

Backfill
Cement Seal: 1 pipe group, 1 pipe
Bentonite Seal: 1 pipe group, 1 pipe
Slough Backfill: 1 pipe group, 1 pipe
Slotted Pipe: 1 pipe group, 1 pipe

CPT ANALYSIS NOTES

Soil Type

Interpretation using chart of Robertson & Campanella (1983). This is a simple but well proven interpretation using cone tip resistance (q_C) and friction ratio (f_R) only. No normalisation for overburden stress is applied. Cone tip resistance measured with the piezocone is corrected with measured pore pressure (u_C).

- sand (and gravel)
- silt-sand
- silt
- clay-silt
- clay
- peat

Liquefaction Screening

The purpose of the screening is to highlight susceptible soils, that is sand and silt-sand in a relatively loose condition. This is not a full liquefaction risk assessment which requires knowledge of the particular earthquake risk at a site and additional analysis. The screening is based on the chart of Shibata and Teparaksa (1988).

- high susceptibility
- medium susceptibility
- low susceptibility

High susceptibility is here defined as requiring a shear stress ratio of 0.2 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Medium susceptibility is here defined as requiring a shear stress ratio of 0.4 to cause liquefaction with D_{50} for sands assumed to be 0.25 mm and for silty sands to be 0.05 mm.

Low susceptibility is all other cases.

Relative Density (D_R)

Based on the method of Baldi et. al. (1986) from data on normally consolidated sand.

Undrained Shear Strength (S_U)

Derived from the bearing capacity equation using $S_U = (q_C - \sigma_{VO})/15$.

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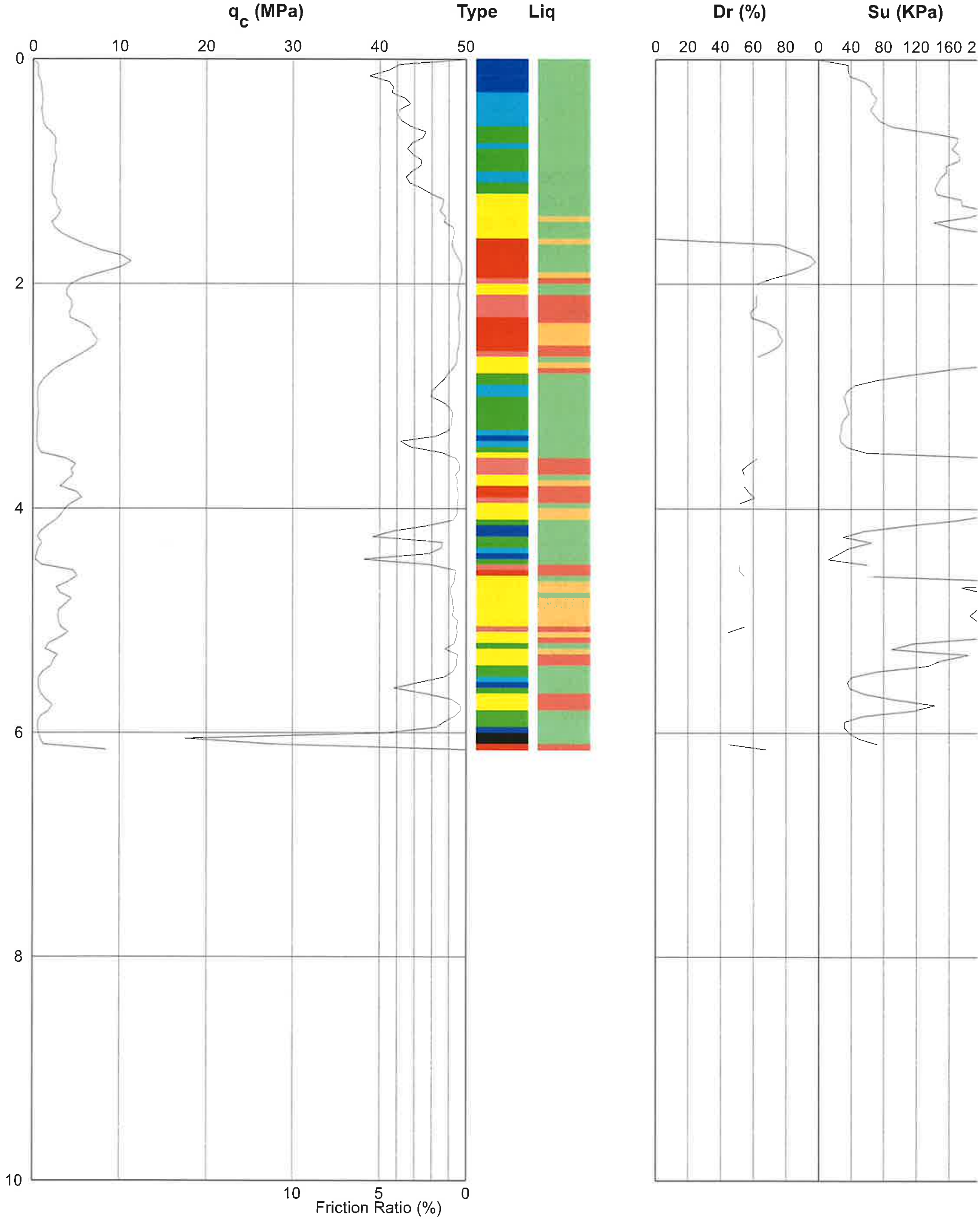
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	9402	Date:	27/08/11
CPT No:	CPTu018	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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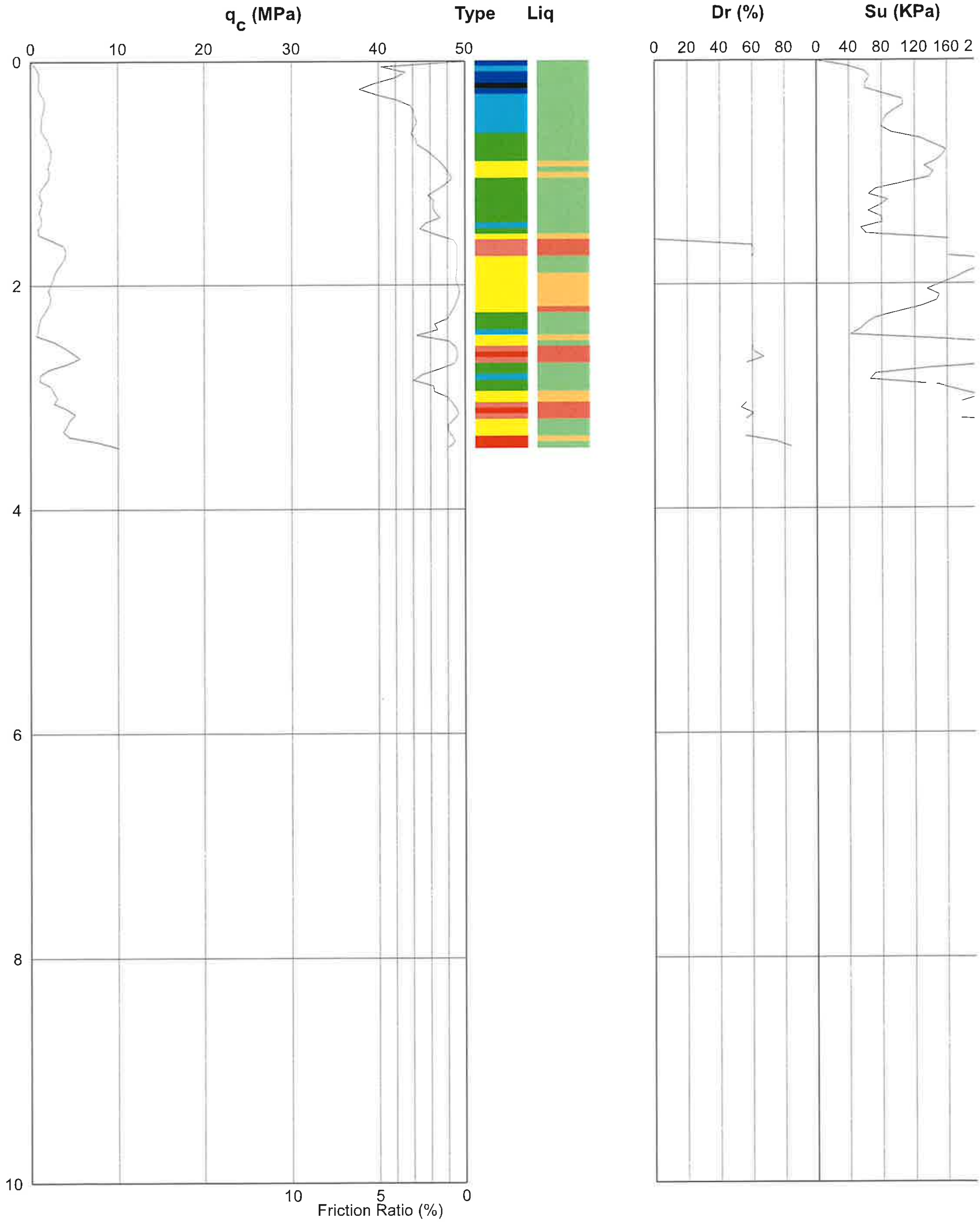
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	9402	Date:	27/08/11
CPT No:	CPTu019	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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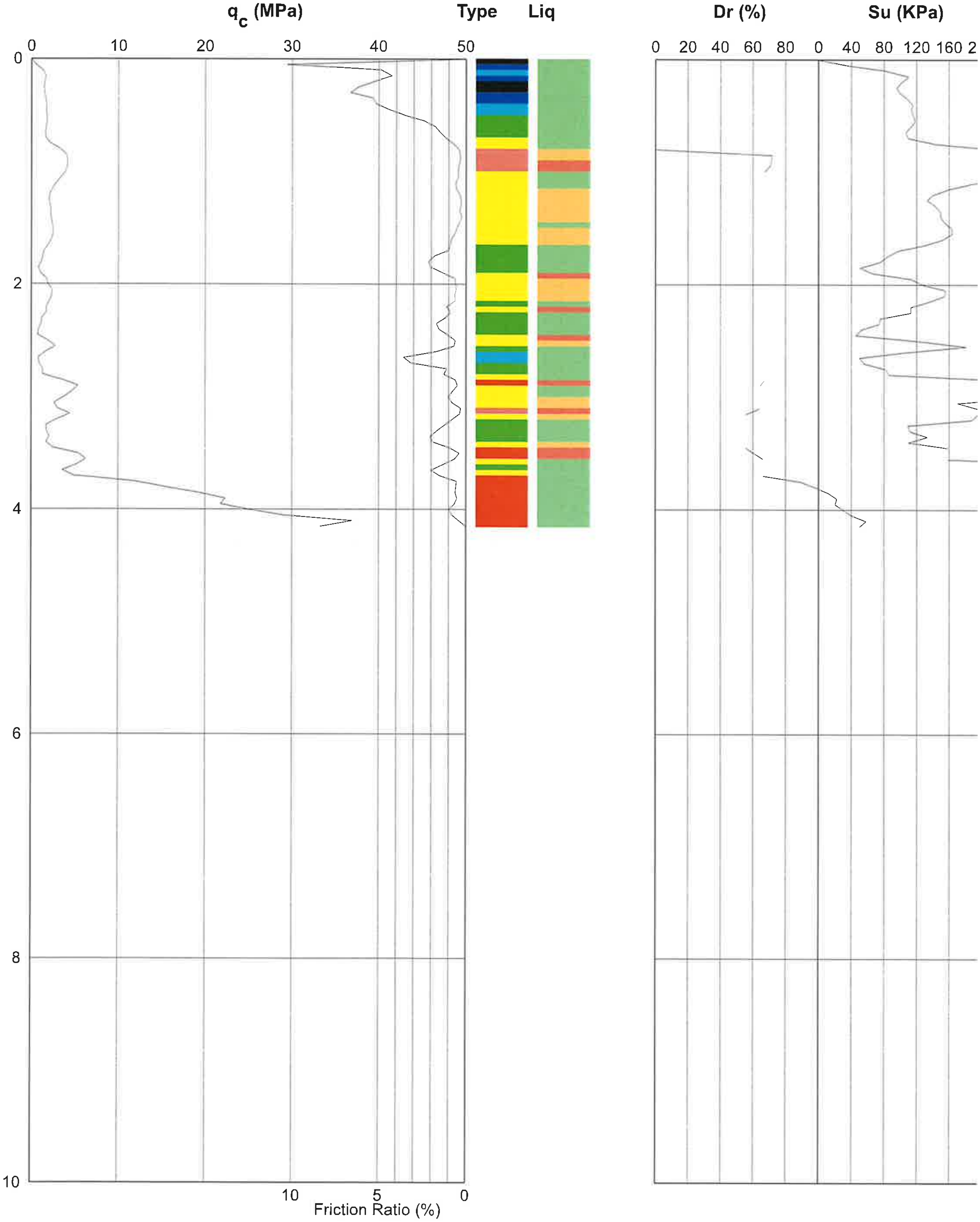
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	9402	Date:	27/08/11
CPT No:	CPTu020	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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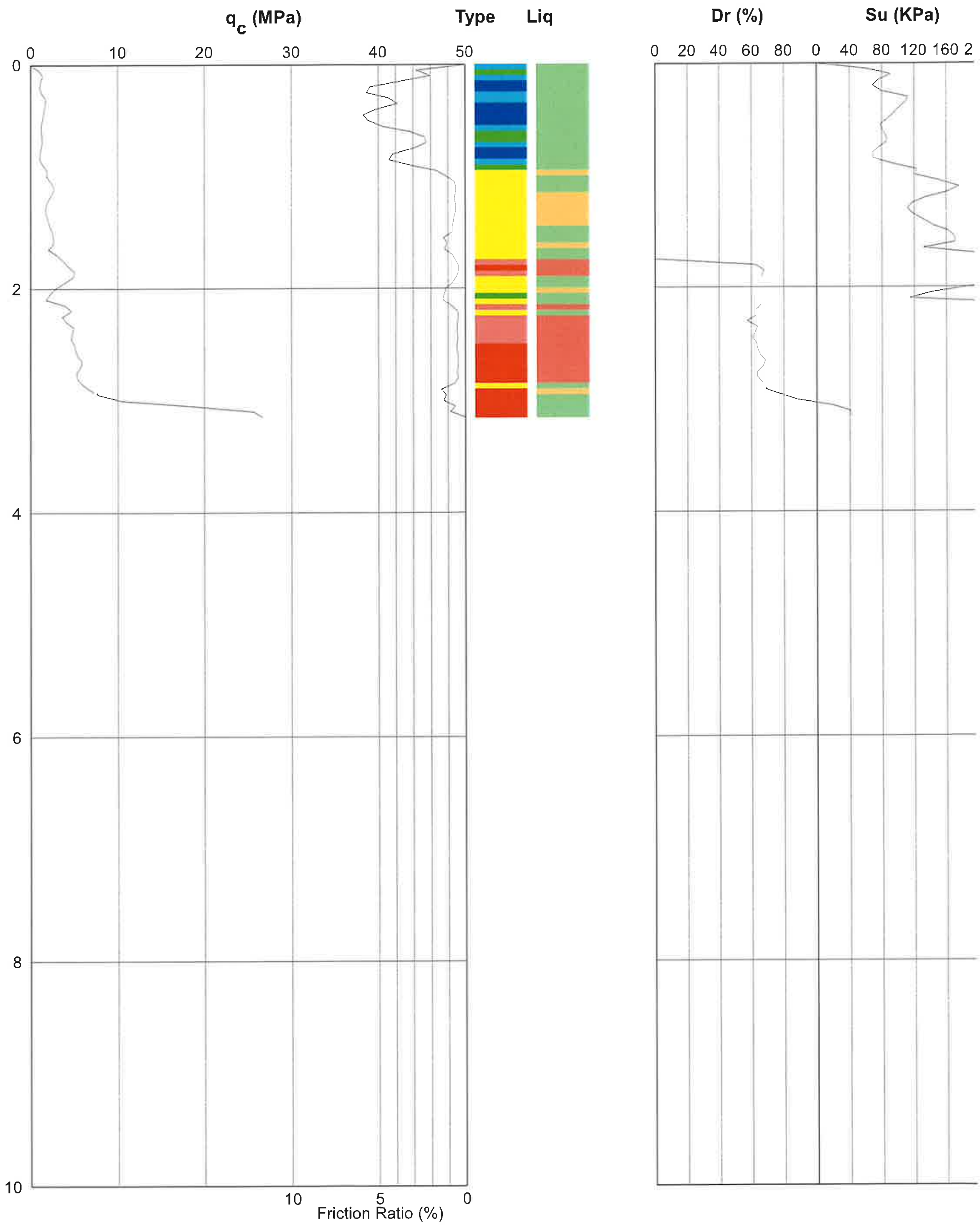
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	9402	Date:	27/08/11
CPT No:	CPTu021	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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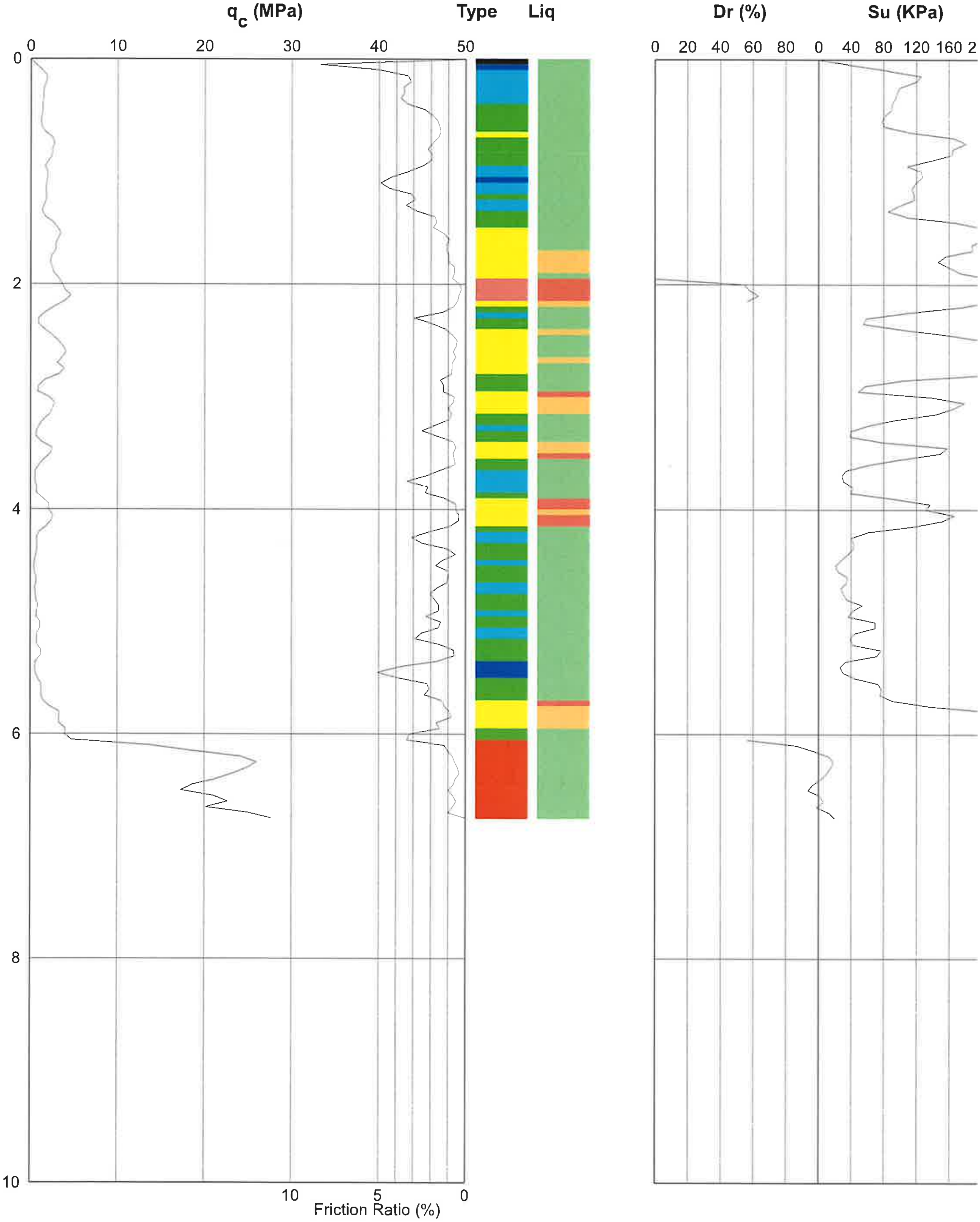
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No:	9402	Date:	27/08/11
CPT No:	CPTu022	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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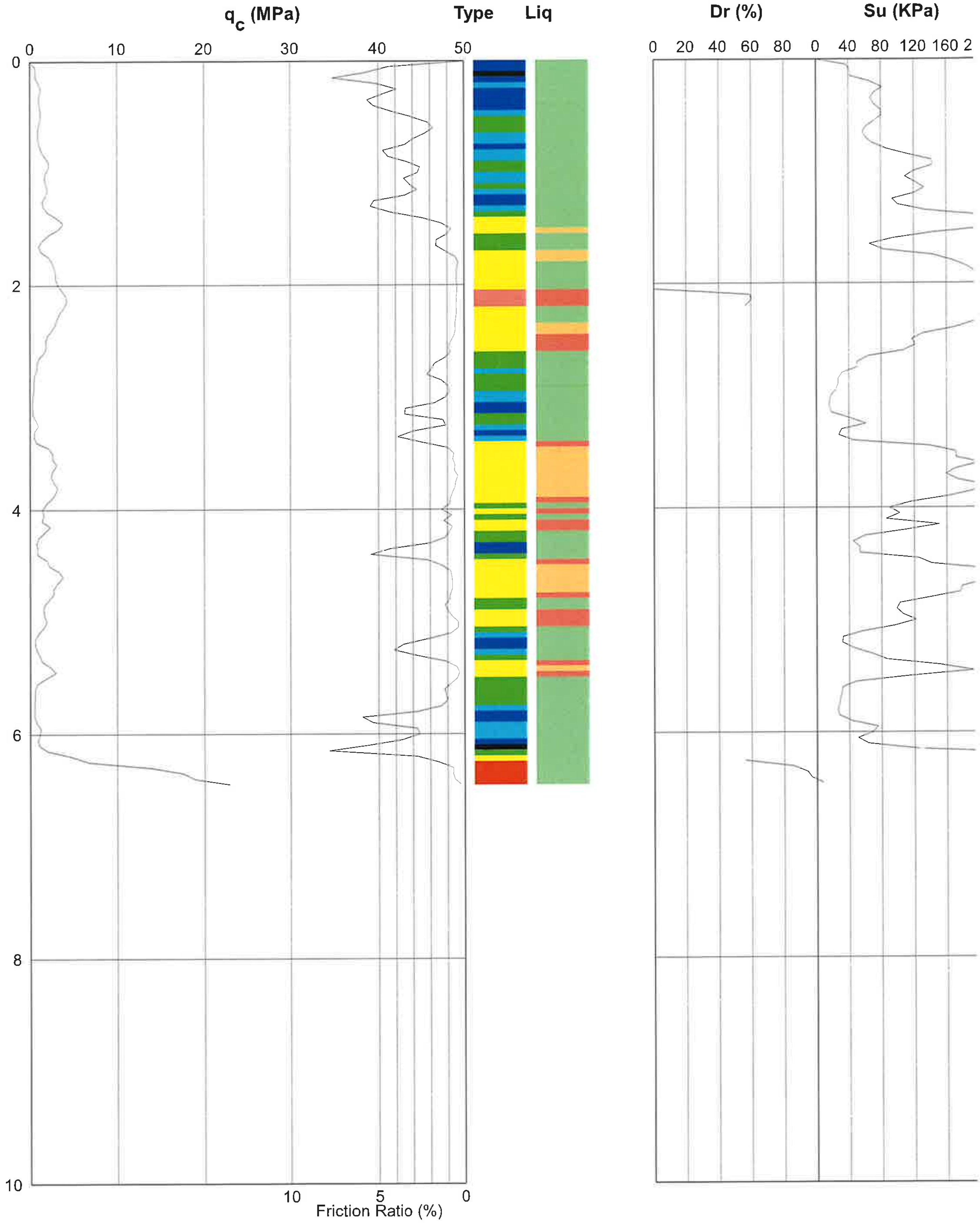
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9402

CPT No: CPTu023

Project: FH C/o Aurecon

Location: Rosemerryn, Edward St, Lincoln

Date: 27/08/11

Operator: J. Kendrick

Remark: Effective Refusal

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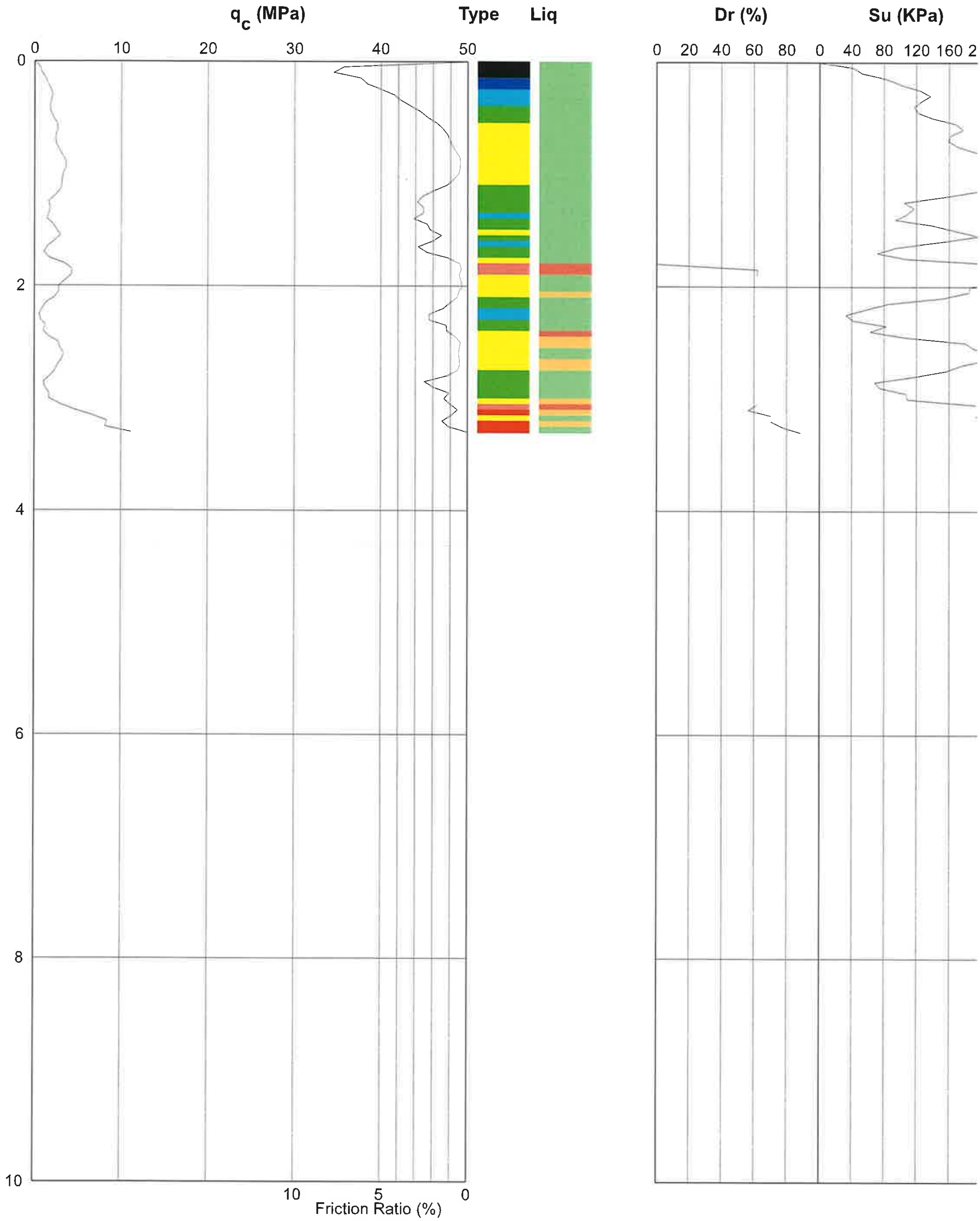
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9402

CPT No: CPTu024

Project: FH C/o Aurecon

Location: Rosemerryn, Edward St, Lincoln

Date: 27/08/11

Operator: J. Kendrick

Remark: Effective Refusal

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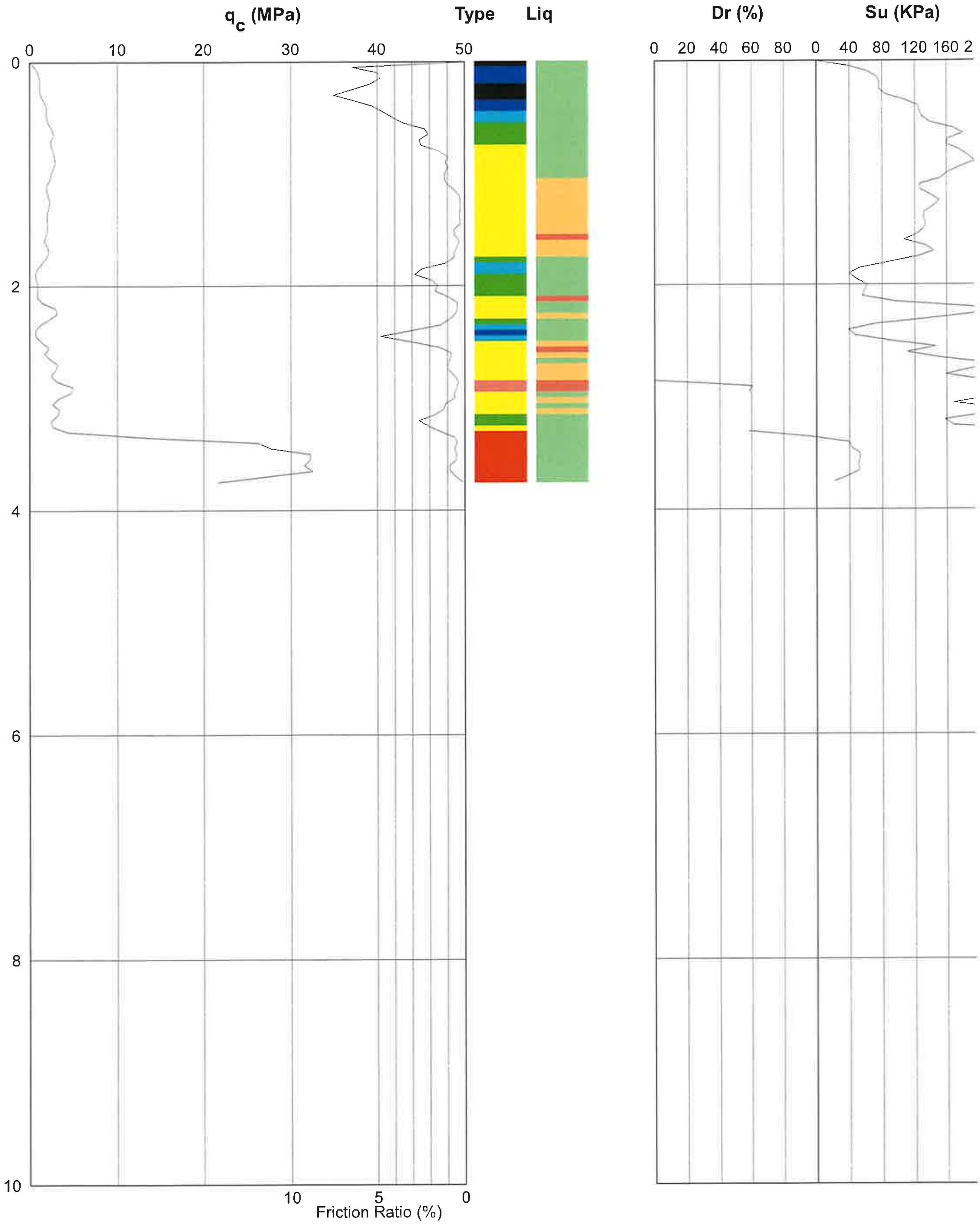

Job No:	9402	Date:	27/08/11
CPT No:	CPTu025	Operator:	J. Kendrick
Project:	FH C/o Aurecon	Remark:	Effective Refusal
Location:	Rosemerryn, Edward St, Lincoln		

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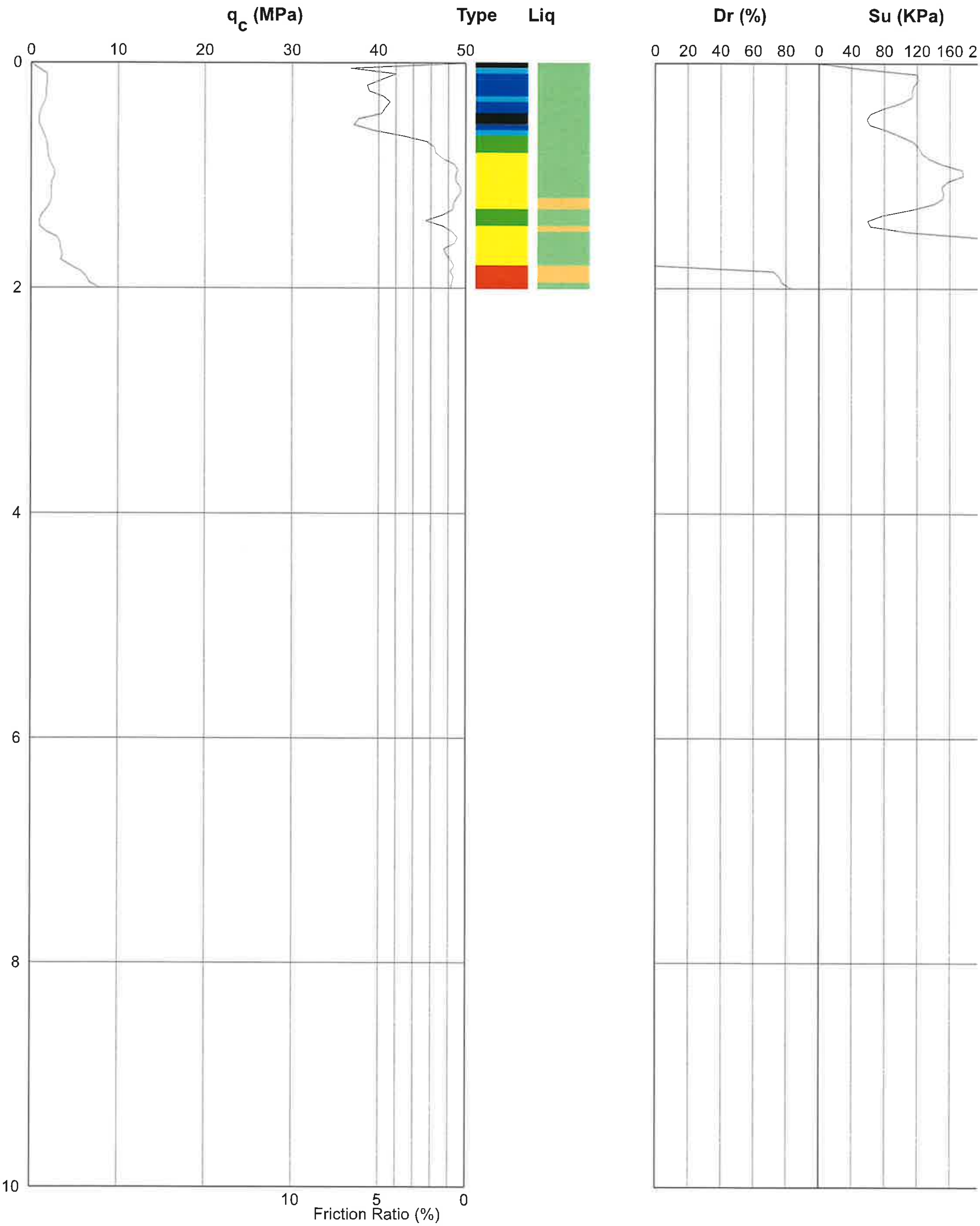
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9402

CPT No: CPTu026

Project: FH C/o Aurecon

Location: Rosemerryn, Edward St, Lincoln

Date: 27/08/11

Operator: J. Kendrick

Remark: Effective Refusal

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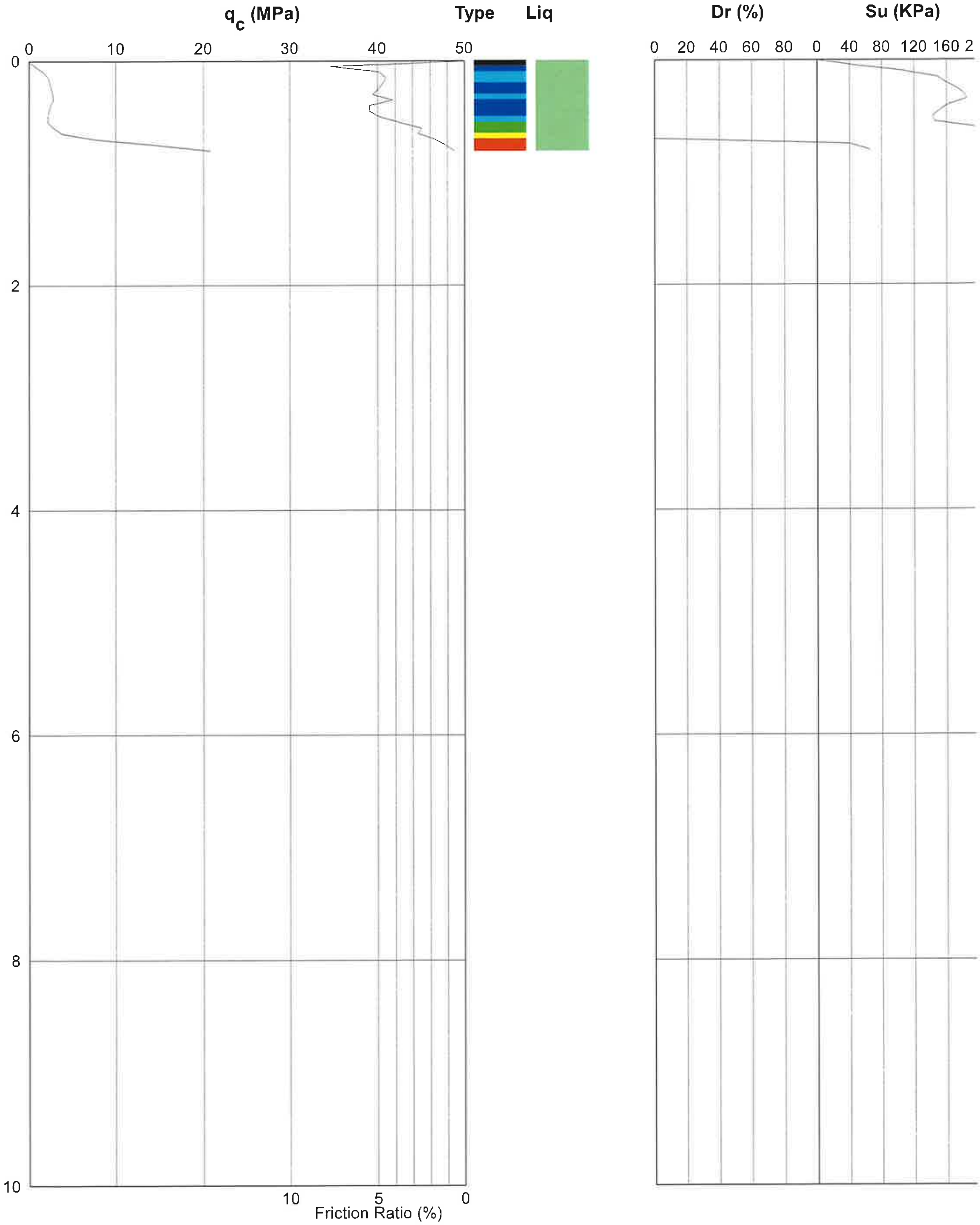
PIEZOCONE PENETROMETER TEST (CPTU) INTERPRETIVE REPORT



Job No: 9402
CPT No: CPTu027
Project: FH C/o Aurecon
Location: Rosemerryn, Edward St, Lincoln

Date: 27/08/11
Operator: J. Kendrick
Remark: Effective Refusal

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN**
Location: **SEE PLAN**
Project Reference: **224464**

TP33

Sheet 1 of 1

TEST PIT INFORMATION	CO-ORDINATES N/A		
Excavator Type: 30t Excavator	Easting: 1560049 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5168133 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and occaisional rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–1.80						SAND; Grey with orange brown mottling. Loose. Moist. Sand fine grained.	
1.80–2.80		▼ 2.8				Sandy GRAVEL; Grey with brown sand. Dense. Wet to saturated. Gravel fine to medium grained, rounded to sub-rounded. Sand fine grained.	
2.80						End of Test Pit at 2.8m (GW Reached)	

Remarks:

Groundwater @ 2.8m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Sheet 1 of 1

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Email christchurch@ap.aurecongroup.com

Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP34

Sheet **1** of **1**

TEST PIT INFORMATION	**CO-ORDINATES NZTM**		
Excavator Type: 30t Excavator	Easting: 1559946 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167634 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.30						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.30–0.70				Shear vane at 0.5m 44/24kPa /kPa /kPa	Pocket Penetrometer at 0.5m kN/m²	SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity.	
0.70–1.60				Shear vane at 1m 107/18kPa /kPa /kPa; Shear vane at 1.5m 27/12kPa /kPa /kPa	Pocket Penetrometer at 1m kN/m²; Pocket Penetrometer at 1.5m kN/m²	Sandy SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity. Sand fine grained.	
1.60–3.20						Sandy SILT; Blue grey. Soft. Saturated. Low plasticity. Sand fine grained.	
3.20						End of Test Pit at 3.2m (Pit Collapse)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Remarks:

Groundwater seepage @ 1.6m
Tree roots @ 1.8m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Sheet **1** of **1**

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP35

Sheet **1** of **1**

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560024 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167818 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.30						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.30–0.50						SILT with minor sand. Grey with orange brown mottling. Firm. Moist. Low plasticity. Sand fine grained.	
0.50–1.00						SAND with minor silt. Grey with orange brown mottling. Loose. Moist. Sand fine grained.	
1.00–1.20						SILT with minor sand and tree roots. Grey with orange brown mottling. Firm. Wet. Low plasticity. Sand fine grained.	
1.20–2.40						SAND. Grey. Loose to medium dense. Wet. Sand fine grained.	
2.40–2.60						SILT with minor sand and tree roots. Grey with orange brown mottling. Firm. Wet. Low plasticity. Sand fine grained.	
2.60–3.20						SAND; Brown. Loose to medium dense. Moist. Sand fine grained.	
3.20–3.30		▼ (3.3)				Sandy GRAVEL; Brown. Dense. Wet. Gravel medium to coarse grained. Rounded. Sand medium grained.	
3.30						End of Test Pit at 3.3m (GW Reached)	

Remarks:

Groundwater seepage @ 1.0m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Sheet **1** of **1**

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP36

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560102 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5168002 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–0.60				Shear vane at 0.5m 107/33kPa /kPa /kPa	Pocket Penetrometer at 0.5m kN/m²	SILT; Grey with brown mottling. Firm. Wet. Low plasticity.	
0.60–1.00						SAND; Dark brown. Loose. Moist. Sand fine to medium grained.	
1.00–1.20						SAND with some silt; Dark brown with orange brown mottling. Loose. Moist. Sand fine to medium grained.	
1.20–1.50						SAND with some silt; Grey. Loose. Wet. Sand fine to medium grained.	
1.50–2.00						SILT with some tree roots; Dark blue grey. Loose to medium dense. Wet. Sand fine grained.	
2.00–2.40						SILT with tree roots; Dark grey. Firm. Wet. Low plasticity.	
2.40–2.80		▼ (2.8)				SAND; Dark brown. Medium dense. Moist. Sand fine grained.	
2.80						End of Test Pit at 2.8m (GW Reached)	

Remarks:

Groundwater seepage @ 1.2m
Tree roots @ 2m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP37

Sheet **1** of **1**

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1559999 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167503 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.30						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.30–0.70				Shear vane at 0.5m: 98/27kPa /kPa /kPa	Pocket Penetrometer at 0.5m: kN/m²	SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity.	
0.70–2.00				Shear vane at 1m: 121/21kPa /kPa /kPa; Shear vane at 1.5m: 38/12kPa /kPa /kPa	Pocket Penetrometer at 1m: kN/m²; Pocket Penetrometer at 1.5m: kN/m²	Sandy SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity. Sand fine grained.	
2.00–2.60						SAND; Dark red brown. Loose. Wet. Sand medium grained.	
2.60–4.00						SAND with some silt and tree roots; Dark blue grey. Medium dense. Wet. Sand fine to medium grained.	
4.00						End of Test Pit at 4m (Pit Collapse)	

Remarks:

Groundwater seepage @ 2.0m
Tree roots @ 3.6m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Sheet **1** of **1**

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP38

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560038 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167595 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00 – 0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20 – 1.00						SAND; Dark grey. Loose to medium dense. Moist. Sand fine grained.	
1.00 – 1.50						SILT with some peat inclusions. Light blue grey. Soft. Wet. Low plasticity.	
1.50 – 2.70						SAND with tree roots; Light blue grey. Loose. Moist. Sand fine grained.	
2.70 – 3.10						Gravelly SAND; Light brown. Medium dense. Moist. Gravel fine grained. Sub angular. Sand fine to medium grained.	
3.10		▼				End of Test Pit at 3.1m (GW Reached)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Remarks:

Tree roots @ 2.5m
Groundwater encountered @ 3.1m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP39

TEST PIT INFORMATION	**CO-ORDINATES NZTM**		
Excavator Type: 30t Excavator	Easting: 1560077 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167687 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–1.00						SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity.	
1.00–1.50						Silty SAND; Grey with orange brown mottling. Loose. Moist. Sand fine grained.	
1.50–3.10		▼ (3.1)				SAND with tree roots; Blue grey. Loose. Wet. Sand medium grained.	
3.10						End of Test Pit at 3.1m (GW Reached)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Remarks:

Tree roots @ 1.5m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP40

TEST PIT INFORMATION
Excavator Type: 30t Excavator
Test Pit Dimensions:
Contractor: Fulton Hogan

CO-ORDINATES NZTM
Easting: 1560116 m
Northing: 5167779 m
Ground Level: N/A

Date Started: 9/09/2011
Date Completed: 9/09/2011

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.70						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.70–1.20				Shear vane at 1m 92/27kPa /kPa /kPa	Pocket Penetrometer at 1m kN/m²	SILT; Grey with orange brown mottling. Stiff. Moist. Low plasticity.	
1.20–1.80						SILT with tree roots; Light blue grey. Firm. Wet. Low plasticity.	
1.80–2.00						SAND with trace silts; Light grey. Loose. Wet. Sand fine grained.	
2.00–2.70						SAND; Brown. Medium dense. Moist. Sand medium grained.	
2.70–3.00						SAND; Light grey. Medium dense. Moist. Sand fine grained.	
3.00–3.50						SAND with tree roots; Light grey. Medium dense. Moist. Sand medium grained.	
3.50–4.00						SILT; Light blue grey. Soft. Wet. Low plasticity.	
4.00		▼				End of Test Pit at 4m (GW Reached)	

Remarks:

Groundwater seepage @ 1.6m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP41

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560155 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167871 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–1.20						SAND; Brown with orange mottling. Loose to medium dense. Moist. Sand fine grained.	
1.20–2.10						Sandy SILT with tree roots; Dark blue grey. Soft. Wet. Low plasticity. Sand fine grained.	
2.10–2.40		▼ (2.4)				SILT; Grey. Soft. Wet. Low plasticity.	
2.40						End of Test Pit at 2.4m (GW Reached)	

Remarks:

Groundwater seepage @ 1.6m
Grondwater encountered @ 2.4m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP42

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560194 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167963 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–0.60						Sandy SILT; Brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.60–1.20						SAND; Orange brown. Loose to medium dense. Moist. Sand fine grained.	
1.20–1.60						SILT with tree roots; Grey. Soft. Wet. Low plasticity.	
1.60–2.00						SAND; Grey. Medium dense. Wet. Sand fine grained.	
2.00–3.80		▼ (3.8)				SAND; Brown and grey. Medium dense. Wet. Sand fine grained.	
3.80						End of Test Pit at 3.8m (GW Reached)	

Remarks:

Groundwater seepage @ 1.8m
Tree roots @ 1.8m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP43

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560233 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5168055 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–0.80						SAND; Brown with orange mottling. Loose to medium dense. Moist. Sand fine grained.	
0.80–2.50						Sandy GRAVEL; Grey with brown sand. Loose to medium dense. Wet to saturated. Gravel medium to coarse grained. Rounded to sub-rounded. Sand fine grained.	
2.50–3.80						Sandy GRAVEL; Grey with brown sand. Dense. Wet to saturated. Gravel medium to coarse grained. Rounded to sub-rounded. Sand fine grained.	
3.80						End of Test Pit at 3.8m (Pit Collapse)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Remarks:

Groundwater seepage @ 3.8m

Logged by: LFS
Input by: LFS
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Location: **SEE PLAN**
Project Reference: **224464**

TP44

TEST PIT INFORMATION	**CO-ORDINATES NZTM**		
Excavator Type: 30t Excavator	Easting: 1560130 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167556 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–1.00						SAND; Brown with orange mottling. Medium dense. Moist. Sand fine grained.	
1.00–1.30						SAND; Orange brown. Medium dense. Moist. Sand medium grained.	
1.30–2.20						Sandy SILT with tree roots; Light grey; Soft. Wet. Low plasticity. Sand fine grained.	
2.20–3.80						Silty SAND with tree roots; Grey. Medium dense. Wet. Sand medium grained.	
3.80						End of Test Pit at 3.8m (Pit Collapse)	

Depth scale: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5

Remarks:

Groundwater seepage @ 3.5m
Tree roots @ 2.2m

Logged by: LFS
Input by: LFS
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Verified by: JK

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Location: **SEE PLAN**
Project Reference: **224464**

TP45

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560208 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167740 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.25						SAND; Brown with orange mottling. Loose. Moist. Sand fine grained.	
0.75						SAND; Reddish brown. Loose. Moist. Sand medium grained.	
1.50						SILT with tree roots; Light blue grey. Firm. Wet. Low plasticity.	
1.80						SAND; Light grey. Medium dense. Moist. Sand medium grained.	
2.30						SILT; Light blue grey. Firm. Wet. Low plasticity.	
2.50						SAND; Light grey. Medium dense. Moist. Sand medium grained.	
3.80		▼				End of Test Pit at 3.8m (GW Reached)	

Remarks:

Groundwater seepage @ 1.6m
Groundwater encountered @ 3.8m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP46

Sheet **1** of **1**

TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560286 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167924 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–0.40						Sandy SILT; Brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.40–0.80				Shear vane at 0.5m: 107/30kPa /kPa /kPa	Pocket Penetrometer at 0.5m: kN/m²	SAND; Brown with orange mottling. Loose to medium dense. Moist. Sand fine grained.	
0.80–1.20						SAND; Grey with orange brown mottling. Loose to medium dense. Wet. Sand fine grained.	
1.20–1.60				Shear vane at 1.5m: 30/15kPa /kPa /kPa	Pocket Penetrometer at 1.5m: kN/m²	SILT; Grey. Soft. Wet. Low plasticity.	
1.60–2.00						Sandy SILT with tree roots; Dark blue grey. Soft. Wet. Low plasticity. Sand fine grained.	
2.00–3.80		▼ (3.8)				SAND; Brown and grey. Medium dense. Wet. Sand fine grained.	
3.80						End of Test Pit at 3.8m (GW Reached)	

Remarks:

Groundwater seepage @ 1.6m
Groundwater encountered @ 3.8m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK

Sheet **1** of **1**

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Client: **FULTON HOGAN LAND DEVELOPMENT**
Project Name: **ROSEMERRYN RESIDENTIAL SUBDIVISION**
Location: **SEE PLAN**
Project Reference: **224464**

TP47

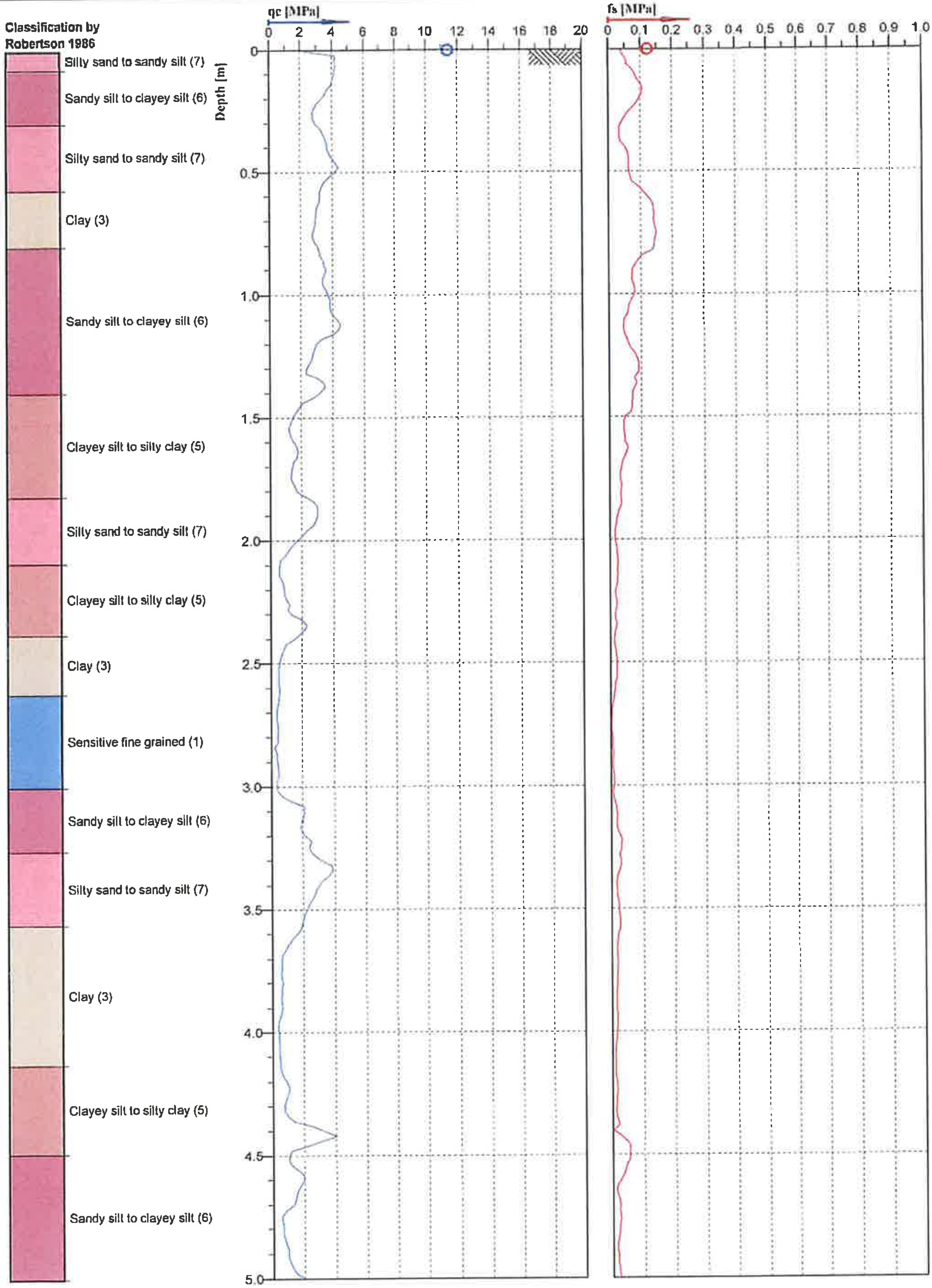
TEST PIT INFORMATION	CO-ORDINATES NZTM		
Excavator Type: 30t Excavator	Easting: 1560143 m	Date Started: 9/09/2011	Logged by: LFS
Test Pit Dimensions:	Northing: 5167333 m	Date Completed: 9/09/2011	Input by: LFS
Contractor: Fulton Hogan	Ground Level: N/A		Checked by: JSM
			Verified by: JK

Depth (m)	Sample	Water Level (m)	Graphic Log	Shear Vane Tests	Pocket Penetrometer Tests	Soil Description	Elevation (m)
0.00–0.20						TOPSOIL SILT with trace sand and rootlets; Dark brown. Firm. Moist. Low plasticity. Sand fine grained.	
0.20–1.20				Shear vane at 0.5m: 98/33kPa /kPa /kPa	Pocket Penetrometer at 0.5m: kN/m²	SILT; Grey with orange brown mottling; Stiff. Moist. Low plasticity.	
				Shear vane at 1m: 74/18kPa /kPa /kPa	Pocket Penetrometer at 1m: kN/m²		
1.20–1.50						Sandy SILT; Grey with orange brown mottling; Stiff. Moist. Low plasticity. Sand fine grained.	
1.50–1.80				Shear vane at 1.5m: 36/12kPa /kPa /kPa	Pocket Penetrometer at 1.5m: kN/m²	Sandy SILT; Light grey; Stiff. Wet. Low plasticity. Sand fine grained.	
1.80–2.70						Silty SAND; Grey. Loose to medium dense. Moist. Sand fine grained.	
2.70–3.00		▼ (3.0)				SILT; Dark grey. Firm. Wet. Low plasticity.	
3.00						End of Test Pit at 3m (GW Reached)	

Remarks:

Groundwater seepage @ 1.2m
Groundwater encountered @ 3.0m

Logged by: LFS
Input by: LFS
Checked by: JSM
Verified by: JK



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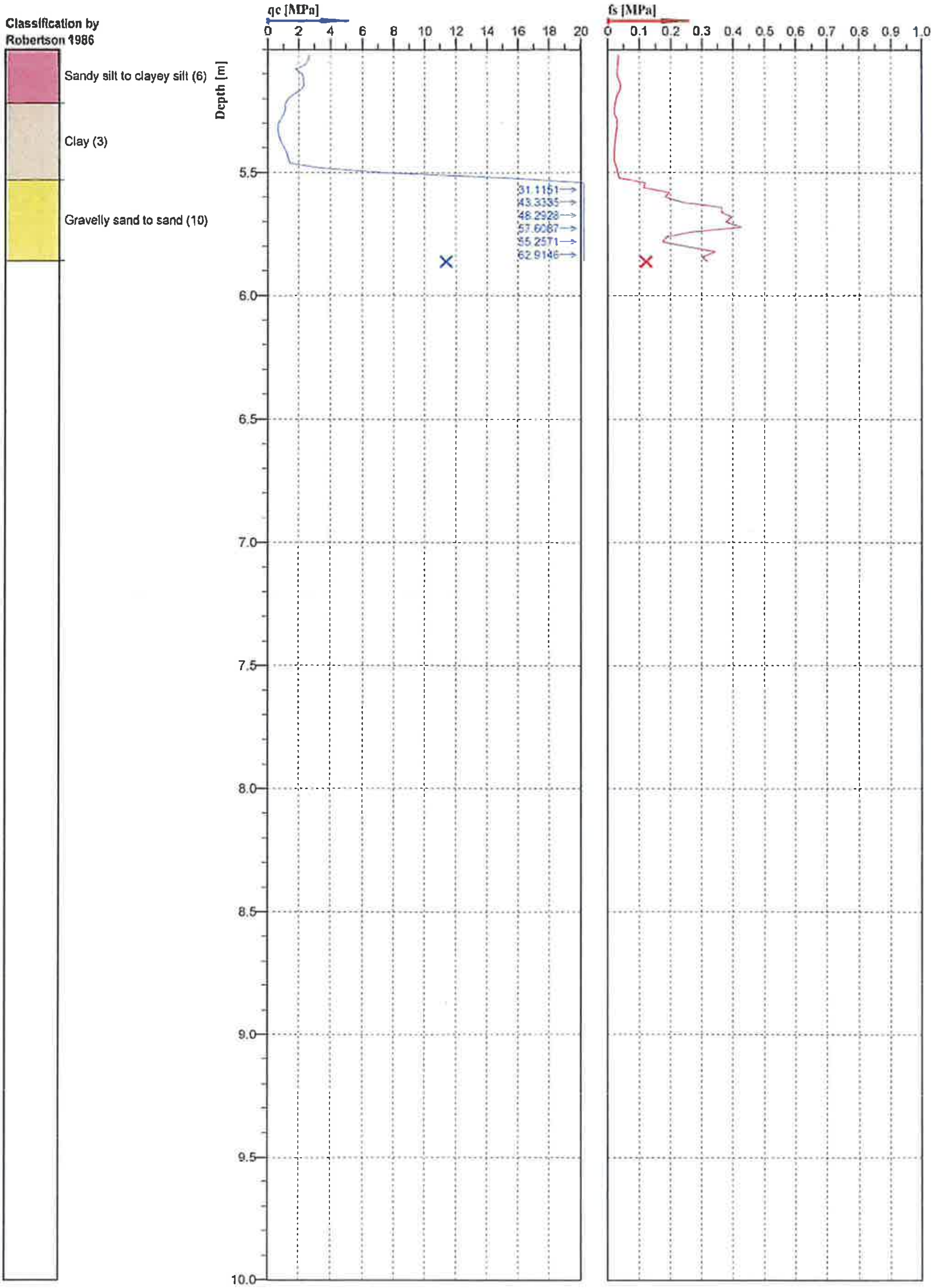
Cone No: 4465
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 1
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 1/2	Fig:
		File: RosemarrynSubdivisionCPT1.cpt	



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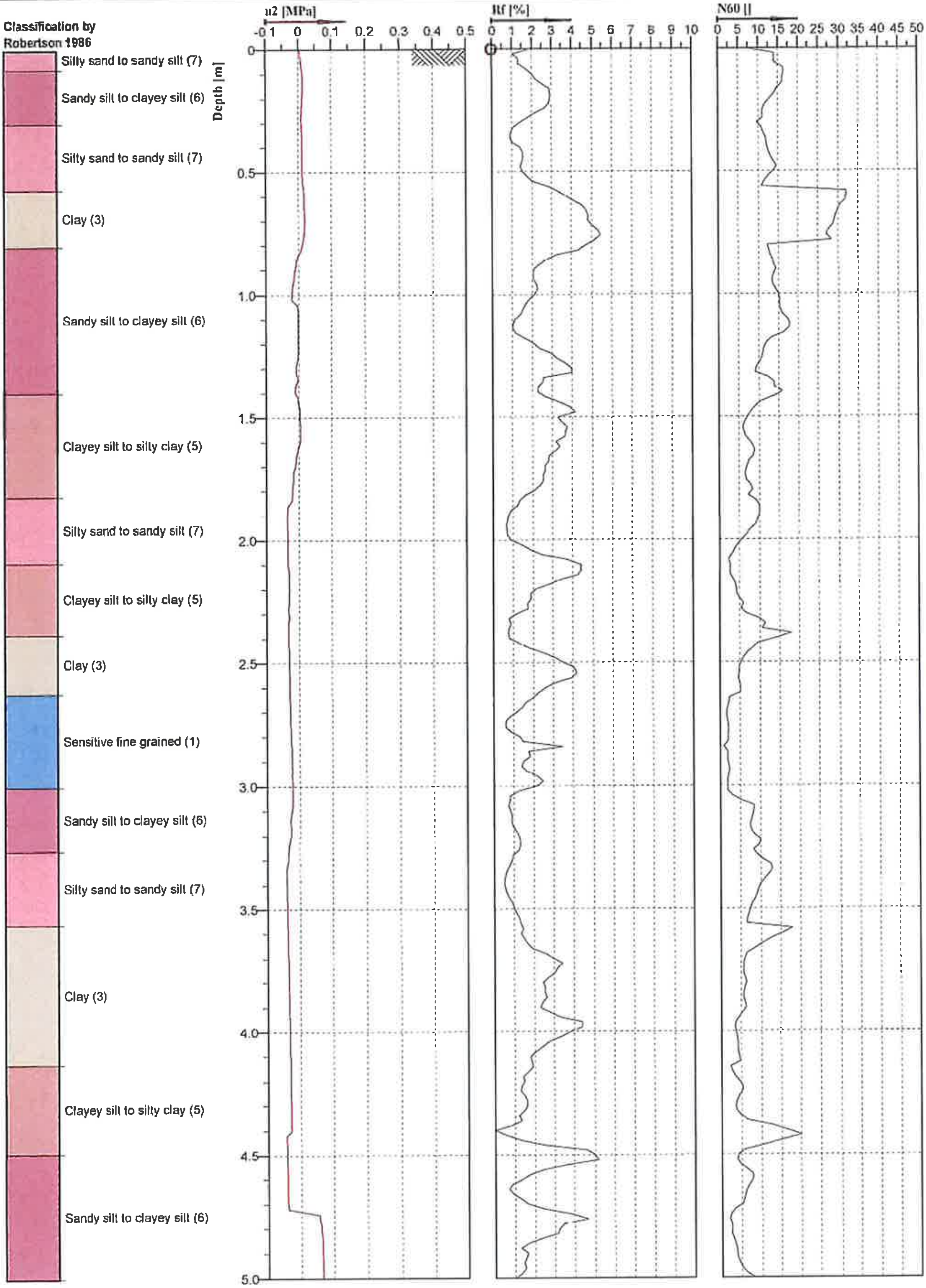
Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 1
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 2/2	Fig:
		File: RosemarrynSubdivisionCPT1.cpt	



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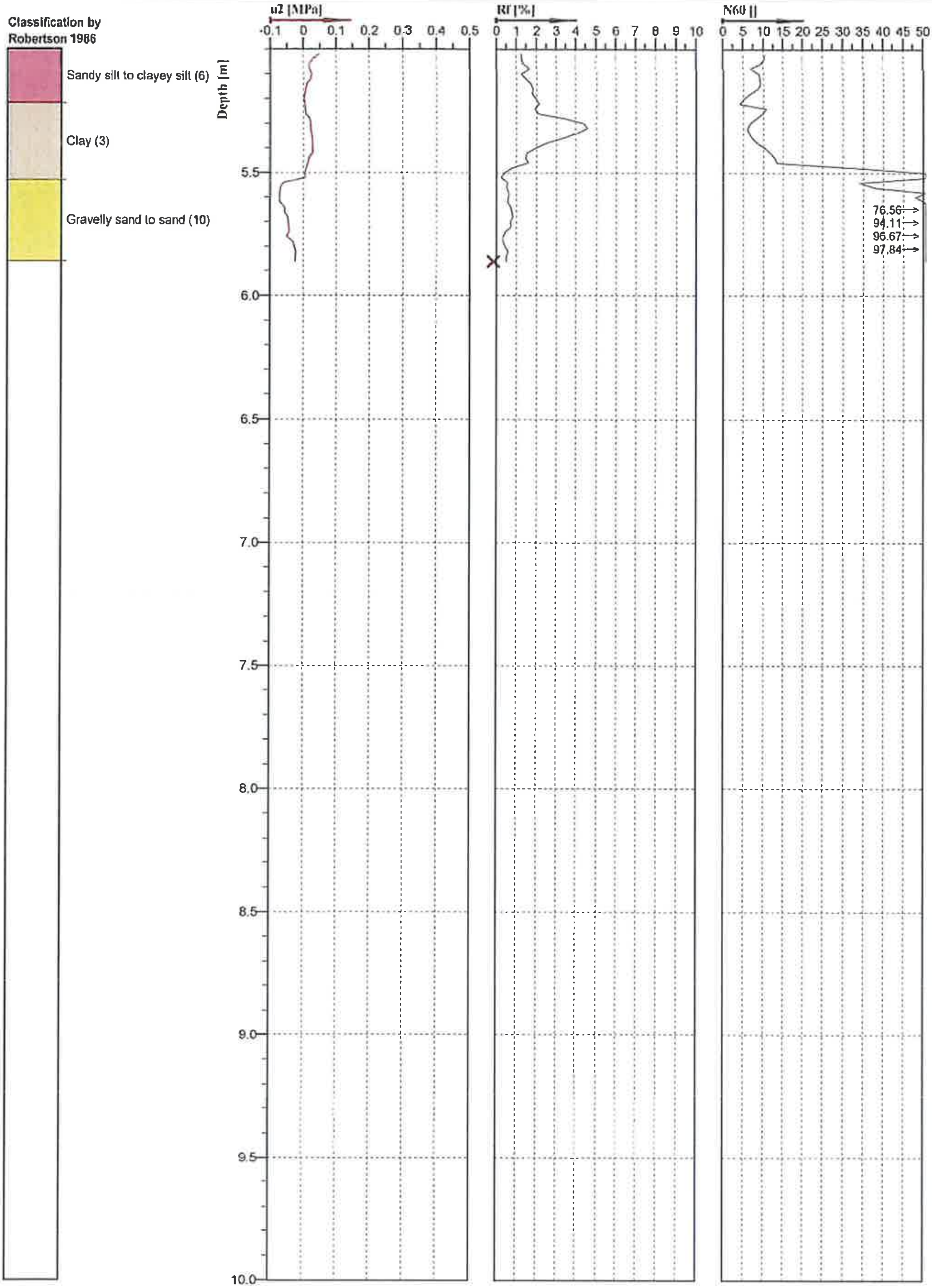
U2

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 1
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 1/2	Fig:
		File: RosemarrynSubdivisionCPT1.cpt	



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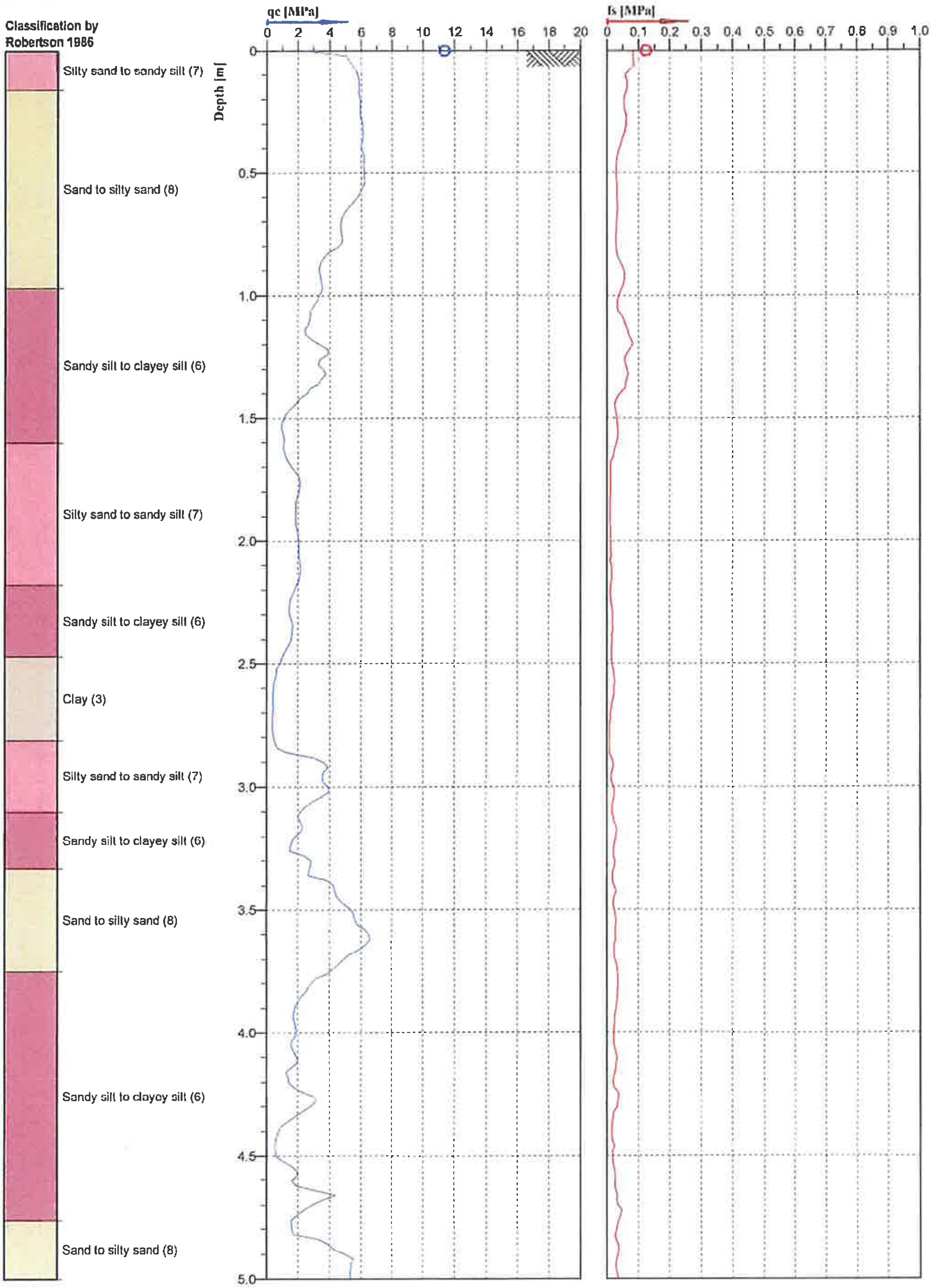
Cone No 4485
Tip area [cm2] 10
Sleeve area [cm2] 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 1
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 2/2	Fig:
		File: RosemarrynSubdivisionCPT1.cpt	



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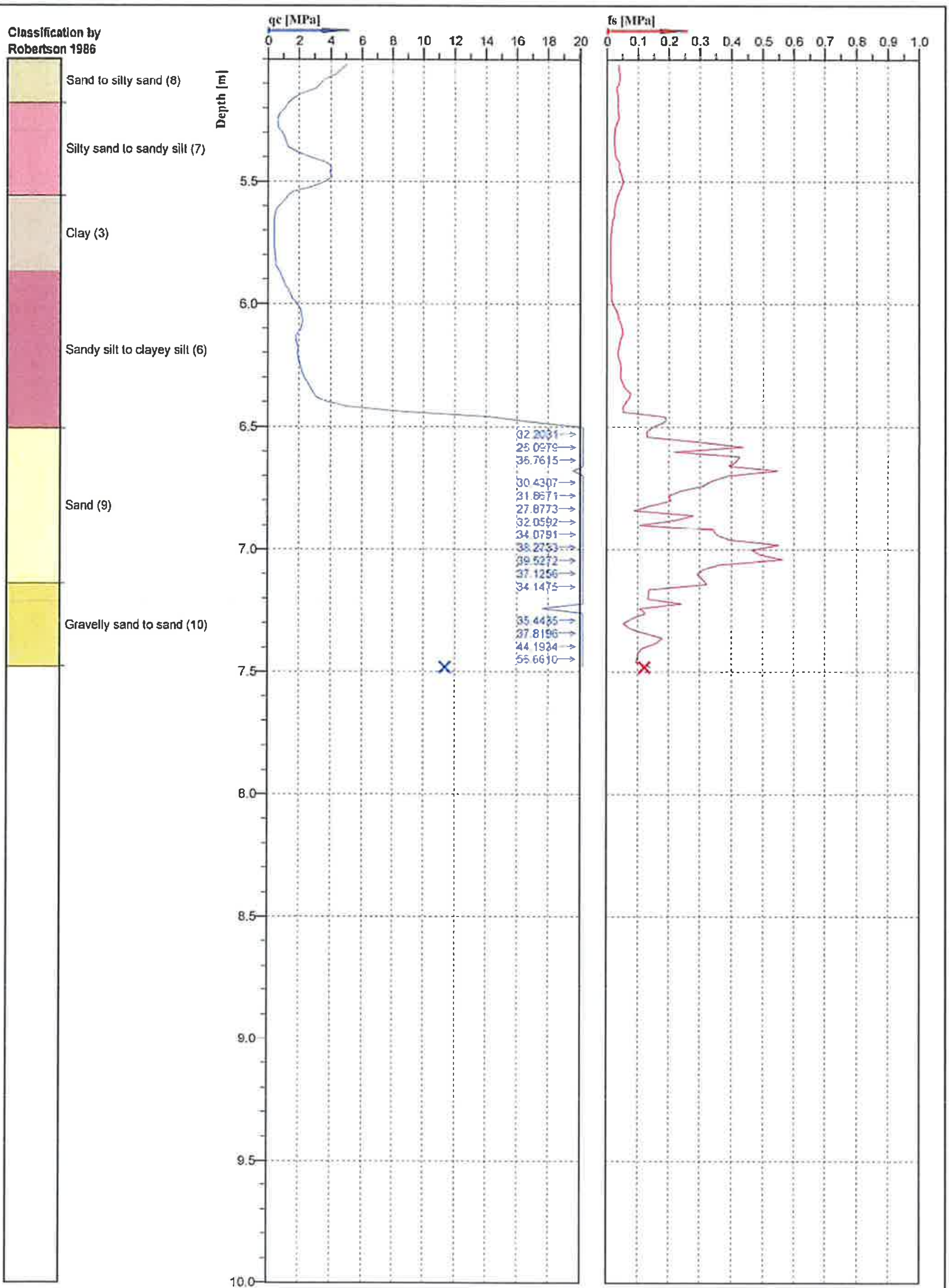
U2

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 2
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 1/2	Fig:
		File: RosemarrynSubdivisionCPT2.cpt	



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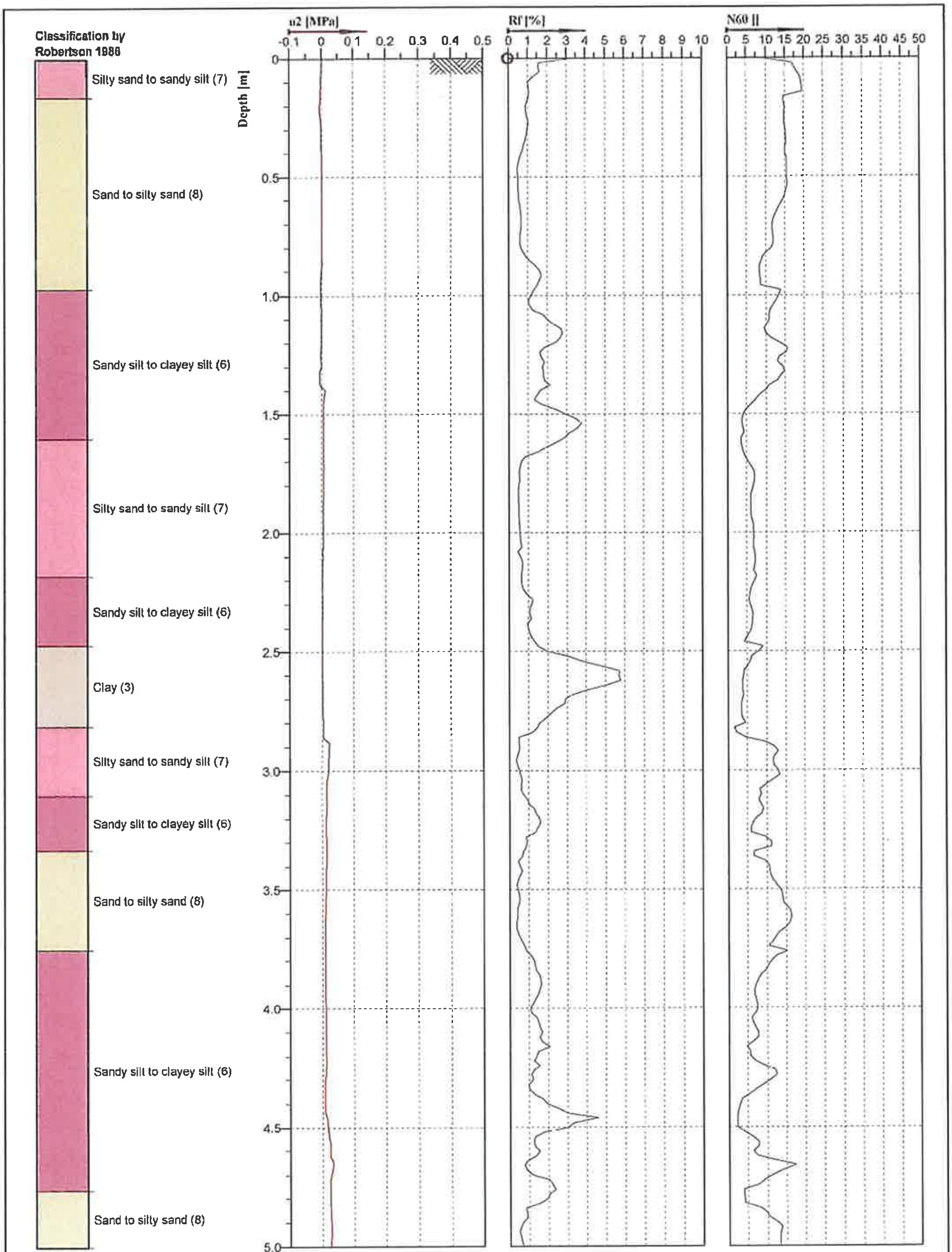
U2

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 2
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 2/2	Fig:
		File: RosemarrynSubdivisionCPT2.cpt	



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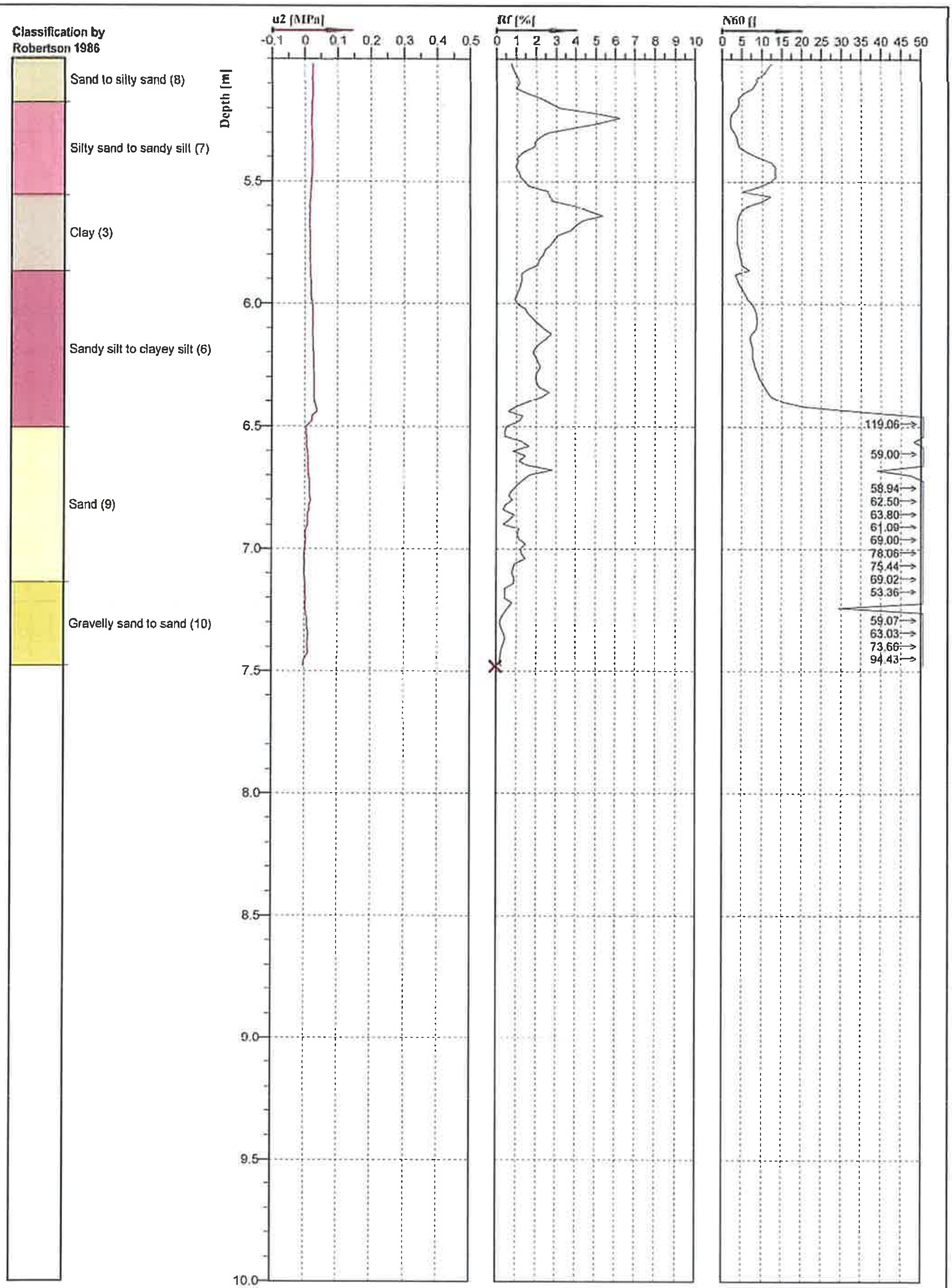
U2

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 2
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 1/2	Fig:
		File: RosemarrynSubdivisionCPT2.cpt	

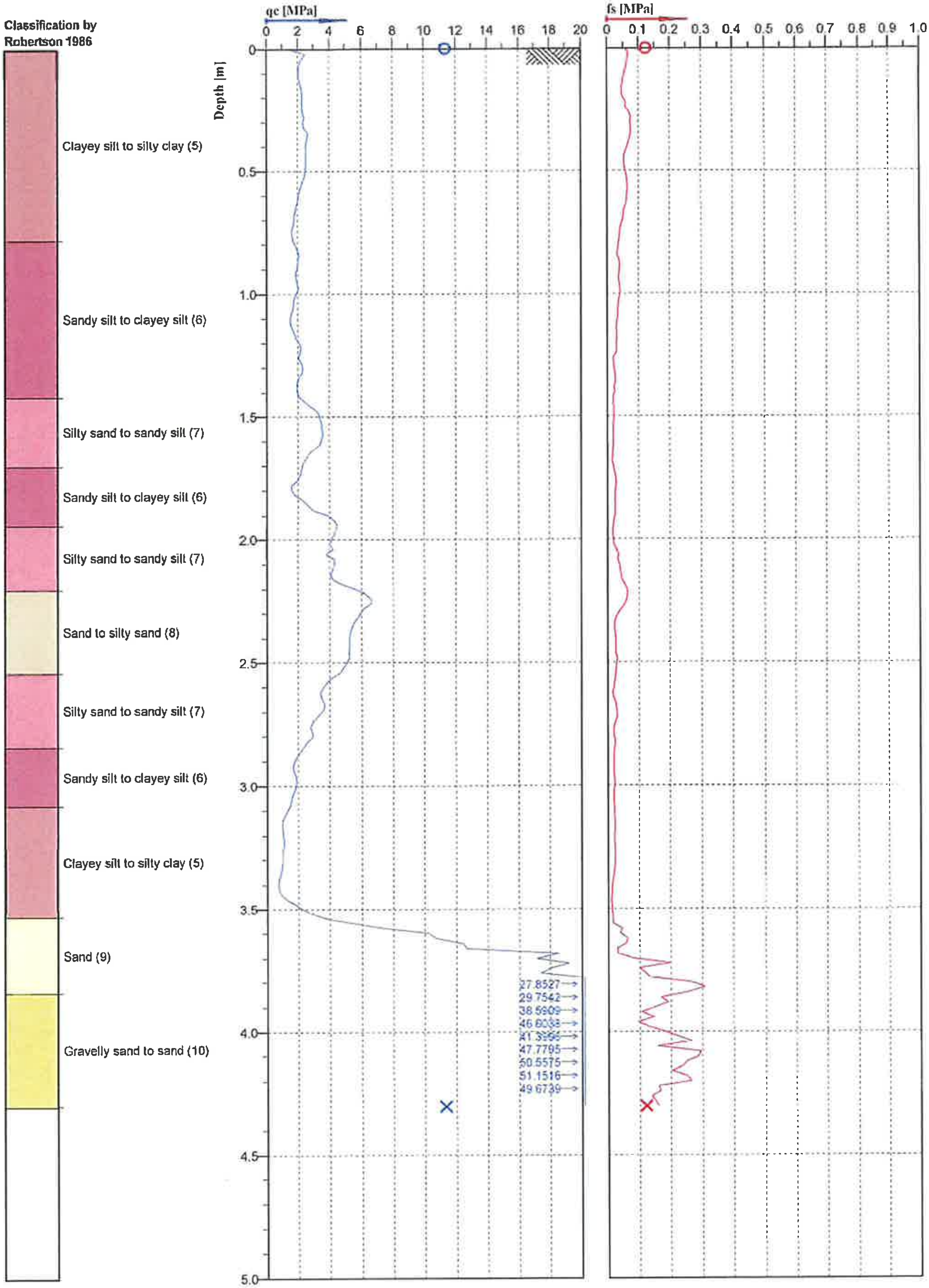


PRO-DRILL
SPECIALIST DRILLING ENGINEERS
0800 477 637

U2

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 2
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale 1 : 22
Project: ROSEMARRYN		Page: 2/2	Fig:
		File: RosemarrynSubdivisionCPT2.cpt	

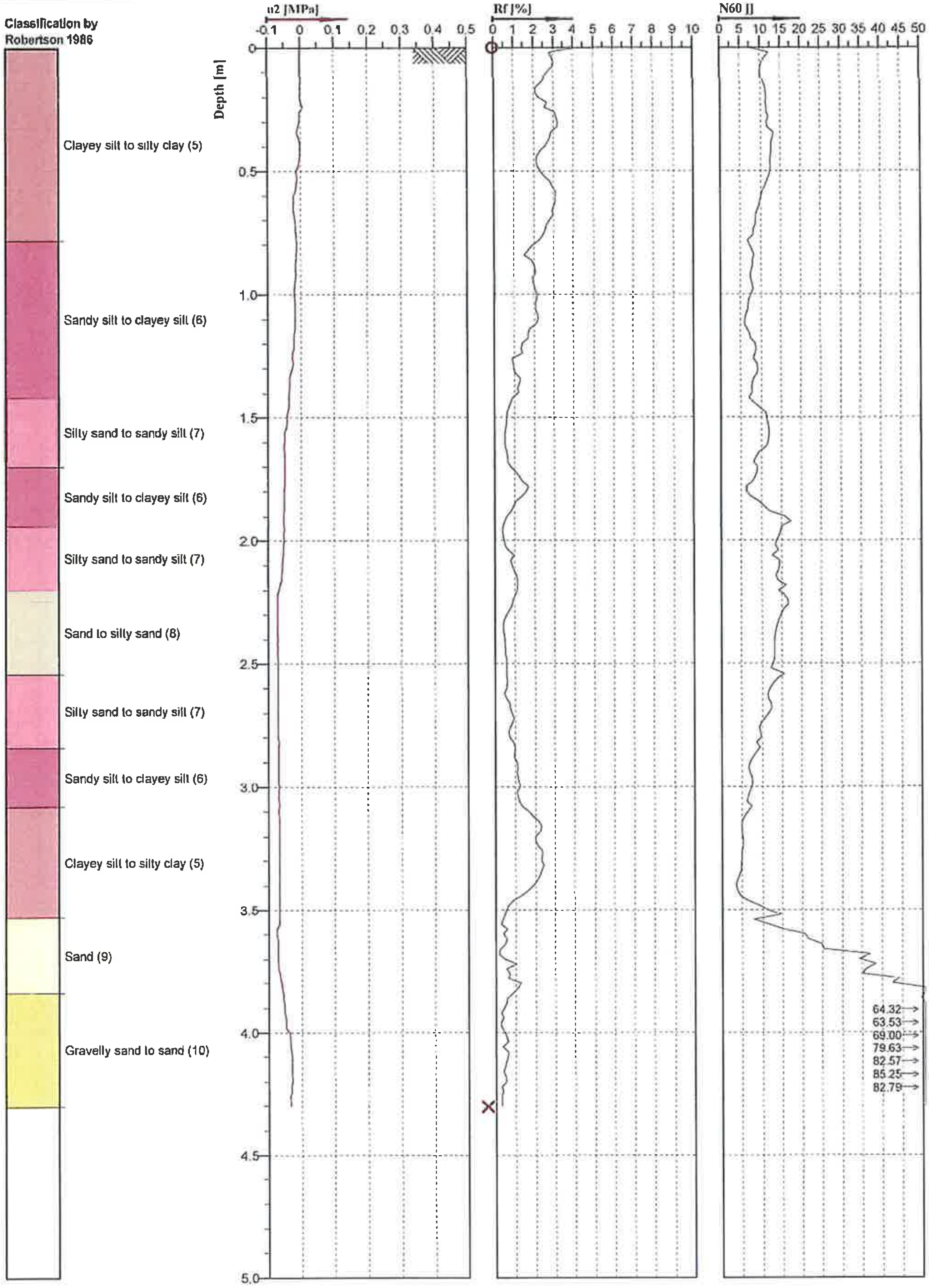


PRO-DRILL
SPECIALIST DRILLING ENGINEERS
0800 477 037

U2

Cone No. 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 27
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page 1/1	Fig:
		File: RosemarrynSubdivisionCPT27.cp	



PRO-DRILL
SPECIALIST DRILLING ENGINEERS
0800 477 637

Cone No: 4485
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: Rosemarryn Subdivision	Position: X: 0.00 m, Y: 0.00 m	Ground level: 0.00	Test no: 27
Project ID:	Client: Aurecon	Date: 4/20/2012	Scale: 1 : 22
Project: ROSEMARRYN		Page: 1/1	Fig:
		File: RosemarrynSubdivisionCPT27.cp	

aurecon
Aurecon (New Zealand) Limited
Unit 1, 150 Cavendish Rd
PO BOX 1061
Christchurch 8140
New Zealand
www.aurecongroup.com
Telephone +64 3 366 0821
Facsimile: +64 3 379 6955
Email: christchurch@ap.aurecongroup.com

Client: **Fulton Hogan Land Development Limited**
Project Name: **Rosemerryn Farm Subdivision**
Location: **Stage 7 to 15**
Project Reference: **224464**

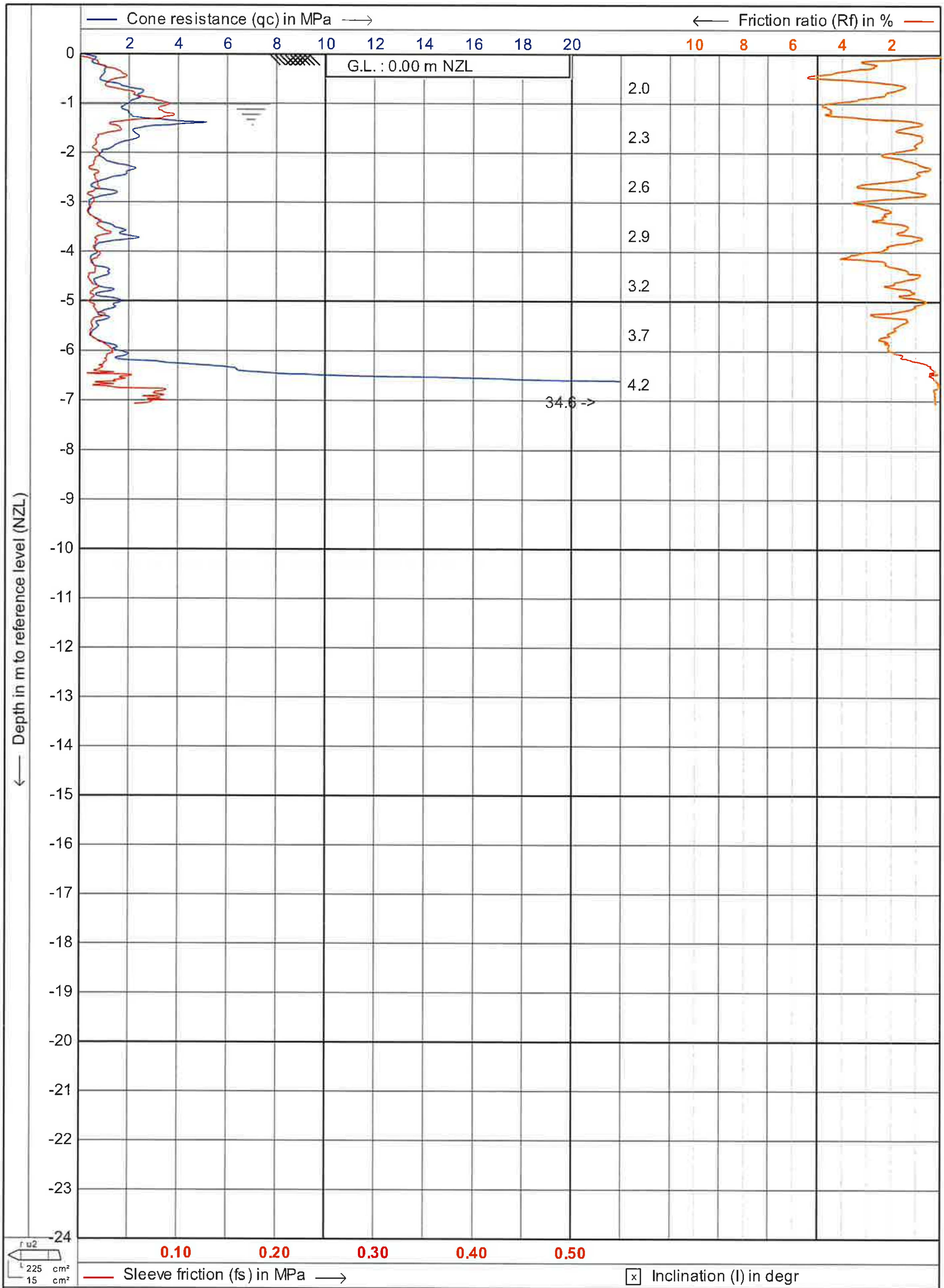
TP01

TEST PIT INFORMATION	CO-ORDINATES N/A		
Excavator Type: 8 Tonne Excavator	Easting: 1557263 m	Date Started: 27/04/2012	Logged by: RS
Test Pit Dimensions: 1.5m x 3m	Northing: 5166808 m	Date Completed: 27/04/2012	Input by: MJF
Contractor: Skellys Limited	Ground Level: 18 m		Checked by: RS
			Verified by: WD

Depth (m)	Sample	Water Level (m)	Pocket Penetrometer Tests	Shear Vane Tests	Graphic Log	Soil Description	Elevation (m)
					0.35	**SILT**, minor sand, dark brown. Stiff, moist, low plasticity, sand is fine grained (TOPSOIL)	
0.5						**Sandy SILT**; light brown. Stiff, moist, low plasticity. Sand is fine grained and poorly graded (ALLUVIAL DEPOSITS).	
1.0					1.10	0.95m Becomes brown mottled grey.	17
1.5						**SAND** with minor silt; brown mottled grey. Loosely packed, moist; sand is fine grained and poorly graded.	
2.0						2.0m Becomes dark grey mottled orange brown.	16
					2.50	2.2m Becomes with some silt.	
2.5		▼				**SILT** with some sand; dark grey. Moist, moderate plasticity; sand is fine grained.	
3.0							15
3.5					3.90		
4.0						End of Test Pit at 3.9m (Maximum Extention of Excavator.)	14
4.5							

Remarks:

Groundwater at 2.7m



DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

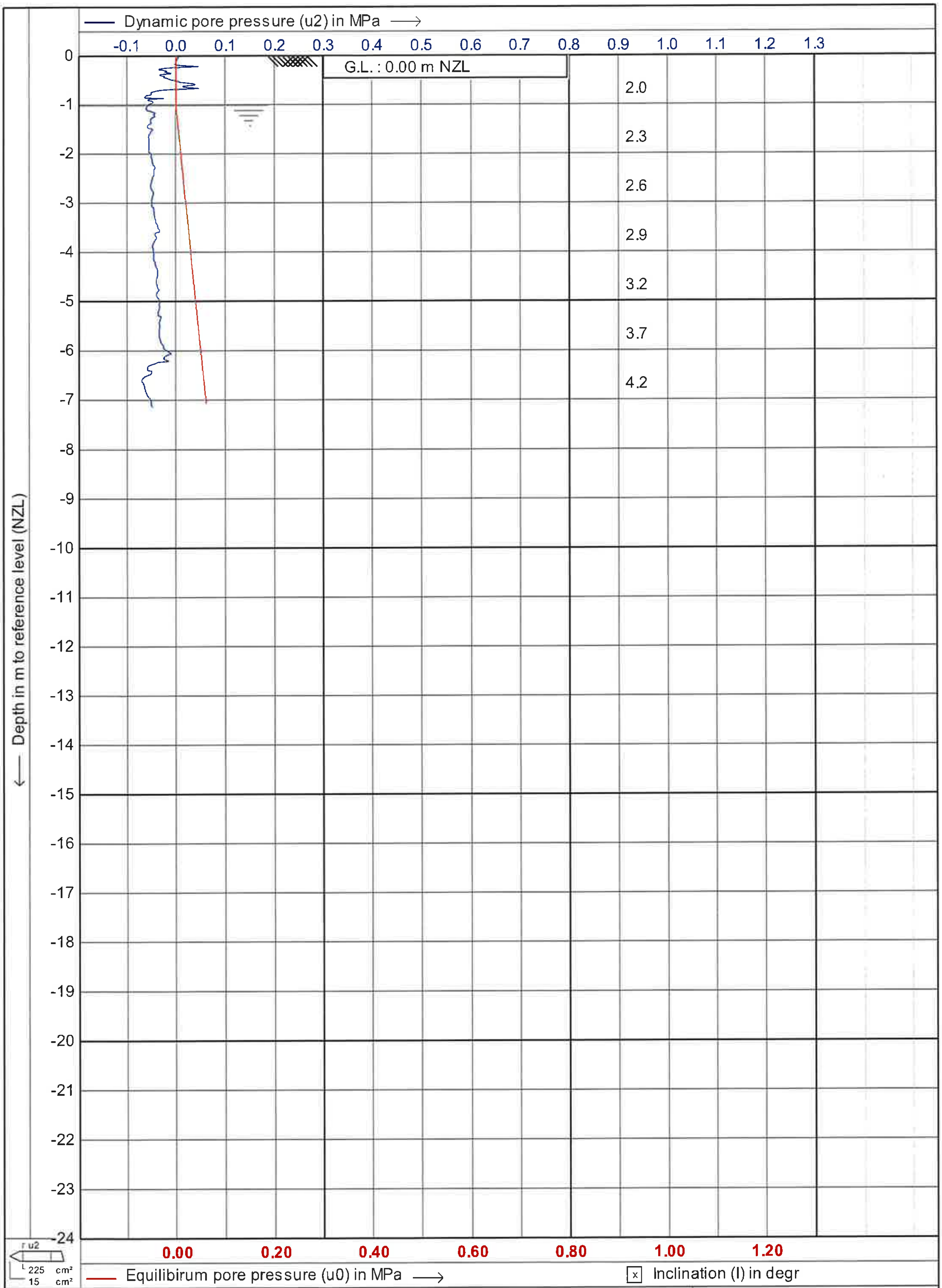
Date : **30-9-2013**

Cone no. : **S15CFIIP.S12008**

Project no. : **224464**

CPT no. : **cpt19**

1/15

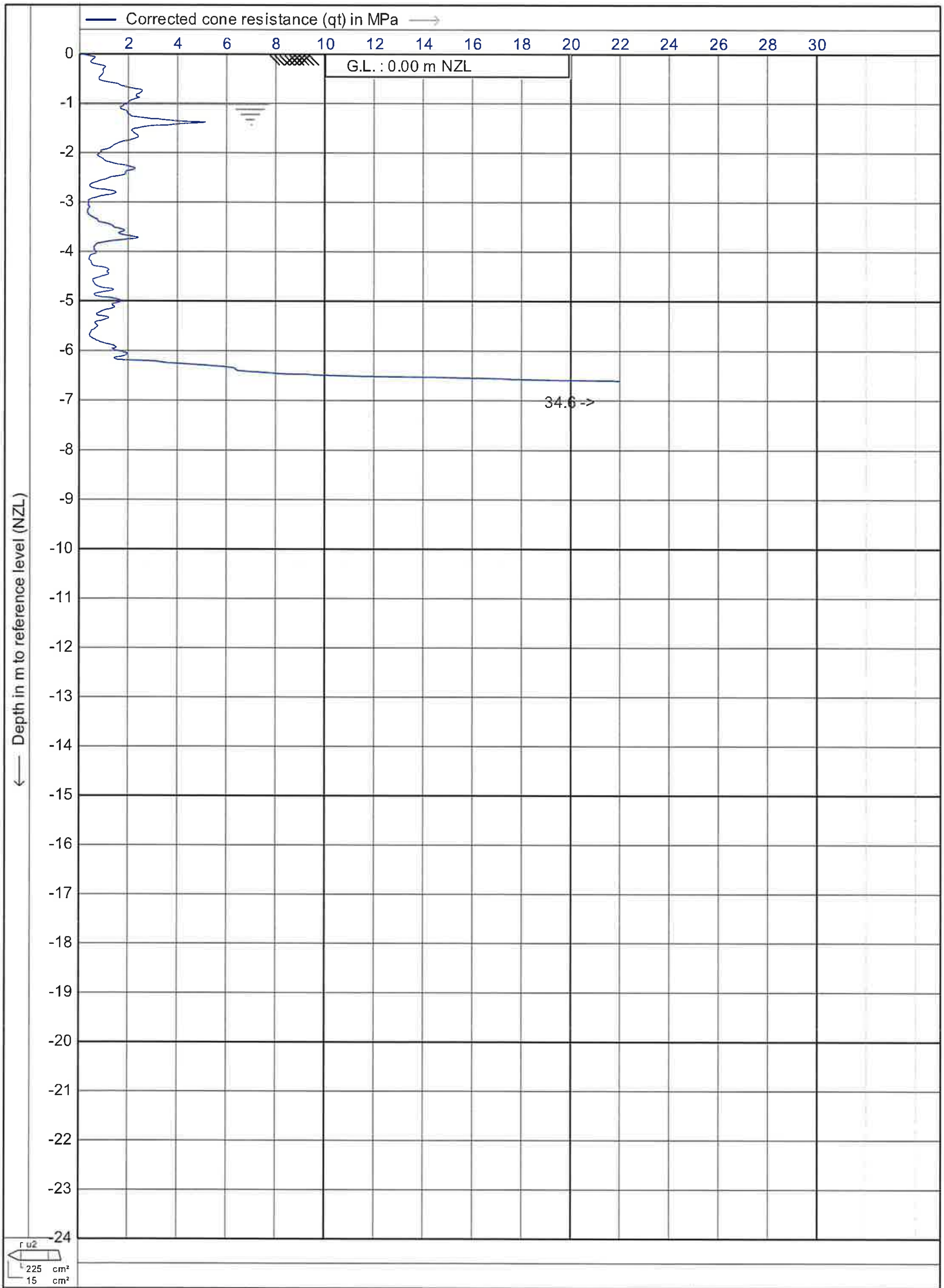


DCN DRILLING LTD
0274 735 011

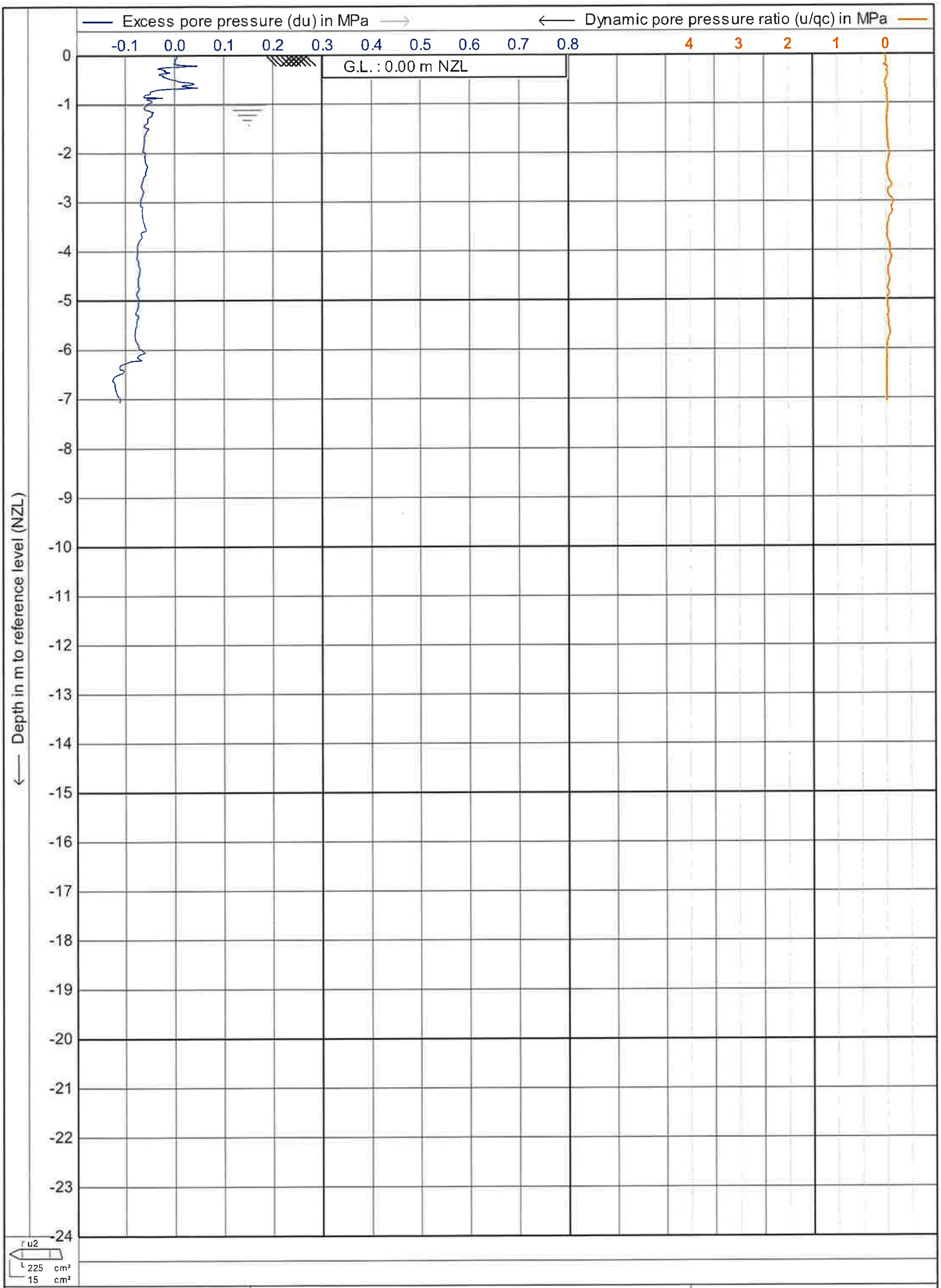
Test according ASTM Standard D 5778-07

Project :	**Rosemerryn Subdivision**
Location:	**Lincoln**
Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt19

2/15



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date	: 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no.	: S15CFIIP.S12008
		Project no.	: 224464
	Location: **Lincoln**	CPT no.	: cpt19 3/15



DCN DRILLING LTD
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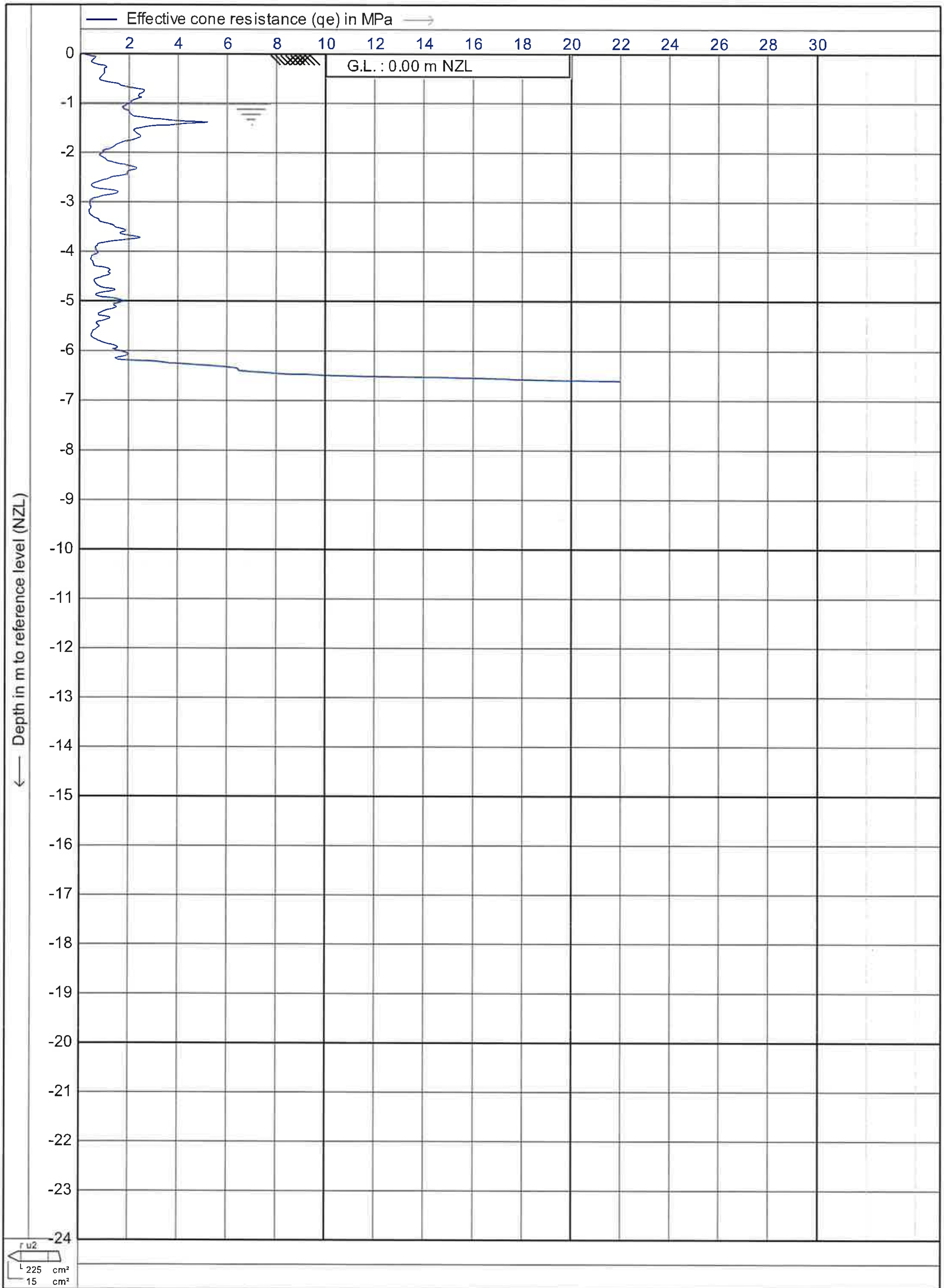
Test according ASTM Standard D 5778-07

Project :	**Rosemerryn Subdivision**	Date	: **30-9-2013**
		Cone no.	: **S15CFIIP.S12008**
		Project no. :	**224464**
Location:	**Lincoln**	CPT no.	: **cpt19** — **4/15**



DCN DRILLING LTD
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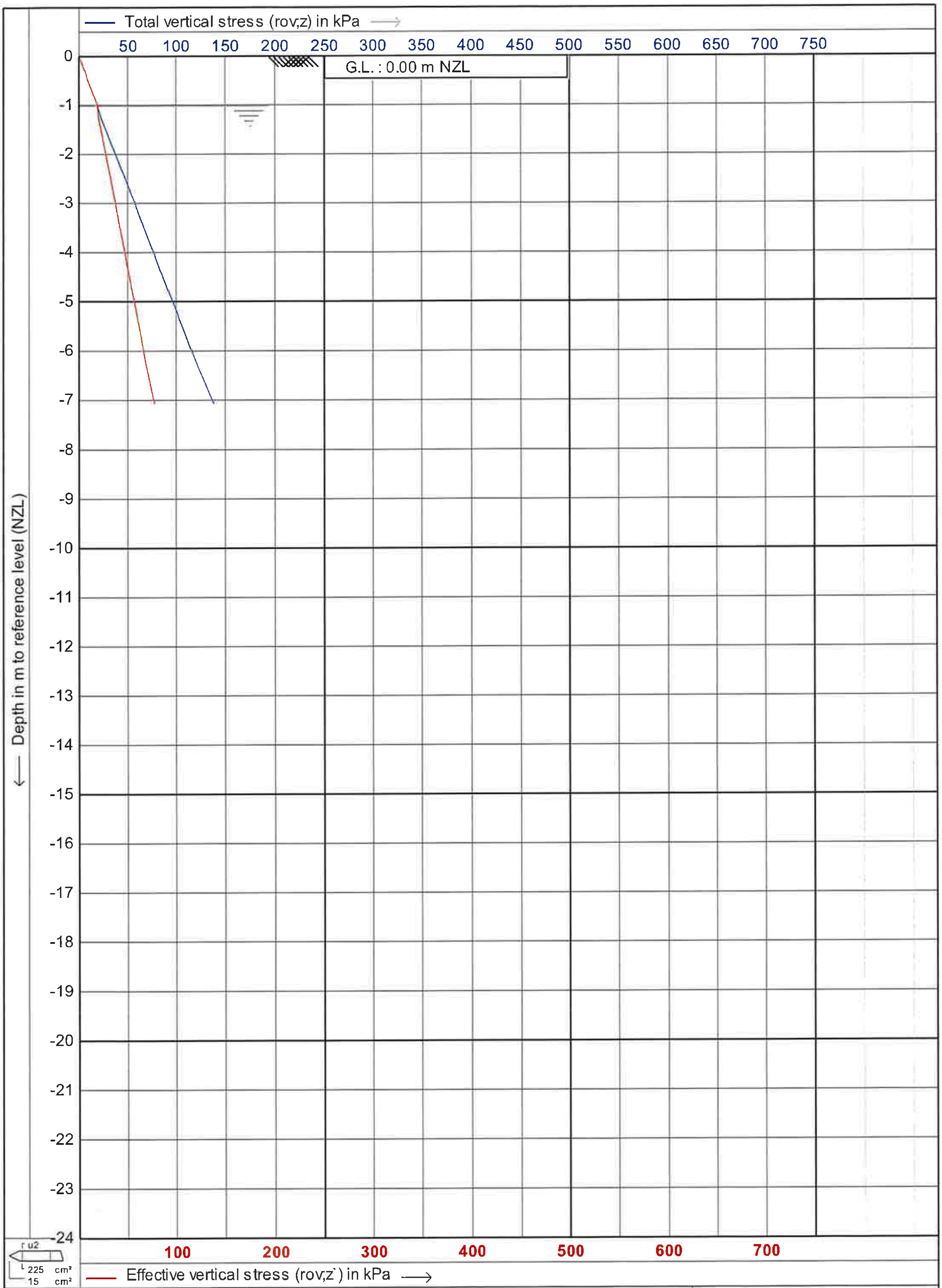
Test according ASTM Standard D 5778-07

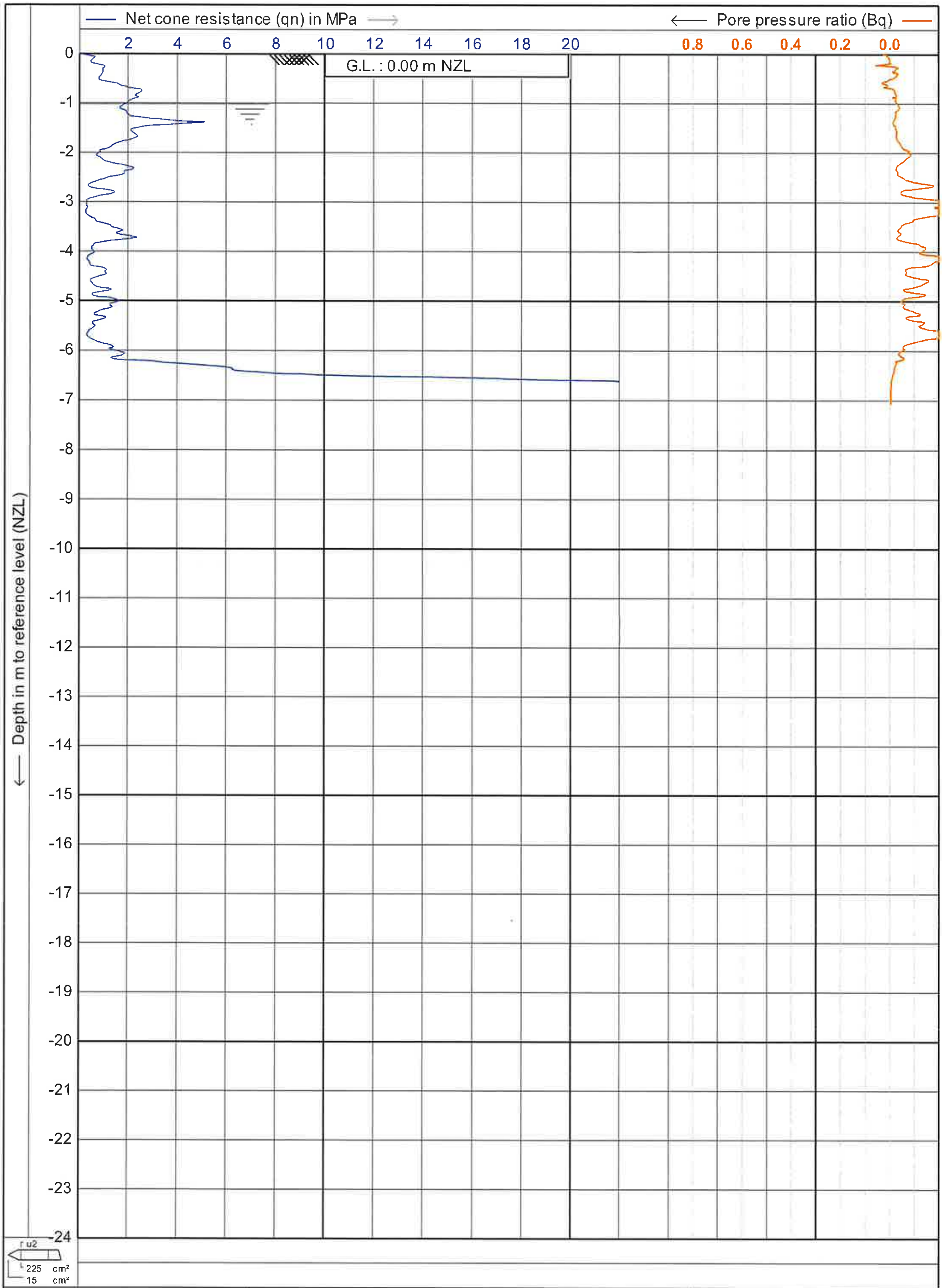
Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt19**



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : 30-9-2013
		Cone no. : S15CFIIP.S12008
	Project : **Rosemerryn Subdivision**	Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt19** 6/15



DCN DRILLING LTD
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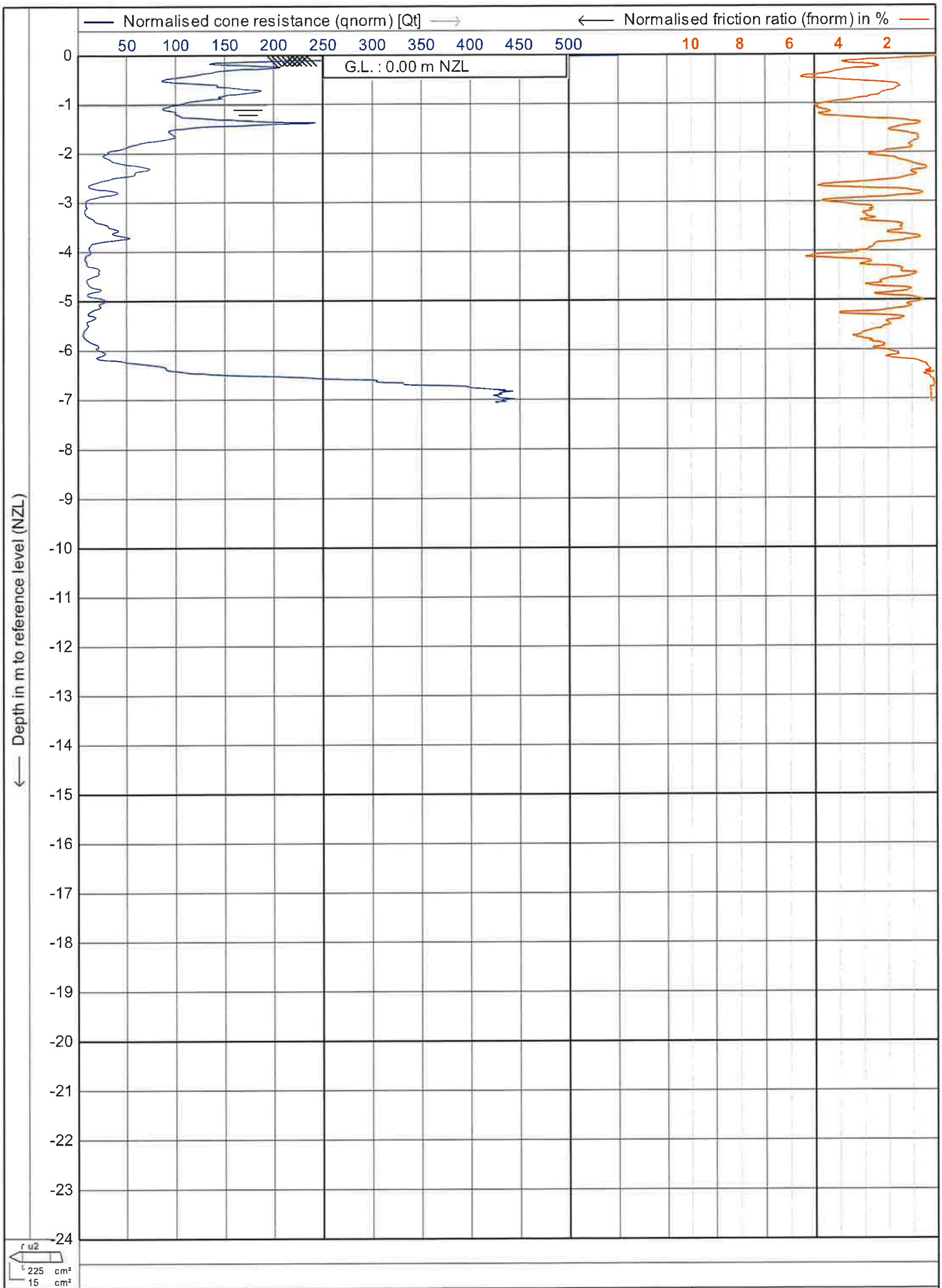
Test according ASTM Standard D 5778-07

Project :	**Rosemerryn Subdivision**
Location:	**Lincoln**

Date	: **30-9-2013**	
Cone no.	: **S15CFIIP.S12008**	
Project no. :	**224464**	
CPT no.	: **cpt19**	**7/15**



DCN DRILLING LTD
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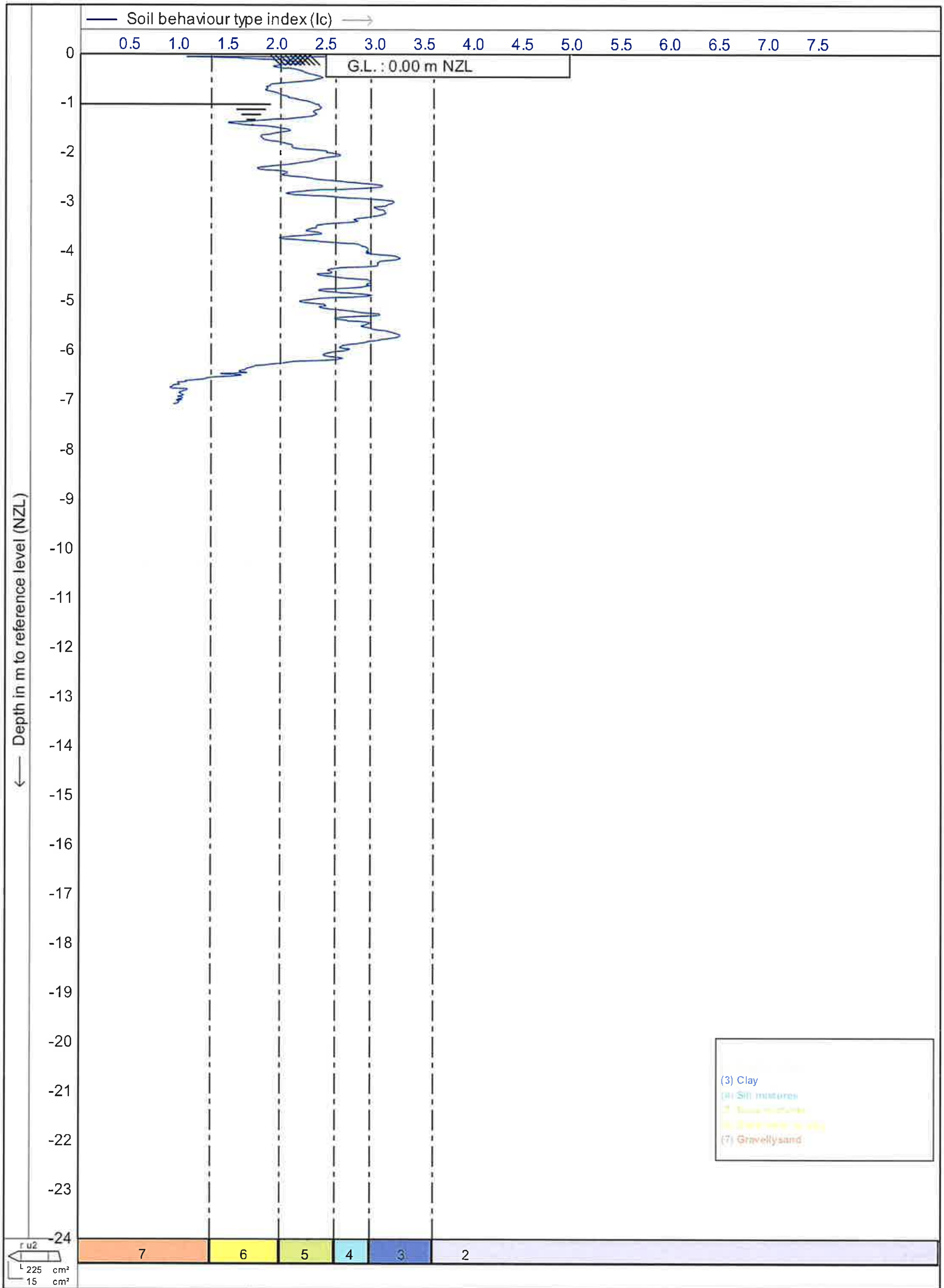
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no.	: 224464
CPT no.	: cpt19

8/15

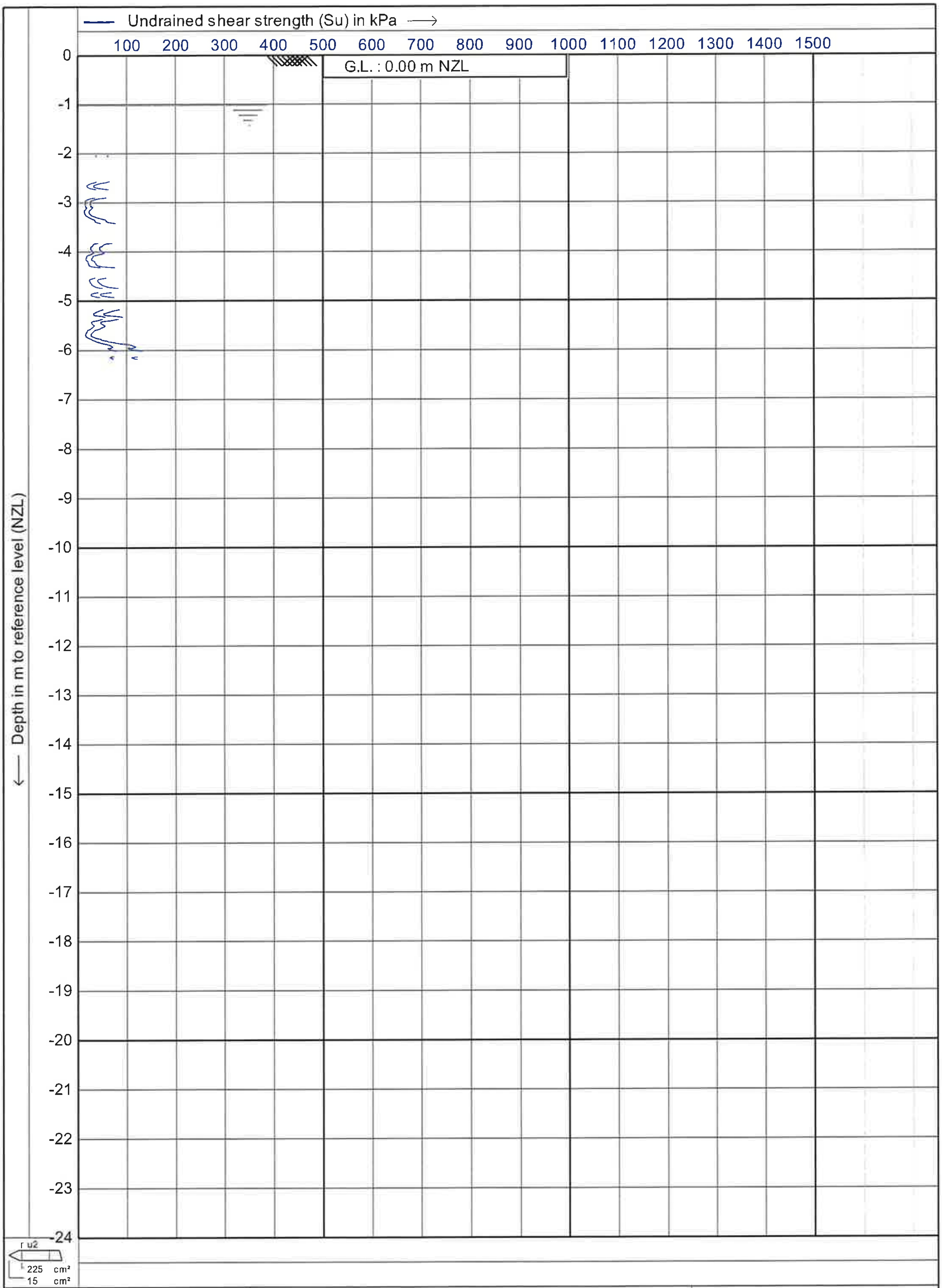


DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07	
Project :	**Rosemerryn Subdivision**
Location:	**Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt19**

9/15



DCN DRILLING LTD
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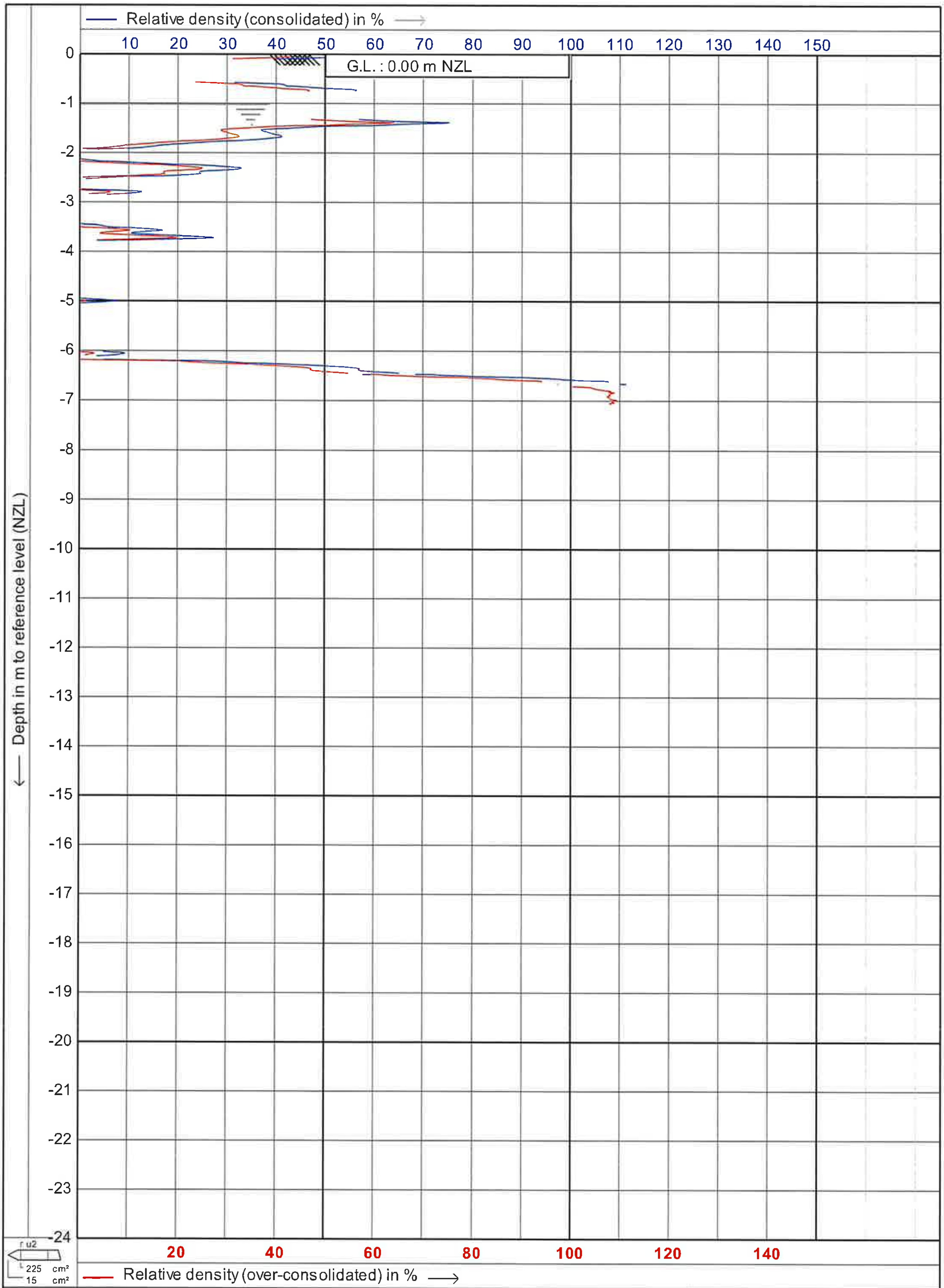
Test according ASTM Standard D 5778-07

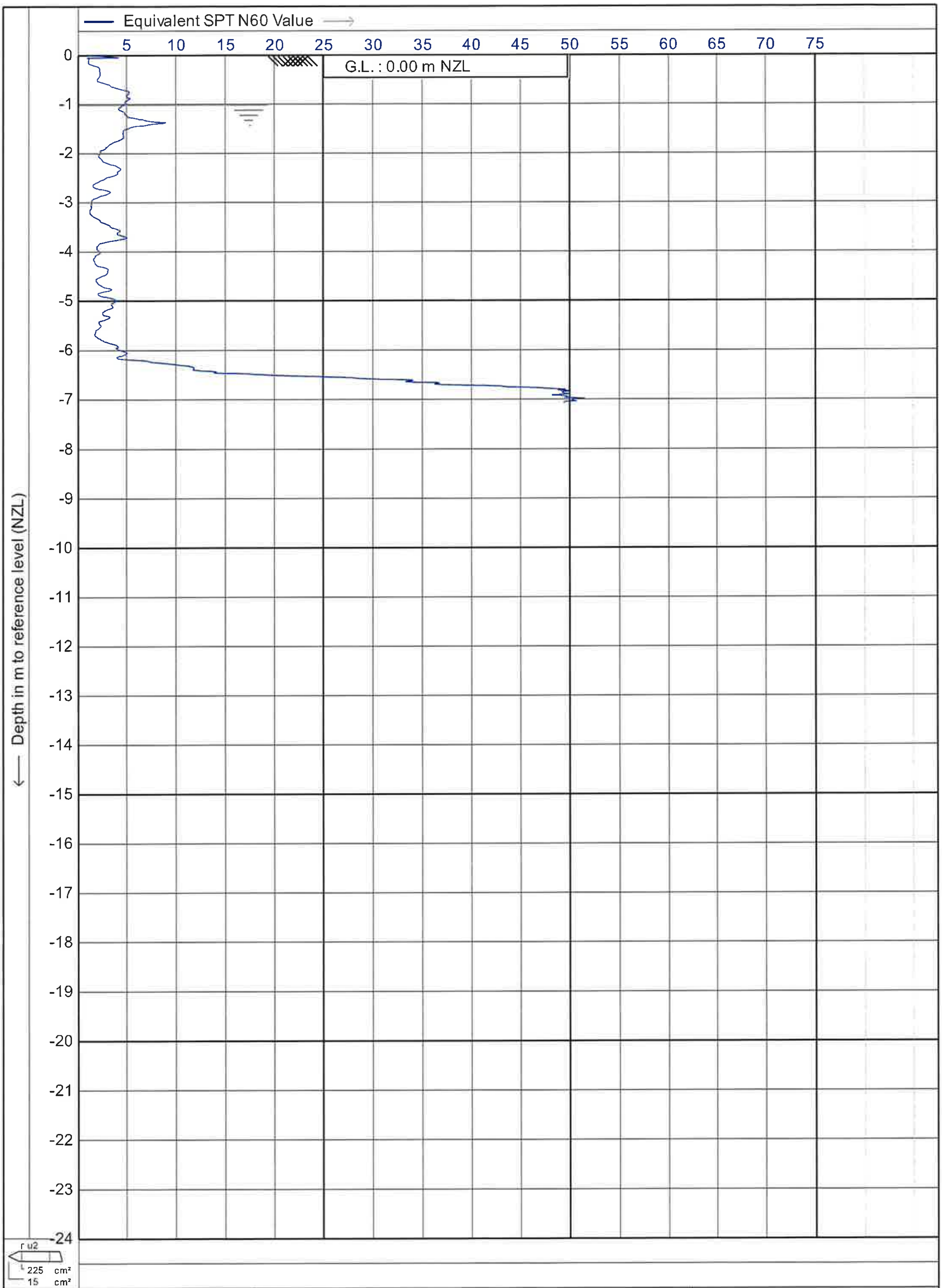
Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt19



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no. : S15CFIIP.S12008
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt19** 11/15



DCN DRILLING LTD
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Test according ASTM Standard D 5778-07

Project :	Rosemerryn Subdivision	Date	: 30-9-2013
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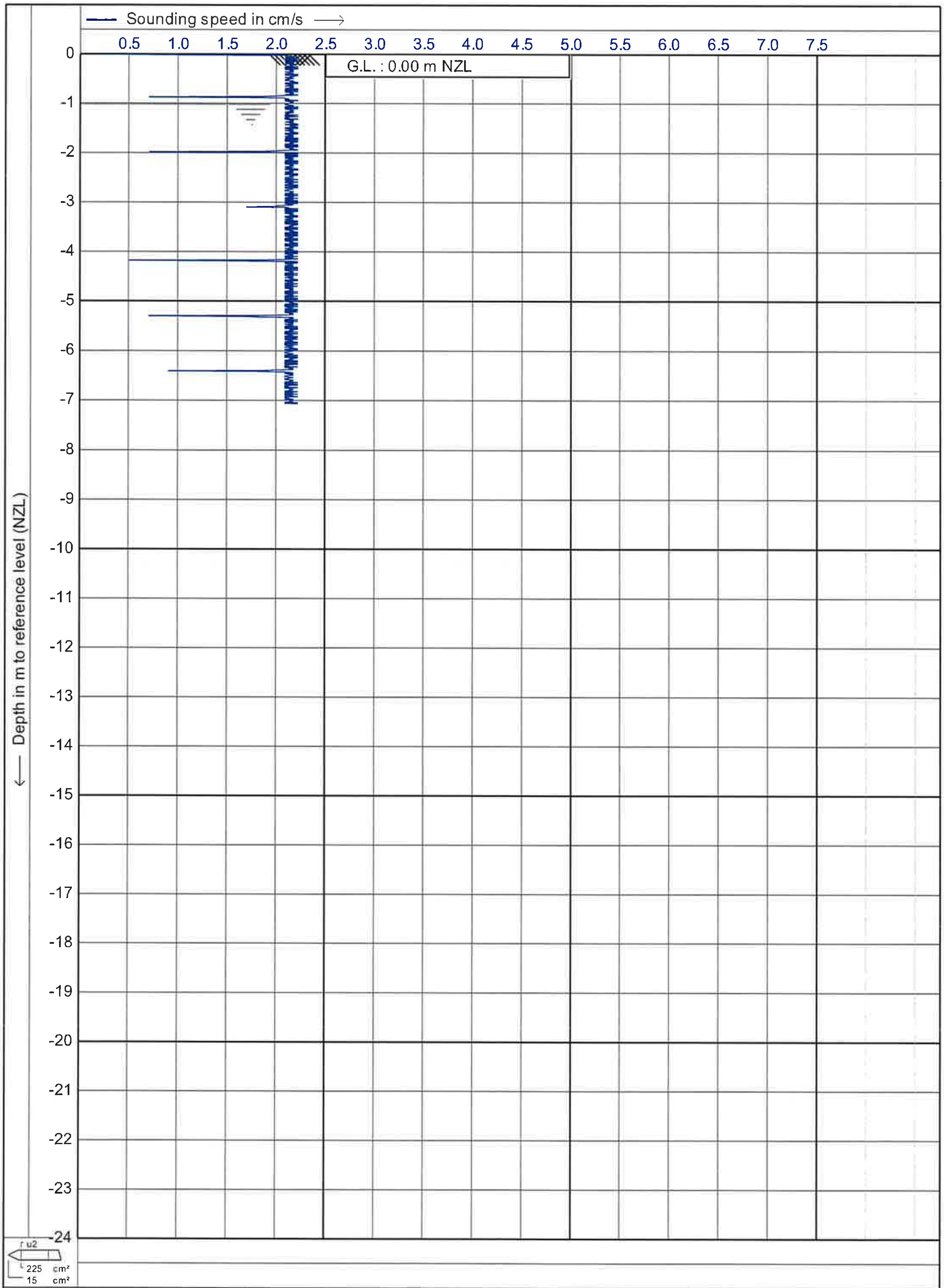
Location:	Lincoln	Project no. :	224464
		CPT no.	: cpt19 12/15



DCN DRILLING LTD
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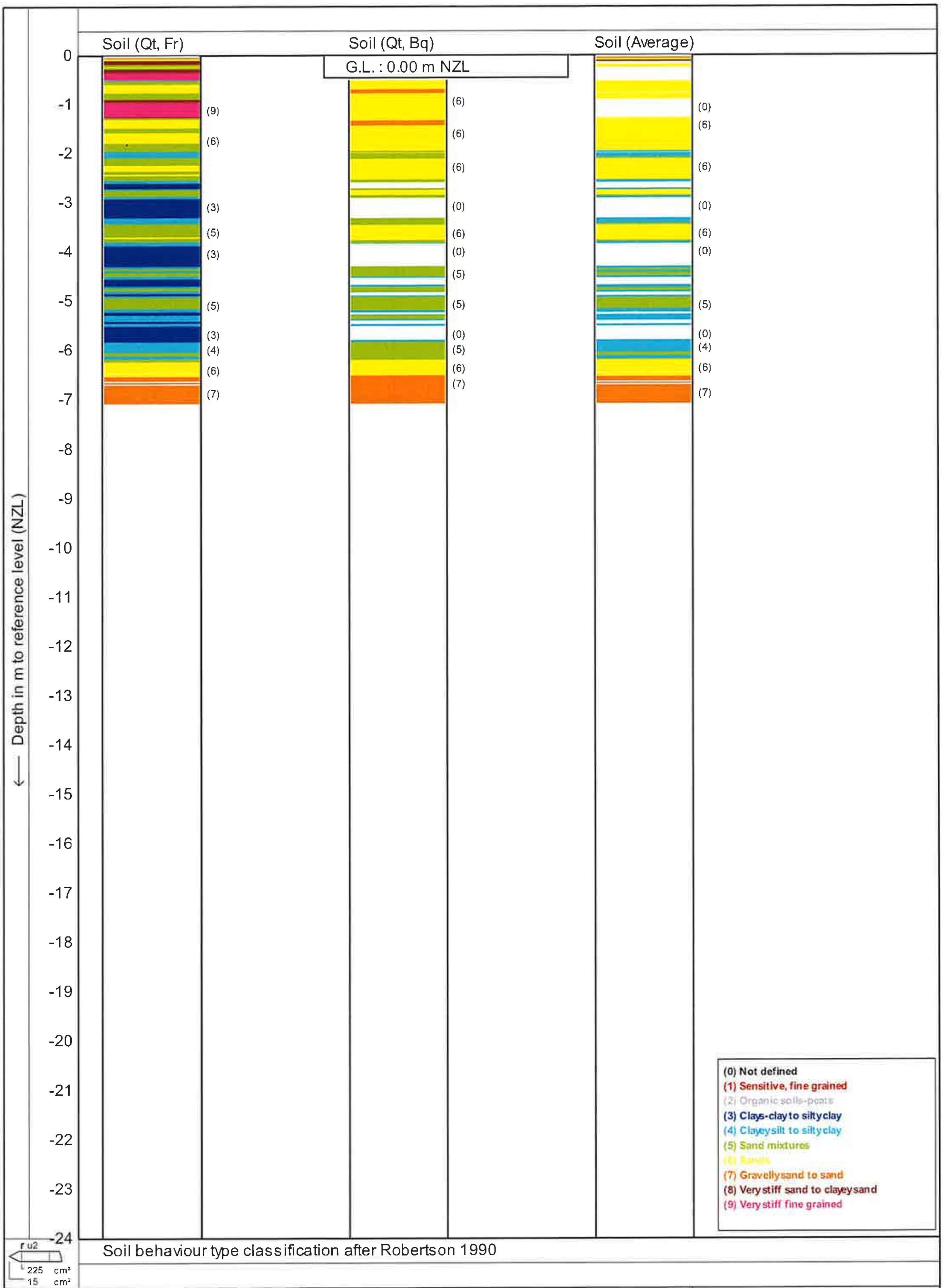
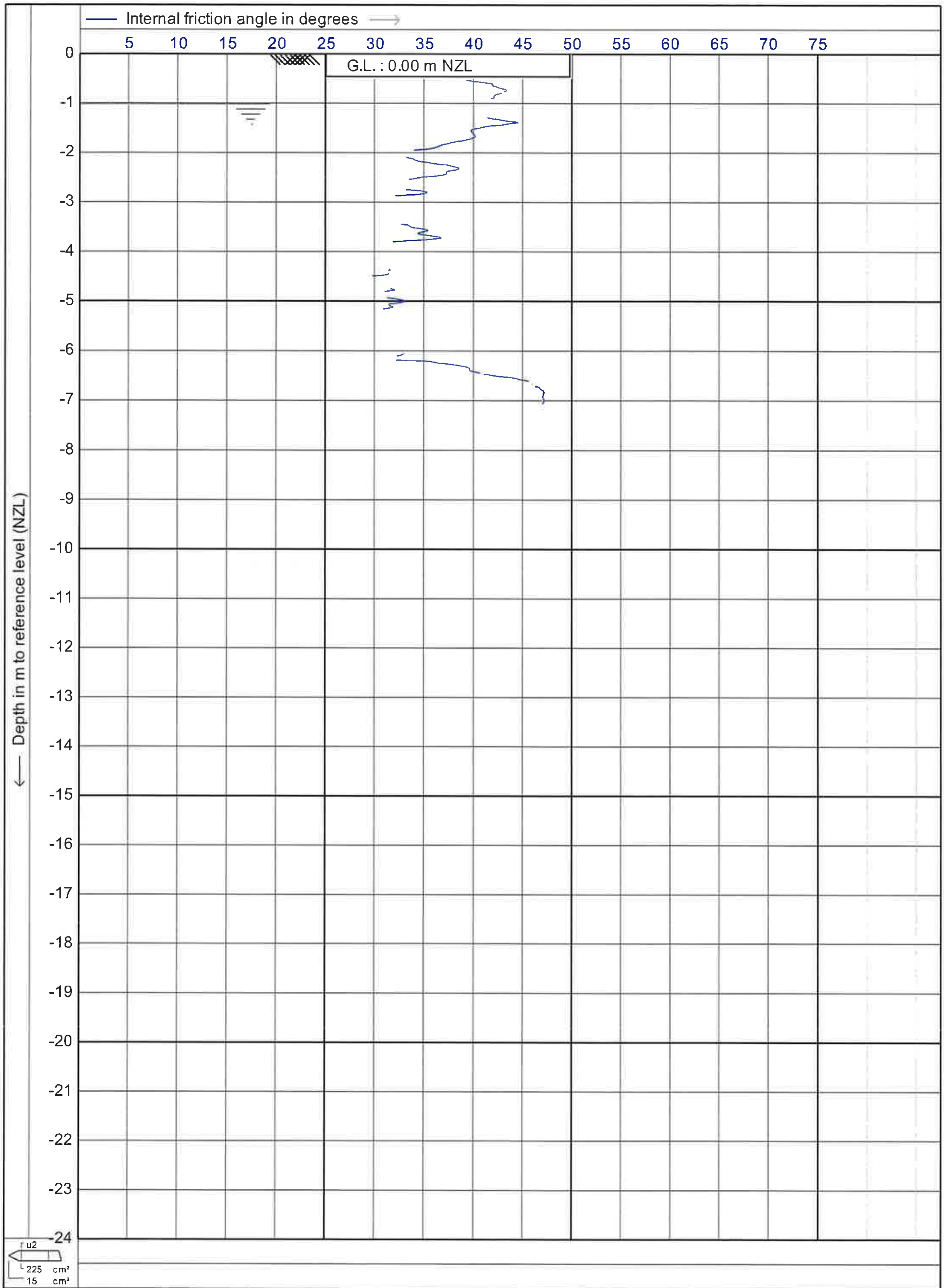
Test according ASTM Standard D 5778-07		Date	: 30-9-2013
Project :	Rosemerryn Subdivision	Cone no.	: S15CFIIP.S12008
		Project no. :	224464
Location:	Lincoln	CPT no.	: cpt19 13/15

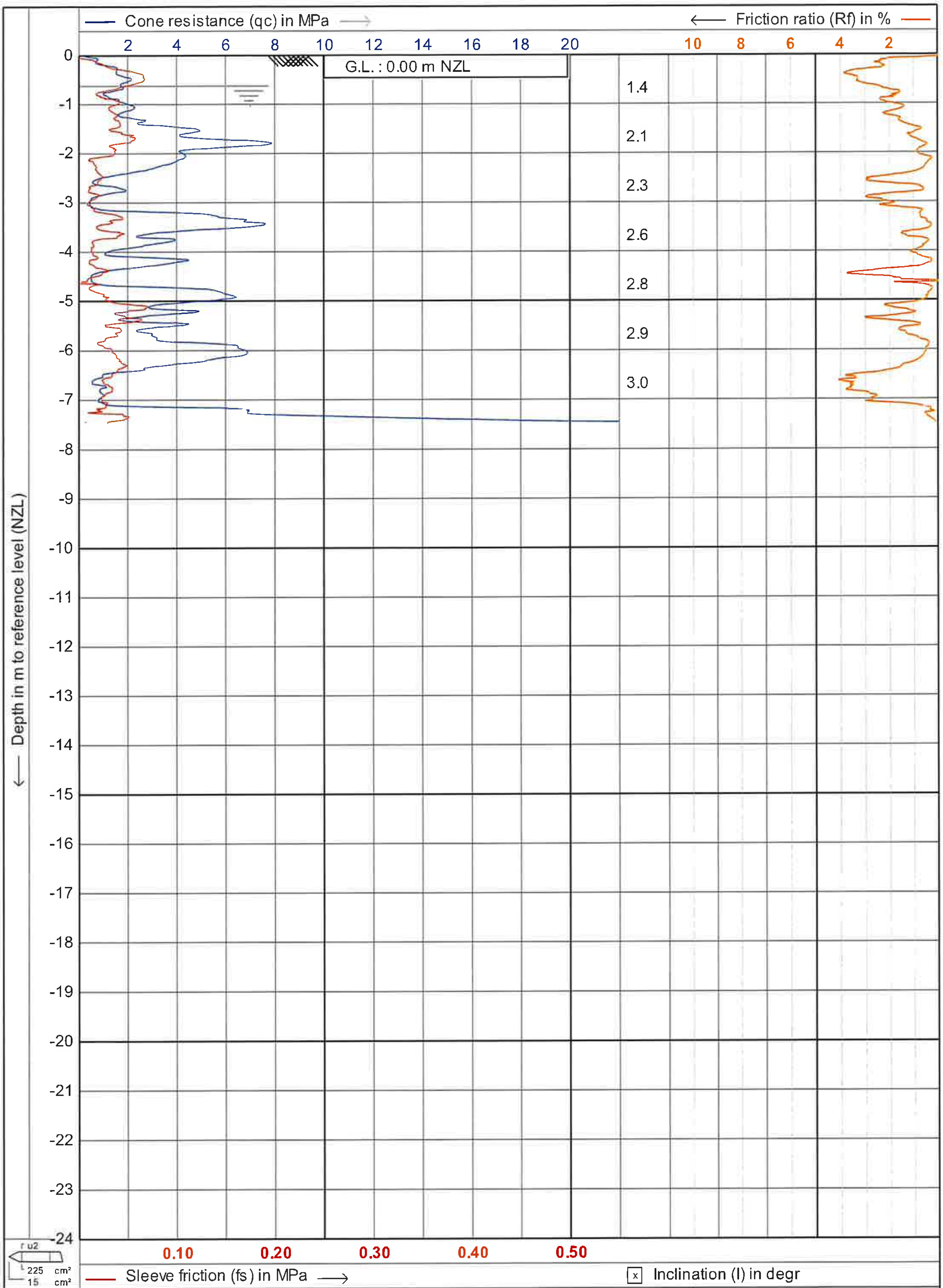


Soil behaviour type classification after Robertson 1990

DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : **30-9-2013**
	Project : **Rosemerryn Subdivision**	Cone no. : **S15CFIIP.S12008**
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt19** — **14/15**



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date	: 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no.	: S15CFIIP.S12008
	Location: **Lincoln**	Project no. :	**224464**
		CPT no.	: **cpt19** 15/15



DCN DRILLING LTD
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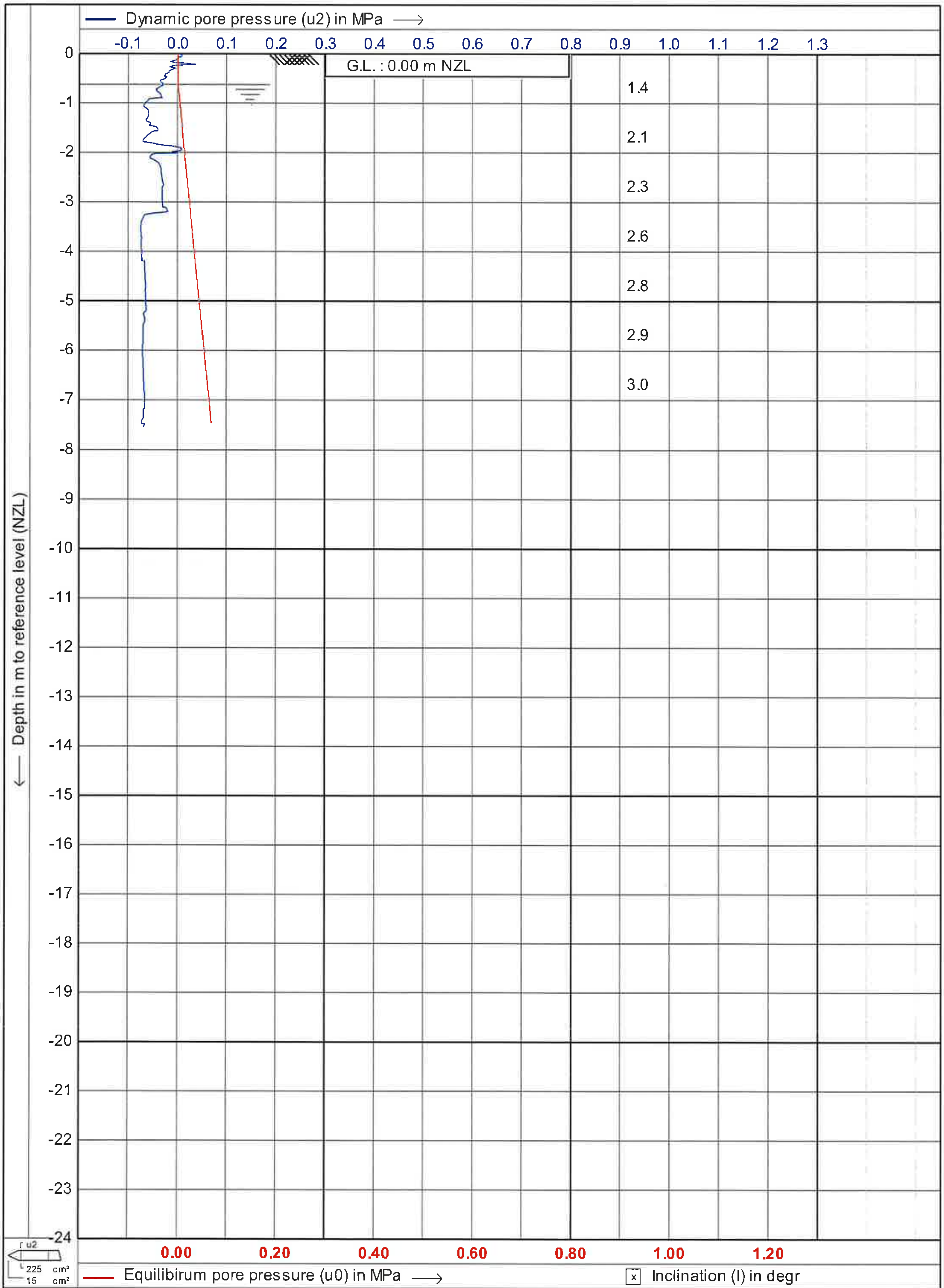
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt21 — 1/15



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	
	Project : **Rosemerryn Subdivision**	Date : **30-9-2013**
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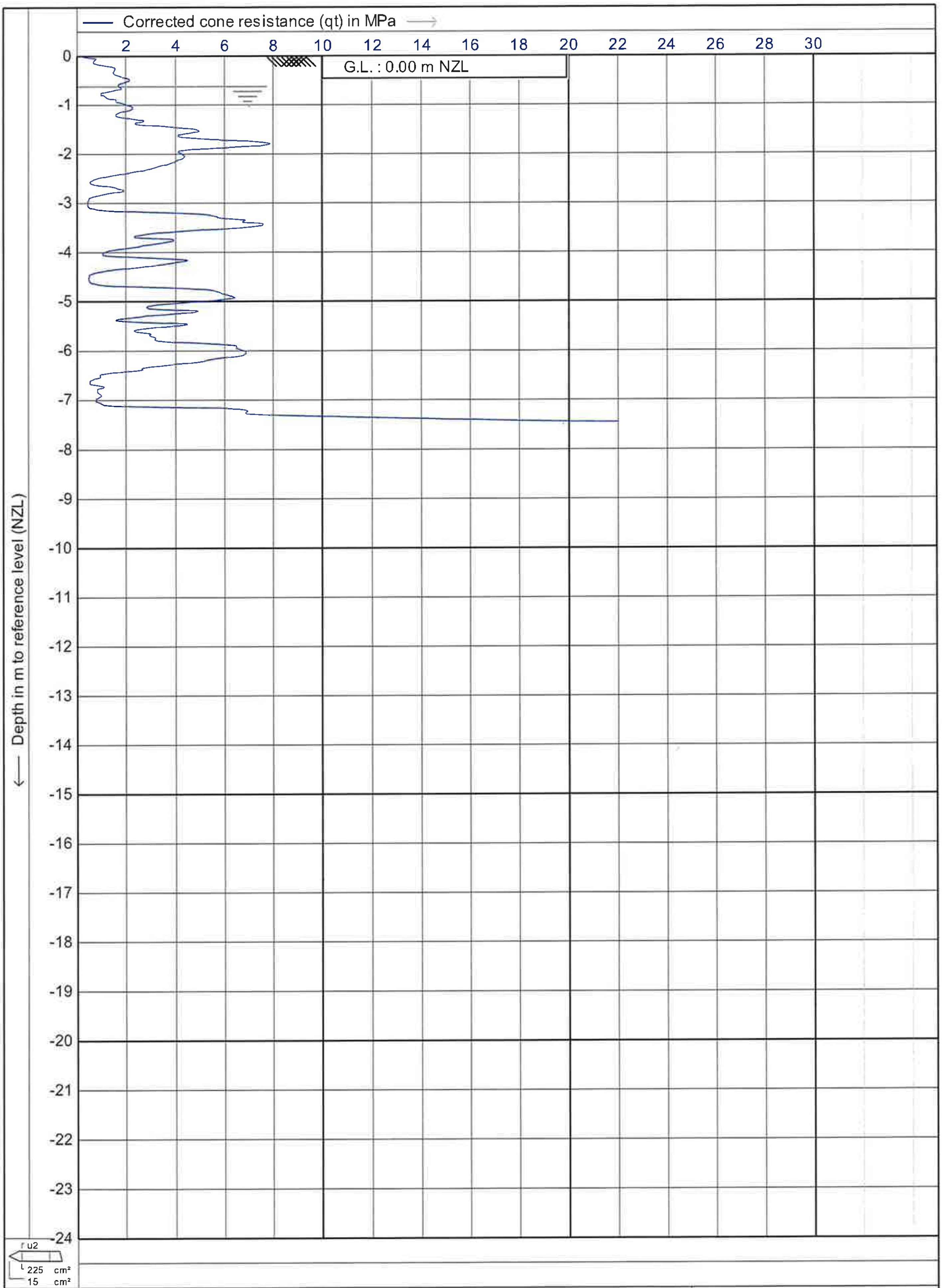
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt21** **2/15**



DCN DRILLING LTD
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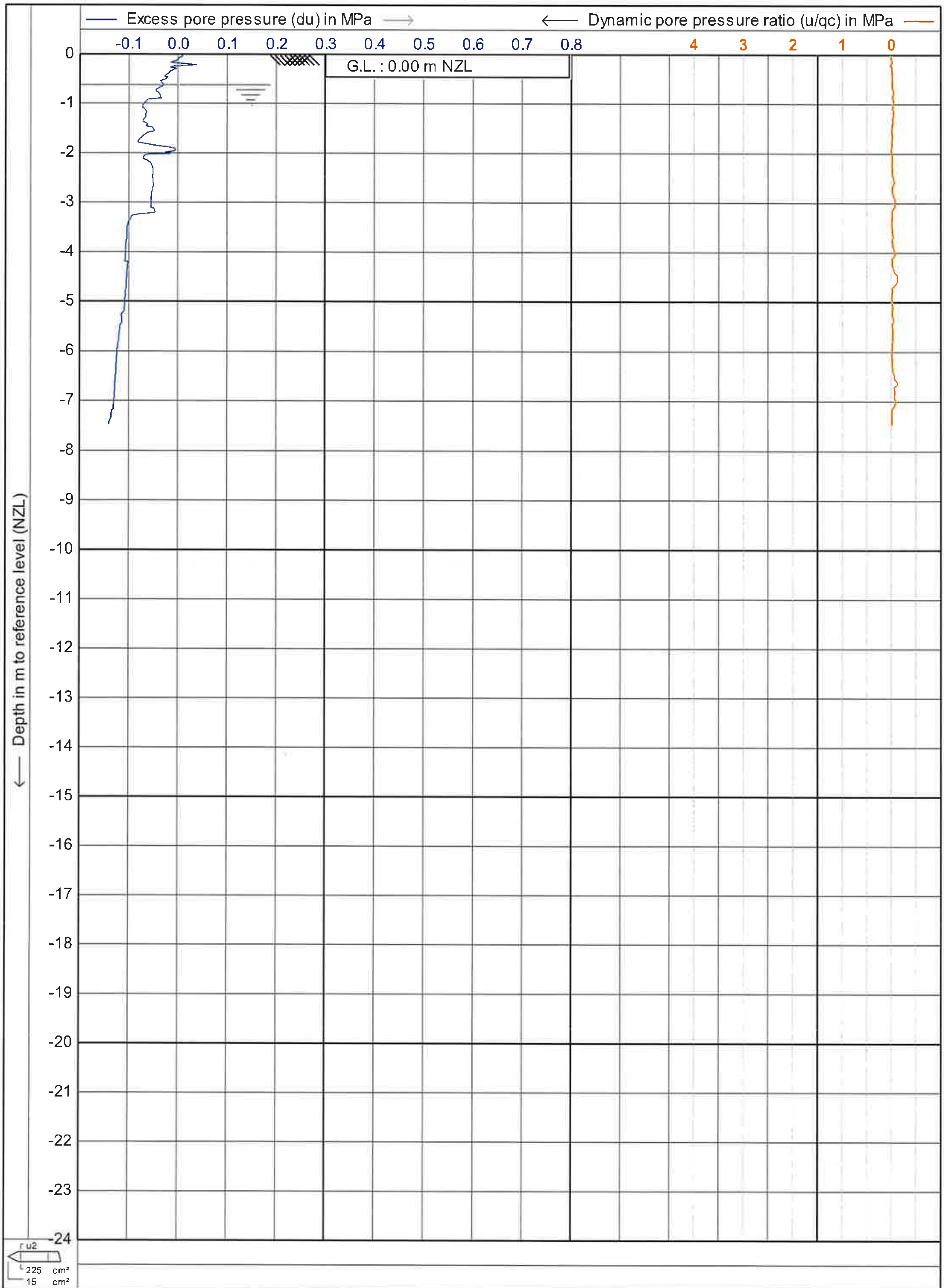
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt21**

3/15



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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

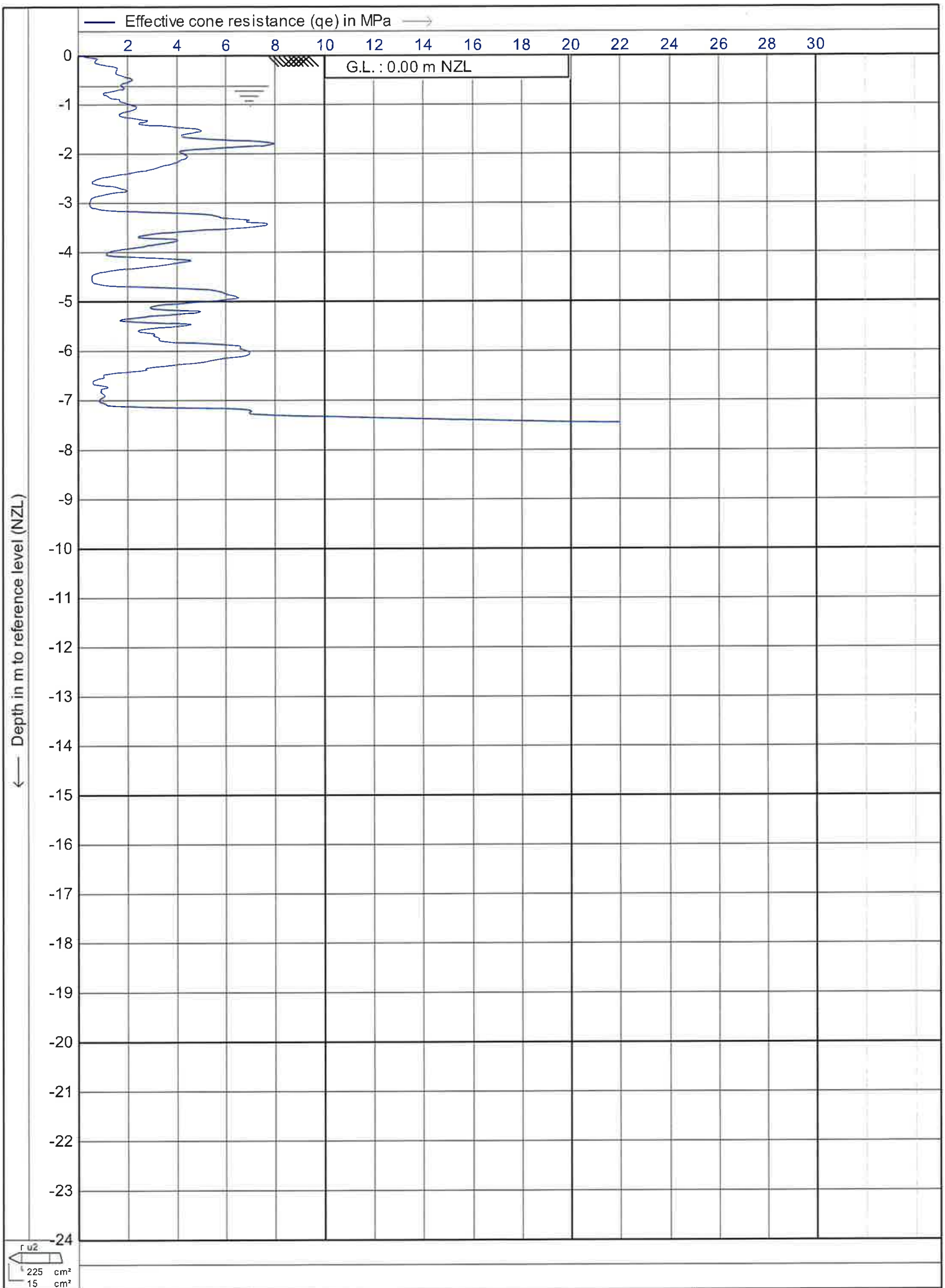
Location: **Lincoln**

Date : **30-9-2013**

Cone no. : **S15CFIIP.S12008**

Project no. : **224464**

CPT no. : **cpt21** **4/15**



DCN DRILLING LTD
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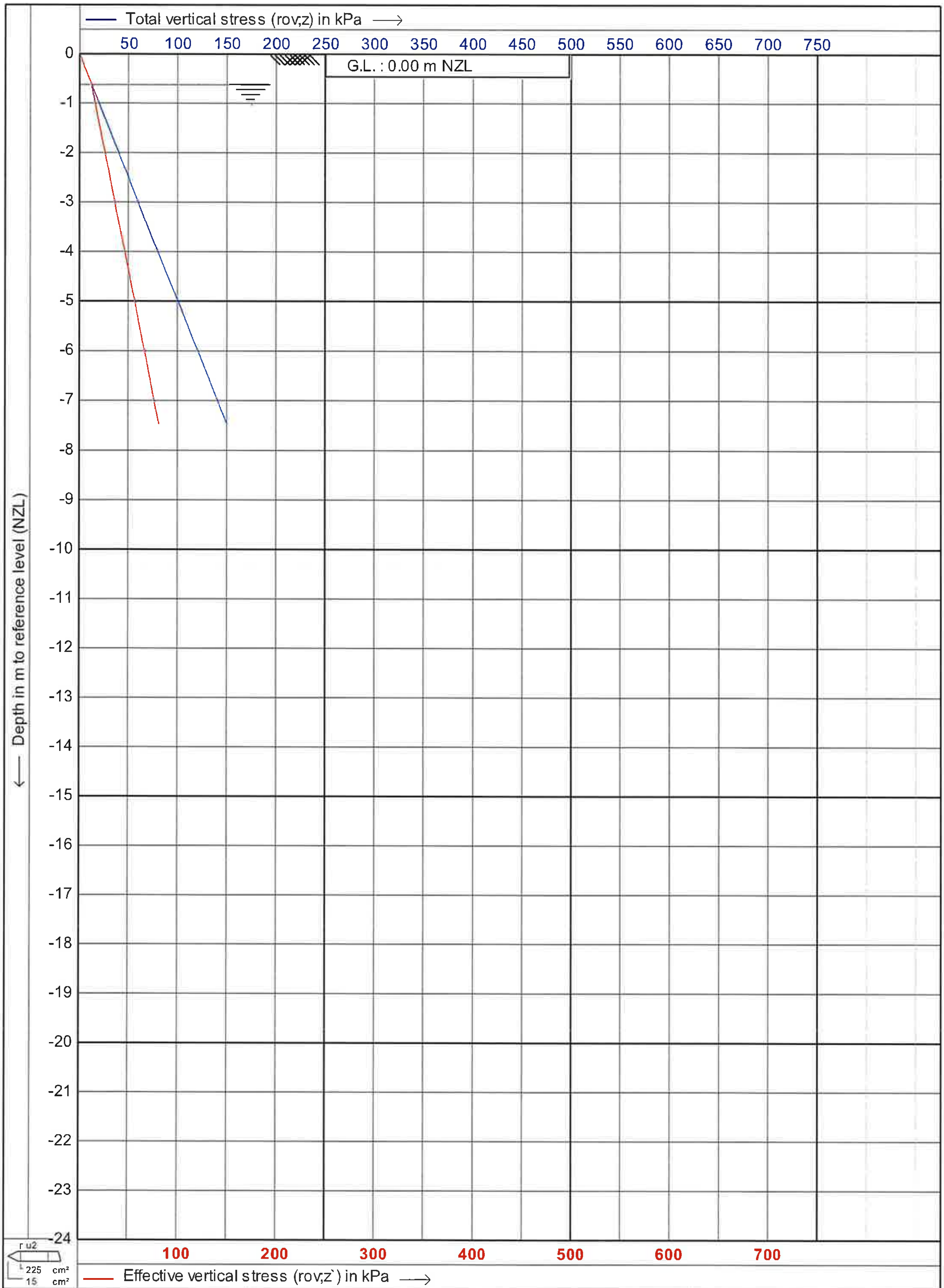
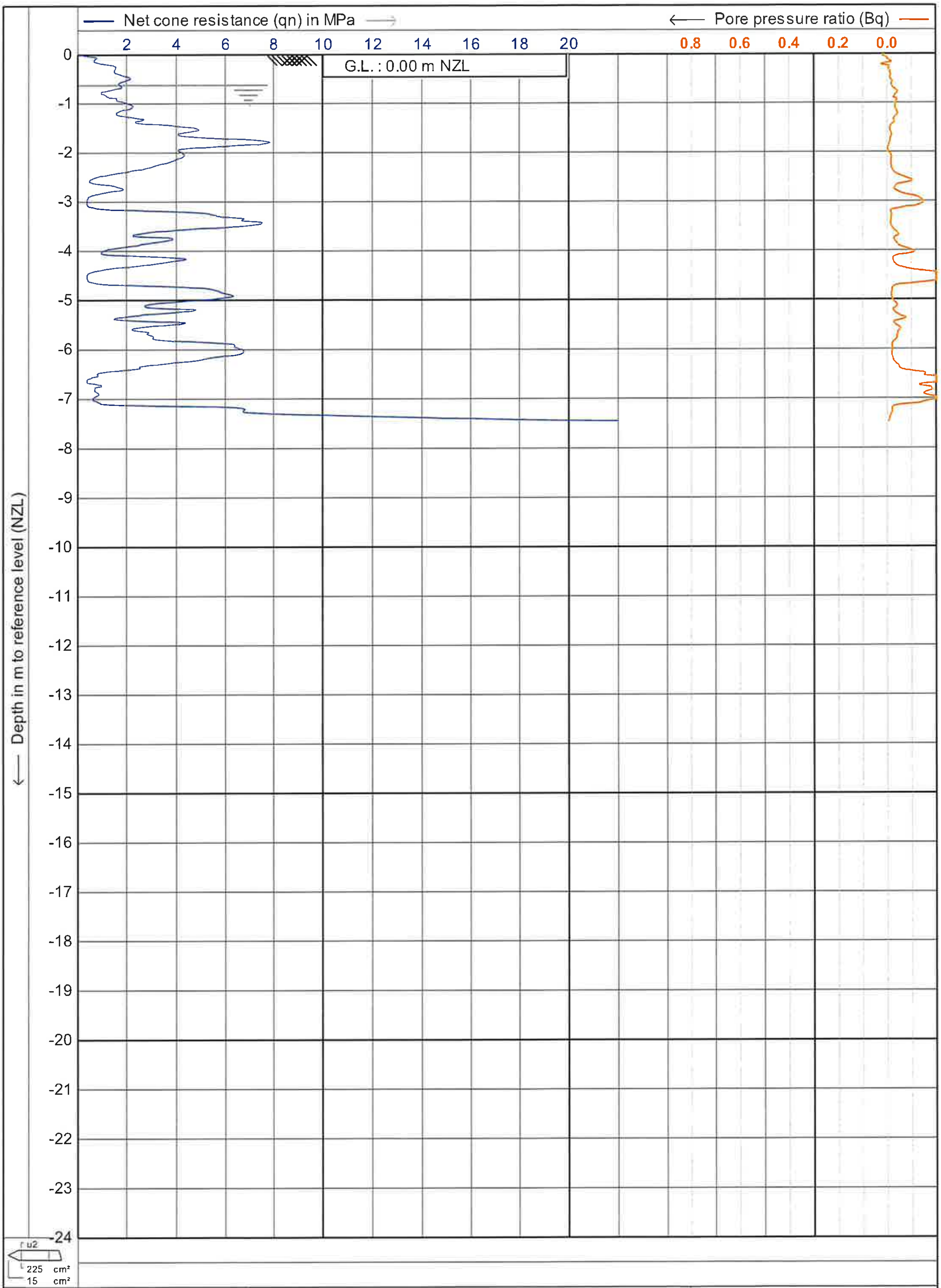
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**	Date	: **30-9-2013**	
Location: **Lincoln**	Cone no.	: **S15CFIIP.S12008**	
	Project no. :	**224464**	
	CPT no.	: **cpt21**	**5/15**



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no. : S15CFIIP.S12008
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt21** 6/15



DCN DRILLING LTD
0274 735 011

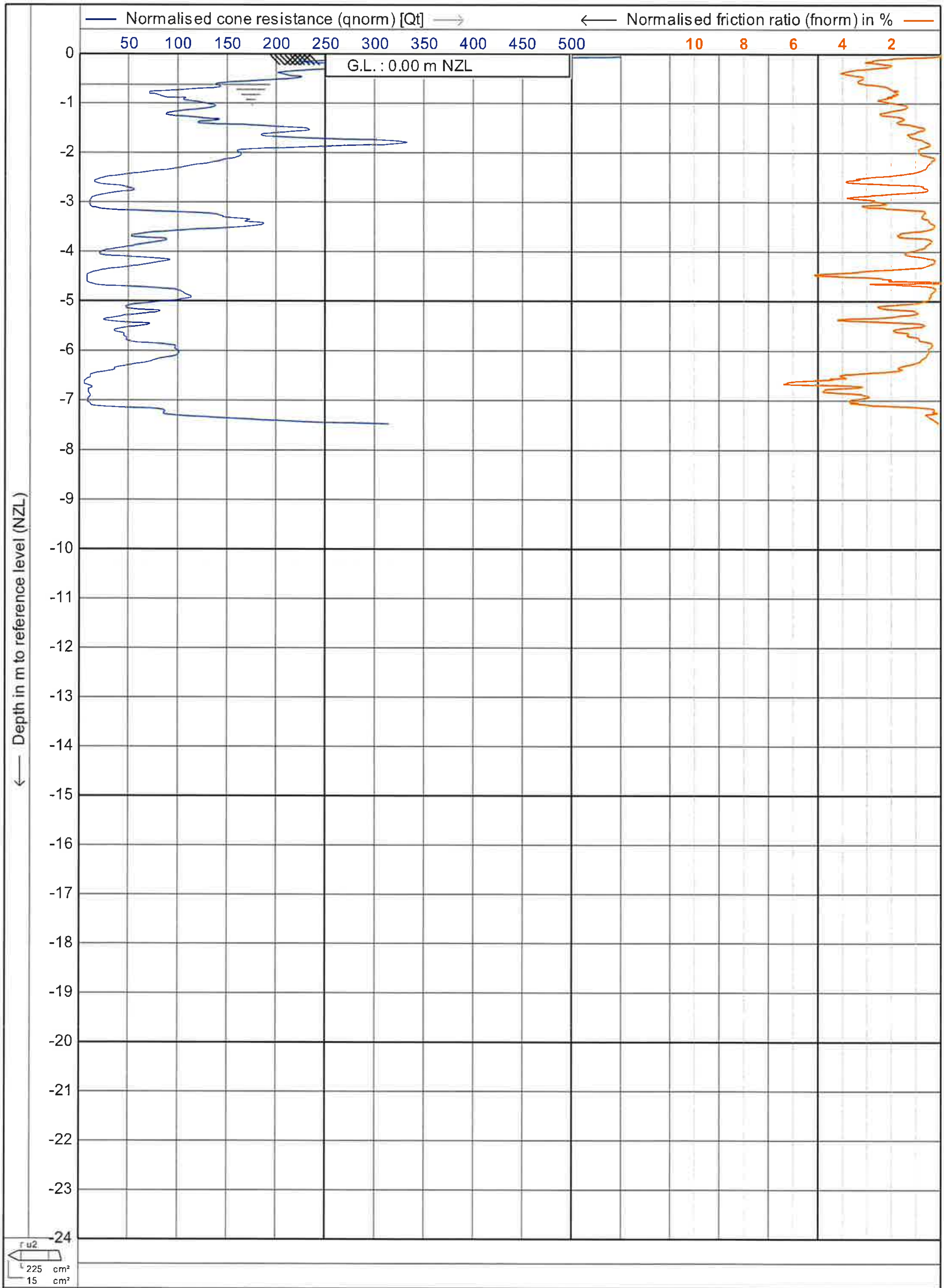
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt21

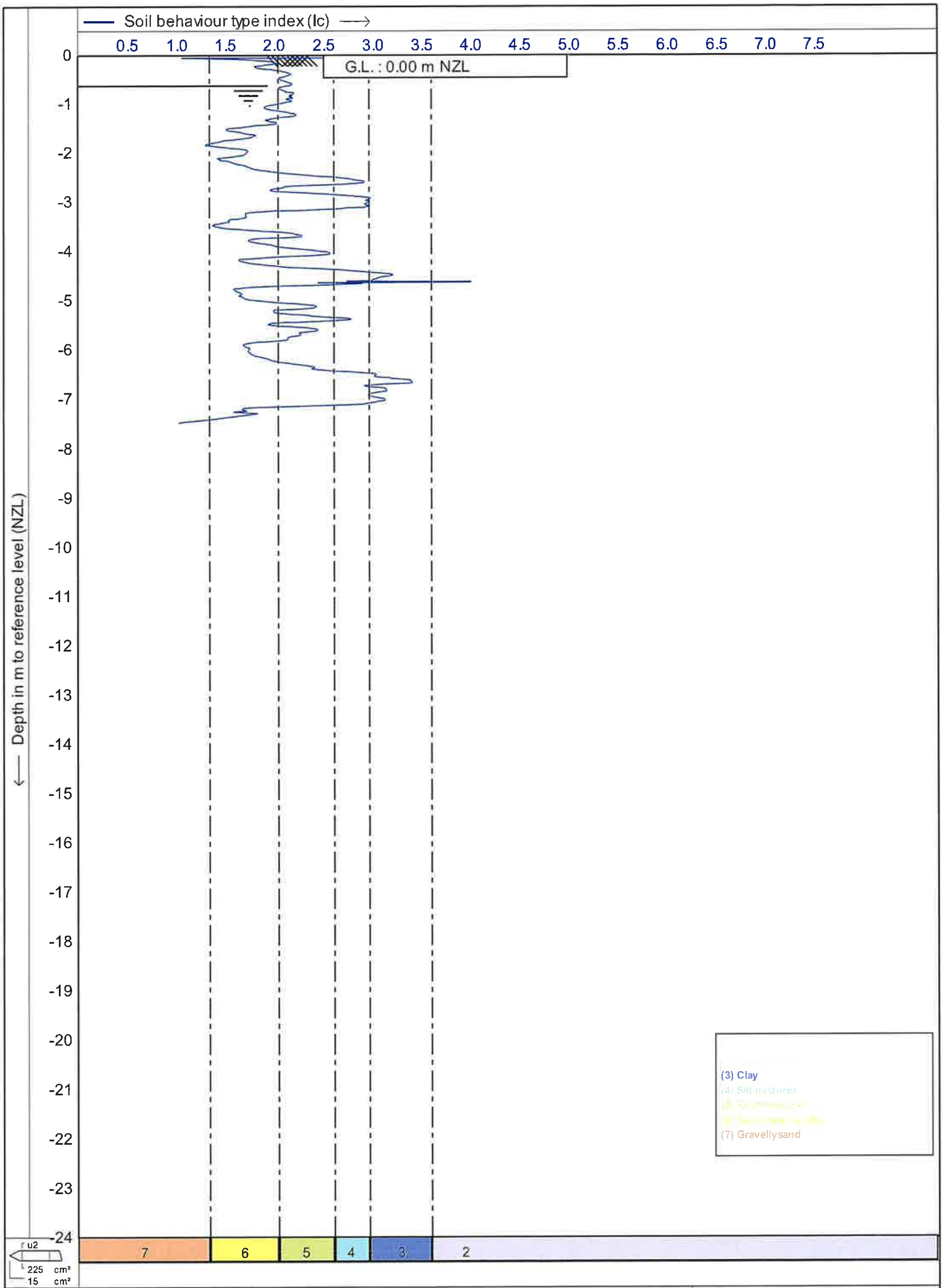
7/15



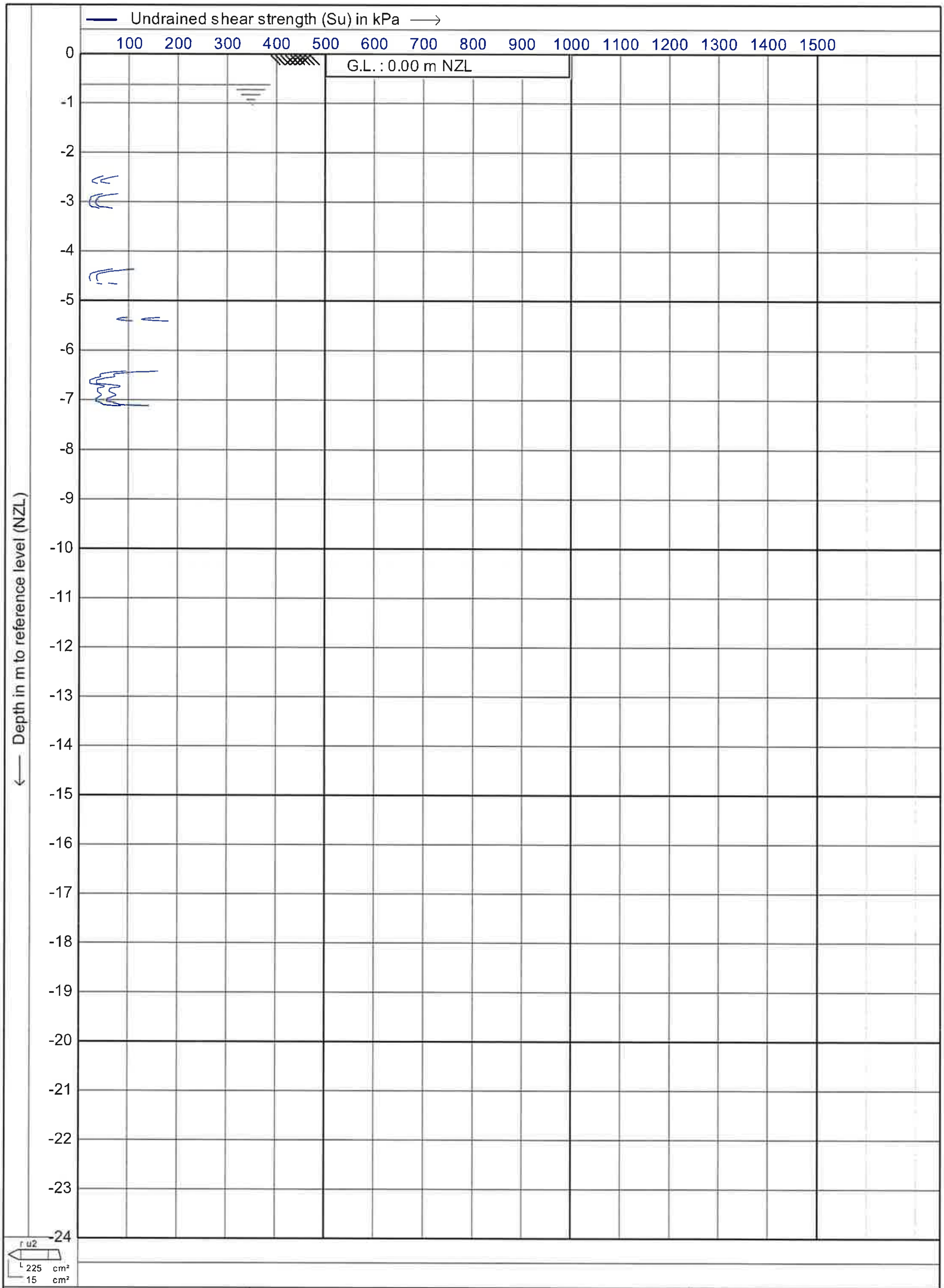
DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07

Project :	**Rosemerryn Subdivision**
Location:	**Lincoln**
Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt21**



DCN DRILLING LTD **0274 735 011**	Test according ASTM Standard D 5778-07	Date : **30-9-2013**
	Project : **Rosemerryn Subdivision**	Cone no. : **S15CFIIP.S12008**
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt21** — **9/15**



DCN DRILLING LTD
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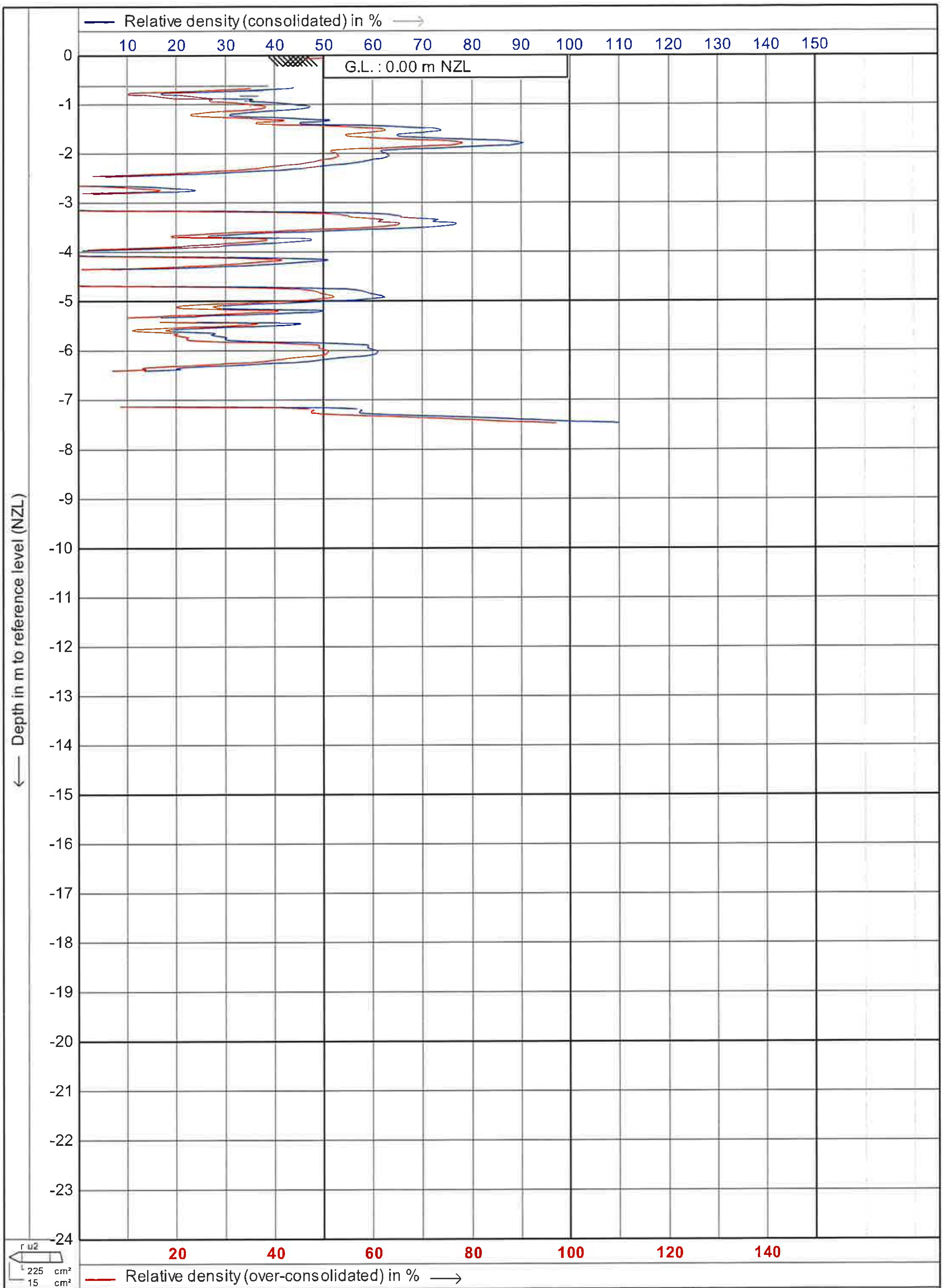
Test according ASTM Standard D 5778-07

Project :	Rosemerryn Subdivision
Location:	Lincoln

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt21

10/15



DCN DRILLING LTD
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Test according ASTM Standard D 5778-07

Project :	Rosemerryn Subdivision
Location:	Lincoln

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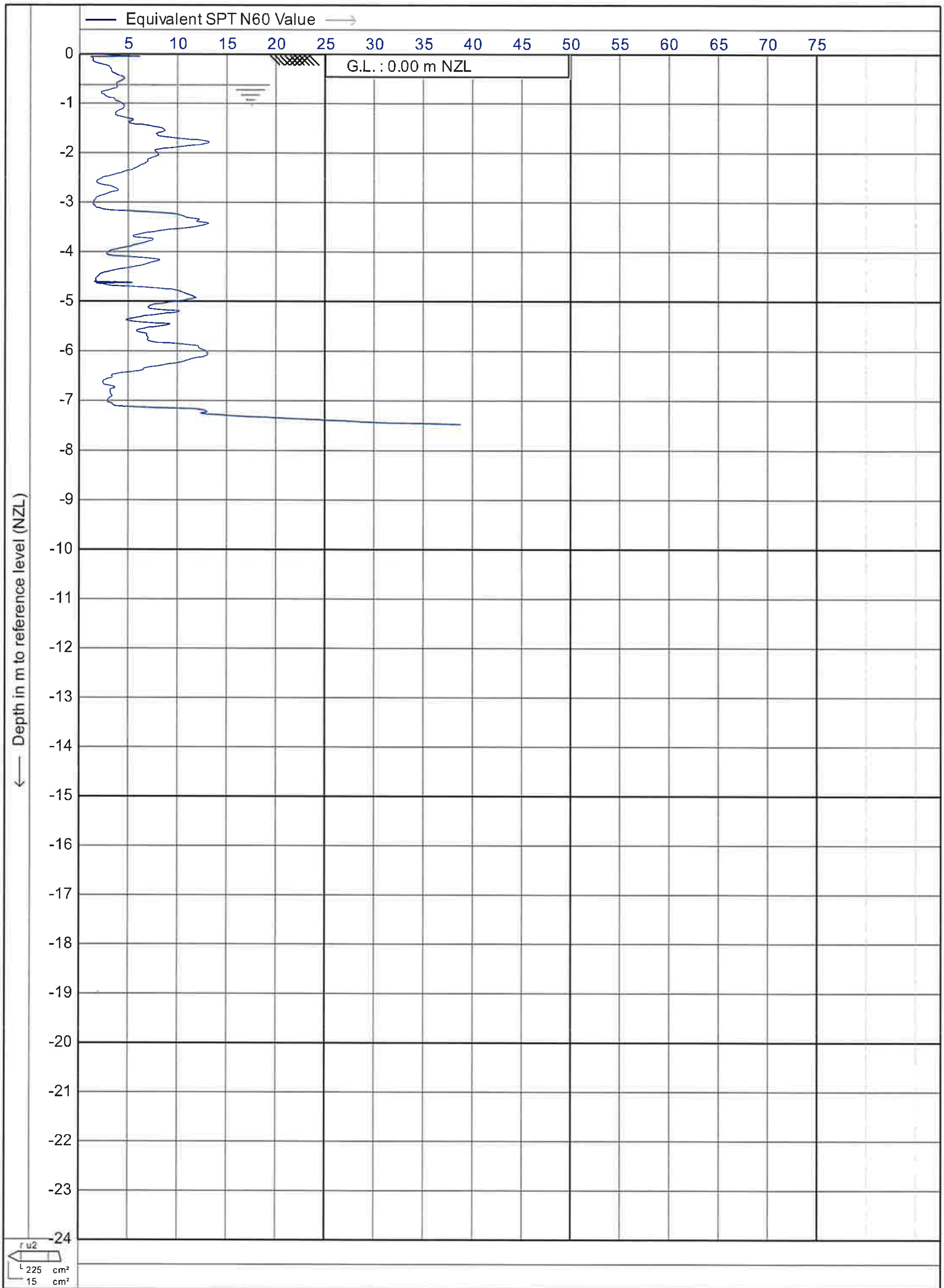
Cone no.	: S15CFIIP.S12008	
Project no. :	224464	
CPT no.	: cpt21	11/15



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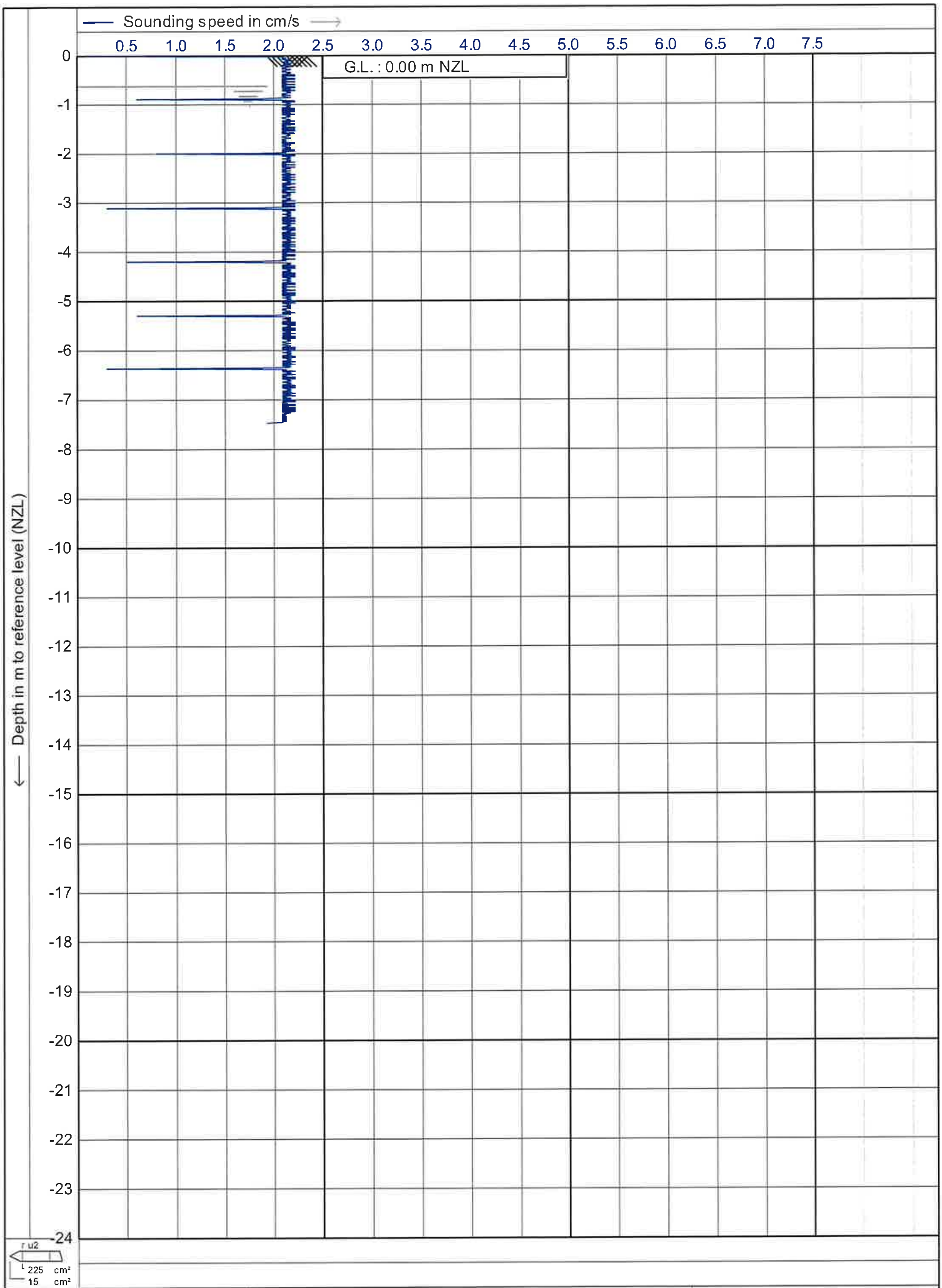
		Project no.	: **224464**
	Location: **Lincoln**	CPT no.	: **cpt21** 12/15



DCN DRILLING LTD
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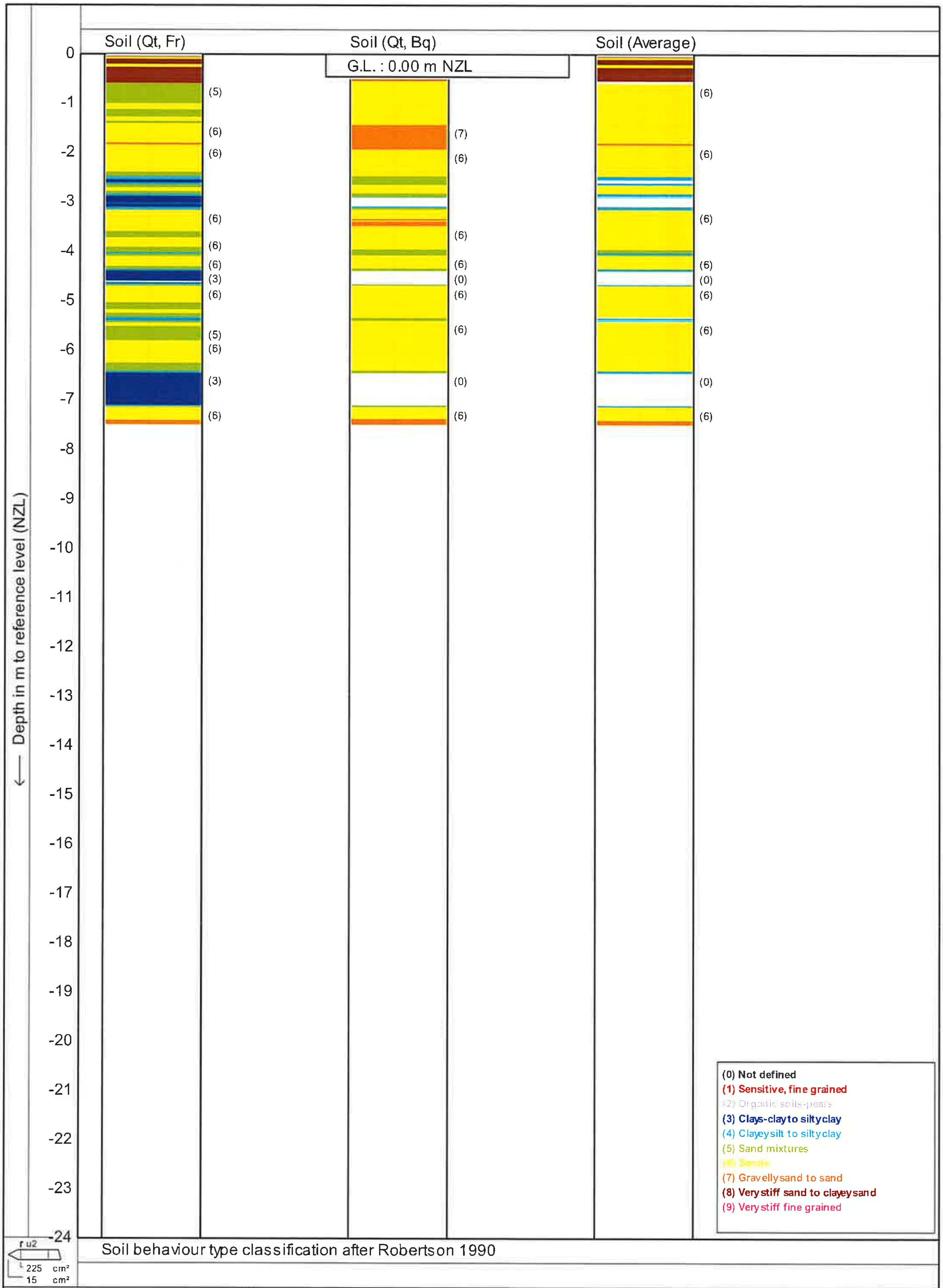
Test according ASTM Standard D 5778-07

Project : Rosemerryn Subdivision	Date : 30-9-2013		
	Cone no. : S15CFIIP.S12008		
Location: Lincoln	Project no. : 224464		
	CPT no. : cpt21	13/15	



Soil behaviour type classification after Robertson 1990

DCN DRILLING LTD
0274 735 011

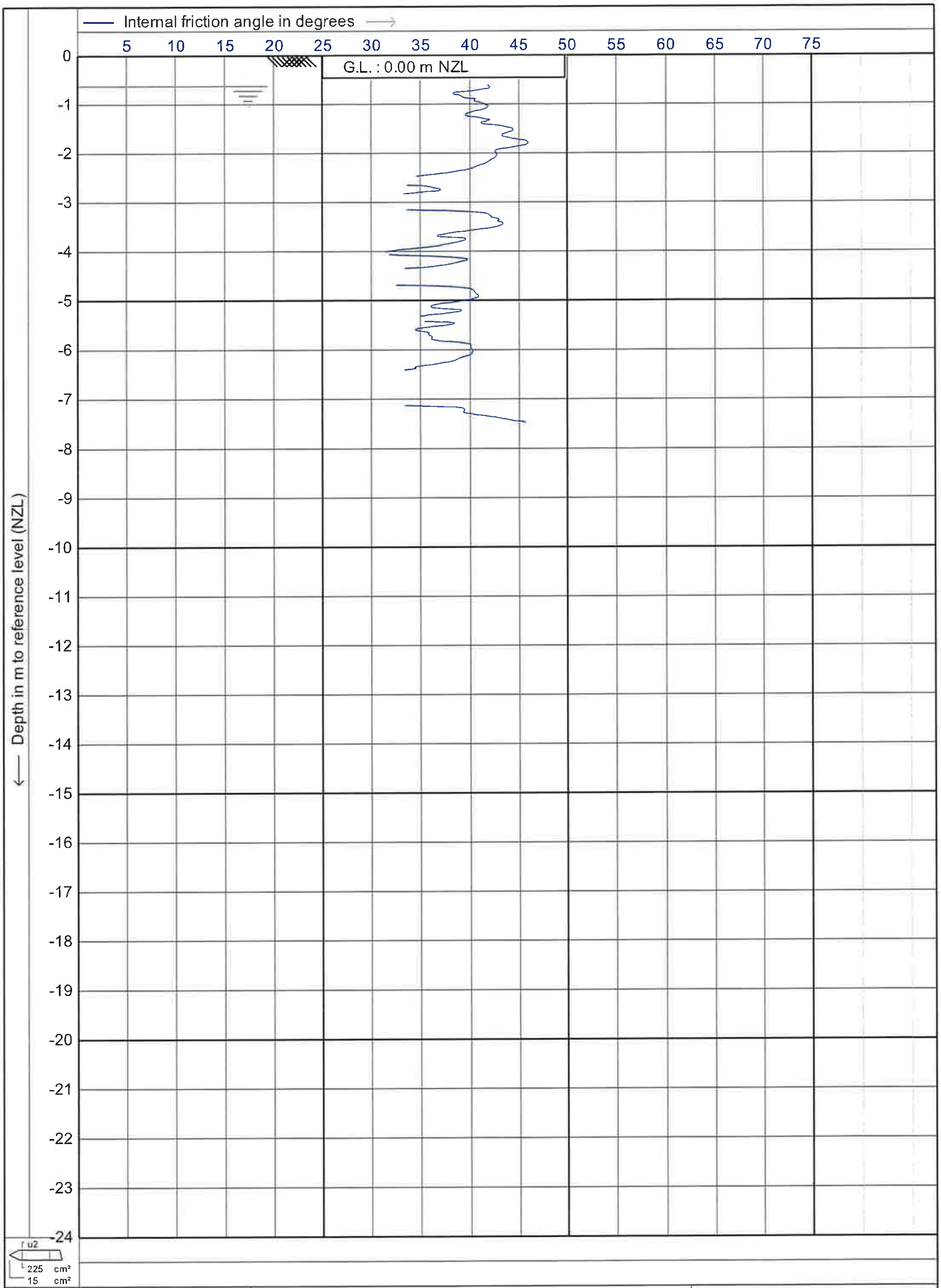
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt21**

14/15



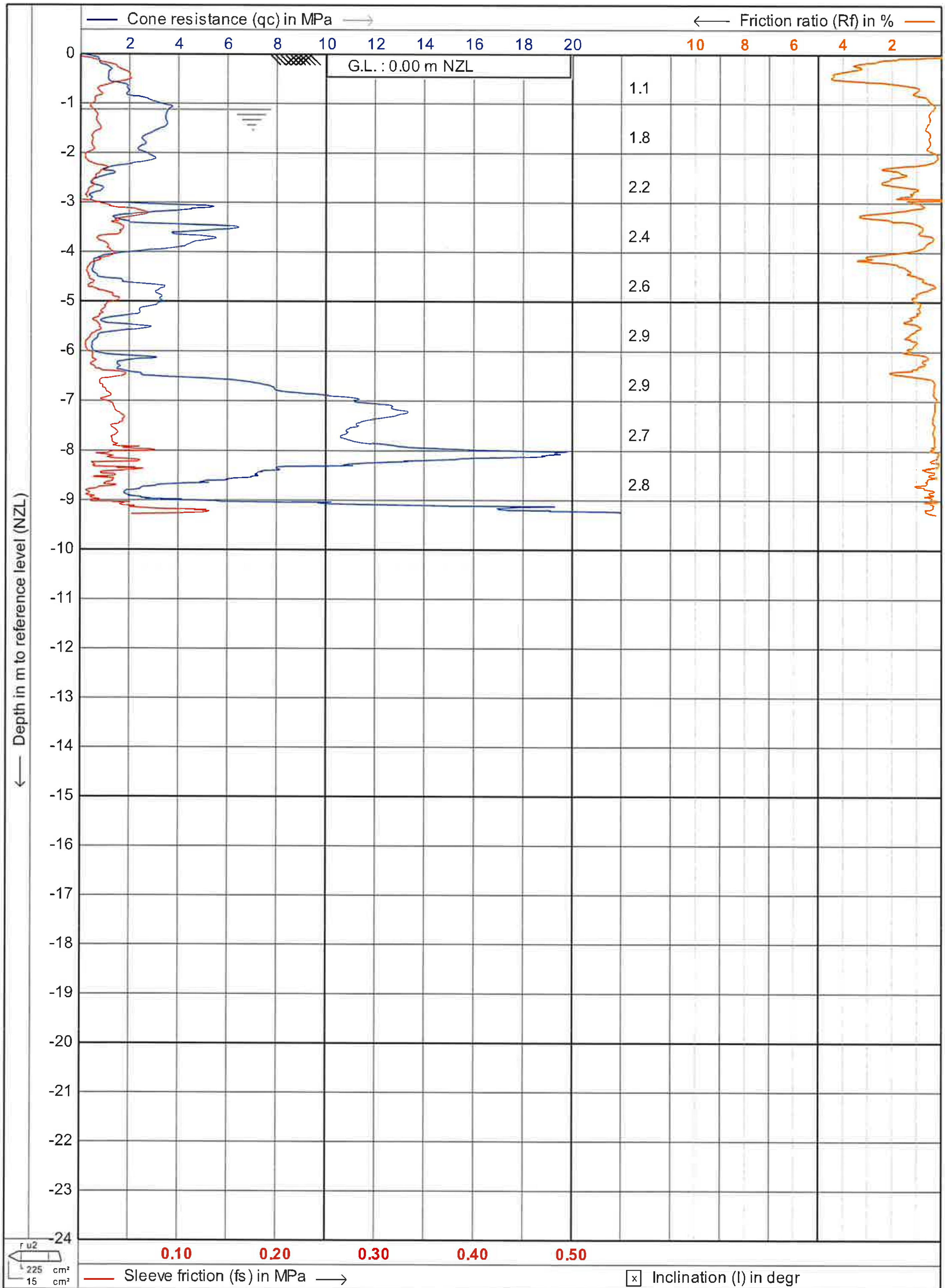
DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt21**



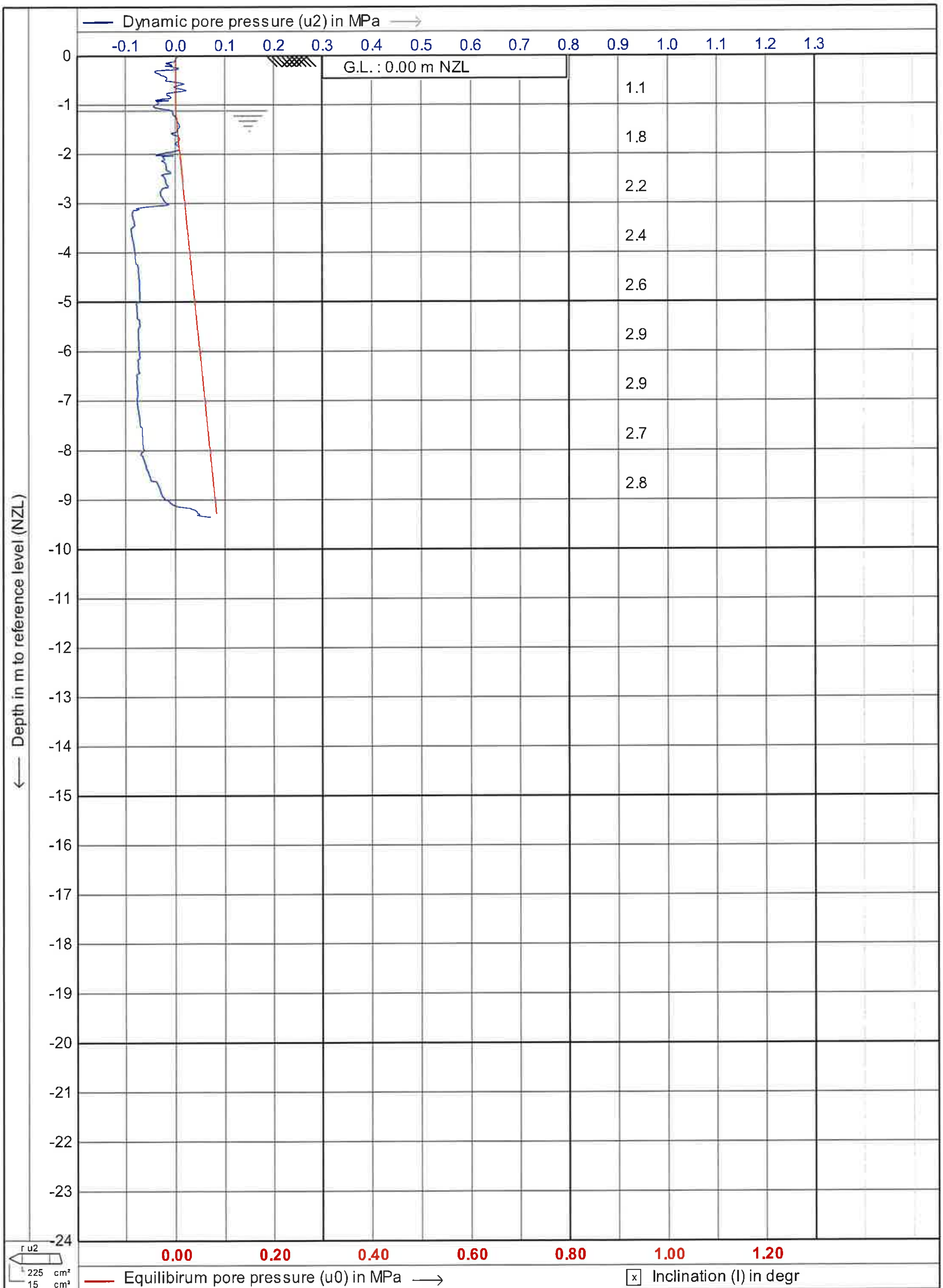
DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07

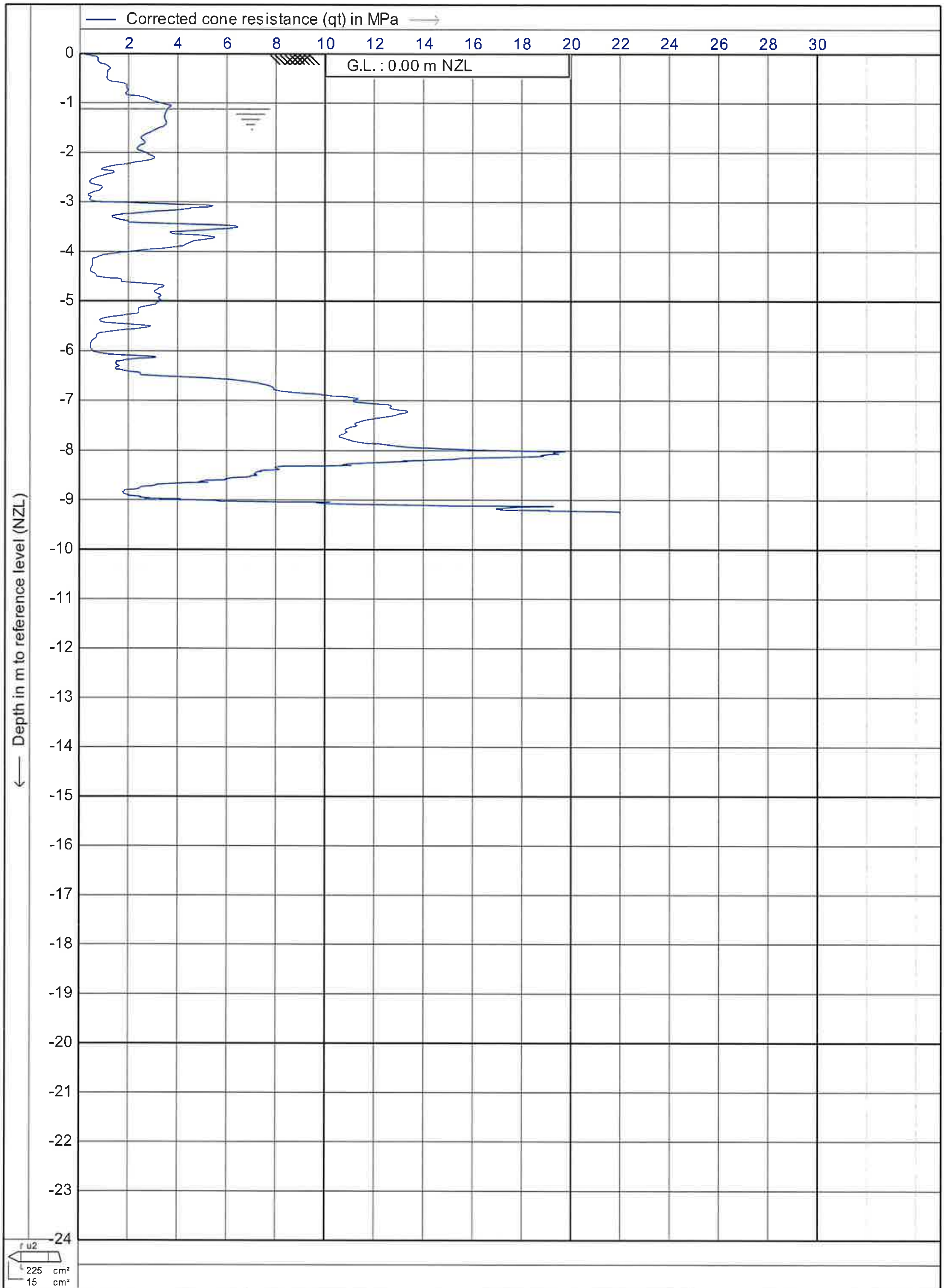
Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: **30-9-2013**
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt22** **1/15**



DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no. : S15CFIIP.S12008
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt22** 2/15



DCN DRILLING LTD
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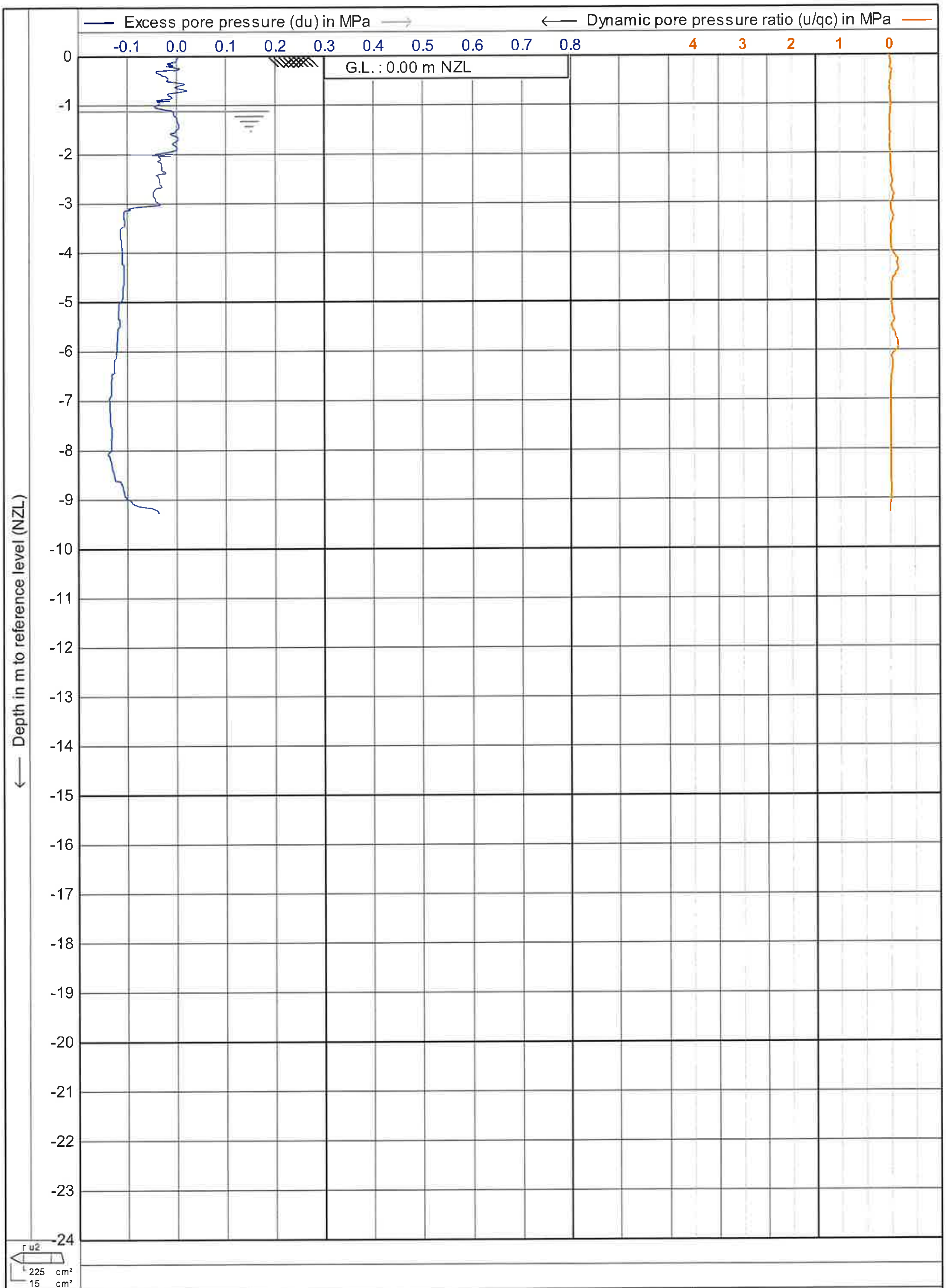
Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt22 — 3/15



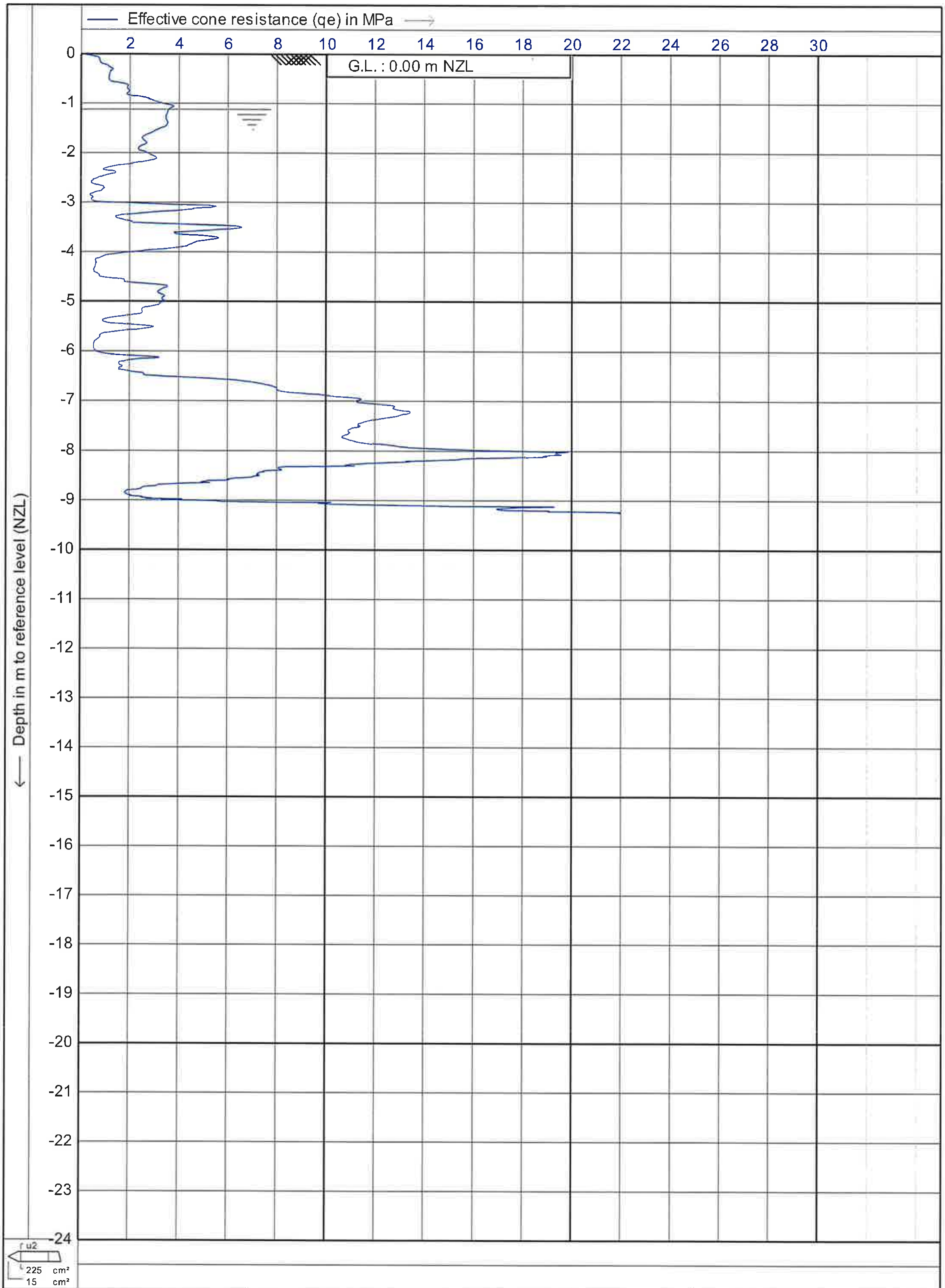
DCN DRILLING LTD
0274 735 011

Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt22
	4/15



DCN DRILLING LTD
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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date : **30-9-2013**

Cone no. : **S15CFIIP.S12008**

Project no. : **224464**

CPT no. : **cpt22**

5/15

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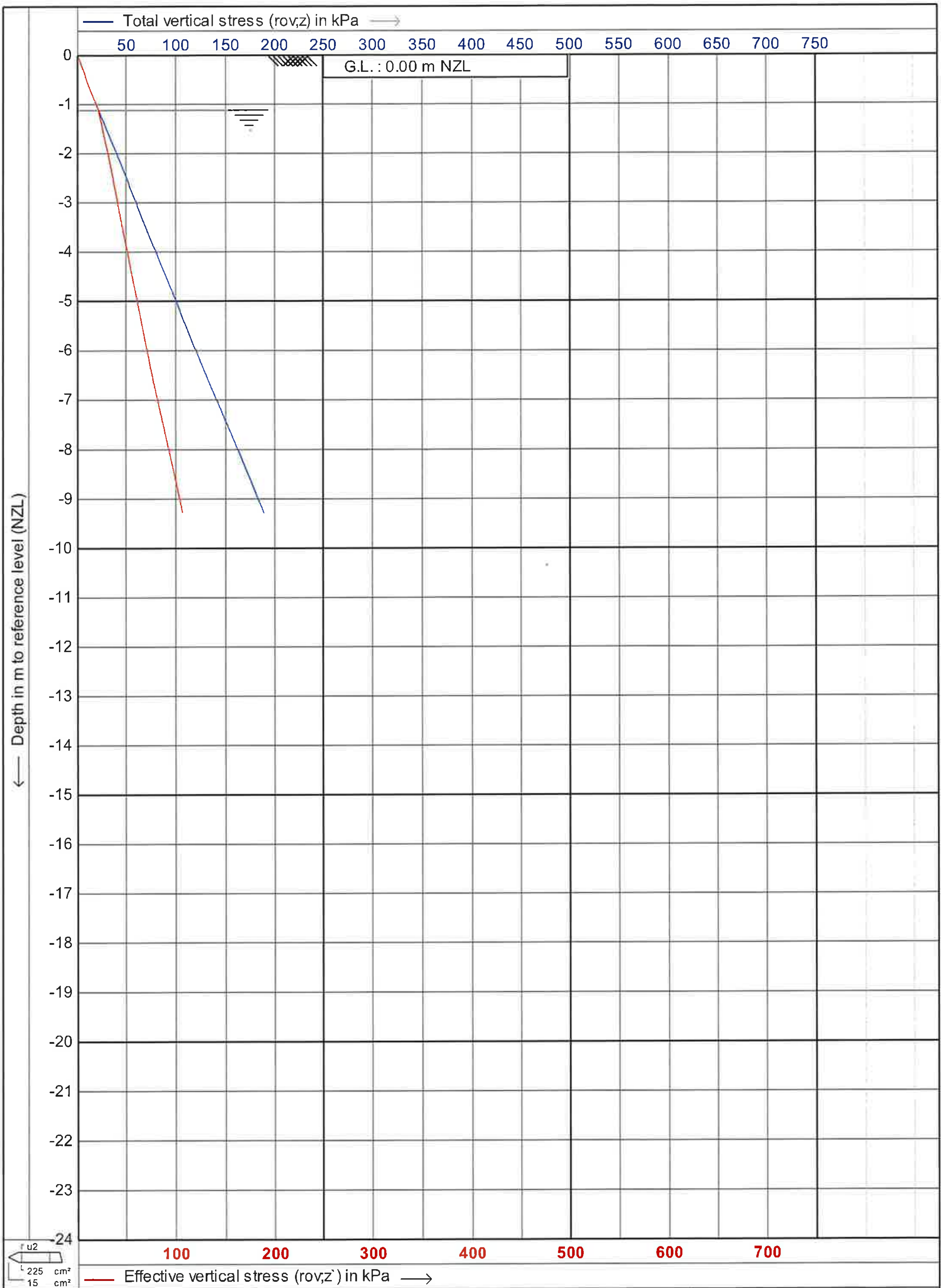

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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

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Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt22
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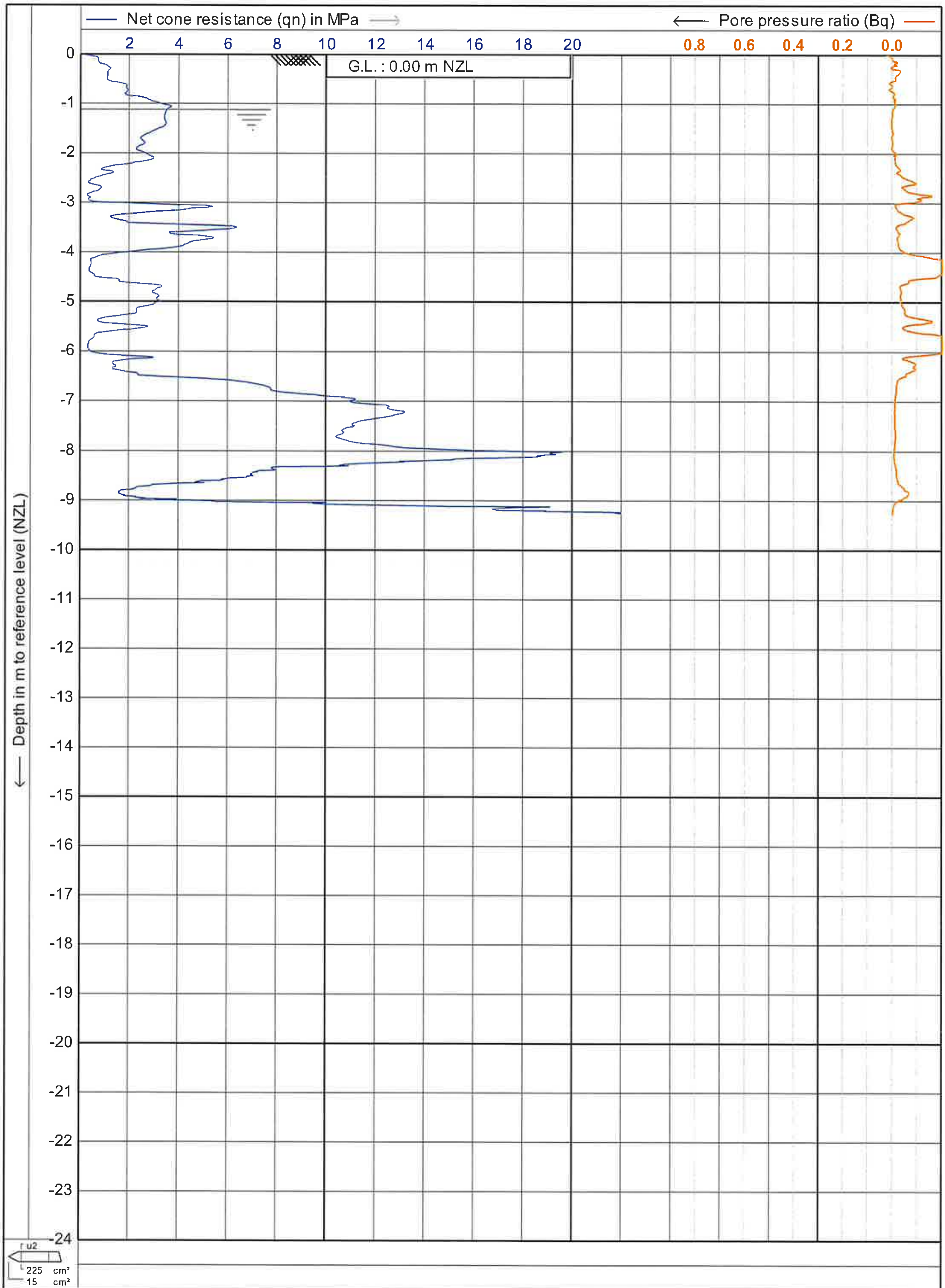

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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

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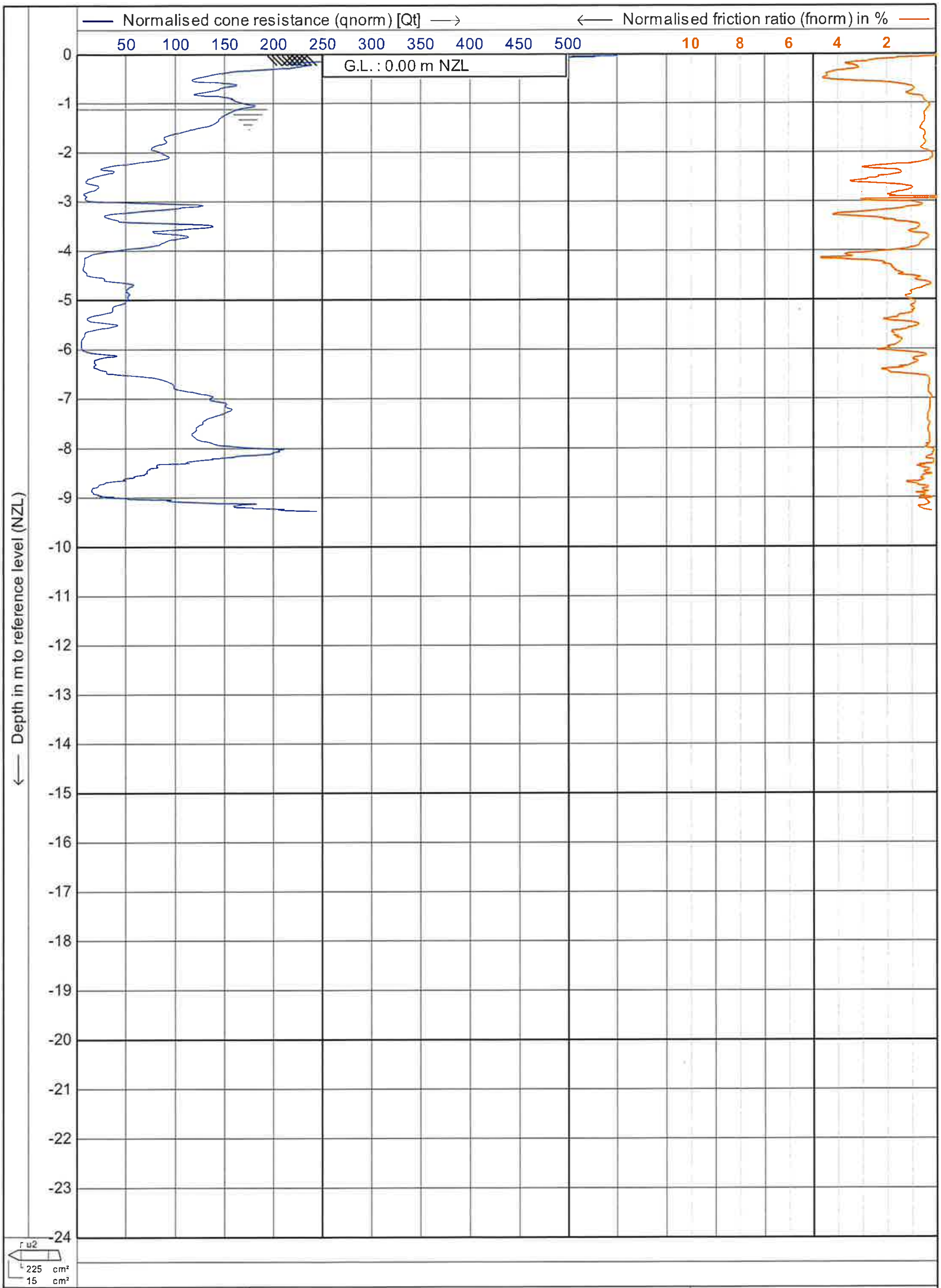
Cone no.	: **S15CFIIP.S12008**
Project no. :	**224464**
CPT no.	: **cpt22**

7/15



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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

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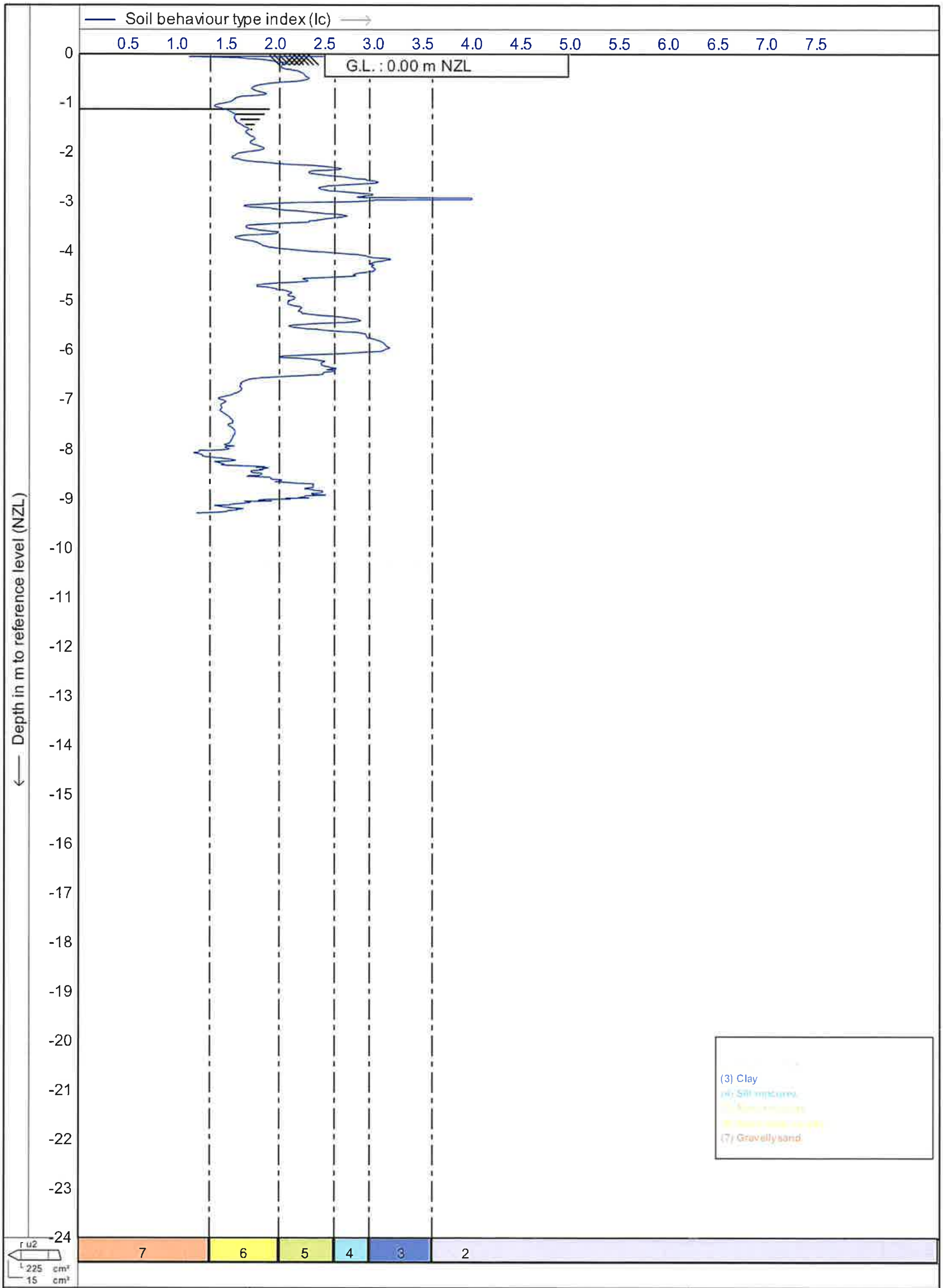
Cone no.	: S15CFIIP.S12008
Project no. :	224464
CPT no.	: cpt22

8/15



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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

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Cone no.	: S15CFIIP.S12008
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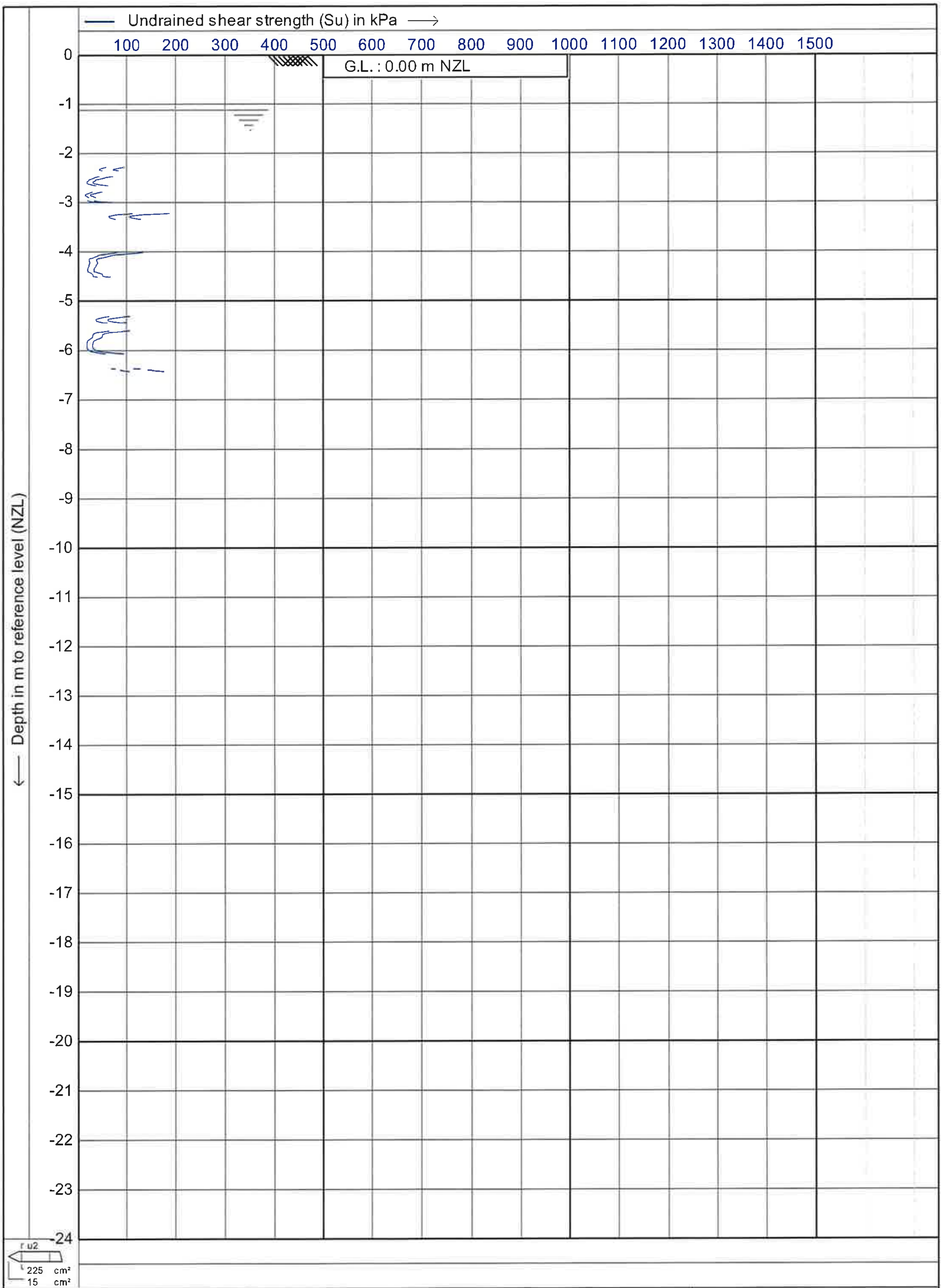
CPT no.	: cpt22

9/15



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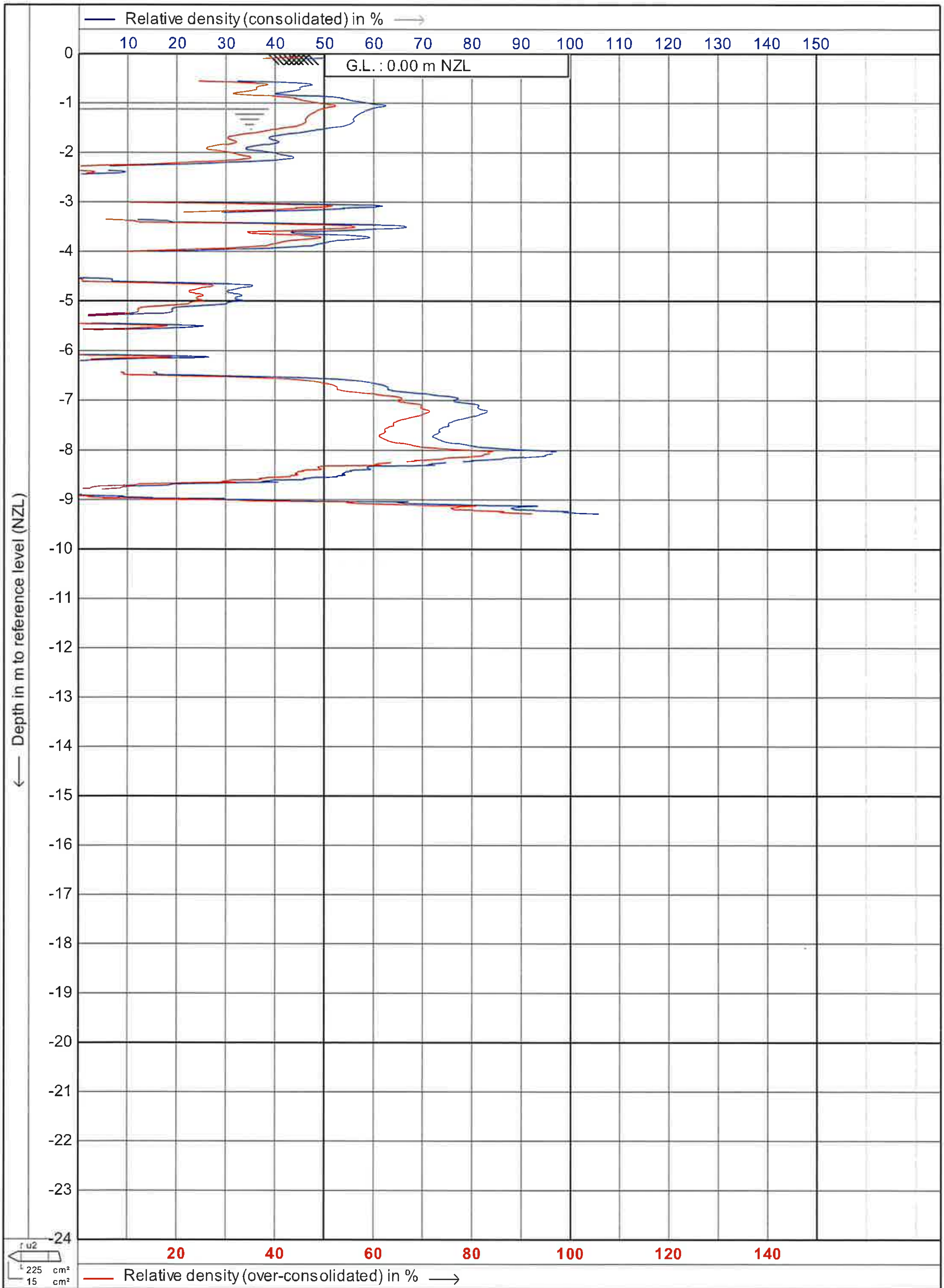
Test according ASTM Standard D 5778-07

Project :	Rosemerryn Subdivision	Date	: 30-9-2013
		Cone no.	: S15CFIIP.S12008
Location:	Lincoln	Project no. :	224464
		CPT no.	: cpt22 10/15



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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

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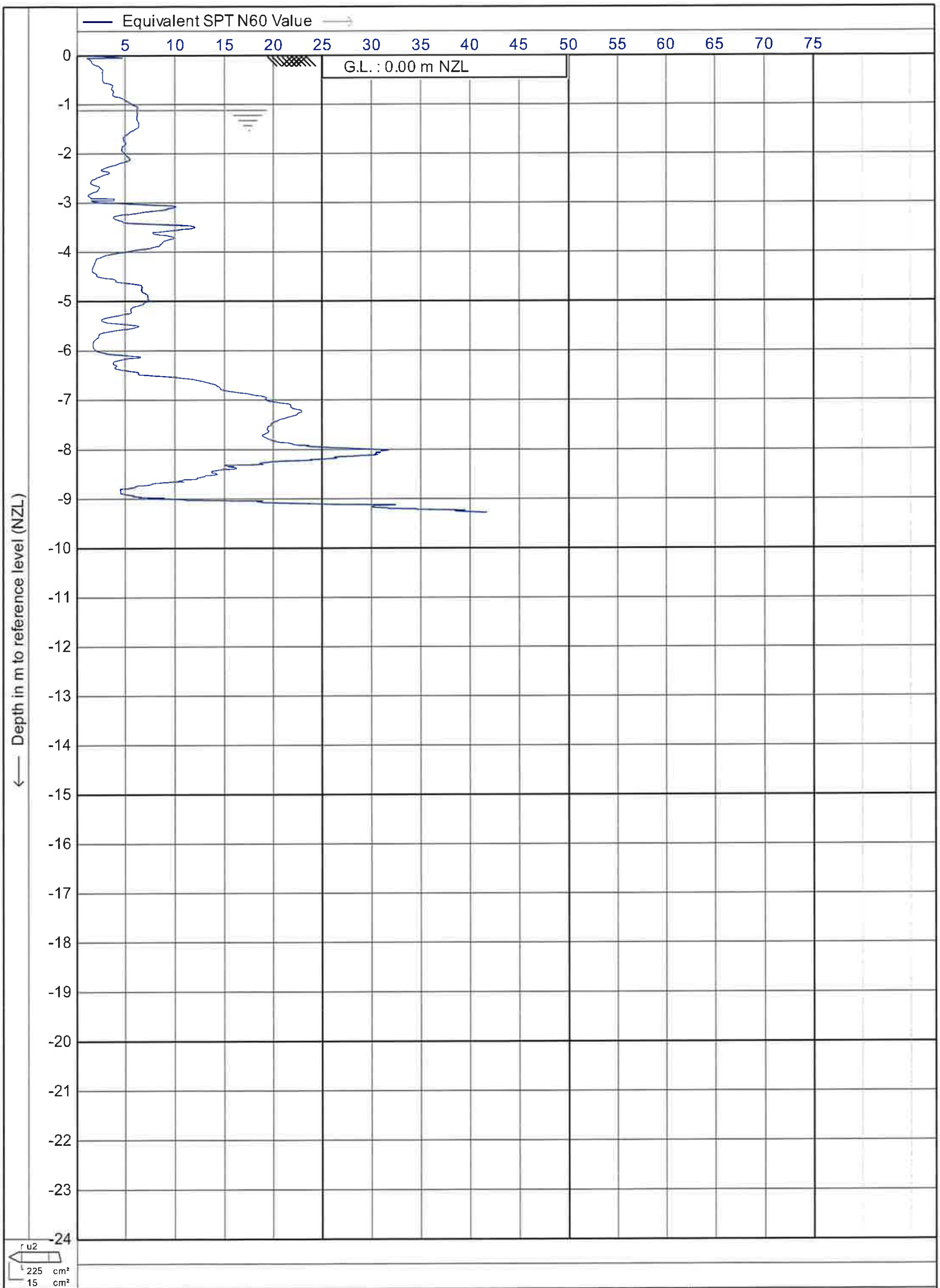
CPT no.	: cpt22



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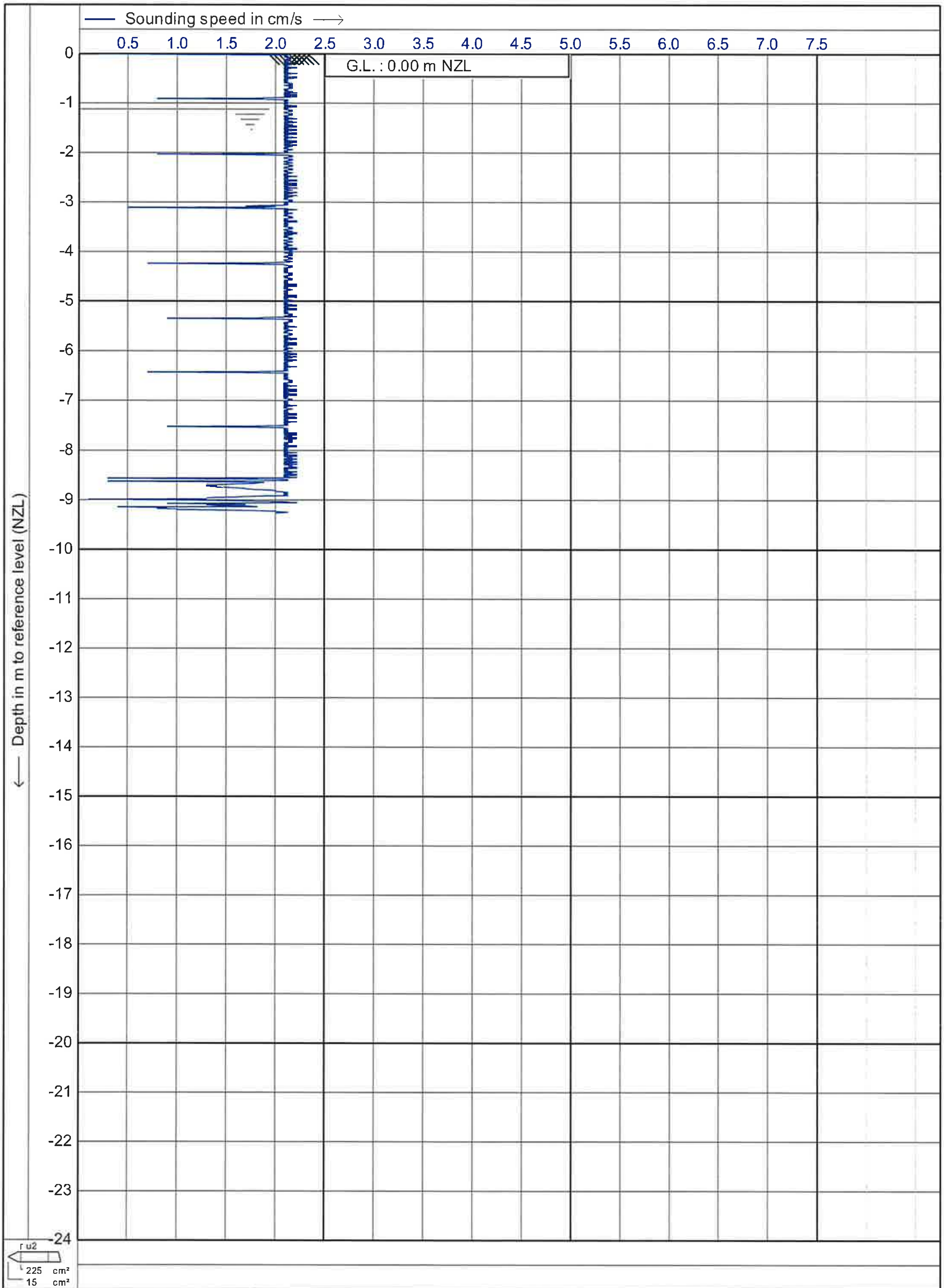
Test according ASTM Standard D 5778-07

Project :	**Rosemerryn Subdivision**	Date	: **30-9-2013**
		Cone no.	: **S15CFIIP.S12008**
Location:	**Lincoln**	Project no. :	**224464**
		CPT no.	: **cpt22** **12/15**



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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date : **30-9-2013**

Cone no. : **S15CFIIP.S12008**

Project no. : **224464**

CPT no. : **cpt22**

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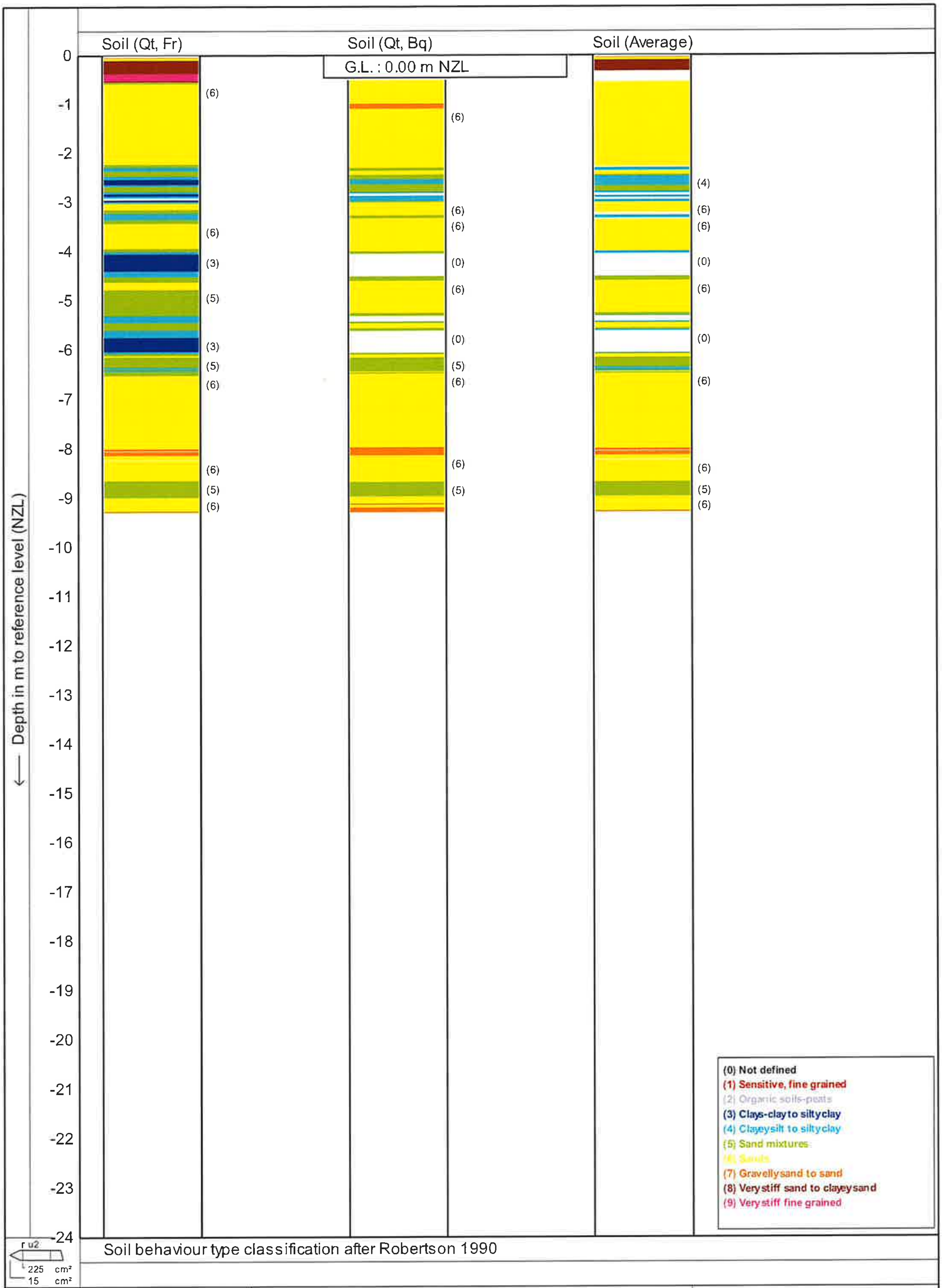

Soil behaviour type classification after Robertson 1990

DCN DRILLING LTD 0274 735 011	Test according ASTM Standard D 5778-07	Date : 30-9-2013
	Project : **Rosemerryn Subdivision**	Cone no. : S15CFIIP.S12008
		Project no. : **224464**
	Location: **Lincoln**	CPT no. : **cpt22** 14/15

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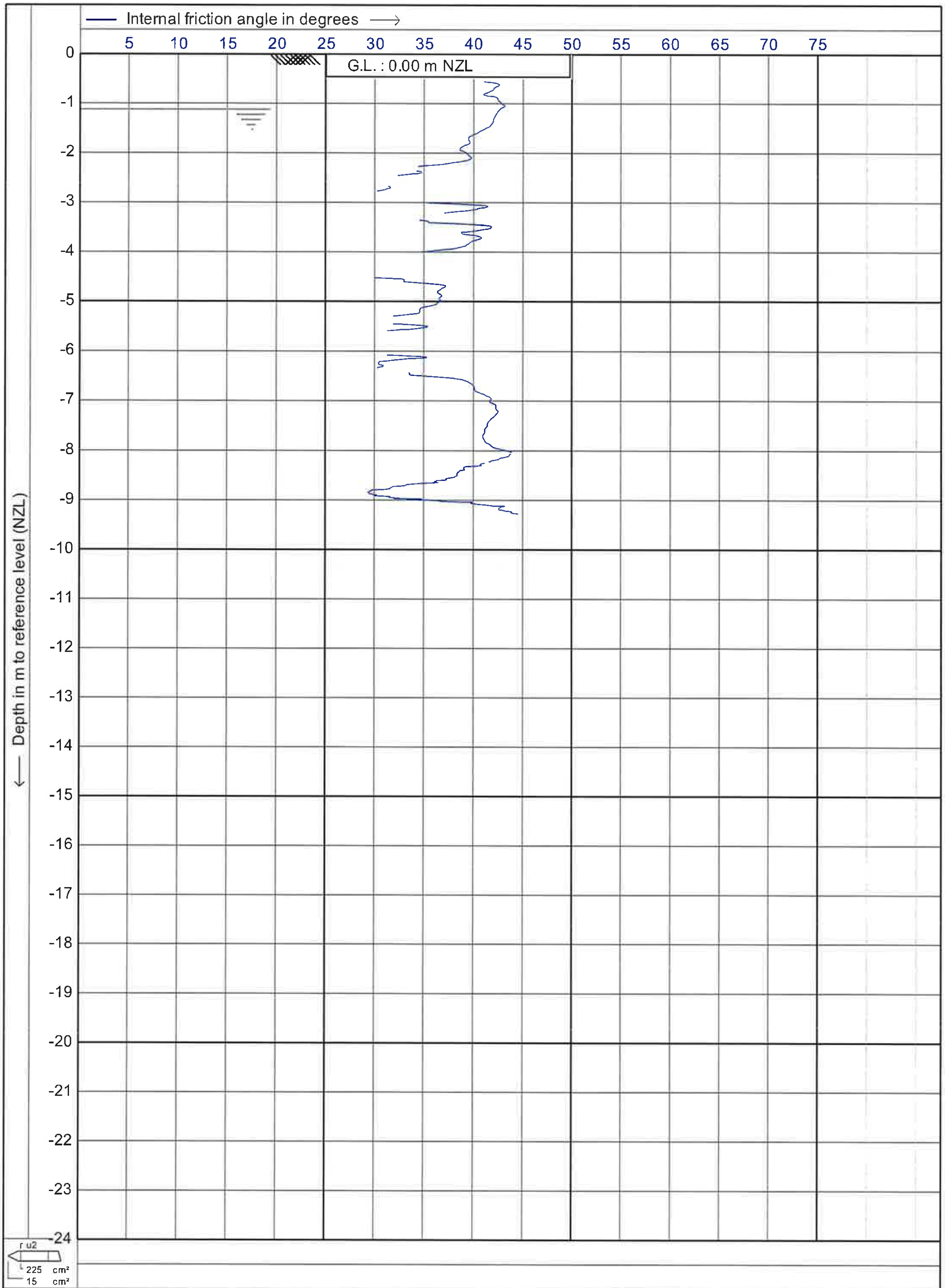

DCN DRILLING LTD
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Test according ASTM Standard D 5778-07

Project : **Rosemerryn Subdivision**

Location: **Lincoln**

Date	: 30-9-2013
Cone no.	: S15CFIIP.S12008
Project no.	: 224464
CPT no.	: cpt22

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BOREHOLE RECORD

HOLE NO.	**BH102**
PROJECT NO.	**224464**

PROJECT **Rosemerryn Subdivision Lincoln**

METHOD **DP**	CO-ORDINATES (NZTM) E 1560211 N 5168161	SHEET 1 of 2
MACHINE & NO. **VTR 9700-D Truck**		DATE from **22/01/2015** to **22/01/2015**
FLUSHING MEDIUM **Water**	ORIENTATION **VERTICAL**	GROUND-LEVEL **+9.00** m RL

Columns: Drilling Progress; Casing depth/size; Water level (m) shift start/end; Water Recovery %; Total core Recovery %; Solid core Recovery %; R.Q.D.; Fracture Index; Tests; Samples (Type, Ref, Depth); Reduced Level; Depth (m); Legend; STRATA DESCRIPTION (SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. *(NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)*)

Drilling Progress: 22/01/2015

Total core Recovery %	Tests	Samples (Type / Depth)	Reduced Level	Depth (m)	Strata Description
20		DT 0.00		0.00	Sandy fine to coarse GRAVEL with some silt and trace rootlets; greyish brown. Dry to moist, subrounded to angular; sand, fine to coarse. (Logged from sample bag)
20	(26, 25, 24, 23, 15, 7) N = 69/262 mm	DT 1.52	+7.48	1.52	Sandy fine to coarse GRAVEL; brownish grey. Dry, subrounded to angular, gap graded; sand, fine to coarse. (Logged from sample bag)
40	(3, 5, 5, 5, 6, 6) N = 22	DT 3.04	+5.96	3.04	Gravelly fine to coarse SAND; greyish brown. Moist; gravel, fine to medium, rounded to subangular.
			+5.76	3.24	3.24m becomes sandy fine to medium GRAVEL.
			+5.25	3.75	3.75m becomes fine to coarse GRAVEL with minor sand.
15	(1, 1, 1, 1, 2, 2) N = 6	DT 4.56	+4.44	4.56	SAND; brown. Wet. (Logged from sample bag)
90	(2, 4, 5, 4, 4, 7) N = 20	DT 6.08	+2.92	6.08	Sandy fine to coarse GRAVEL; grey. Dry, rounded to subangular; sand, fine to coarse.
			+2.80	6.20	6.20m becomes fine to coarse GRAVEL with some silt and minor sand; reddish brown. Dry.
40	(4, 7, 7, 5, 5, 4) N = 21	DT 7.60	+1.40	7.60	Fine to coarse GRAVEL with minor sand; grey. Dry, rounded to subangular; sand, fine to coarse.
			+1.10	7.90	Silty fine to coarse GRAVEL with some sand; greyish brown. Dry, subrounded to angular; sand, fine to coarse.
100	(5, 8, 8, 7, 12, 12) N = 39	DT 9.12	-0.12	9.12	Fine to coarse GRAVEL with minor sand; grey and reddish grey. Dry, rounded to angular; sand, medium to coarse.

Legend:
- Small Disturbed Sample
- Large Disturbed Sample
- SPT Liner Sample
- Thin Wall Undisturbed Sample
- U100 Undisturbed Sample
- Pocket Penetrometer Test
- Piston Sample
- Water Level
- Impression Packer Test
- Standard Penetration Test
- Permeability Test
- Piezometer / Standpipe Tip
- Packer Test
- In-situ Vane Shear Test

LOGGED **T. PLUNKET**
DATE **29/01/2015**
CHECKED **B. SUCKLING**
DATE **05/02/2015**

REMARKS

Coorindates and ground level based on hand held GPS, likely accurate to +/- 5m.

Groundwater level not recorded.

SPT hammer energy ratio 79%.

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BOREHOLE RECORD

HOLE NO.	BH102
PROJECT NO.	224464

PROJECT	Rosemerryn Subdivision Lincoln
METHOD	DP
MACHINE & NO.	VTR 9700-D Truck
FLUSHING MEDIUM	Water
CO-ORDINATES (NZTM)	E 1560211 N 5168161
ORIENTATION	VERTICAL
SHEET	2 of 2
DATE from	22/01/2015 to 22/01/2015
GROUND-LEVEL	+9.00 m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/ end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples (Type / Ref / Depth)	Reduced Level	Depth (m) 10.00	Legend	STRATA DESCRIPTION (SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK))
22/01/2015				100					DT 10.64	-1.64	10.64		
								(3, 3, 6, 5, 4, 4) N = 19					End of Dynamic probe sampling at 10.64m, on 22/01/2015 *Termination Reason:* Target depth reached.

Report ID: AGS4 BOREHOLE RECORD || Project: 224464 ROSEMERRYN 2015 BHS.GPJ || Library: AGS 4_0.GLB || Date: 9 February 2015

Small Disturbed Sample
Large Disturbed Sample
SPT Liner Sample
Thin Wall Undisturbed Sample
U100 Undisturbed Sample
Pocket Penetrometer Test
Piston Sample
Water Level
Impression Packer Test
Standard Penetration Test
Permeability Test
Piezometer / Standpipe Tip
Packer Test
In-situ Vane Shear Test

LOGGED T. PLUNKET
DATE 29/01/2015
CHECKED B. SUCKLING
DATE 05/02/2015

REMARKS

Coorindates and ground level based on hand held GPS, likely accurate to +/- 5m.

Groundwater level not recorded.

SPT hammer energy ratio 79%.

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BOREHOLE RECORD

HOLE NO.	BH103
PROJECT NO.	224464

PROJECT **Rosemerryn Subdivision Lincoln**

METHOD **DP**	CO-ORDINATES (NZTM) E 1560056 N 5167722	SHEET 1 of 2
MACHINE & NO. **VTR 9700-D Truck**		DATE from 28/01/2015 to 28/01/2015
FLUSHING MEDIUM **Water**	ORIENTATION **VERTICAL**	GROUND-LEVEL +9.00 m RL

Drilling Progress: 28/01/2015. Water level: groundwater level marked at approx. 2.0 m.

Total core Recovery %	Tests	Samples (Type / Depth)	Reduced Level	Depth (m)	STRATA DESCRIPTION
15		DT 0.00		0.00	Mix of SILT with minor sand and trace rootlets; dark brown. Dry, low plasticity; sand, fine to medium. (TOPSOIL) and; SILT with some sand; light brown mottled orange. Dry, low plasticity; sand, fine to medium. (Logged from sample bag)
90	(1, 1, 2, 2, 1, 2) N = 7	1.52, DT	+7.48	1.52	
			+7.40	1.60	Sandy SILT; greyish brown. Stiff, wet, low plasticity; sand, fine to medium. 1.60m becomes silty fine to medium SAND; grey. Wet.
			+7.00	2.00	
			+6.95	2.05	PEAT; dark brown. Fibrous, saturated.
			+6.90	2.10	Peaty SILT; greyish brown. Firm, saturated, low plasticity; peat, fibrous.
			+6.30	2.70	SILT with some sand and trace organics; grey. Firm to stiff, wet, low plasticity; organics are fibrous.
65	(4, 8, 7, 7, 6, 6) N = 26	3.04, DT	+5.96	3.04	Silty fine to medium SAND; brown. Wet.
			+5.75	3.25	Gravelly fine to coarse SAND; greyish brown. Wet; gravel, fine to coarse, subrounded to subangular. 3.25m becomes Sandy fine to coarse GRAVEL.
60	(4, 7, 12, 11, 9, 8) N = 40	4.56, DT	+4.44	4.56	Fine to coarse SAND with minor gravel; brown. Wet; gravel, fine to medium, subrounded to angular.
			+4.20	4.80	Sandy fine to coarse GRAVEL; greyish brown. Wet, subrounded to angular; sand, fine to coarse. 4.95m - 5.15m reddish brown.
60	(8, 13, 10, 7, 6, 5) N = 28	6.08, DT	+2.92	6.08	Fine to coarse SAND; brown. Wet.
			+2.75	6.25	Sandy fine to medium GRAVEL; greyish brown. Wet, subrounded to angular; sand, fine to coarse.
			+2.60	6.40	Fine to coarse GRAVEL; grey. Wet, rounded to subangular.
			+2.45	6.55	Sandy fine to coarse GRAVEL; greyish brown. Wet, subrounded to angular; sand, fine to coarse.
100	(8, 12, 13, 12, 12, 14) N = 51	7.60, DT	+1.40	7.60	Fine to coarse SAND; brown. Wet.
			+1.10	7.90	7.90m becomes gravelly fine to coarse SAND. Gravel, fine to medium, rounded to subangular.
			+0.90	8.10	Fine to coarse GRAVEL with minor sand; grey. Wet, subrounded to subangular; sand, fine to coarse.
			+0.70	8.30	No sample recieved.
			+0.50	8.50	Sandy fine to coarse GRAVEL; greyish brown. Wet, subrounded to angular; sand, fine to coarse.
45	(3, 11, 13, 13, 12, 10) N = 48	9.12, DT			9.50m - 9.55m white.

Legend: Small Disturbed Sample; Large Disturbed Sample; SPT Liner Sample; Thin Wall Undisturbed Sample; U100 Undisturbed Sample; Pocket Penetrometer Test; Piston Sample; Water Level; Impression Packer Test; Standard Penetration Test; Permeability Test; Piezometer / Standpipe Tip; Packer Test; In-situ Vane Shear Test

LOGGED T. PLUNKET
DATE 29/01/2015
CHECKED B. SUCKLING
DATE 05/02/2015

REMARKS

Coorindates and ground level based on hand held GPS, likely accurate to +/- 5m.

Groundwater level recorded at 2.0m.

SPT hammer energy ratio 79%.

Aurecon New Zealand Ltd, Unit 1, 150 Cavendish Road, Casebrook, Christchurch. Tel: +64 3 366 0821 Fax: +64 3 379 6955 christchurch@aurecongroup.com

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BOREHOLE RECORD

HOLE NO.	BH103
PROJECT NO.	224464

PROJECT	Rosemerryn Subdivision Lincoln
METHOD	DP
MACHINE & NO.	VTR 9700-D Truck
FLUSHING MEDIUM	Water
CO-ORDINATES (NZTM)	E 1560056 N 5167722
ORIENTATION	VERTICAL
SHEET	2 of 2
DATE from	28/01/2015 to 28/01/2015
GROUND-LEVEL	+9.00 m RL

Drilling Progress	Casing depth/size	Water level (m) shift start/ end	Water Recovery %	Total core Recovery %	Solid core Recovery %	R.Q.D.	Fracture Index	Tests	Samples (Type, Ref, Depth)	Reduced Level	Depth (m) 10.00	Legend	STRATA DESCRIPTION SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION GRADING, BEDDING, PLASTICITY, ETC. *(NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)*
28/01/2015				45				(9, 12, 13, 11, 10, 6) N = 40	DT 10.64	-1.64	10.64		End of Dynamic probe sampling at 10.64m, on 28/01/2015 *Termination Reason:* Target depth reached.

Legend	
Small Disturbed Sample	Water Level
Large Disturbed Sample	Impression Packer Test
SPT Liner Sample	Standard Penetration Test
Thin Wall Undisturbed Sample	Permeability Test
U100 Undisturbed Sample	Piezometer / Standpipe Tip
Pocket Penetrometer Test	Packer Test
Piston Sample	In-situ Vane Shear Test

LOGGED	T. PLUNKET
DATE	29/01/2015
CHECKED	B. SUCKLING
DATE	05/02/2015

REMARKS

Coorindates and ground level based on hand held GPS, likely accurate to +/- 5m.

Groundwater level recorded at 2.0m.

SPT hammer energy ratio 79%.

Report ID: AGS4 BOREHOLE RECORD || Project: 224464 ROSEMERRYN 2015 BHS.GPJ || Library: AGS 4_0.GLB || Date: 9 February 2015

January 2015

MASW Investigation:

Rosemerryn Farm

Lincoln

Report prepared for Aurecon

PROVISIONAL REPORT

Southern Geophysical Ltd

3/28 Tanya St, Bromley, Christchurch 8062

03 384 4302

www.southerngeophysical.com

Data collected and report prepared by:

Christian Rüegg, Geophysicist

Rebecca Gilbert, Geologist

Michael Finnemore, Senior Geophysicist

Table of Contents

SGL JOB 1103

SITE SAFE MEMBER

Summary:

A series of nine MASW (Multi-channel Analysis of Surface Waves) lines were surveyed at Rosemerryn Farm near Lincoln on January 15th and January 16th, 2015. The survey was designed to image variations in shear-wave velocities to a maximum depth of 25 m. The MASW data was of good quality. The material in the first 5 m below ground is of low shear-velocity across much of the site (100 m/s to 150 m/s), with a jump to 200 m/s at around 5 m depth, generally increasing to over 500 m/s between 15 m and 20 m depth.

Methodology:

MASW is a geophysical technique that uses the dispersive nature of surface waves to determine a model of the shear wave velocity versus depth of the subsurface.

The MASW data was collected with a 24 channel seismic array. The geophone spacing was 1 m and the seismic source was an accelerated weight drop (AWD). The source offset from the nearest receiver was kept constant at 10 m for the MASW Lines. Recording parameters for the MASW survey were set with a 0.25 ms sample interval, 1.5 s record length, 24 dB gains, and an electric trigger system. MASW points were collected at 10 m intervals along the lines.

The field records were processed using the Kansas Geological Survey software package SurfSeis4 ©. The geometry was set according to the survey parameters and the dispersion curves were generated and edited. The inversions were run using a 10 layer variable depth model.

Results:

The output shear-wave velocity data is included as a series of CSV files (supplementary to this report). The velocity data was interpolated into 2D MASW profiles for the MASW lines

A total of nine MASW lines were surveyed at the site (Figure 1). The MASW data was generally of good quality, although ambient noise from wind did affect a number of shot records.

Conclusions:

The MASW results provide a model of Vs values across the Rosemerryn Farm site to a depth between 20 m and 25 m (Figures 2 to 7). The near surface material, to a depth of 4 m, is of relatively low velocity (<100 m/s to 180 m/s). This low velocity layer seems to be laterally continuous across much of the site, with the exception of the northern part of the site. MASW Lines 03, 04, and the first 45 m of Line 05 show higher velocity material in the near surface. Correlation with borehole information would allow changes in shear-wave velocity at gravel and other geological interfaces to be determined.

Disclaimer:

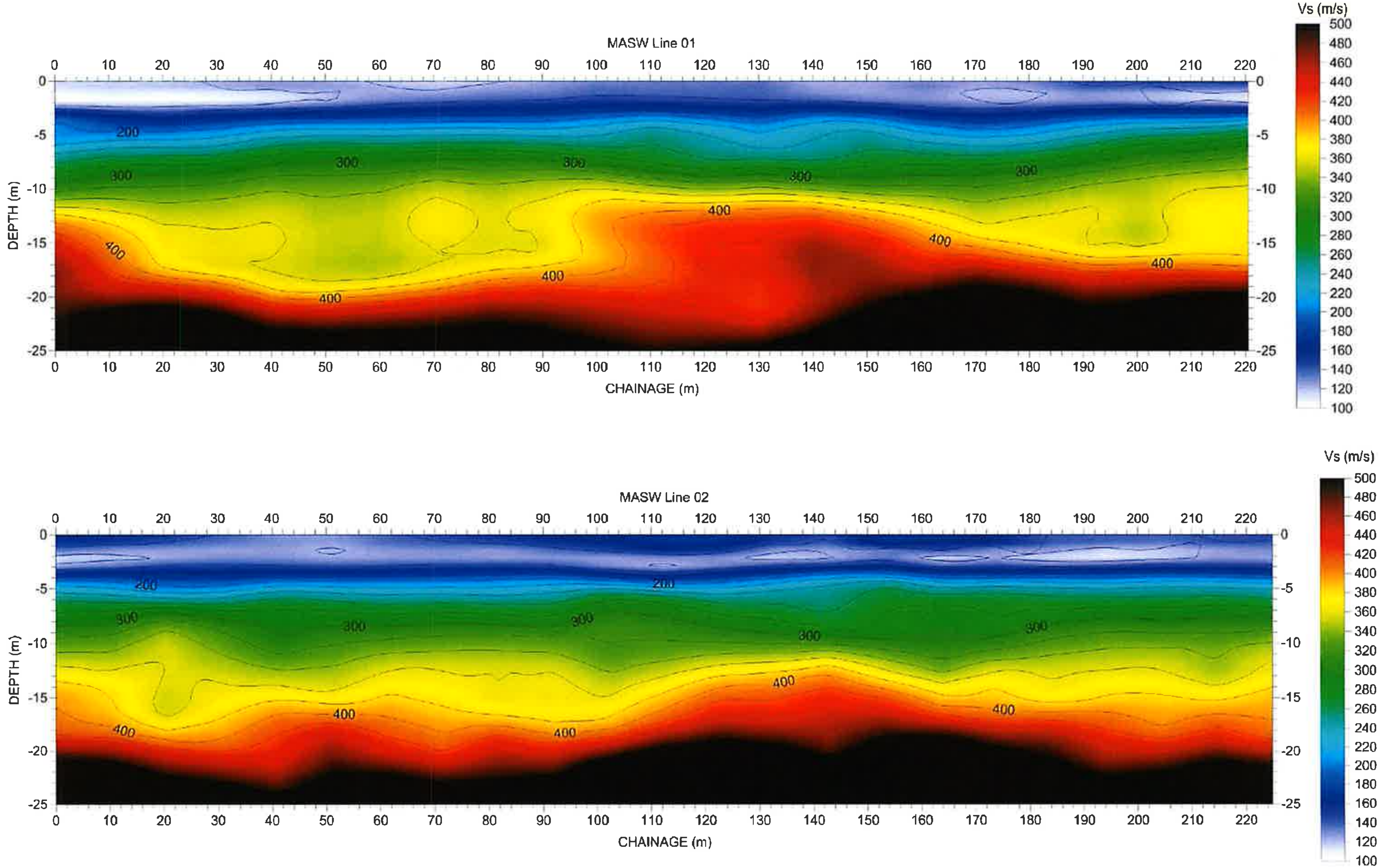
This document has been provided by Southern Geophysical Ltd subject to the following:

Non-invasive geophysical testing has limitations and is not a complete source of testing. Often there is a need to couple non-invasive methods with invasive testing methods, such as drilling, especially in cases where the non-invasive testing indicates anomalies.

This document has been prepared for the particular purpose outlined in the project proposal and no responsibility is accepted for the use of this document, in whole or in part, in other contexts or for any other purpose. Southern Geophysical Ltd did not perform a complete assessment of all possible conditions or circumstances that may exist at the site. Conditions may exist which were undetectable given the limited nature of the enquiry Southern Geophysical Ltd was retained to undertake with respect to the site. Variations in conditions often occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account. Accordingly, additional studies and actions may be required by the client.

We collected our data and based our report on information which was collected at a specific point in time. The passage of time affects the information and assessment provided by Southern Geophysical Ltd. It is understood that the services provided allowed Southern Geophysical Ltd to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes for whatever reason. Where data is supplied by the client or other sources, including where previous site investigation data have been used, it has been assumed that the information is correct. No responsibility is accepted by Southern Geophysical Ltd for incomplete or inaccurate data supplied by others. This document is provided for sole use by the client and is confidential to that client and its professional advisers. No responsibility whatsoever for the contents of this document will be accepted to any person other than the client. Any use which a third party makes of this document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Southern Geophysical Ltd accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

TITLE- **Figure 1: MASW Location Plan**	NOTES-	Coordinates NZ2000 TM Grid. Aerial photograph post February 2011, sourced from LINZ. <u>MASW</u> Line labels show the chainage along the line. Points are the midpoint of a 23 m 24 channel MASW array with 1 m receiver spacing and 10 m shot offset.	N A3
LOCATION- **Rosemerryn Farm, Lincoln**			**Southern Geophysical Ltd** www.southerngeophysical.com



LINE-	Figure 2: MASW Lines 01 and 02
LOCATION-	Rosemerryn Farm, Lincoln

NOTES Contour intervals of 20 m/s (Vs).
See site map for location of points.

SCALE: 2:1

A3

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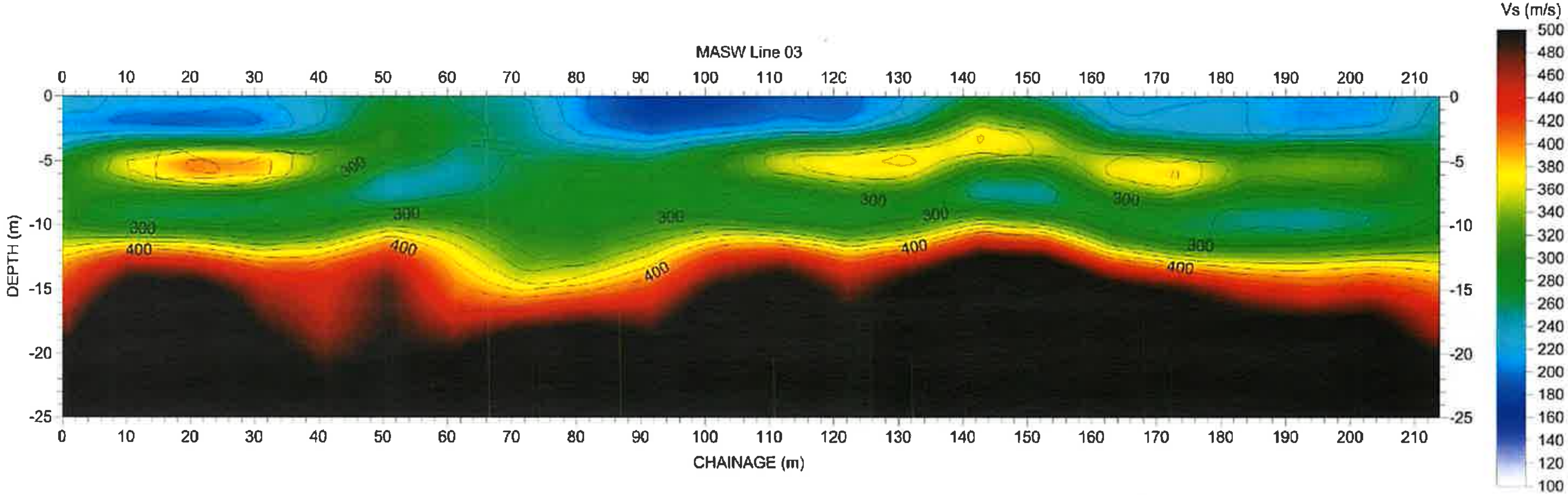
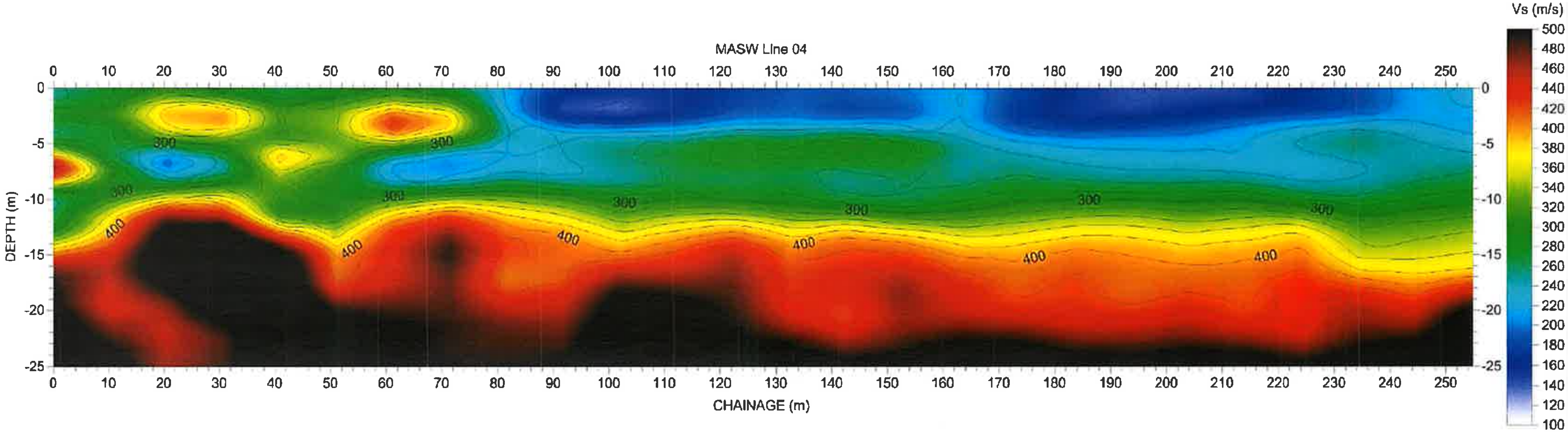
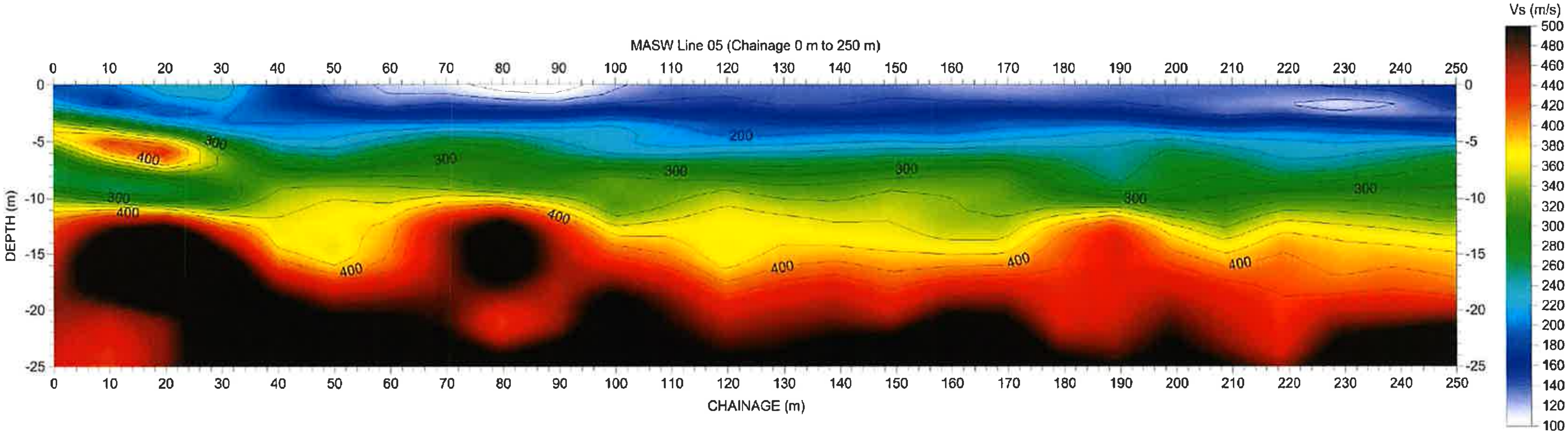
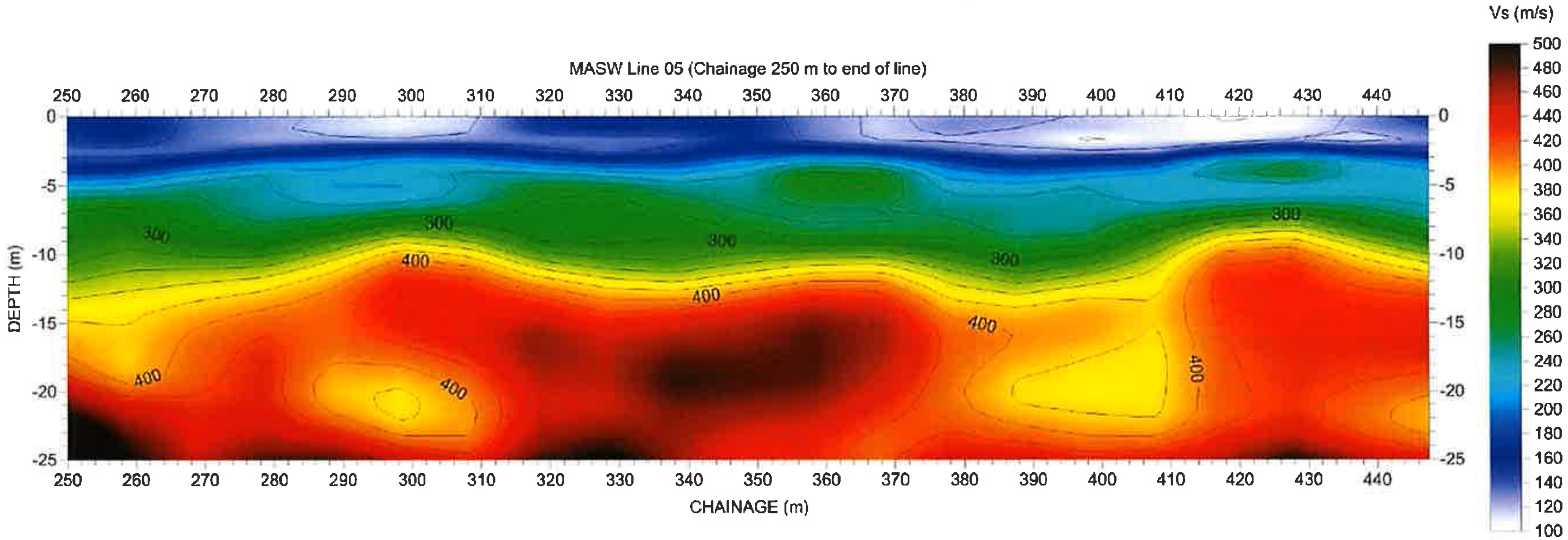




LINE- **Figure 3: MASW Lines 03 and 04**	NOTES Contour intervals of 20 m/s (Vs). See site map for location of points.	SCALE: 2:1	**Southern Geophysical Ltd** www.southerngeophysical.com
LOCATION- **Rosemerryn Farm, Lincoln**		A3	





LINE- **Figure 4: MASW Line 05**

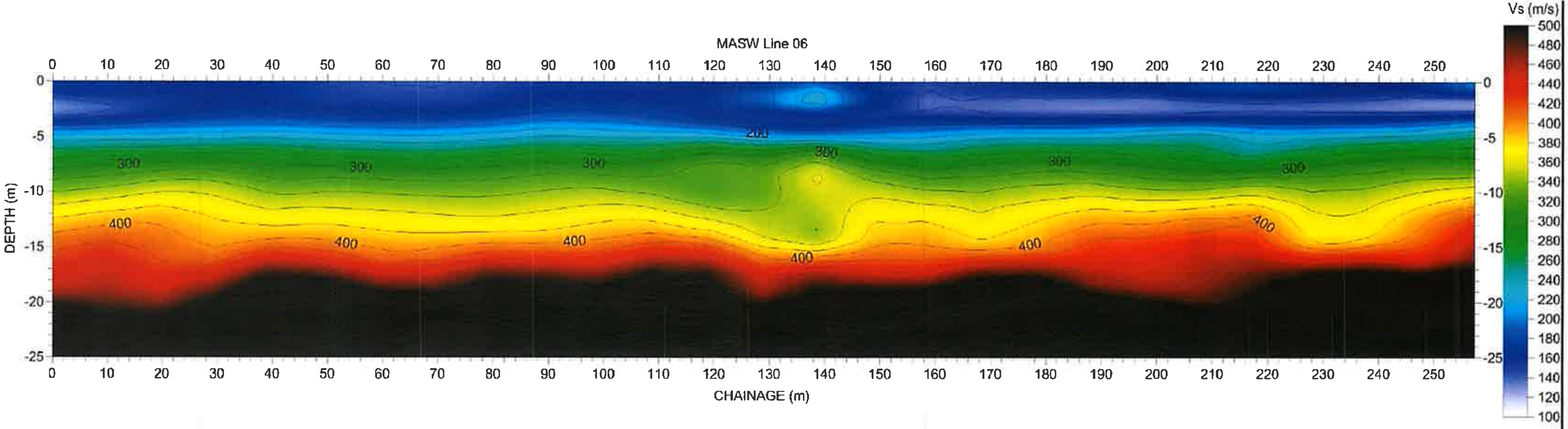
LOCATION- **Rosemerryn Farm, Lincoln**

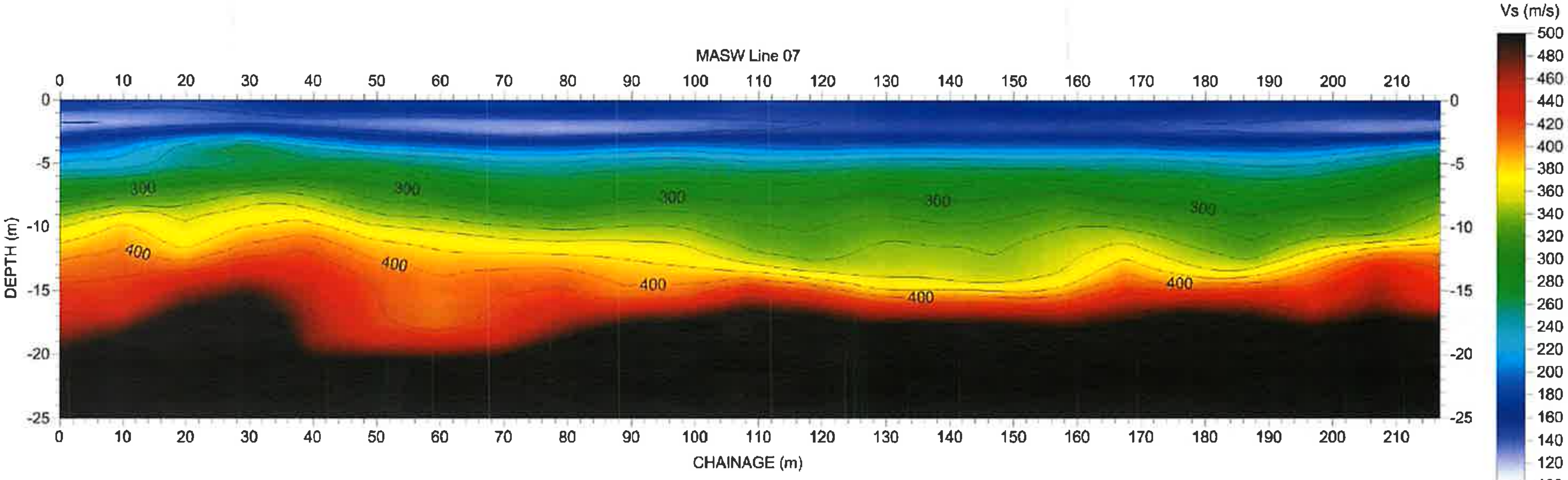
NOTES Contour intervals of 20 m/s (Vs).
See site map for location of points.

SCALE: 2:1

A3

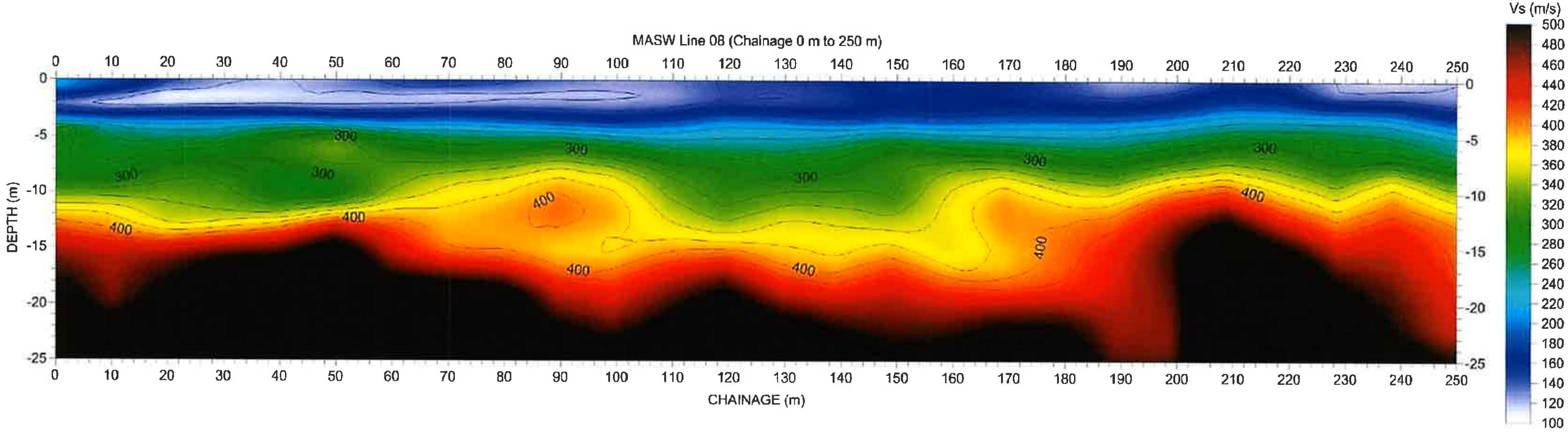
Southern Geophysical Ltd
www.southerngeophysical.com

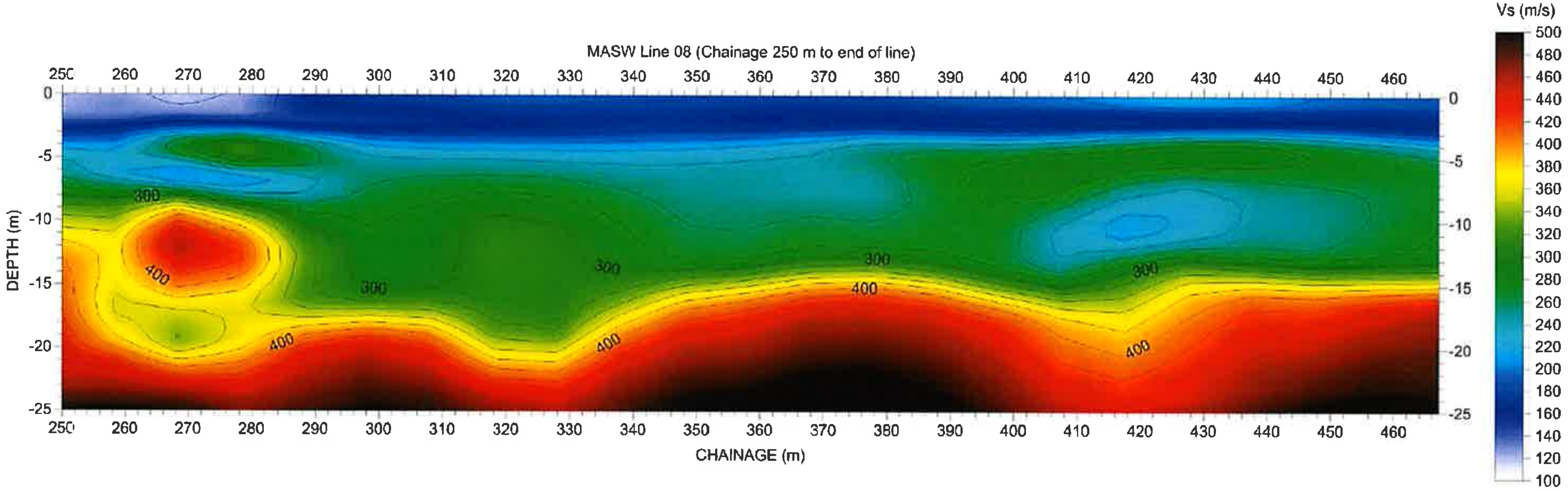




LINE- **Figure 5: MASW Lines 06 and 07**	NOTES Contour intervals of 20 m/s (Vs). See site map for location of points.
LOCATION- **Rosemerryn Farm, Lincoln**	SCALE: 2:1 / A3

Southern Geophysical Ltd
www.southerngeophysical.com





LINE- **Figure 6: MASW Line 08**

LOCATION- **Rosemerryn Farm, Lincoln**

NOTES Contour intervals of 20 m/s (Vs).
See site map for location of points.

SCALE: 2:1

A3

Southern Geophysical Ltd

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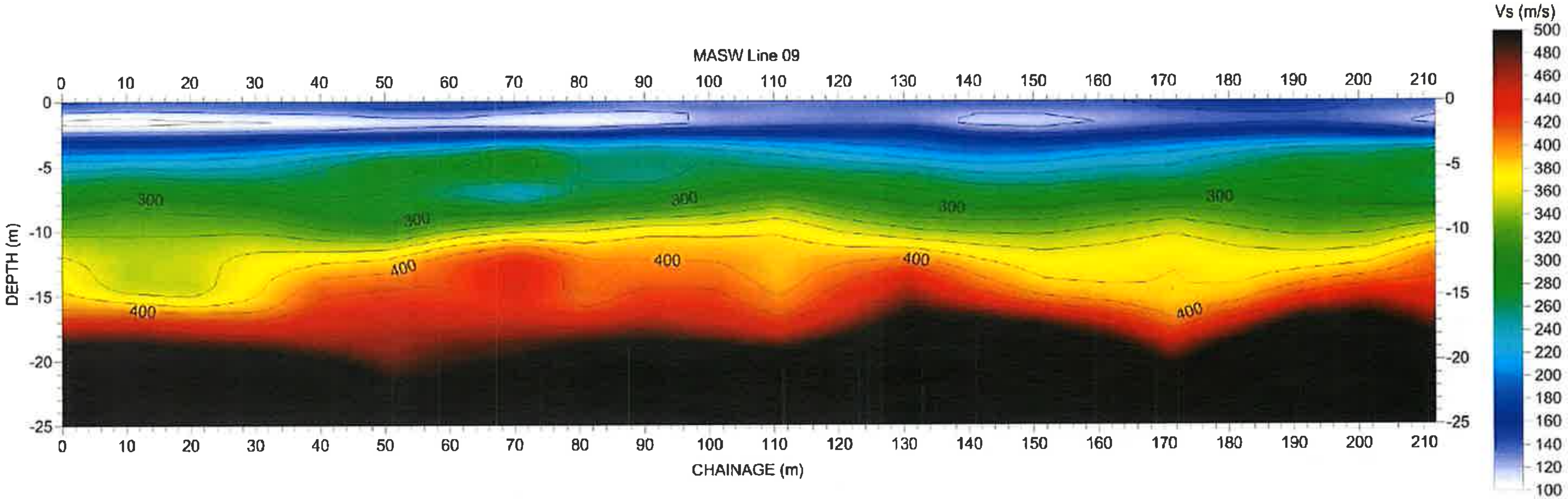


LINE- **Figure 7: MASW Line 09**	NOTES Contour intervals of 20 m/s (Vs). See site map for location of points.	SCALE: 2:1	**Southern Geophysical Ltd** www.southerngeophysical.com
LOCATION- **Rosemerryn Farm, Lincoln**		A3	

E

2018 CPT Logs

CONE PENETRATION TEST (CPT) REPORT

McMILLAN Drilling GROUP

Client: Aurecon NZ Ltd

Location: Rosemerryn
Ellesmere Road, Lincoln

Printed: 22/05/2018

McMILLAN Drilling

CONE PENETRATION TEST

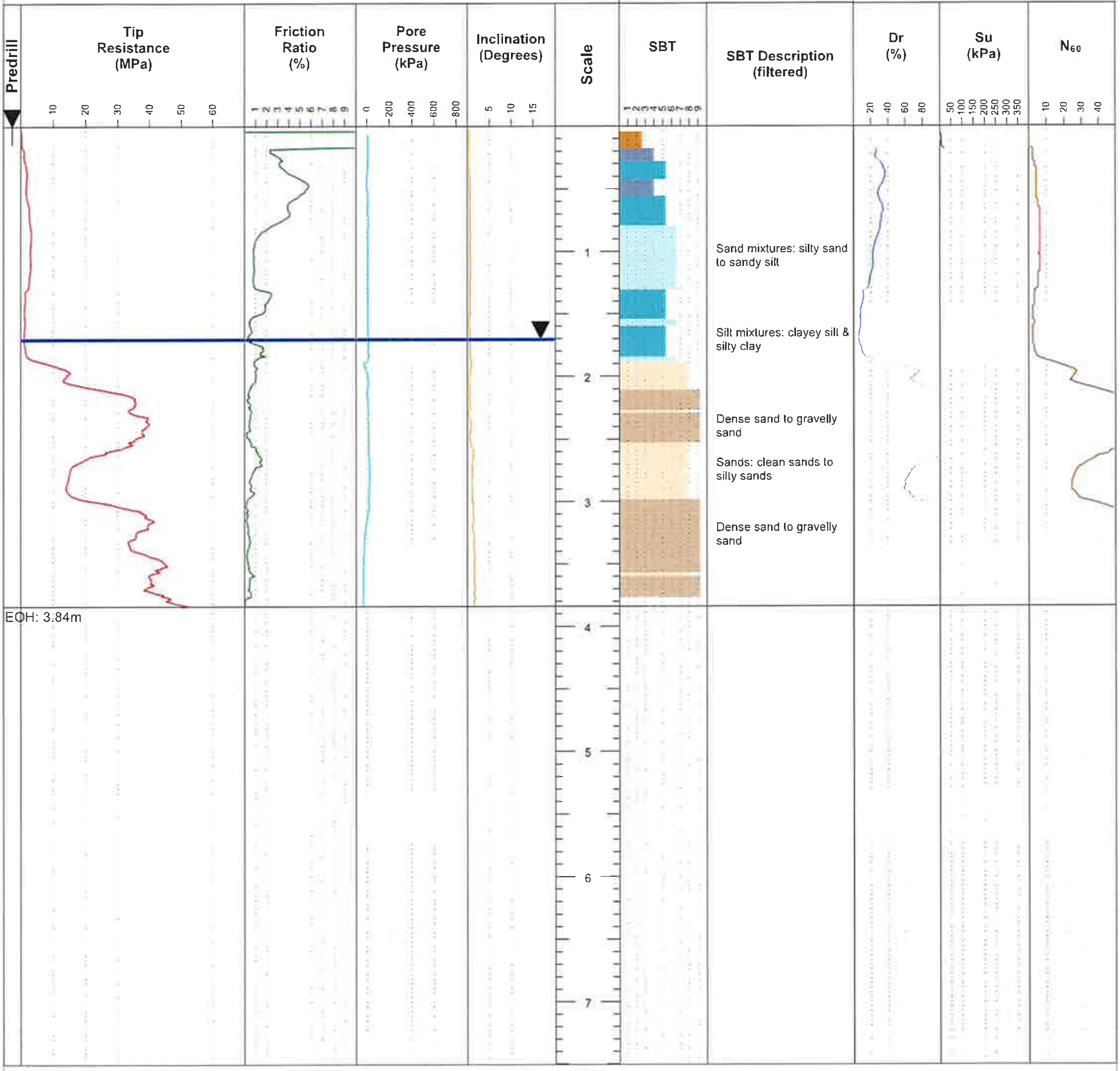
Job:	17414
CPT No.:	CPTu201

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 3.84
Elevation (m): 0.00
Datum: Ground

North (m): 5168164.36
East (m): 1560168.76
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3707 **Final:** 1.38
Local Friction (MPa) Initial: -0.0114 **Final:** -0.0128
Pore Pressure (KPa) Initial: 0.0029 **Final:** -0.0051

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.70
Collapse: 2.30

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 3.84

McMILLAN Drilling

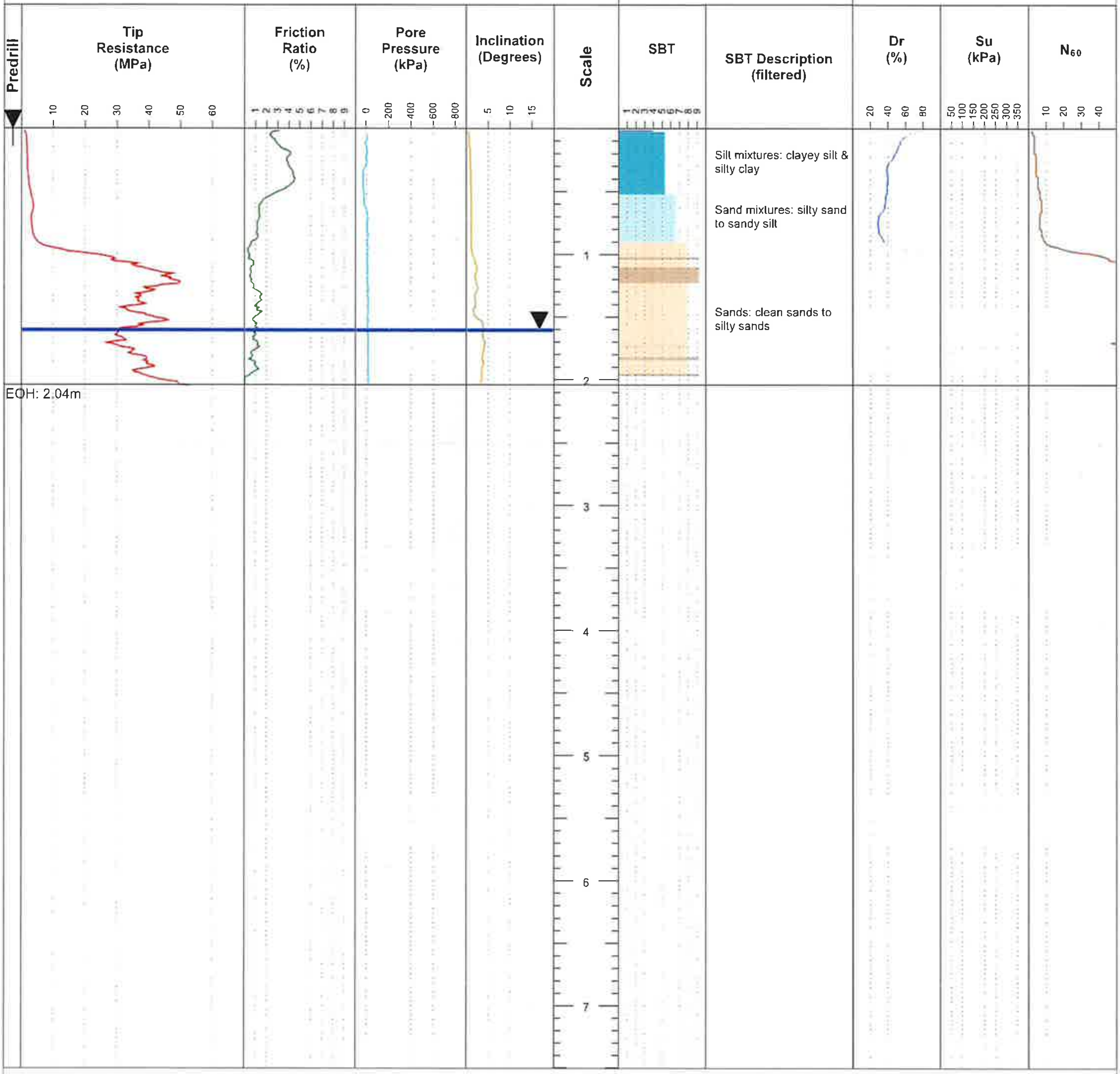
CONE PENETRATION TEST

Job:	17414
CPT No.:	CPTu202

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 2.04
Elevation (m): 0.00
Datum: Ground

North (m): 5168060.30
East (m): 1560449.46
Grid: NZTM



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10
Tip Resistance (MPa) Initial: 1.985 **Final:** 2.1001
Local Friction (MPa) Initial: 0.0236 **Final:** 0.02
Pore Pressure (KPa) Initial: 0.0039 **Final:** -0.0043

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.60
Collapse: 1.70

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0 Undefined	5 Sand mixtures: silty sand to sandy silt
1 Sensitive fine-grained	6 Sands: clean sands to silty sands
2 Clay - organic soil	7 Dense sand to gravelly sand
3 Clays: clay to silty clay	8 Stiff sand to clayey sand
4 Silt mixtures: clayey silt & silty clay	9 Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 2.04

McMILLAN Drilling

CONE PENETRATION TEST

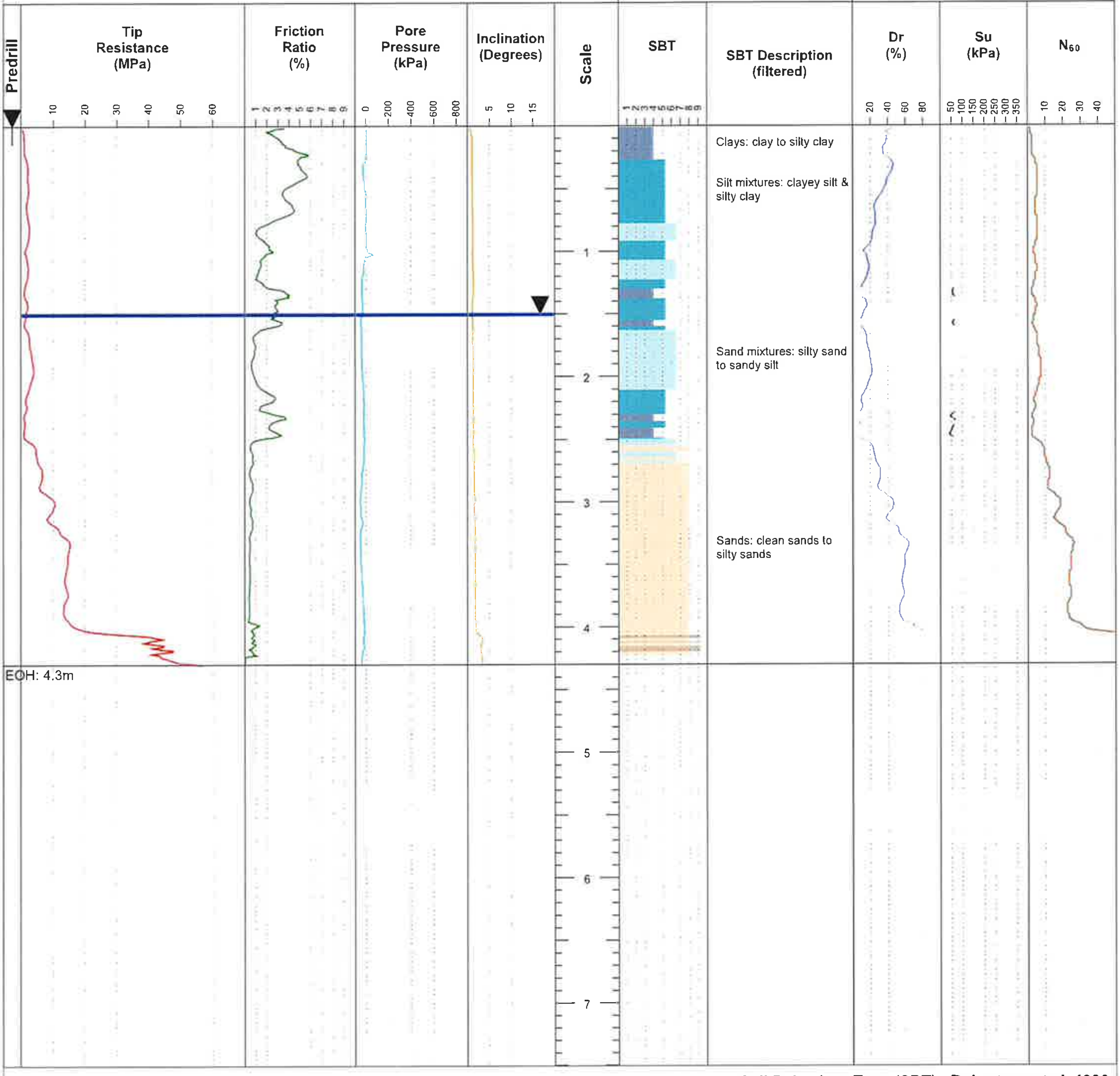
Job:	17414
CPT No.:	CPTu203

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 4.30
Elevation (m): 0.00
Datum: Ground

North (m): 5168046.70
East (m): 1560168.56
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wylie
Rig: Geomil Panther 100
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10
Tip Resistance (MPa) Initial: 1.9945 **Final:** 2.0254
Local Friction (MPa) Initial: 0.0235 **Final:** 0.0197
Pore Pressure (KPa) Initial: 0.0075 **Final:** 0.0015

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.50
Collapse: 1.70

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 4.30

McMILLAN Drilling

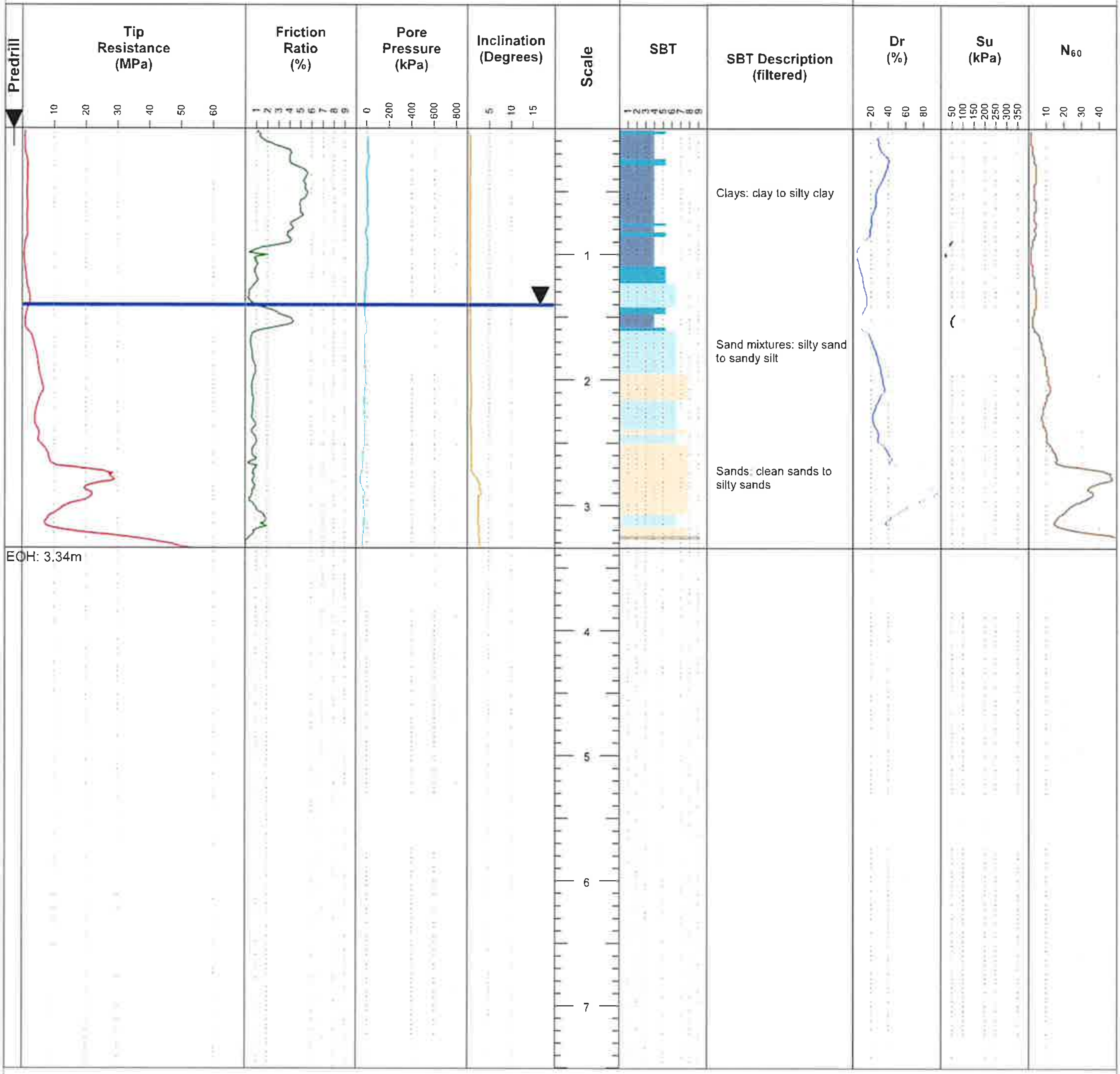
CONE PENETRATION TEST

Job:	17414
CPT No.:	CPTu204

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 3.34
Elevation (m): 0.00
Datum: Ground

North (m): 5167966.63
East (m): 1560278.93
Grid: NZTM



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3563 **Final:** 1.3881
Local Friction (MPa) Initial: -0.0114 **Final:** -0.0132
Pore Pressure (KPa) Initial: 0.0072 **Final:** -0.0017

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.40
Collapse: 2.40

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0 Undefined	5 Sand mixtures: silty sand to sandy silt
1 Sensitive fine-grained	6 Sands: clean sands to silty sands
2 Clay - organic soil	7 Dense sand to gravelly sand
3 Clays: clay to silty clay	8 Stiff sand to clayey sand
4 Silt mixtures: clayey silt & silty clay	9 Stiff fine-grained

Notes & Limitations

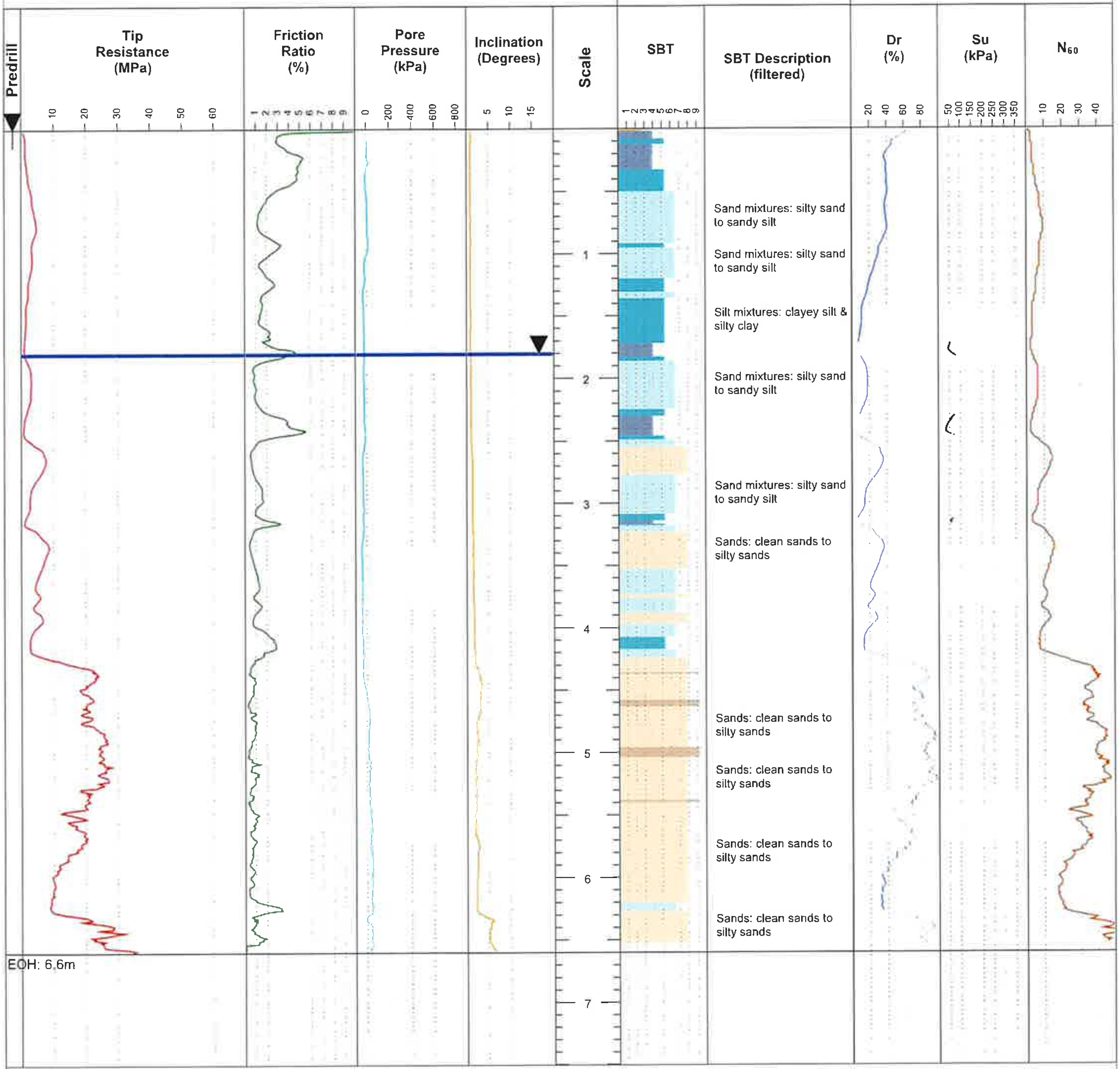
Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warrant the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 3.34

McMILLAN Drilling	CONE PENETRATION TEST	Job:	17414
		CPT No.:	CPTu205

Name: Rosemerryn **Client:** Aurecon NZ Ltd **Location:** Ellesmere Road, Lincoln	**Hole Depth (m):** 6.60 **Elevation (m):** 0.00 **Datum:** Ground	**North (m):** 5167953.13 **East (m):** 1560131.90 **Grid:** NZTM



Operator: R. Wyllie	**Date:** 22/05/2018	**Effective Refusal**	
Rig: Geomil Panther 100	**Predrill:** 0.00	**Tip:**	
Cone Reference: 160925	**Water Level:** 1.80	**Gauge:**	
Cone Area Ratio: 0.75	**Collapse:** 4.00	**Inclinometer:**	✓
Cone Type: I-CFXYP20-15		**Other:**	
Tip Resistance (MPa) Initial: -1.4917	**Final:** -1.3956		
Local Friction (MPa) Initial: 0.0198	**Final:** 0.011	**Target Depth:**	
Pore Pressure (KPa) Initial: 0.0085	**Final:** 0.003		

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warrant the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks

Effective Refusal

Hole Depth (m): 6.60

Sheet 1 of 1

CONE PENETRATION TEST

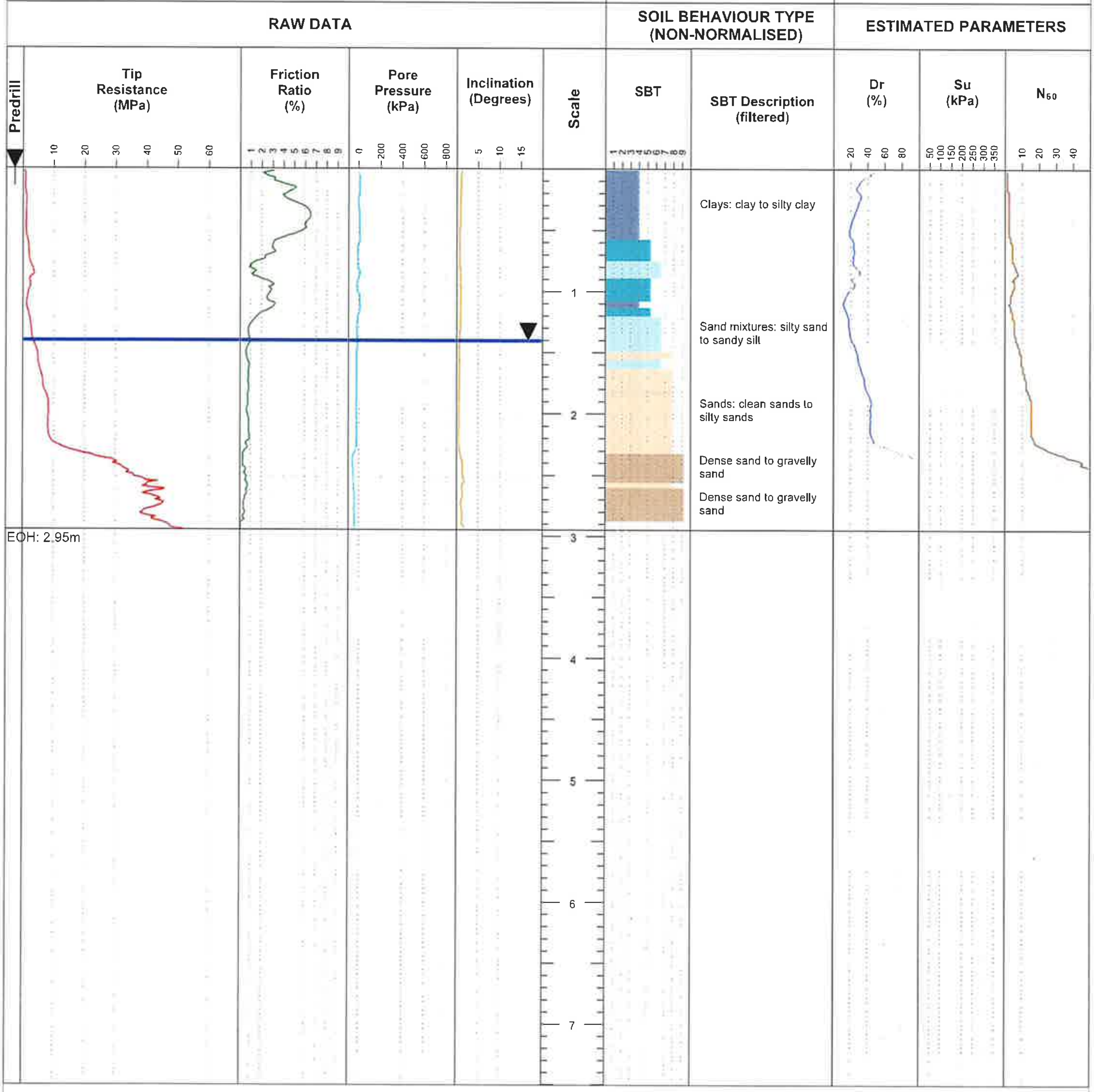
McMILLAN Drilling

Job:	17414
CPT No.:	CPTu206

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 2.95
Elevation (m): 0.00
Datum: Ground

North (m): 5167904.89
East (m): 1560386.70
Grid: NZTM



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 160925
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: -1.4662 **Final:** -1.4953
Local Friction (MPa) Initial: 0.0218 **Final:** 0.0114
Pore Pressure (KPa) Initial: 0.0072 **Final:** -0.0002

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.40
Collapse: 1.60

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 2.95

McMILLAN Drilling

CONE PENETRATION TEST

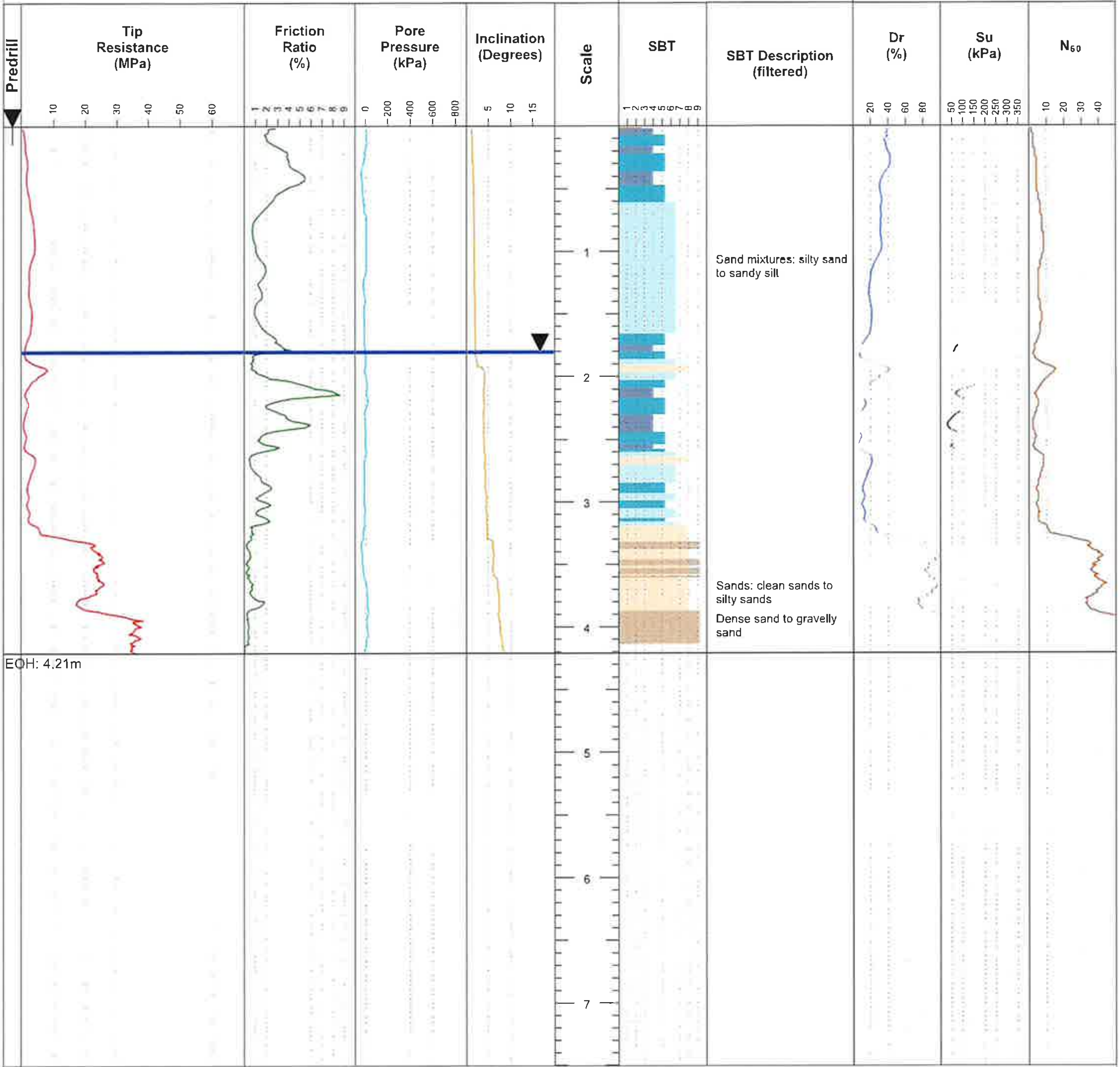
Job:	17414
CPT No.:	CPTu207

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 4.21
Elevation (m): 0.00
Datum: Ground

North (m): 5167868.48
East (m): 1560206.99
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3756 **Final:** 1.3779
Local Friction (MPa) Initial: -0.009 **Final:** -0.0123
Pore Pressure (KPa) Initial: -0.0031 **Final:** -0.0058

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.80
Collapse: 3.40

Effective Refusal
Tip:
Gauge:
Inclinometer: ✓
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 4.21

McMILLAN Drilling

CONE PENETRATION TEST

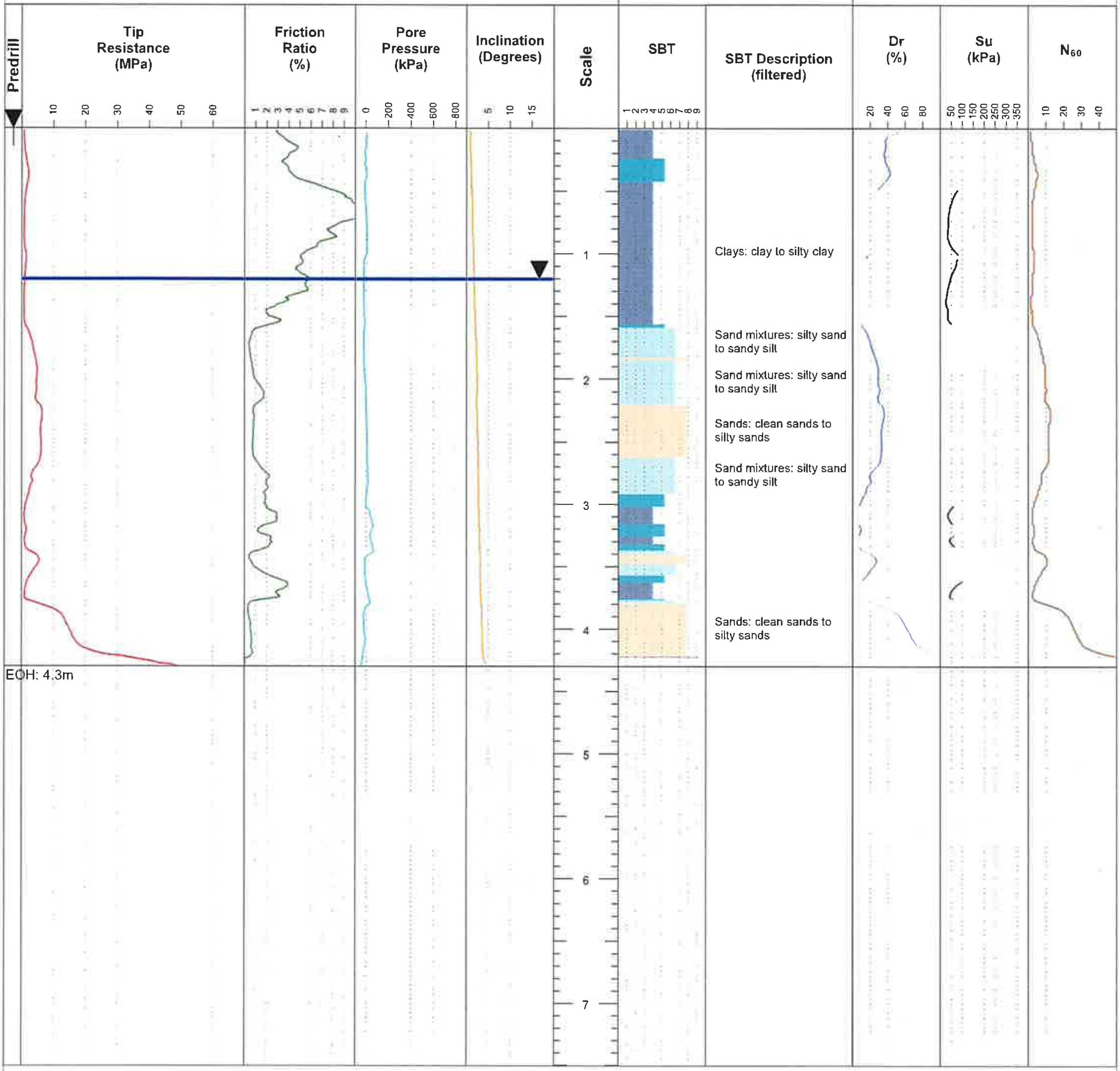
Job:	17414
CPT No.:	CPTu208

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 4.30
Elevation (m): 0.00
Datum: Ground

North (m): 5167796.27
East (m): 1560069.52
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 160925
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: -1.5601 **Final:** -1.4439
Local Friction (MPa) Initial: 0.0173 **Final:** 0.0116
Pore Pressure (KPa) Initial: 0.0052 **Final:** 0.0036

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.20
Collapse: 1.50

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 4.30

McMILLAN Drilling

CONE PENETRATION TEST

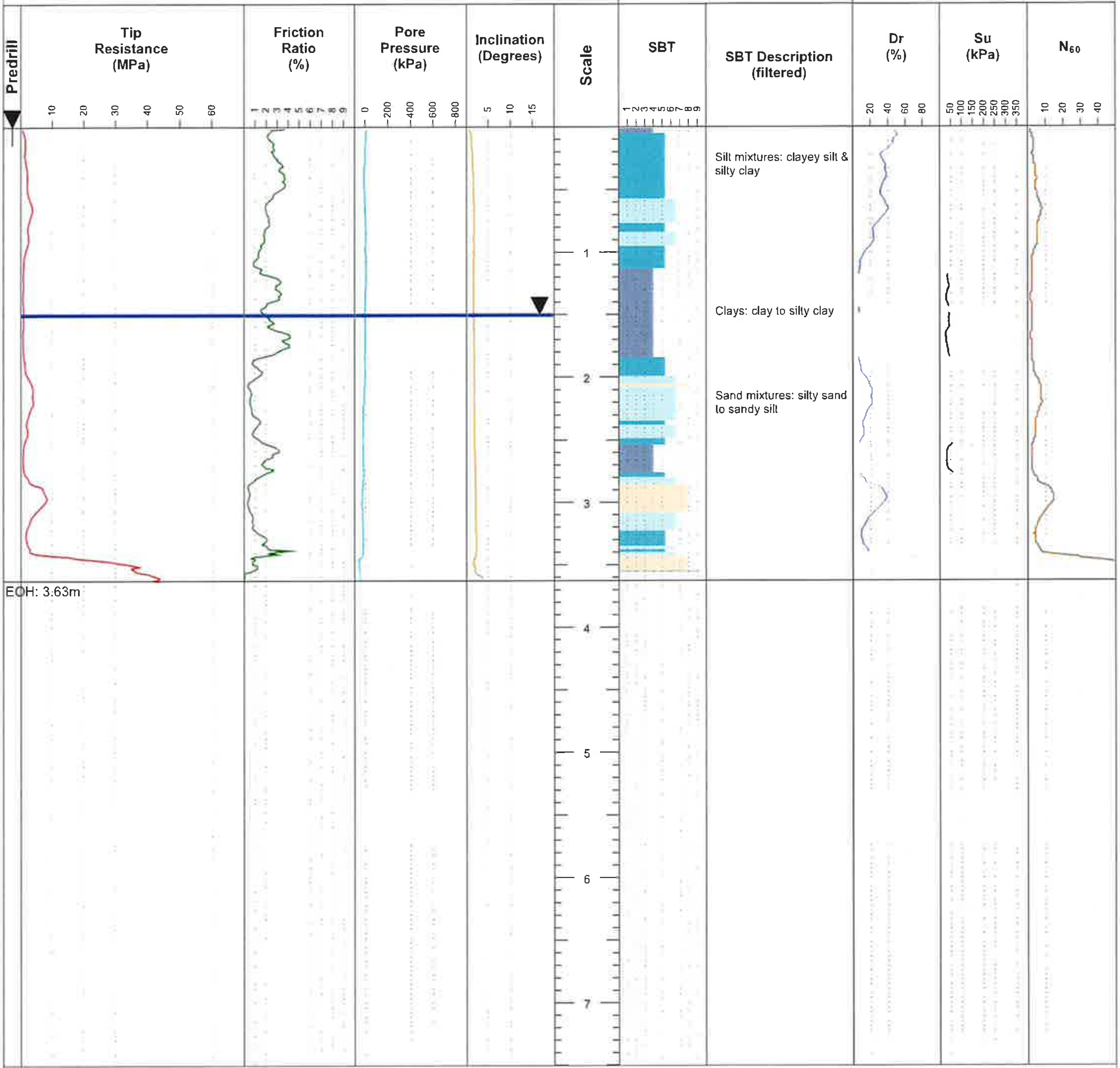
Job:	17414
CPT No.:	CPTu209

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 3.63
Elevation (m): 0.00
Datum: Ground

North (m): 5167738.57
East (m): 1560318.04
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10
Tip Resistance (MPa) Initial: 1.9897 **Final:** 1.9199
Local Friction (MPa) Initial: 0.0224 **Final:** 0.02
Pore Pressure (KPa) Initial: 0.0041 **Final:** 0.0025

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.50
Collapse: 2.70

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 3.63

McMILLAN Drilling

CONE PENETRATION TEST

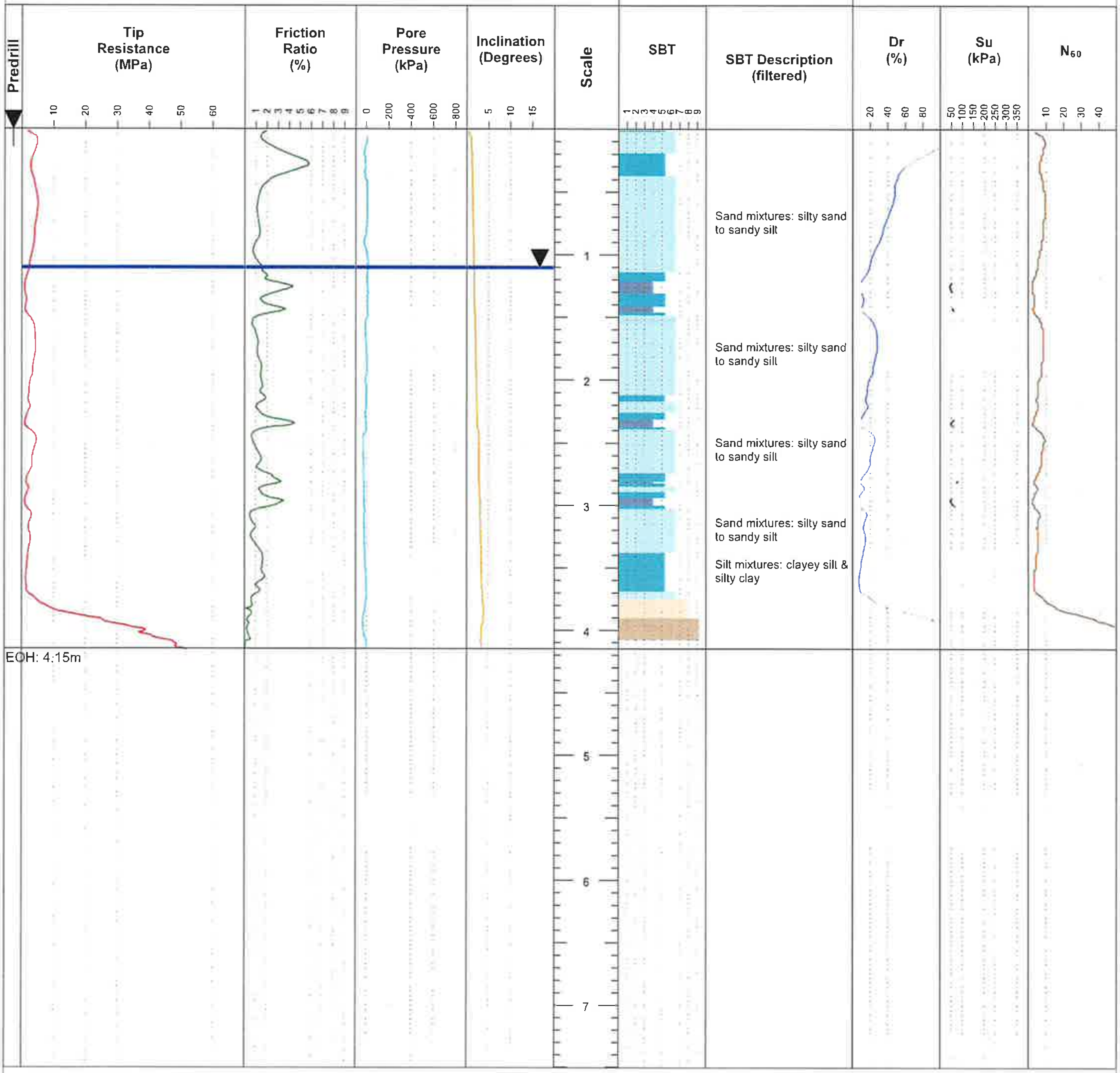
Job:	17414
CPT No.:	CPTu210

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 4.15
Elevation (m): 0.00
Datum: Ground

North (m): 5167704.95
East (m): 1560131.44
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3671 **Final:** 1.4049
Local Friction (MPa) Initial: -0.0117 **Final:** -0.0165
Pore Pressure (KPa) Initial: 0.0214 **Final:** 0.0195

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.10
Collapse: 2.40

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0 Undefined	5 Sand mixtures: silty sand to sandy silt
1 Sensitive fine-grained	6 Sands: clean sands to silty sands
2 Clay - organic soil	7 Dense sand to gravelly sand
3 Clays: clay to silty clay	8 Stiff sand to clayey sand
4 Silt mixtures: clayey silt & silty clay	9 Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warrant the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 4.15

CONE PENETRATION TEST

McMILLAN Drilling

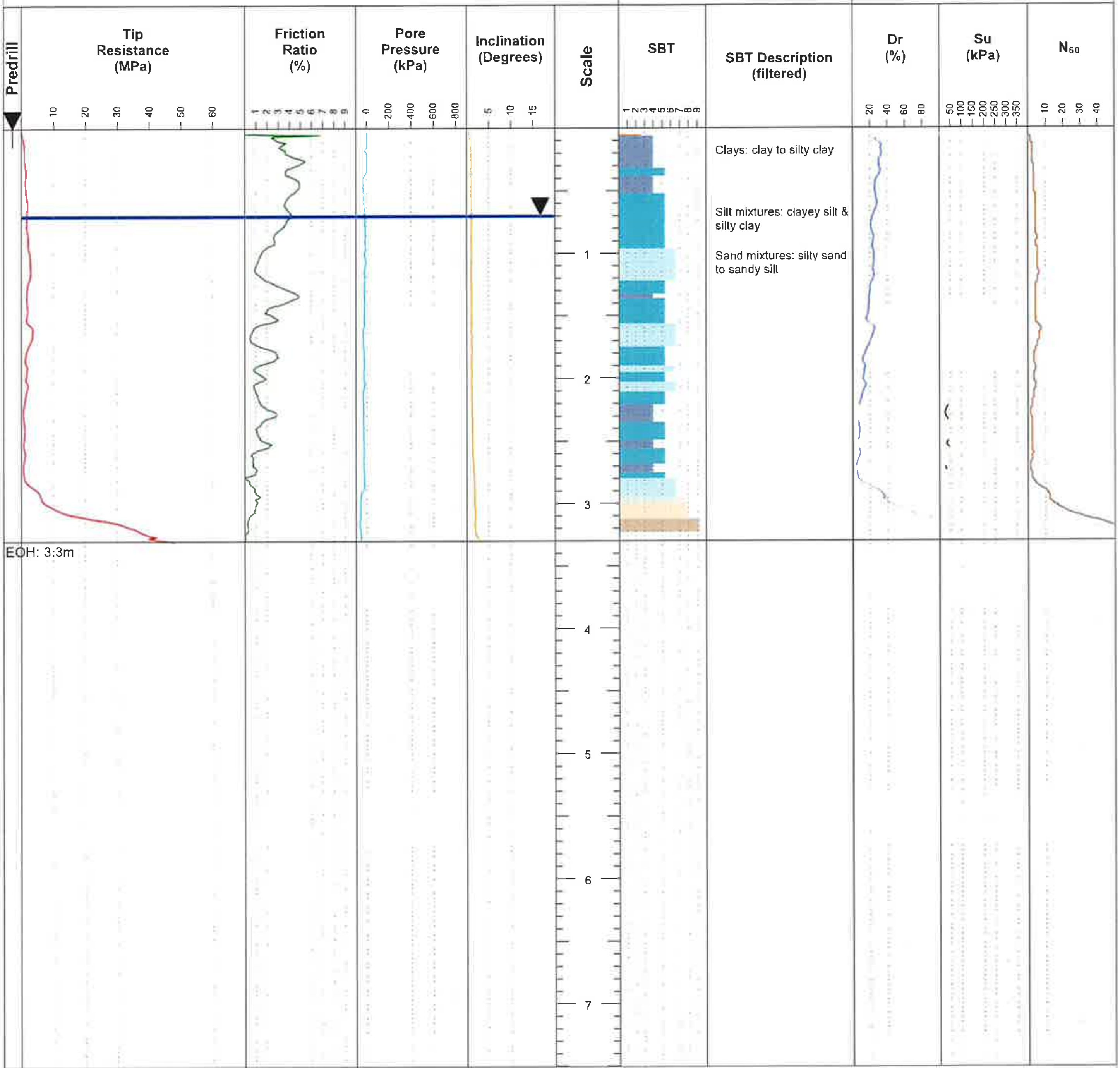
Job:	17414
CPT No.:	CPTu211

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 3.30
Elevation (m): 0.00
Datum: Ground

North (m): 5167607.96
East (m): 1560251.75
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3397 **Final:** 1.4119
Local Friction (MPa) Initial: -0.0133 **Final:** -0.0148
Pore Pressure (KPa) Initial: 0.0163 **Final:** 0.0127

Date: 18/05/2018
Predrill: 0.00
Water Level: 0.70
Collapse: 0.80

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0 Undefined	5 Sand mixtures: silty sand to sandy silt
1 Sensitive fine-grained	6 Sands: clean sands to silty sands
2 Clay - organic soil	7 Dense sand to gravelly sand
3 Clays: clay to silty clay	8 Stiff sand to clayey sand
4 Silt mixtures: clayey silt & silty clay	9 Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 3.30

McMILLAN Drilling

CONE PENETRATION TEST

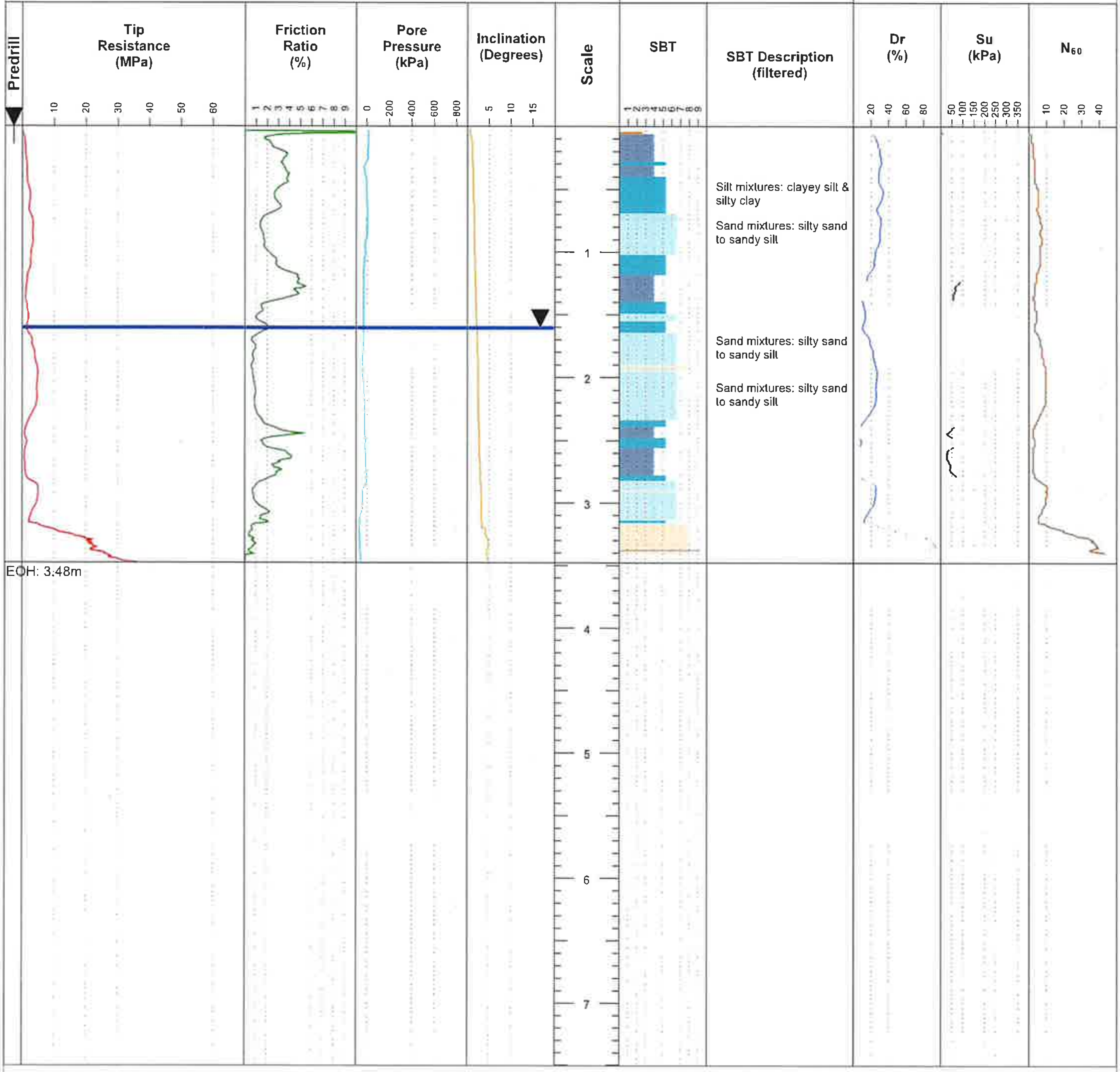
Job:	17414
CPT No.:	CPTu212

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 3.48
Elevation (m): 0.00
Datum: Ground

North (m): 5167607.43
East (m): 1560109.60
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 160925
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 2.0645 **Final:** 1.814
Local Friction (MPa) Initial: 0.0225 **Final:** 0.021
Pore Pressure (KPa) Initial: 0.0059 **Final:** 0.005

Date: 18/05/2018
Predrill: 0.00
Water Level: 1.60
Collapse: 2.20

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

Data shown on this report has been assessed to provide a basic interpretation in terms of Soil Behaviour Type (SBT) and various geotechnical soil and design parameters using methods published in P. K. Robertson and K.L. Cabal (2010), Guide to Cone Penetration Testing for Geotechnical Engineering, 4th Edition. The interpretations are presented only as a guide for geotechnical use, and should be carefully reviewed by the user. Both McMillan Drilling Ltd & Geroc Solutions Ltd do not warranty the correctness or the applicability of any of the geotechnical soil and design parameters shown and does not assume any liability for any use of the results in any design or review. The user should be fully aware of the techniques and limitations of any method used to derive data shown in this report.

Remarks
Effective Refusal

Hole Depth (m): 3.48

MCMILLAN Drilling

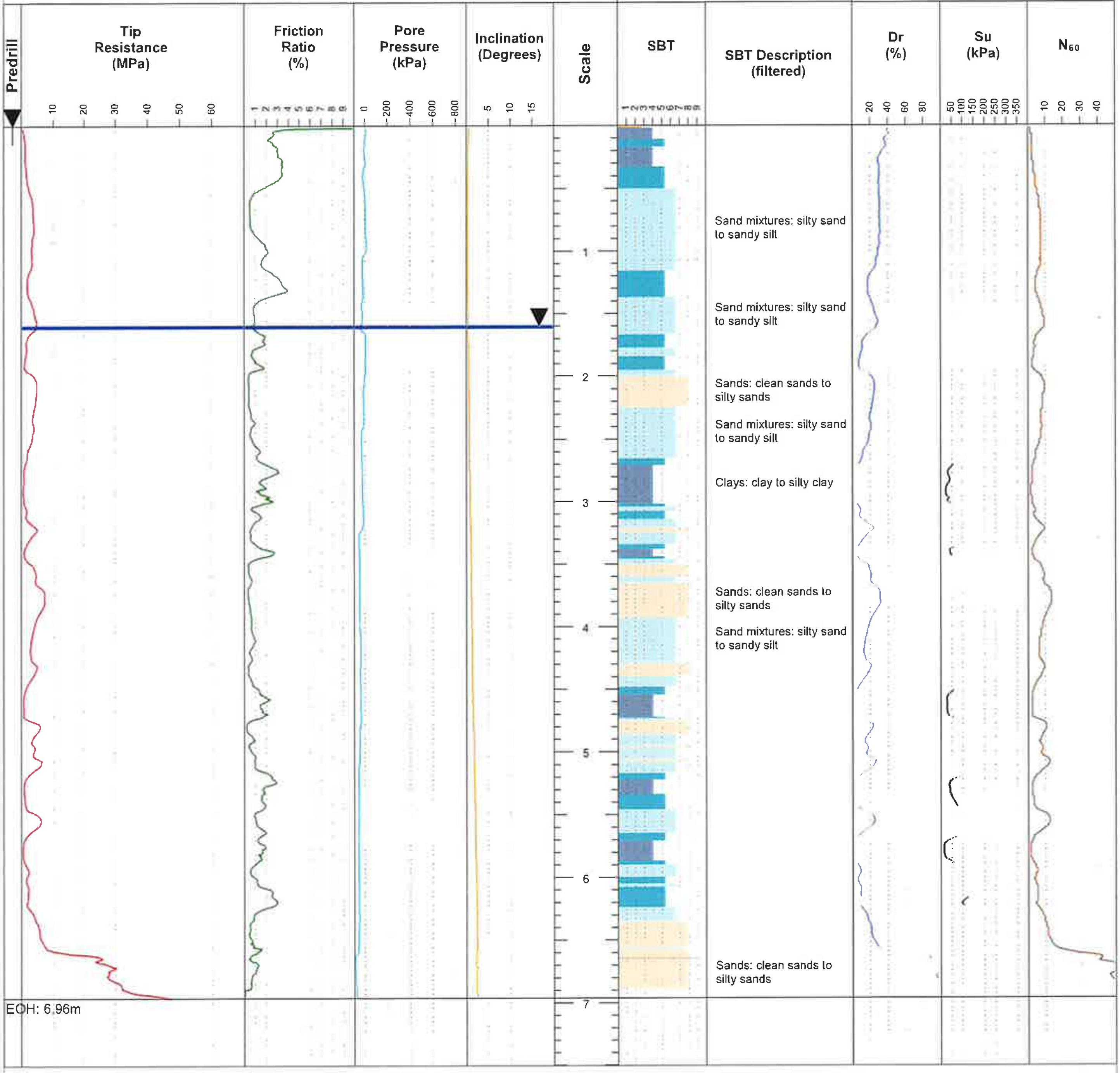
CONE PENETRATION TEST

Job: 17414
CPT No.: CPTu213

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 6.96
Elevation (m): 0.00
Datum: Ground

North (m): 5167536.38
East (m): 1560020.37
Grid: NZTM



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10
Tip Resistance (MPa) Initial: 2.0674 **Final:** 1.9701
Local Friction (MPa) Initial: 0.0212 **Final:** 0.0193
Pore Pressure (KPa) Initial: 0.0045 **Final:** 0.0008

Date: 18/05/2018
Predrill: 0.00
Water Level: 1.60
Collapse: 2.80

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 6.96

Sheet 1 of 1

McMILLAN Drilling

CONE PENETRATION TEST

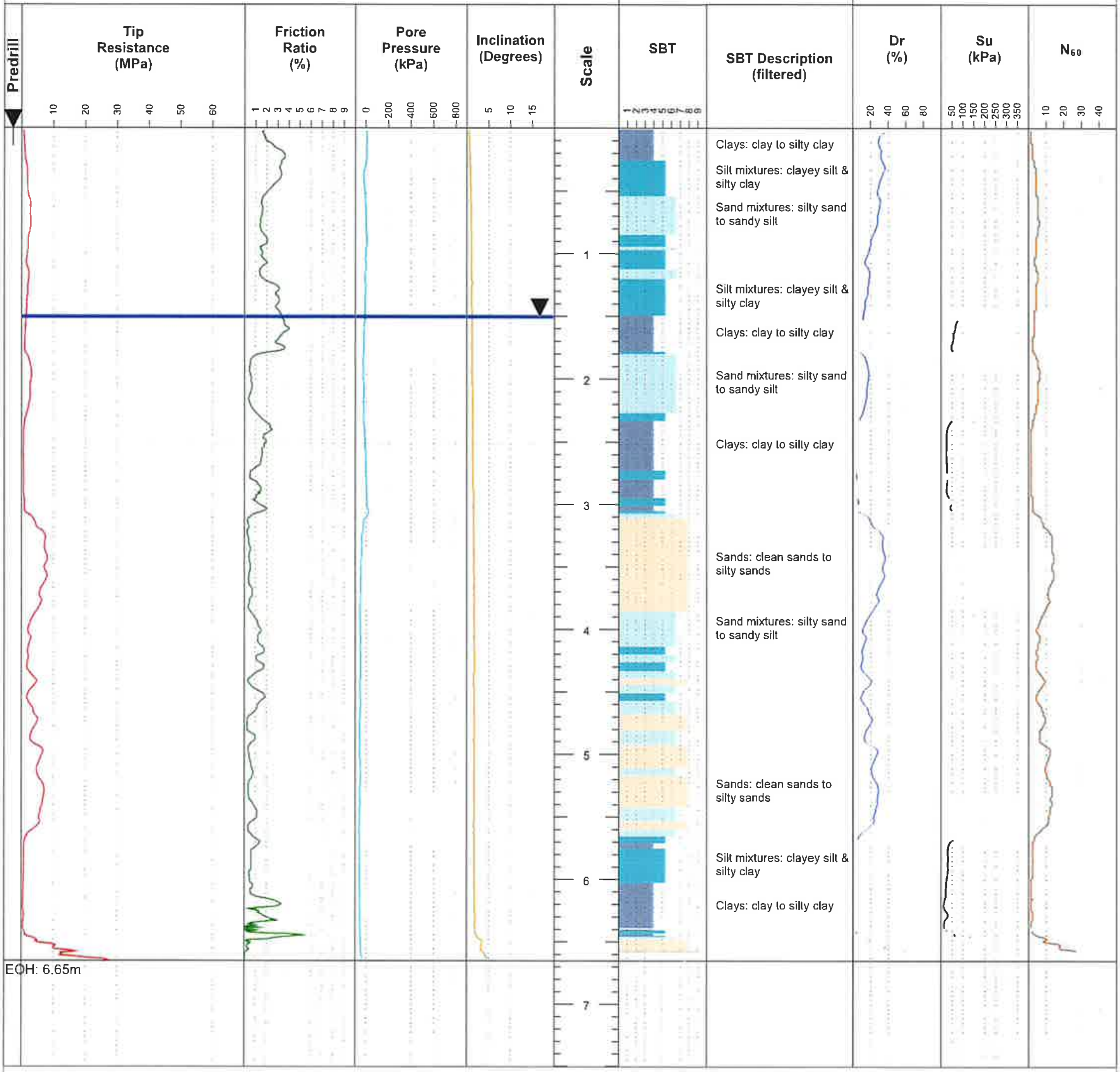
Job:	17414
CPT No.:	CPTu214

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 6.65
Elevation (m): 0.00
Datum: Ground

North (m): 5167506.97
East (m): 1560201.51
Grid: NZTM

RAW DATA | SOIL BEHAVIOUR TYPE (NON-NORMALISED) | ESTIMATED PARAMETERS



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10
Tip Resistance (MPa) Initial: 2.0319 **Final:** 2.0591
Local Friction (MPa) Initial: 0.0189 **Final:** 0.0194
Pore Pressure (KPa) Initial: 0.0075 **Final:** 0.0033

Date: 18/05/2018
Predrill: 0.00
Water Level: 1.50
Collapse: 2.60

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:
Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 6.65

McMILLAN Drilling

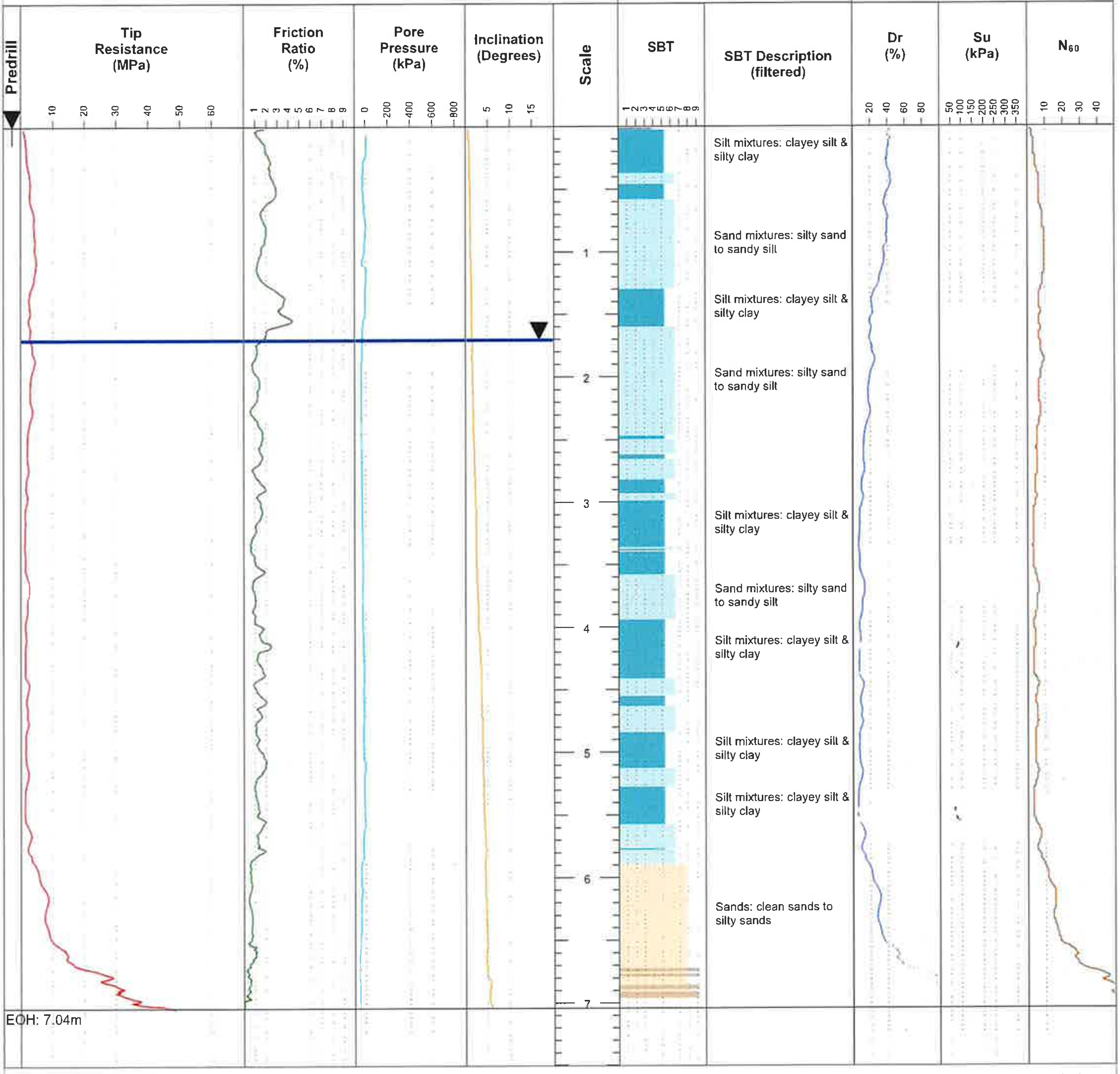
CONE PENETRATION TEST

Job:	17414
CPT No.:	CPTu215

Name: Rosemerryn
Client: Aurecon NZ Ltd
Location: Ellesmere Road, Lincoln

Hole Depth (m): 7.04
Elevation (m): 0.00
Datum: Ground

North (m): 5167361.82
East (m): 1560111.23
Grid: NZTM



Operator: R. Wyllie
Rig: Geomil Panther 100
Cone Reference: 160925
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15
Tip Resistance (MPa) Initial: 1.3107 **Final:** 2.0432
Local Friction (MPa) Initial: 0.0272 **Final:** 0.02
Pore Pressure (KPa) Initial: 0.0111 **Final:** 0.003

Date: 18/05/2018
Predrill: 0.00
Water Level: 1.70
Collapse: 3.30

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:

Target Depth:

Soil Behaviour Type (SBT) - Robertson et al. 1986

0	Undefined	5	Sand mixtures: silty sand to sandy silt
1	Sensitive fine-grained	6	Sands: clean sands to silty sands
2	Clay - organic soil	7	Dense sand to gravelly sand
3	Clays: clay to silty clay	8	Stiff sand to clayey sand
4	Silt mixtures: clayey silt & silty clay	9	Stiff fine-grained

Notes & Limitations

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Remarks
Effective Refusal

Hole Depth (m): 7.04

TEST DETAIL

PointID: CPTu201
Sounding: 201

Operator: R. Wyllie
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.70
Collapse: 2.30

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:

Tip Resistance (MPa) Initial: 1.3707 **Final:** 1.38
Local Friction (MPa) Initial: -0.0114 **Final:** -0.0128
Pore Pressure (kPa) Initial: 0.0029 **Final:** -0.0051
Target Depth:

PointID: CPTu202
Sounding: 202

Operator: R. Wyllie
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.60
Collapse: 1.70

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:

Tip Resistance (MPa) Initial: 1.985 **Final:** 2.1001
Local Friction (MPa) Initial: 0.0236 **Final:** 0.02
Pore Pressure (kPa) Initial: 0.0039 **Final:** -0.0043
Target Depth:

PointID: CPTu203
Sounding: 203

Operator: R. Wyllie
Cone Reference: 151125
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-10

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.50
Collapse: 1.70

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:

Tip Resistance (MPa) Initial: 1.9945 **Final:** 2.0254
Local Friction (MPa) Initial: 0.0235 **Final:** 0.0197
Pore Pressure (kPa) Initial: 0.0075 **Final:** 0.0015
Target Depth:

PointID: CPTu204
Sounding: 204

Operator: R. Wyllie
Cone Reference: 170302
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.40
Collapse: 2.40

Effective Refusal
Tip: ✓
Gauge:
Inclinometer:
Other:

Tip Resistance (MPa) Initial: 1.3563 **Final:** 1.3881
Local Friction (MPa) Initial: -0.0114 **Final:** -0.0132
Pore Pressure (kPa) Initial: 0.0072 **Final:** -0.0017
Target Depth:

PointID: CPTu205
Sounding: 205

Operator: R. Wyllie
Cone Reference: 160925
Cone Area Ratio: 0.75
Cone Type: I-CFXYP20-15

Date: 22/05/2018
Predrill: 0.00
Water Level: 1.80
Collapse: 4.00

Effective Refusal
Tip:
Gauge:
Inclinometer: ✓
Other:

Tip Resistance (MPa) Initial: -1.4917 **Final:** -1.3956
Local Friction (MPa) Initial: 0.0198 **Final:** 0.011
Pore Pressure (kPa) Initial: 0.0085 **Final:** 0.003
Target Depth:

TEST DETAIL

PointID: CPTu206
Sounding: 206

Operator:	R. Wyllie	**Date:**	22/05/2018	**Effective Refusal**	
Cone Reference:	160925	**Predrill:**	0.00	**Tip:**	✓
Cone Area Ratio:	0.75	**Water Level:**	1.40	**Gauge:**	
Cone Type:	I-CFXYP20-15	**Collapse:**	1.60	**Inclinometer:**	
				Other:	
Tip Resistance (MPa) Initial:	-1.4662	**Final:**	-1.4953		
Local Friction (MPa) Initial:	0.0218	**Final:**	0.0114		
Pore Pressure (kPa) Initial:	0.0072	**Final:**	-0.0002	**Target Depth:**	

PointID: CPTu207
Sounding: 207

Operator:	R. Wyllie	**Date:**	22/05/2018	**Effective Refusal**	
Cone Reference:	170302	**Predrill:**	0.00	**Tip:**	
Cone Area Ratio:	0.75	**Water Level:**	1.80	**Gauge:**	
Cone Type:	I-CFXYP20-15	**Collapse:**	3.40	**Inclinometer:**	✓
				Other:	
Tip Resistance (MPa) Initial:	1.3756	**Final:**	1.3779		
Local Friction (MPa) Initial:	-0.009	**Final:**	-0.0123		
Pore Pressure (kPa) Initial:	-0.0031	**Final:**	-0.0058	**Target Depth:**	

PointID: CPTu208
Sounding: 208

Operator:	R. Wyllie	**Date:**	22/05/2018	**Effective Refusal**	
Cone Reference:	160925	**Predrill:**	0.00	**Tip:**	✓
Cone Area Ratio:	0.75	**Water Level:**	1.20	**Gauge:**	
Cone Type:	I-CFXYP20-15	**Collapse:**	1.50	**Inclinometer:**	
				Other:	
Tip Resistance (MPa) Initial:	-1.5601	**Final:**	-1.4439		
Local Friction (MPa) Initial:	0.0173	**Final:**	0.0116		
Pore Pressure (kPa) Initial:	0.0052	**Final:**	0.0036	**Target Depth:**	

PointID: CPTu209
Sounding: 209

Operator:	R. Wyllie	**Date:**	22/05/2018	**Effective Refusal**	
Cone Reference:	151125	**Predrill:**	0.00	**Tip:**	✓
Cone Area Ratio:	0.75	**Water Level:**	1.50	**Gauge:**	
Cone Type:	I-CFXYP20-10	**Collapse:**	2.70	**Inclinometer:**	
				Other:	
Tip Resistance (MPa) Initial:	1.9897	**Final:**	1.9199		
Local Friction (MPa) Initial:	0.0224	**Final:**	0.02		
Pore Pressure (kPa) Initial:	0.0041	**Final:**	0.0025	**Target Depth:**	

PointID: CPTu210
Sounding: 210

Operator:	R. Wyllie	**Date:**	22/05/2018	**Effective Refusal**	
Cone Reference:	170302	**Predrill:**	0.00	**Tip:**	✓
Cone Area Ratio:	0.75	**Water Level:**	1.10	**Gauge:**	
Cone Type:	I-CFXYP20-15	**Collapse:**	2.40	**Inclinometer:**	
				Other:	
Tip Resistance (MPa) Initial:	1.3671	**Final:**	1.4049		
Local Friction (MPa) Initial:	-0.0117	**Final:**	-0.0165		
Pore Pressure (kPa) Initial:	0.0214	**Final:**	0.0195	**Target Depth:**	

TEST DETAIL

PointID: CPTu211
Sounding: 211

Operator: R. Wyllie	**Date:** 18/05/2018	**Effective Refusal**
Cone Reference: 170302	**Predrill:** 0.00	**Tip:** ✓
Cone Area Ratio: 0.75	**Water Level:** 0.70	**Gauge:**
Cone Type: I-CFXYP20-15	**Collapse:** 0.80	**Inclinometer:**
		Other:
Tip Resistance (MPa) Initial: 1.3397	**Final:** 1.4119	
Local Friction (MPa) Initial: -0.0133	**Final:** -0.0148	
Pore Pressure (kPa) Initial: 0.0163	**Final:** 0.0127	**Target Depth:**

PointID: CPTu212
Sounding: 212

Operator: R. Wyllie	**Date:** 18/05/2018	**Effective Refusal**
Cone Reference: 160925	**Predrill:** 0.00	**Tip:** ✓
Cone Area Ratio: 0.75	**Water Level:** 1.60	**Gauge:**
Cone Type: I-CFXYP20-15	**Collapse:** 2.20	**Inclinometer:**
		Other:
Tip Resistance (MPa) Initial: 2.0645	**Final:** 1.814	
Local Friction (MPa) Initial: 0.0225	**Final:** 0.021	
Pore Pressure (kPa) Initial: 0.0059	**Final:** 0.005	**Target Depth:**

PointID: CPTu213
Sounding: 213

Operator: R. Wyllie	**Date:** 18/05/2018	**Effective Refusal**
Cone Reference: 151125	**Predrill:** 0.00	**Tip:** ✓
Cone Area Ratio: 0.75	**Water Level:** 1.60	**Gauge:**
Cone Type: I-CFXYP20-10	**Collapse:** 2.80	**Inclinometer:**
		Other:
Tip Resistance (MPa) Initial: 2.0674	**Final:** 1.9701	
Local Friction (MPa) Initial: 0.0212	**Final:** 0.0193	
Pore Pressure (kPa) Initial: 0.0045	**Final:** 0.0008	**Target Depth:**

PointID: CPTu214
Sounding: 214

Operator: R. Wyllie	**Date:** 18/05/2018	**Effective Refusal**
Cone Reference: 151125	**Predrill:** 0.00	**Tip:** ✓
Cone Area Ratio: 0.75	**Water Level:** 1.50	**Gauge:**
Cone Type: I-CFXYP20-10	**Collapse:** 2.60	**Inclinometer:**
		Other:
Tip Resistance (MPa) Initial: 2.0319	**Final:** 2.0591	
Local Friction (MPa) Initial: 0.0189	**Final:** 0.0194	
Pore Pressure (kPa) Initial: 0.0075	**Final:** 0.0033	**Target Depth:**

PointID: CPTu215
Sounding: 215

Operator: R. Wyllie	**Date:** 18/05/2018	**Effective Refusal**
Cone Reference: 160925	**Predrill:** 0.00	**Tip:** ✓
Cone Area Ratio: 0.75	**Water Level:** 1.70	**Gauge:**
Cone Type: I-CFXYP20-15	**Collapse:** 3.30	**Inclinometer:**
		Other:
Tip Resistance (MPa) Initial: 1.3107	**Final:** 2.0432	
Local Friction (MPa) Initial: 0.0272	**Final:** 0.02	
Pore Pressure (kPa) Initial: 0.0111	**Final:** 0.003	**Target Depth:**

CPT CALIBRATION AND TECHNICAL NOTES

These notes describe the technical specifications and associated calibration references pertaining to the following cone types:

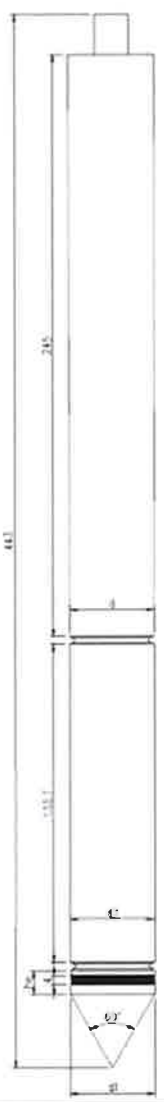
- I-CFXY-10 measuring cone resistance, sleeve friction and inclination (standard cone, 10cm²);
- I-CFXY-15 measuring cone resistance, sleeve friction and inclination (standard cone, 15cm²);
- I-CFXYP20-10 measuring cone resistance, sleeve friction, inclination and pore pressure (piezocone, 10cm²);
- I-CFXYP20-15 measuring cone resistance, sleeve friction, inclination and pore pressure (piezocone, 15cm²);
- I-C5F0p15XYP20-10 measuring sensitive cone resistance, sleeve friction, inclination and pore pressure (piezocone, 10cm²).

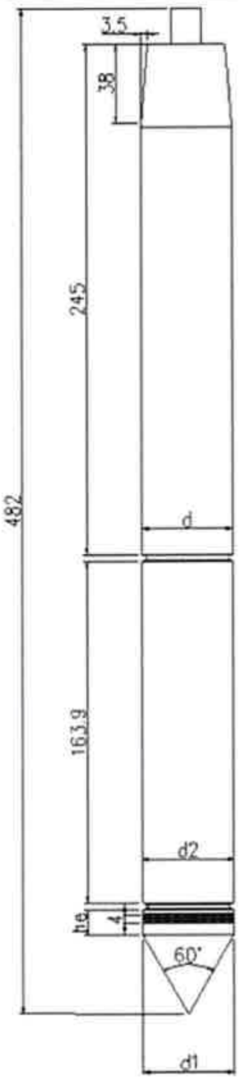
Dimensions

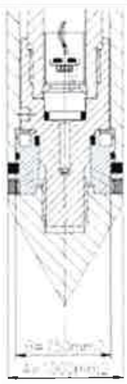
Dimensional specifications for all cone types are detailed below. All tolerances are routinely checked prior to testing and measurements taken are manually recorded on CPT field sheets. All field sheets are kept on file and available on request.

A.P. van den Berg Machinefabriek tel.: +31 (0)513-631355 info@apvandenberg.com	**DEVIATION of Straightness + MINIMUM Dimensions tip, friction jacket, cone adapter**	Standards: EN ISO 22476-1 APB-standard	

Type of cone:	Icone 10 cm²	Icone 15 cm²
<u>ALLOWABLE SIZE VARIATION</u>		
Diameter of tip:	$35,3 \le d1 \le 36,0$	$43,2 \le d_1 \le 44,1$
Diameter of centering ring CFP	$35,3 \le d1 \le 36,0$	$43,2 \le d_1 \le 44,1$
Diameter of friction jacket:	$d_1 \le d_2 < d_1 + 0,35$	$d_1 \le d_2 < d_1 + 0,43$
Height dimension of tip edge:	$7 \le h_e \le 10$	$9 \le h_e \le 12$
<u>PRODUCTION DIMENSIONS</u>		
Tip:	$d_1 = 35,7^{+0,2}_{0}$	$d_1 = 43,8^{+0,2}_{0}$
Jacket (C-cone):	$d_2 = 35,7^{+0,2}_{0}$	$d_2 = 43,7^{+0,2}_{0}$
Friction jacket (CF-cone):	$d_2 = 35,9^{+0,1}_{0}$	$d_2 = 44,0^{+0,1}_{0}$
Tip for used cone:	$d_1 = 35,5^{+0,1}_{0}$	$d_1 = 43,5^{+0,1}_{0}$
<u>MINIMUM DIMENSIONS</u>		
Minimum diameter jacket (C-cone):	$d_2 = 35,2$ (APB standard)	$d_2 = 43,0$ (APB standard)
Minimum diameter friction jacket (CF-cone):	$d_2 = 35,3$	$d_2 = 43,2$
Use "used cone"-tip when friction jacket diameter:	$d_2 \le 35,65$	$d_2 \le 43,7$
Minimum diameter of cone adaptor:	d = 35,3	d = 43,8
Maximum deviation of straightness:	1 mm on a length of 1000 mm (max. oscillation 1,0 mm.)	1 mm on a length of 1000 mm (max. oscillation: 2.0 mm)



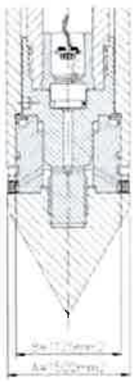




Cone area ratio

$\alpha = A / B = 0.75$

$\beta = 1 - A / B = 0.25$



McMILLAN Drilling GROUP

CPT CALIBRATION AND TECHNICAL NOTES (cont.)

Calibration

Each cone has a unique identification number that is electronically recorded and reported for each CPT test. The identification number enables the operator to compare 'zero-load offsets' to manufacturer calibrated zero-load offsets.

The recommended maximum zero-load offset for each sensor is determined as ± 5% of the nominal measuring range.

In addition to maximum zero-load offsets, McMillan Drilling also limits the difference in zero load offset before and after the test as ± 2% of the maximum measuring range. See table below:

	Tip (MPa)	Friction (MPa)	Pore Pressure (MPa)
Maximum Measuring Range:	150	1.50	3.00
Nominal Measuring Range:	75	1.00	2.00
Max. 'zero-load offset':	7.5	0.10	0.20
Max 'before and after test':	3	0.03	0.06

Note: The zero offsets are electronically recorded and reported for each test in the same units as that of each sensor.

TEST CERTIFICATE
Icone (all versions)

Supplier:	A.P. v.d. Berg Machinefabriek, Heerenveen The Netherlands
Production-order:	73444
Client:	McMillan
Cone-type:	I-CFXYP20-10
Cone-number:	151125

To test / To check item	**Required value**	**Checked value**
Check Quad-ring groove behind friction sleeve with check ring; **Sample testing: 1 of every 5 Icones is tested.**	Sleeve fixed	OK
Isolation-resistance.	>0.5 GΩ	1 GΩ
Straightness: Icone 5, 10 and 15 cm^2 S < 2.2. mm. At Icone base: S < 0,2 mm	S<= 2,2 mm	1,1 mm
"Classic calibration" NOT present! Check of calibration-file: "Classic calibration" removed.	O.K.	✓
Check alarm-settings Icone. Alarm values are set. (Kill Shutdown).	O.K.	OK
Software version - check at opening screen.	version:	2.0
Calibration date of Icone; check cone data [F1]..[F1].	O.K.	OK
Initial zero-Value Tip after calibration – within 1.0 % of nominal load.	Value:	-0.003 MPa
Initial zero-Value Local Friction after calibration – within 1.0% of nominal load.	Value:	0.0021 MPa
Initial zero-Value Pore Pressure after calibration – within 1.0% of nominal load.	Value:	0.8 kPa
Initial zero-Value Inclination X. -1°< X <+1°	Value:	0.3 °
Initial zero-Value Inclination Y. -1° < Y <+1°	Value:	-0.1 °
Measurements Tip resistance OK?	Tested range	0-75 MPa
Influence Tip load on **Local Friction and Pore Pressure:** Max. tip load: 5 cm^2: 65 MPa; 10 cm^2: 100 MPa; 15 cm^2: 75 MPa.	LF < 10 kPa PP <½% nom	4 KPa 0,2 KPa (100 MPa)
Measurements local friction OK?	Tested range:	0-1 MPa
Local friction at max. load.	Tested value:	1,5 MPa
Measurements Pore Pressure OK?	Tested range:	0-2000 kPa
Measure Pore Pressure to 150%.	Tested value:	3000 KPa
Measurements Inclination OK?	Tested range:	24-0-24
Cone recognition on disconnecting and connecting Icone again?	Yes	OK

Remarks:

Calibrated by: C.J. Auwerda	Date: 28-10-2016	Sign.: [signature]
Final check: J.W. van der Maar	Date: 31-10-2016	Sign.: [signature]

OK [signature]

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McMILLAN Drilling GROUP

TEST CERTIFICATE
Icone (all versions)

Supplier:	A.P. v.d. Berg Machinefabriek, Heerenveen The Netherlands
Production-order:	72614
Client:	Mc Millan
Cone-type:	I-CFXYP20-15
Cone-number:	160925

To test / To check item	Required value	Checked value
Check Quad-ring groove behind friction sleeve with check ring; **Sample testing: 1 of every 5 Icones is tested.**	Sleeve fixed	/
Isolation-resistance.	>0.5 GΩ	1.1 GΩ
Straightness: Icone 5, 10 and 15 cm^2 S < 2.2. mm. At Icone base: S < 0,2 mm	S<= 2,2 mm	0.4 mm
"Classic calibration" NOT present! Check of calibration-file: "Classic calibration" removed.	O.K.	/
Check alarm-settings Icone. Alarm values are set. (Kill Shutdown).	O.K.	O.K.
Software version - check at opening screen.	version:	2.0
Calibration date of Icone; check cone data [F1]..[F1].	O.K.	O.K.
Initial zero-Value Tip after calibration – within 1.0 % of nominal load.	Value:	-0.003 MPa
Initial zero-Value Local Friction after calibration – within 1.0% of nominal load.	Value:	0,0001 MPa
Initial zero-Value Pore Pressure after calibration – within 1.0% of nominal load.	Value:	-1.4 kPa
Initial zero-Value Inclination X. -1°< X <+1° Initial zero-Value Inclination Y. -1° < Y <+1°	Value: Value:	-0.2 ° 0.3 °
Measurements Tip resistance OK?	Tested range	0 - 75 MPa
Influence Tip load on **Local Friction and Pore Pressure:** Max. tip load: 5 cm^2: 65 MPa; 10 cm^2: 100 MPa; 15 cm^2: 75 MPa.	LF < 10 kPa PP <½% nom	4 kPa 0.1 kPa
Measurements local friction OK?	Tested range:	0 - 1 MPa
Local friction at max. load.	Tested value:	1.5 MPa
Measurements Pore Pressure OK?	Tested range:	0-2000 kPa
Measure Pore Pressure to 150%.	Tested value:	3000 kPa
Measurements Inclination OK?	Tested range:	24-0-+24
Cone recognition on disconnecting and connecting Icone again?	Yes	Yes
Remarks: —		

Calibrated by: W de Jong	Date: 28-09-16	Sign.: [signature]
Final check: J.W van der Meer	Date: 28-09-16	Sign.: [signature]

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McMILLAN Drilling GROUP

TEST CERTIFICATE
Icone (all versions)

Supplier:	A.P. v.d. Berg Machinefabriek, Heerenveen The Netherlands
Production-order:	74378
Client:	Mc Millan
Cone-type:	I-CFXYP20-15
Cone-number:	170302

To test / To check item		**Required value**	**Checked value**	
Check Quad-ring groove behind friction sleeve with check ring; **Sample testing: 1 of every 5 Icones is tested.**		Sleeve fixed	/	
Isolation-resistance.		>0.5 GΩ	5 GΩ	
Straightness: Icone 5, 10 and 15 cm² S < 2.2. mm. At Icone base: S < 0,2 mm		S<= 2,2 mm	0,35 mm	
"Classic calibration" NOT present! Check of calibration-file: "Classic calibration" removed.		O.K.	/	
Check alarm-settings Icone. Alarm values are set. (Kill Shutdown).		O.K.	OK	
Software version - check at opening screen.		version:	2.0	
Calibration date of Icone; check cone data [F1]..[F1].		O.K.	OK	
Initial zero-Value Tip after calibration – within 1.0 % of nominal load.		Value:	0,007 MPa	0.006 MPa
Initial zero-Value Local Friction after calibration – within 1.0% of nominal load.		Value:	-0,002 MPa	-0,001 MPa
Initial zero-Value Pore Pressure after calibration – within 1.0% of nominal load.		Value:	0,2 kPa	-5.5 kPa
Initial zero-Value Inclination X. Initial zero-Value Inclination Y.	-1°< X <+1° -1° < Y <+1°	Value: Value:	0,2 ° 0,4 °	
Measurements Tip resistance OK?		Tested range	0-7,5 MPa	
Influence Tip load on **Local Friction and Pore Pressure:** Max. tip load: 5 cm²: 65 MPa; 10 cm²: 100 MPa; 15 cm²: 75 MPa.		LF < 10 kPa PP <½% nom	0,8 kPa 2 kPa	
Measurements local friction OK?		Tested range:	0-1 MPa	
Local friction at max. load.		Tested value:	1,5 MPa	
Measurements Pore Pressure OK?		Tested range:	0-2000 kPa	
Measure Pore Pressure to 150%.		Tested value:	3000 kPa	
Measurements Inclination OK?		Tested range:	24-0-24	
Cone recognition on disconnecting and connecting Icone again?		Yes	OK	

Remarks:

Calibrated by: C.J. Cauwejan	Date: 02/03/2017	Sign.: [signature]
Final check: J.W. van der Meer	Date: 02/03/2017	Sign.: [signature]

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McMILLAN Drilling GROUP

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2018 Borehole Logs

Bore Log

McMILLAN Drilling GROUP

Client:	Aurecon NZ Ltd	**Bore No.:**	**BH201**
Project:	Rosemerryn	**Job No.:**	**17414**

Site Location: Ellesmere Road, Lincoln
Grid Reference: 1560343.49mE 5168107.7mN NZTM
Rig Operator: C. Nee
Rig Model & Mounting: AMS VTR9570 - track

Date Commenced: 17/05/2018
Date Completed: 17/05/2018
Elevation (m): 0.00
Datum: Ground

Description	Method	Drivability (1 2 3 4 5)	Recovery (25 50 75)	Depth	Graphic Log	SPT N-value (Uncorrected) (10 20 30 40 50)	In-Situ Tests (Uncorrected)	Samples - Permeability tests	Installation & Resources
No sample recovery.	Wash boring - 70mm OD			0.5 – 5.0	N/R				1.00m stick up; Bentonite (0.2 bags) to 0.80m; Filter sand (0.7 bags); 32 mm Blank pipe (4.0m) to 4.00m; 32 mm Slotted pipe with geotextile filter sock (1.0m) to 5.00m

EOH: 5.2m

Remarks

Geotechnical investigation borehole

Static water levels:
1.40m bgl at casing depth of 5.00m; 18/5/2018, 4:40 pm

No liters water added

Additional Resources:

Plastic Liner / PVC Splits	m	-
Core boxes	no.	
Flush Mounted Toby Box		
- Standard	ea	
- Environmental	ea	
Above Ground Protective Surround	ea	
Geotextile Sock	m	1.0
Hand Clear Location	ea	
Decontaminate Equipment	ea	✓

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

Bore Log

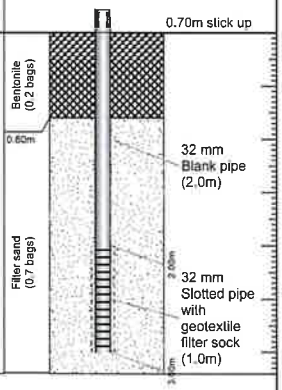
McMILLAN Drilling GROUP	**Client:** Aurecon NZ Ltd	**Bore No.:** BH202
	Project: Rosemerryn	**Job No.:** 17414

Site Location: Ellesmere Road, Lincoln
Grid Reference: 1560239.44mE 5167880.67mN NZTM
Rig Operator: C. Nee
Rig Model & Mounting: AMS VTR9570 - track

Date Commenced: 17/05/2018
Date Completed: 17/05/2018
Elevation (m): 0.00
Datum: Ground

Description	Method	Drivability (1 2 3 4 5)	Recovery (25 50 75)	Depth	Graphic Log	SPT N-value (Uncorrected) (10 20 30 40 50)	In-Situ Tests (Uncorrected)	Samples - Permeability tests	Installation & Resources
No sample recovery.	Wash boring - 70mm OD			0.5, 1.0, 1.5, 2.0, 2.5, 3.0	N/R				0.70m stick up

EOH: 3.2m



Remarks

Geotechnical investigation borehole

Static water levels:
1.45m bgl at casing depth of 3.00m; 18/5/2018, 4:47 pm

No liters water added

Additional Resources:

Plastic Liner / PVC Splits	m	-
Core boxes	no.	
Flush Mounted Toby Box		
- Standard	ea	
- Environmental	ea	
Above Ground Protective Surround	ea	
Geotextile Sock	m	1.0
Hand Clear Location	ea	
Decontaminate Equipment	ea	✓

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

120 High Street, Southbridge 7602, Canterbury, New Zealand ph: (03) 324 2571 fax: (03) 324 2431 web: www.drilling.co.nz

Hole Depth: 3.2m

Created: 21/05/2018 12:37:36 p.m.

Bore Log

MCMILLAN Drilling GROUP	**Client:** Aurecon NZ Ltd	**Bore No.:** BH203
	Project: Rosemerryn	**Job No.:** 17414

Site Location: Ellesmere Road, Lincoln
Grid Reference: 1560173.8mE 5167679.57mN NZTM
Rig Operator: C. Nee
Rig Model & Mounting: AMS VTR9570 - track

Date Commenced: 17/05/2018
Date Completed: 17/05/2018
Elevation (m): 0.00
Datum: Ground

Description	Method	Drivability (1 2 3 4 5)	Recovery (25 50 75)	Depth	Graphic Log	SPT N-value (Uncorrected) (10 20 30 40 50)	In-Situ Tests (Uncorrected)	Samples - Permeability tests	Installation & Resources
No sample recovery.	Wash boring - 70mm OD			0.5, 1.0, 1.5, 2.0, 2.5, 3.0	N/R				0.70m stick up; Bentonite (0.2 bags) to 0.80m; Filter sand (0.7 bags); 32 mm Blank pipe (2.0m); 2.00m; 32 mm Slotted pipe with geotextile filter sock (1.0m); 3.00m

EOH: 3.1m

Remarks

Geotechnical investigation borehole

Static water levels:
1.40m bgl at casing depth of 3.00m; 18/5/2018, 4:50 pm

No liters water added

Additional Resources:

Plastic Liner / PVC Splits	m	-
Core boxes	no.	
Flush Mounted Toby Box		
- Standard	ea	
- Environmental	ea	
Above Ground Protective Surround	ea	
Geotextile Sock	m	1.0
Hand Clear Location	ea	
Decontaminate Equipment	ea	✓

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

McMILLAN Drilling GROUP

Bore Log

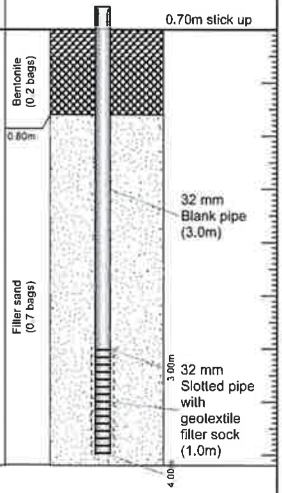
Client: Aurecon NZ Ltd	**Bore No.:**	BH204
Project: Rosemerryn	**Job No.:**	17414

Site Location: Ellesmere Road, Lincoln
Grid Reference: 1560065.43mE 5167384.18mN NZTM
Rig Operator: C. Nee
Rig Model & Mounting: AMS VTR9570 - track

Date Commenced: 17/05/2018
Date Completed: 17/05/2018
Elevation (m): 0.00
Datum: Ground

Description	Method	Drivability (1 2 3 4 5)	Recovery (25 50 75)	Depth	Graphic Log	SPT N-value (Uncorrected) (10 20 30 40 50)	In-Situ Tests (Uncorrected)	Samples - Permeability tests	Installation & Resources
No sample recovery.	Wash boring - 70mm OD			0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0	N/R				

EOH: 4.1m



Remarks

Geotechnical investigation borehole

Static water levels:
1.50m bgl at casing depth of 4.00m; 18/5/2018, 4:00 pm

No liters water added

Additional Resources:

Plastic Liner / PVC Splits	m	-
Core boxes	no.	
Flush Mounted Toby Box		
- Standard	ea	
- Environmental	ea	
Above Ground Protective Surround	ea	
Geotextile Sock	m	1.0
Hand Clear Location	ea	
Decontaminate Equipment	ea	✓

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

120 High Street, Southbridge 7602, Canterbury, New Zealand ph: (03) 324 2571 fax: (03) 324 2431 web: www.drilling.co.nz

Hole Depth: 4.1m

Created: 21/05/2018 12:37:36 p.m.

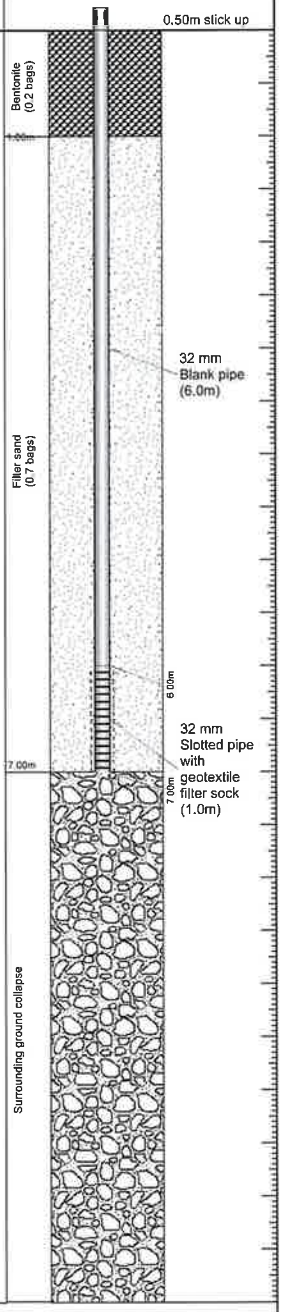
Bore Log

McMILLAN Drilling GROUP	**Client:** Aurecon NZ Ltd	**Bore No.:** BH205
	Project: Rosemerryn	**Job No.:** 17414

Site Location: Ellesmere Road, Lincoln
Grid Reference: 1559804.09mE 5167801.92mN NZTM
Rig Operator: C. Nee
Rig Model & Mounting: AMS VTR9570 - track

Date Commenced: 18/05/2018
Date Completed: 18/05/2018
Elevation (m): 0.00
Datum: Ground

Description	Depth (m)	Method	Recovery	In-Situ Tests (Uncorrected)	Samples / Permeability tests
SILT with some peat; dark brown.	0.00	Dual tube - 70mm OD	45%		
Fine SAND with trace of silt; light brown.	0.25m				
Fine to medium SAND; brown.	1.60m		100%	SPT (S) 1.50m 1, 1 / 1, 1, 1, 1 450mm N = 4	SPTLS 1.50 - 1.95m
Fine SAND; grey.	2.50m				
Fine SAND; brown.	2.90m		100%	SPT (S) 3.00m 1, 1 / 1, 2, 2, 2 450mm N = 7	SPTLS 3.00 - 3.45m
Fine to coarse GRAVEL with some sand; brown. Sand, medium.	4.05m		60%	SPT (C) 4.50m 16, 13 / 14, 13, 15, 12 450mm N = 54	
			35%	SPT (C) 6.00m 5, 3 / 3, 2, 2, 1 450mm N = 8	
Fine to medium GRAVEL with minor sand; brown. Sand, medium.	7.50m		60%	SPT (C) 7.50m 0, 0 / 0, 0, 0, 0 450mm N = 0	
Fine SAND with trace of gravel; brown. Gravel, fine.	7.90m				
WOOD.	8.80m			SPT (S) 9.00m 0, 0 / 1, 1, 1, 1 450mm N = 4	SPTLS 9.00 - 9.04m
Fine to coarse GRAVEL with some sand; brown. Sand, fine to medium.	9.05m				
			65%	SPT (C) 10.50m 17, 16 / 20, 22, 14, 4 405mm Effective Refusal N = 60+	
				SPT (C) 12.00m 6, 7 / 5, 4, 3, 5 450mm N = 17	
EOH: 12m					



Remarks

Geotechnical investigation borehole with SPT testing

Static water levels:
1.45m bgl at casing depth of 9.00m; 18/5/2018, 1:00 pm
1.50m bgl at casing depth of 7.00m; 18/5/2018, 2:30 pm

500 liters water added

Safety auto trip hammer #396 used (energy ratio 83.3%)

Additional Resources:

Item	Unit	Qty
Plastic Liner / PVC Splits	m	10.5
Core boxes	no.	
Flush Mounted Toby Box		
- Standard	ea	
- Environmental	ea	
Above Ground Protective Surround	ea	
Geotextile Sock	m	1.0
Hand Clear Location	ea	
Decontaminate Equipment	ea	✓

Drivability

1 Easy Push - No Hammer \ Fast Penetration
2 Relatively Easy Push - Light Hammer \ Relatively Fast
3 Medium Push - Consistent Hammer \ Medium
4 Hard Push - Full Hammer \ Somewhat Slow
5 Very Hard Push - Full Hammer \ Very Slow

BOREHOLE RECORD

aurecon
www.aurecongroup.com

HOLE NO.	BH205
PROJECT NO.	224464

PROJECT: Rosemerryn Subdivision Lincoln

METHOD	Borehole	CO-ORDINATES (NZTM) E 1559804 N 5167802	SHEET 1 of 1
MACHINE & NO.	AMS VTR9570 - track		DATE from 18/05/2018 to 18/05/2018
FLUSHING MEDIUM	Water	ORIENTATION VERTICAL	GROUND-LEVEL m RL

STRATA DESCRIPTION: SUBORDINATE FRACTION, MAJOR FRACTION, MINOR FRACTION, COLOUR, STRUCTURE, STRENGTH, MOISTURE CONDITION, GRADING, BEDDING, PLASTICITY, ETC. (NZ GEOTECHNICAL SOCIETY - FIELD DESCRIPTION OF SOIL AND ROCK)

Total core Recovery %	Tests	Samples (Type / Depth)	Depth (m)	Strata Description
45		BH 0.00	0.00–0.35	SILT with minor sand; dark brown, Moist, low plasticity; sand, fine.
			0.35–0.70	SILT with minor sand; grey mottled orange and brown. Moist, low plasticity; sand, fine. 0.50m Becomes with some sand.
			0.70–1.50	CORELOSS
100	(1, 1, 1, 1, 1, 1) N = 4	BH 1.50	1.50–4.50	Fine to coarse SAND with minor silt; light brown grey. Moist. 2.50m Becomes bluish grey. Wet. 2.60m - 3.00m Becomes with some organic silt lenses; dark brown. Wet, slightly odorous. 3.00m Becomes fine to coarse, orange brown. 4.30m Becomes with some fine to coarse gravel, subangular to subrounded.
100	(1, 1, 1, 2, 2, 2) N = 7	BH 3.00		
60	(16, 13, 14, 13, 15, 12) N = 54	BH 4.50	4.50–6.00	Fine to coarse GRAVEL with some sand and minor silt; grey. Saturated, subangular to subrounded; sand, fine to coarse.
35	(5, 3, 3, 2, 2, 1) N = 8	BH 6.00	6.00–6.90	Gravelly fine to medium SAND; dark brown. Saturated, gravel, fine to coarse, subangular to subrounded.
			6.90–7.50	Fine to coarse GRAVEL with some sand; grey. Saturated, subangular to subrounded; sand, fine to coarse.
60	(0, 0, 0, 0, 0, 0) N = 0	BH 7.50	7.50–8.00	Fine to medium GRAVEL with some sand; dark brown. Saturated, subangular to subrounded; sand, fine to coarse.
			8.00–8.50	Fine to medium SAND, dark brown. Saturated.
			8.50–8.90	Fine to medium GRAVEL with some sand; dark brown. Saturated, subangular to subrounded; sand, fine to coarse.
10	(0, 0, 1, 1, 1, 1) N = 4	BH 9.00	8.90–9.30	Wood fragment
65	(17, 16, 20, 22, 14, 4) N = 60/255 mm	BH 10.50	9.30–12.00	Fine to coarse GRAVEL with some sand and minor silt; grey. Saturated, subangular to subrounded; sand, fine to coarse.
	(6, 7, 5, 4, 3, 5) N = 17	12.00	12.00	End of Borehole at 12.00m, on 18/05/2018 *Termination Reason:*Target depth reached.

Legend: Small Disturbed Sample; Large Disturbed Sample; SPT Liner Sample; Thin Wall Undisturbed Sample; U100 Undisturbed Sample; Pocket Penetrometer Test; Piston Sample; Water Level; Impression Packer Test; Standard Penetration Test; Permeability Test; Piezometer / Standpipe Tip; Packer Test; In-situ Vane Shear Test

LOGGED	C. WILSON
DATE	30/05/2018
CHECKED	J. MUIRSON
DATE	18/06/2018

REMARKS

Coorindates and ground level based on hand held GPS, likely accurate to +/- 5m.

Static water levels: 1.45m bgl at casing depth of 9.00m; 18/5/2018, 1:00 pm 1.50m bgl at casing depth of 7.00m; 18/5/2018, 2:30 pm

500 liters water added

Safety auto trip hammer #396 used (energy ratio 83.3%)

Aurecon NZ Ltd, 93 Cambridge Terrace, Christchurch 8140. Tel: Fax:

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2018 MASW Report

May 2018

GEOPHYSICAL REPORT

MASW Investigation:

Rosemerryn Stages 19 to 24, Lincoln

Report prepared for Aurecon

Southern Geophysical Ltd

3/28 Tanya St, Bromley, Christchurch 8062
Ph: 03 384 4302
Web: www.southerngeophysical.com

Data collected and report prepared for Southern Geophysical by:

Christian Rüegg (MSc), Geophysicist

Mike Finnemore (PhD), Geophysicist

Nick McConachie (BSc), Geologist

Rebecca Gilbert (PgDip), Geologist

Table of Contents

SGL Job 1610

Report Version 1

Summary:

A series of Multi-channel Analysis of Surface Waves (MASW) surveys were undertaken at stages 19 to 24 of the Rosemerryn subdivision, Lincoln on May 24, 2018. The geophysical testing included five MASW lines, orientated South to North across a series of farm paddocks. The profiles show a low velocity unit in the top 5 m of the sections, with a marked increase to 250 m/s between 4 m and 6 m depth. Velocities increase with depth to over 500 m/s at around 15 m to 20 m depth.

Methodology:

MASW is a geophysical technique that uses the dispersive nature of surface waves to model shear-wave velocity versus depth.

A MASW survey is undertaken as a series of lines or points across the surface of the site. The MASW lines in this survey were collected using a 24-channel towed seismic array, with 4.5 Hz geophones. The geophone spacing was 1 m and the source offset was 10 m. The active source was a 12 lb sledgehammer impacting an aluminium plate. Recording parameters for the MASW survey were set with a 0.125 ms sample interval, 1 s record length, 24 dB gains, and an electric trigger system. Shot records were collected at 5 m spacing along the line where possible.

The field records were processed using the Kansas Geological Survey software package SurfSeis5 ©. The geometry was set according to the survey parameters and the dispersion curves were generated and edited. The inversions were run using a 10 layer variable depth model.

The velocity data was interpolated into 2D V_s profiles for the MASW lines. The output shear-wave velocity data is included as a series of data files (CSV format), supplementary to this report.

The midpoint of the MASW seismic array at each shot record was recorded with a Trimble GeoXH GPS system. The GPS points were differentially corrected and output using the New Zealand Geodetic Datum (NZGD) 2000, with Mt Pleasant

2000 coordinates. The site did not have significant elevation changes, and the profiles have not been corrected for topography.

Results:

Five MASW lines with a total length of 1125 meters were surveyed at the site (Figure 1). The site had moderate levels of ambient noise due to traffic on nearby roads. The MASW profiles did not show any major velocity inversions, with shear-wave velocities gradually increasing from less than 100 m/s to over 500 m/s at between 15 m and 20 m depth (Figures 2 to 4). The velocities in the upper 5 m are low, which is consistent with previous MASW surveys conducted at the subdivision. It is recommended that the MASW profiles be correlated with any intrusive investigations to add geological context to the shear-wave velocities.

Disclaimer:

This document has been provided by Southern Geophysical Ltd subject to the following:

Non-invasive geophysical testing has limitations and is not a complete source of testing. Often there is a need to couple non-invasive methods with invasive testing methods, such as drilling, especially in cases where the non-invasive testing indicates anomalies.

This document has been prepared for the particular purpose outlined in the project proposal and no responsibility is accepted for the use of this document, in whole or in part, in other contexts or for any other purpose. Southern Geophysical Ltd did not perform a complete assessment of all possible conditions or circumstances that may exist at the site. Conditions may exist which were undetectable given the limited nature of the enquiry Southern Geophysical Ltd was retained to undertake with respect to the site. Variations in conditions often occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account. Accordingly, additional studies and actions may be required by the client.

We collected our data and based our report on information which was collected at a specific point in time. The passage of time affects the information and assessment provided by Southern Geophysical Ltd. It is understood that the services provided allowed Southern Geophysical Ltd to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes for whatever reason. Where data is supplied by the client or other sources, including where previous site investigation data have been used, it has been assumed that the information is correct. No responsibility is accepted by Southern Geophysical Ltd for incomplete or inaccurate data supplied by others. This document is provided for sole use by the client and is confidential to that client and its professional advisers. No responsibility whatsoever for the contents of this document will be accepted to any person other than the client. Any use which a third party makes of this document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Southern Geophysical Ltd accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

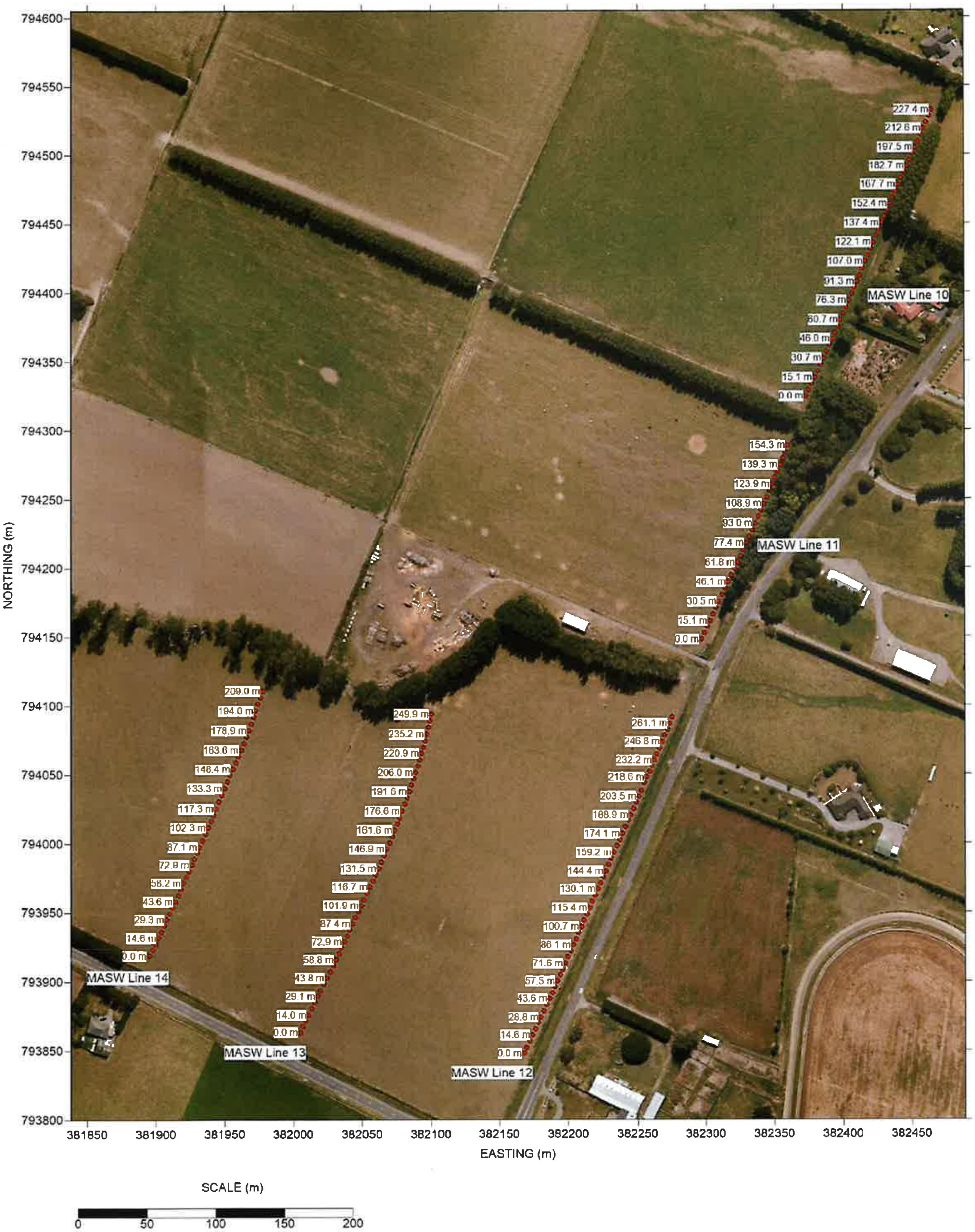
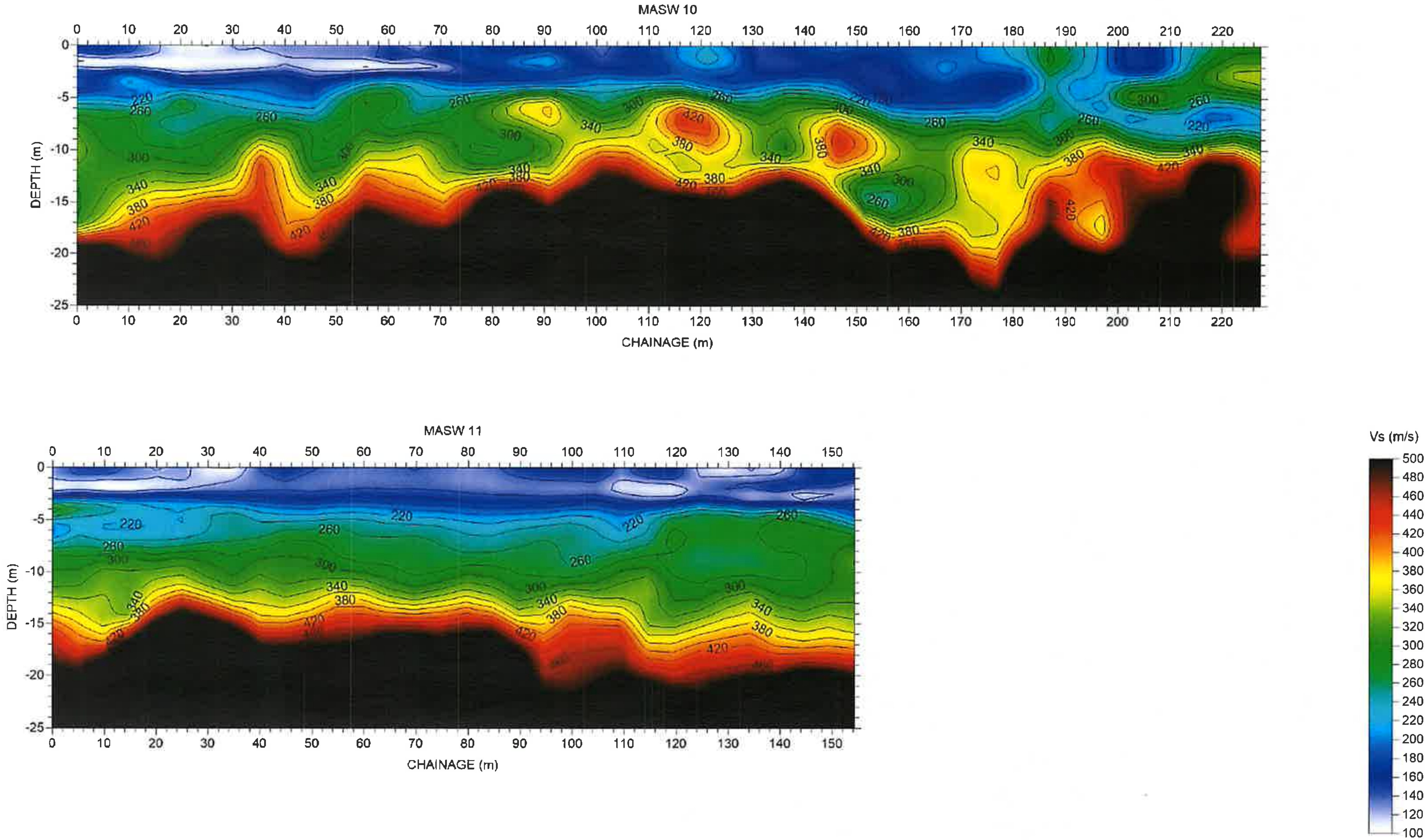


Figure 1: MASW Survey Locations	NOTES- Coordinates Mt Pleasant 2000. Aerial photograph sourced from LINZ, Crown Copyright © MASW Line labels show the chainage along the MASW Lines.	N A3	Southern Geophysical Ltd www.southerngeophysical.com
Rosemerryn Stages 19 to 24, Lincoln			



DRAWING **Figure 2: MASW 2D Vs Profiles 10 and 11**

LOCATION- **Rosemerryn Stages 19 to 24, Lincoln**

NOTES MASW Vs profile has contour intervals of 20 m/s (Vs).

The image scales are:
MASW: 2:1

See site map for location of points

A3

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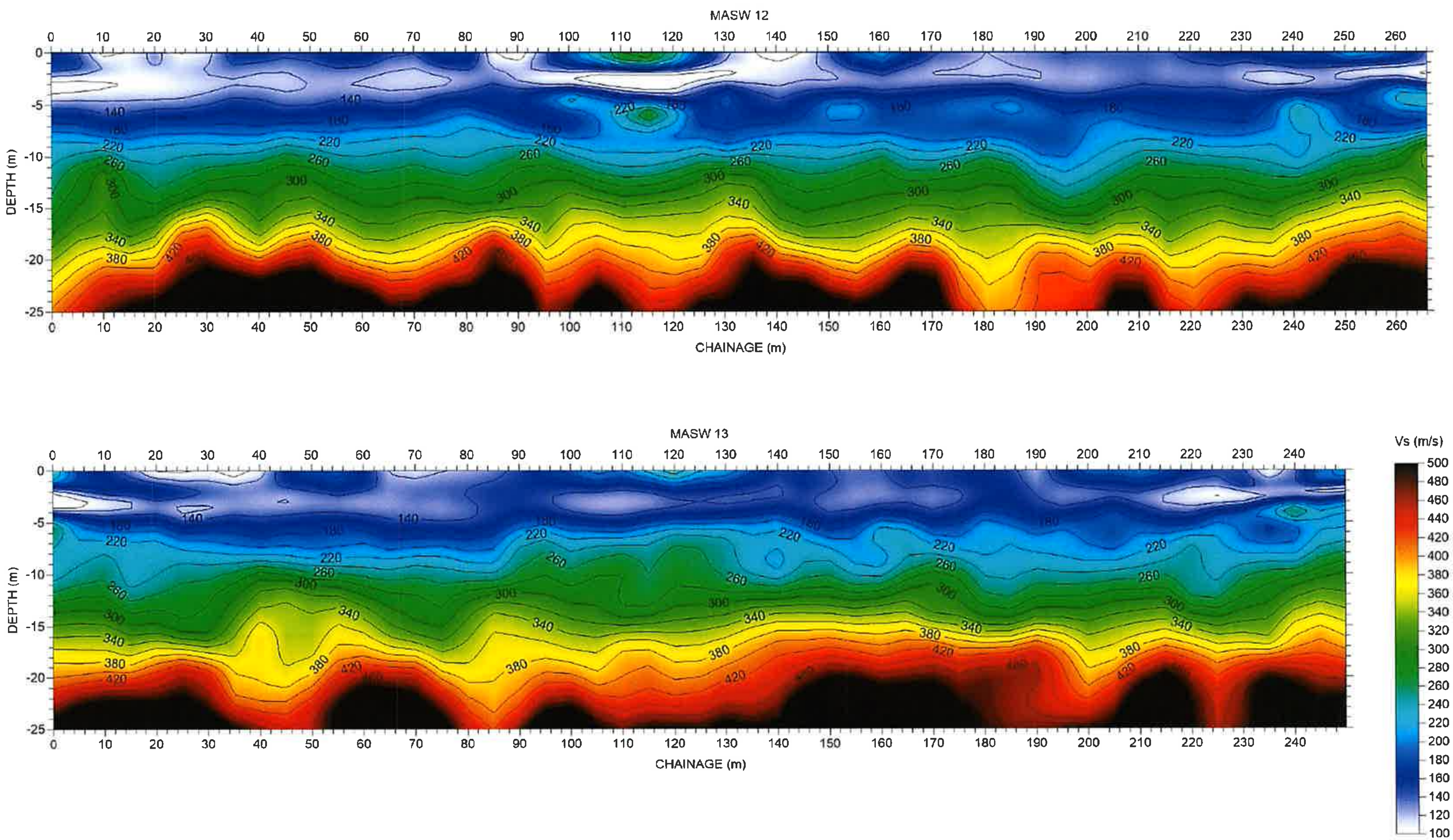

DRAWING- **Figure 3: MASW 2D Vs Profiles 12 and 13**

LOCATION- **Rosemerryn Stages 19 to 24, Lincoln**

NOTES MASW Vs profile has contour intervals of 20 m/s (Vs).

The image scales are:
MASW: 2:1

See site map for location of points

A3

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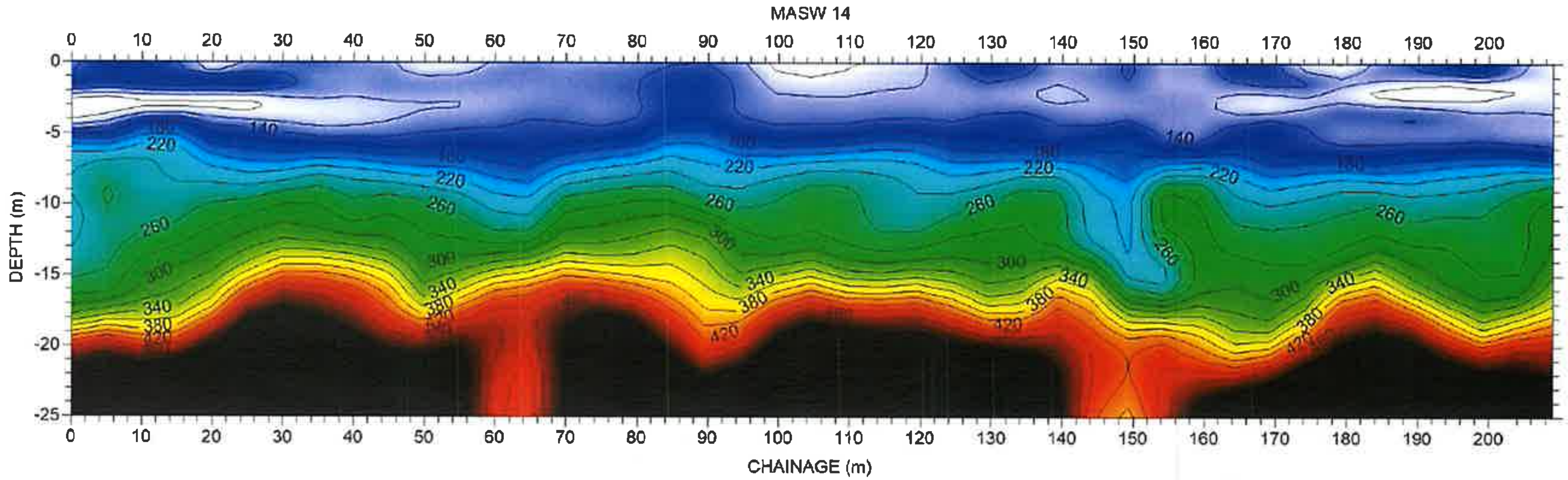

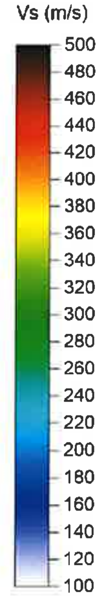

DRAWING- **Figure 4: MASW 2D Vs Profile 14**	NOTES MASW Vs profile has contour intervals of 20 m/s (Vs).
LOCATION- **Rosemerryn Stages 19 to 24, Lincoln**	The image scales are: MASW: 2:1

See site map for location of points

A3

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Liquefaction Results

Client: Fulton Hogan Land Development
Project: Rosemerryn Subdivsior
Subject: Stages 19 to 24 Liquefaction Analysis

Date: Jun-18
Job Number: 224464
By: JMM

Liquefaction Results - CPTs relevant to Stages 19 to 24

Year	CPT	Depth (m)	Ground Profile	GWL (m bgl)	SLS-a (0.13g, Mw7.5) Total Settlement (mm)	Index Settlement (mm)	LSN	Liquefiable Layers		Ishihara
2011	18	6.2	3	1.5	29	N/A	7	3.5	5.4	No
2011	19	3.4	2	1	14	N/A	6	2.1	2.8	No
2011	20	4.3	2	1.5	8	N/A	3	Limited		No
2011	21	3.2	2	1.5	3	N/A	1	Limited		No
2011	22	6.8	3	1.5	20	N/A	5	2	4.2	No
								5.7	6	
2011	23	6.5	3	1.5	30	N/A	7	3.4	5.5	No
2011	24	3.4	2	1	11	N/A	5	2.4	3.1	No
2011	25	3.7	2	1.5	5	N/A	2	Limited		No
2011	26	2	1	1.5	0	N/A	0	Limited		No
2011	27	0.7	1	1.5	0	N/A	0	N/A		No
2012	1	5.86	3	1.5	15	N/A	3	3	3.6	No
								4.4	5.2	
2012	2	7.84	3	1.5	33	N/A	8	2.9	5.2	No
								5.9	6.4	
2012	4	9.7	3	1	38	N/A	10	3.1	5.8	No
2012	27	4.3	3	1	11	N/A	4	Limited		No
2013	19	7.1	3	1.5	28	N/A	6	3.5	5.1	No
								6	6.3	
2013	21	7.5	3	1.5	44	N/A	9	3.6	7.4	No
2013	22	9.4	3	1.5	61	N/A	11	4.5	6.8	No
2018	201	3.64	1	1.5	1	N/A	0	Limited		No
2018	202	2.04	1	1.5	0	N/A	0	Limited		No
2018	203	4.3	2	1.5	2	N/A	1	Limited		No
						N/A				
2018	204	3.34	2	1.5	1	N/A	0	Limited		No
2018	205	6.6	2	1.5	5	N/A	1	Limited		No
2018	206	2.95	2	1.5	0	N/A	0	Limited		No
2018	207	4.21	2	1.5	3	N/A	1	Limited		No
2018	208	4.3	2	1.5	3	N/A	1	Limited		No
2018	209	3.63	2	1.5	5	N/A	2	Limited		No
						N/A				
2018	210	4.15	2	1	10	N/A	5	3	3.8	No
2018	211	3.3	2	1	7	N/A	3	Limited		No
2018	212	3.48	2	1	5	N/A	2	Limited		No
						N/A				
2018	213	6.96	3	1.5	44	N/A	10	Multiple (2m to 6.5m)		No
2018	214	6.05	3	1.5	34	N/A	8	3m to 5.7m		No
						N/A				
2018	215	7.04	3	1.5	54	N/A	12	2.7m to 6.5m		No

Year	CPT	SLS-b (0.19g, Mw6.0) Total Settlement (mm)	Index Settlement (mm)	LSN	Liquefiable Layers		Ishihara	ULS (0.35g, Mw7.5) Total Settlement (mm)	Index Settlement (mm)	LSN	Liquefiable Layers		Ishihara
2011	18	53	N/A	14	2	2.8	No	75	N/A	23	1.5	2.8	Yes
					3.5	5.4					3.5	5.4	
2011	19	37	N/A	17	1.6	3.3	No	50	N/A	25	1.5	3.4	Yes
2011	20	27	N/A	10	1.9	3.6	No	46	N/A	19	1.5	3.7	Yes
2011	21	12	N/A	5	2	2.9	No	37	N/A	17	1.5	3	Yes
2011	22	42	N/A	12	2	4.2	No	63	N/A	23	1.5	4.2	Yes
					5.7	6					5.7	6	
2011	23	58	N/A	16	1.8	2.6	No	76	N/A	25	1.5	2.6	Yes
					3.4	5.5					3.4	5.5	
2011	24	30	N/A	13	1.8	3.1	No	43	N/A	22	1	3.3	Yes
2011	25	19	N/A	8	2.1	3.3	No	36	N/A	16	1.5	1.8	No
											2.1	3.3	
2011	26	1	N/A	1	Limited		No	12	N/A	7	1.5	2	No
2011	27	0	N/A	0	N/A		No	0	N/A	0	N/A		No
2012	1	29	N/A	8	3	3.6	No	40	N/A	12	1.8	2.4	No
					4.4	5.2					3	3.6	
											4.4	5.2	
2012	2	71	N/A	19	1.8	5.2	Yes	93	N/A	28	1.7	5.2	Yes
					5.9	6.4					5.9	6.4	
2012	4	61	N/A	19	1.3	5.8	Maybe	90	N/A	35	1	5.8	Yes
2012	27	31	N/A	14	1.1	3.1	Yes	57	N/A	30	1	3.1	Yes
2013	19	46	N/A	12	2.2	5.1	No	59	N/A	19	1.5	5.2	Yes
					6	6.4					6	6.5	
2013	21	77	N/A	18	2	7.4	No	106	N/A	28	1.5	6.4	Yes
2013	22	92	N/A	20	3	6.8	No	134	N/A	33	1.5	8	Yes
2018	201	4	N/A	3	Limited		No	11	N/A	6	1.5	1.7	No
2018	202	0	N/A	0	Limited		No	0	N/A	0	Limited		No
2018	203	8	N/A	3	Limited		No	29	N/A	13	1.6	2.1	No
			N/A						N/A		2.5	3.2	No
2018	204	5	N/A	2	Limited		No	28	N/A	12	1.6	2.65	Yes
2018	205	17	N/A	5	3.2	4.2	No	56	N/A	20	1.8	4.3	Yes
2018	206	0	N/A	0	Limited		No	12	N/A	7	1.5	2.2	No
2018	207	13	N/A	5	2.5	3.2	No	29	N/A	12	1.5	3.2	Yes
2018	208	14	N/A	5	Limited		No	42	N/A	18	1.6	3	Yes
2018	209	18	N/A	7	1.9	2.5	No	33	N/A	13	1.8	2.5	Yes?
			N/A		3	3.3	No		N/A		2.8	3.4	
2018	210	34	N/A	13	2	3.8	No	56	N/A	26	1.5	3.8	Yes
2018	211	17	N/A	9	1.4	2	No	29	N/A	17	1	2.2	Yes
2018	212	16	N/A	8	1.4	2.4	No	36	N/A	19	1.4	2.4	Yes
			N/A		2.8	3.2			N/A		2.8	3.2	
2018	213	78	N/A	21	3	6.55	Yes	103	N/A	31	1.5	6.6	Yes
2018	214	62	N/A	16	3	5.7	No	84	N/A	23	1.8	2.3	Yes?
			N/A						N/A		3	5.6	Yes
2018	215	54	N/A	23	2.6	6.4	Yes	124	N/A	35	1.5	6.6	Yes

Year	CPT	Sept 2010 (0.33g, Mw7.1) Total Settlement (mm)	Index Settlement (mm)	LSN	Liquefiable Layers		Ishihara	Sept 2010 (0.19g, Mw7.1) Total Settlement (mm)	Index Settlement (mm)	LSN	Liquefiable Layers		Ishihara
2011	18	74	N/A	23	1.5	2.8	Yes	60	N/A	16	1.9	2.8	No
					3.5	5.4					3.5	5.4	
2011	19	49	N/A	24	1.5	3.4	Yes	43	N/A	20	1.6	3.4	Yes
2011	20	46	N/A	19	1.5	3.7	Yes	35	N/A	14	1.9	3.7	No
2011	21	37	N/A	17	1.5	3	Yes	19	N/A	9	2	2.9	No
2011	22	63	N/A	23	1.5	4.2	Yes	49	N/A	15	2	4.2	No
					5.7	6					5.7	6.1	
2011	23	76	N/A	25	1.5	2.6	Yes	66	N/A	20	1.8	2.6	No
					3.4	5.5					3.4	5.5	
2011	24	43	N/A	15	1	3.3	Yes	33	N/A	11	1.7	3.2	No
2011	25	36	N/A	16	1.5	1.8	No	26	N/A	11	2.6	3.3	No
					2.1	3.3							
2011	26	11	N/A	7	1.5	2	No	3	N/A	2	1.5	2	No
2011	27	0	N/A	0	N/A		No	6	N/A	0	N/A		No
2012	1	40	N/A	12	1.8	2.4	No	34	N/A	10	1.8	2.4	No
					3	3.6					3	3.6	
					4.4	5.2					4.4	5.2	
2012	2	93	N/A	28	1.7	5.2	Yes	84	N/A	24	1.7	5.2	Yes
					5.9	6.4					5.9	6.4	
2012	4	89	N/A	35	1	5.8	Yes	71	N/A	24	1.5	5.9	No
2012	27	56	N/A	30	1	3.1	Yes	40	N/A	19	1.1	3.1	Yes
2013	19	59	N/A	19	1.5	5.2	Yes	50	N/A	15	1.7	5.2	No
					6	6.5					6	6.4	
2013	21	105	N/A	29	1.5	6.4	Yes	89	N/A	22	2	6.4	No
2013	22	132	N/A	32	1.5	8	Yes	100	N/A	24	2	6.9	No
2018	201	10	N/A	6	1.5	1.7	No	7	N/A	4	1.5	1.7	No
2018	202	0	N/A	0	Limited		No	0	N/A	0	Limited		No
2018	203	28	N/A	13	1.6	2.1	No	13	N/A	6	1.6	2.1	No
			N/A		2.5	3.2	No		N/A		2.5	2.9	No
2018	204	25	N/A	12	1.9	2.65	Yes	9	N/A	4	1.6	2.4	No
2018	205	57	N/A	19	1.8	4.3	Yes	29	N/A	9	1.9	4.2	Yes
2018	206	10	N/A	6	1.5	2.2	No	1	N/A	1	Limited		No
2018	207	29	N/A	12	1.5	3.2	Yes	19	N/A	7	2.6	3.25	No
2018	208	41	N/A	17	1.6	3	Yes	20	N/A	8	1.6	3	No
2018	209	33	N/A	13	1.8	2.5	Yes?	25	N/A	10	1.9	2.5	No
			N/A		2.8	3.4			N/A		2.8	3.4	No
2018	210	56	N/A	28	1.5	3.8	Yes	42	N/A	17	1.4	3.8	No
2018	211	29	N/A	17	1	2.2	Yes	20	N/A	11	1.4	2.2	No
2018	212	35	N/A	10	1.4	2.4	Yes	24	N/A	12	1.4	2.4	No
			N/A		2.8	3.2			N/A		2.8	3.2	
2018	213	102	N/A	31	1.5	6.6	Yes	89	N/A	25	1.7	6.6	Yes
2018	214	84	N/A	23	1.8	2.3	Yes?	71	N/A	19	1.8	2.4	No
			N/A		3	5.6	Yes		N/A		3.1	5.6	
2018	215	123	N/A	35	1.5	6.6	Yes	104	N/A	26	2.3	6.5	Yes

RMA Assessment

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RMA Section 106 (1 & 1A) Assessment – Quarryview Subdivision - 253852

Client	Fulton Hogan Land Developmer	Project No.	224464
Prepared by	James Muirson	Reviewed by	Jan Kupec

Risk Rating Matrix

Most Likely Consequence	5 - Very likely	4 - Good chance	3 - Likely	2 - Unlikely	1 - Very unlikely
	Likelihood of occurrence				
A - Disastrous	Extreme	Extreme	Extreme	Extreme	High
B - Critical	Extreme	Extreme	Extreme	High	High
C - Serious	Extreme	High	High	Moderate	Moderate
D - Significant	High	High	Moderate	Low	Low
E - Minor	Moderate	Moderate	Low	Low	Low

IDENTIFY NATURAL HAZARD		ASSESS RISK Section 1A (a) & (b)				RESIDUAL RISK ASSESSMENT Section 1A (a) & (b)				
Risk Source (Hazard)	Damage	Likelihood	Consequence	Risk Rating	Control Measure (Risk Treatment)	Likelihood	Consequence	Risk Rating	Subsequent use of the land accelerate, worsen, or result in material damage resulting from hazard Section 1A (c)	Comments or Recommendations
Earthquake/Seismic										
Liquefaction induced ground damage (settlement, sand boils, cracking)	Liquefaction in major seismic events is likely but is likely to be TC2 equivalent	3 - Likely	D - Significant	Moderate	Mitigation strategies in the form of strengthened structural foundations or ground improvement have been provided	1 - Very unlikely	E - Minor	Low	No	Development can proceed provided recommendations in this report are followed and appropriate engineering measures implemented.
Liquefaction induced lateral spreading	Liquefaction induced lateral spreading is unlikely due to the lack of free, sloping faces.	1 - Very unlikely	E - Minor	Low	No specific mitigation measure proposed at this stage	1 - Very unlikely	E - Minor	Low	No	
Seismic Induced Slope Instability (incl Mass Movement)	The site is relatively flat and as such is not likely to be at risk from seismically induced mass movement	1 - Very unlikely	E - Minor	Low	No specific mitigation measure proposed at this stage	1 - Very unlikely	E - Minor	Low	No	
Seismic Induced Rockfall	No rockfall sources above site.	1 - Very unlikely	E - Minor	Low	No specific mitigation measure proposed at this stage	1 - Very unlikely	E - Minor	Low	No	
Seismic Induced Cliff Collapse	No cliff above site.	1 - Very unlikely	E - Minor	Low	No specific mitigation measure proposed at this stage	1 - Very unlikely	E - Minor	Low	No	
Fault Rupture	No known active faults near the site.	1 - Very unlikely	E - Minor	Low	No specific mitigation measure proposed at this stage	1 - Very unlikely	E - Minor	Low	No	
Landslip/Landslide/Land Instability/Subsidence										
Landslide/Landslip	No evidence of slips around the development sites and due to lack of slopes, slips are unlikely.	1 - Very unlikely	E - Minor	Low	N/A	1 - Very unlikely	E - Minor	Low	No	Development can proceed provided recommendations in this report are followed and appropriate engineering measures implemented.
Deep Sealed Landslide	No evidence of deep seated instability	1 - Very unlikely	E - Minor	Low	N/A	1 - Very unlikely	E - Minor	Low	No	
Earth/Debris flows	No earthflow sources above site nor any evidence of previous earthflows affecting site	1 - Very unlikely	E - Minor	Low	N/A	1 - Very unlikely	E - Minor	Low	No	
Rockfall or Topple	No rockfall sources above site	1 - Very unlikely	E - Minor	Low	N/A	1 - Very unlikely	E - Minor	Low	No	
Other										
Soft Ground Settlement	Potential for settlement of building foundations and other infrastructure due to the presence of soft silts, at depths of 2m to 3m.	2 - Unlikely	D - Significant	Low	Soft soils are reasonable depth so unlikely to cause settlement provided appropriate foundation design is undertaken and includes the use of enhanced slabs.	2 - Unlikely	E - Minor	Low	No	Development can proceed provided recommendations in this report are followed and appropriate engineering measures implemented.

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RMA Section 106 (1 & 1A) Assessment – Quarryview Subdivision - 253852

Client	Fulton Hogan Land Developmei	Project No.	224464
Prepared by	James Muirson	Reviewed by	Jan Kupec

Risk Rating Matrix

	Likelihood of occurrence				
Most Likely Consequence	5 - Very likely	4 - Good chance	3 - Likely	2 - Unlikely	1 - Very unlikely
A - Disastrous	Extreme	Extreme	Extreme	Extreme	High
B - Critical	Extreme	Extreme	Extreme	High	High
C - Serious	Extreme	High	High	Moderate	Moderate
D - Significant	High	High	Moderate	Low	Low
E - Minor	Moderate	Moderate	Low	Low	Low

IDENTIFY NATURAL HAZARD		ASSESS RISK Section 1A (a) & (b)				RESIDUAL RISK ASSESSMENT Section 1A (a) & (b)				
Risk Source (Hazard)	Damage	Likelihood	Consequence	Risk Rating	Control Measure (Risk Treatment)	Likelihood	Consequence	Risk Rating	Subsequent use of the land accelerate, worsen, or result in material damage resulting from hazard Section 1A (c)	Comments or Recommendations
Erosion	Due to finer nature of soil, erosion is possible either by concentrated stormwater runoff or subsurface seepages.	3 - Likely	E - Minor	Low	Adequate site stormwater control to be incorporated with site development and exposed soil covered with topsoil/vegetation.	2 - Unlikely	E - Minor	Low	No	As part of the civil design of the subdivision adequate stormwater and erosion control will be required. If subsoil seeps are encountered during site development then these will need to be assessed

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