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WARRINGAH COUNCIL
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Construction
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REPORT

TO

WARRINGAH COUNCIL

ON

GEOTECHNICAL INVESTIGATION

FOR

PROPOSED LIGHT POLES

AT

NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

3 March 2011

Ref: 24681LBrpt

Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS
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1 INTRODUCTION

This report presents the results of a geotechnical investigation for the proposed light poles at the northern end of Nolan Reserve on Pittwater Road, North Manly, NSW. The investigation was commissioned by Mr Scot Hedge of Warringah Council and was carried out in accordance with our proposal dated 4 February 2011 (Ref: P33534LB).

As shown on the supplied drawings by Cordula Consulting Pty Ltd (Job No. 09426, Drawing Nos S01 and S02, Rev B, dated 18/8/10) light poles are proposed around the perimeter of the ovals within Nolan Reserve. This investigation was for the six north-westernmost poles, around Fields 1 and 2 and Junior Field 1, as shown on Figure 1. The drawings show that the light poles will be supported by bored piles, with a preliminary design being 900mm diameter piles founded at depths of 3.6m or 4m within material adequate for an allowable bearing pressure of 150kPa. Although the drawings quote a geotechnical investigation report, Mr Rick Briske has advised that no geotechnical investigation for the light poles has previously been undertaken.

The purpose of the investigation was to obtain geotechnical information on subsurface conditions at each proposed light pole location as a basis for comments and recommendations on parameters for the design of footings for the proposed poles.

2 INVESTIGATION PROCEDURE

Electrical Friction Cone Penetrometer (EFCP) tests 1 to 5 and 6c were carried out to depths ranging from 7.43m to 30.53m below the existing ground surface using our truck mounted EFCP testing rig. At test location 6, two tests (EFCP6 and EFCP6b) refused at shallow depth of 0.41m and 0.42m, but EFCP6c was able to penetrate the upper soils and was carried out to a depth of 9.61m. Prior to our arrival the proposed light pole locations were marked on site by Warringah Council. The test locations were located as close as practical to the marked pole locations. Prior to testing, the test locations were checked for underground services using electronic service detection equipment.

EFCP testing involves continuously pushing a testing probe with a 35mm diameter conical tip into the soil using the hydraulic rams of our ballasted truck mounted EFCP rig. Measurements are made during testing of the end resistance of the cone tip and the frictional resistance of a separate 134mm long sleeve located directly behind the cone.

EFCP testing does not provide sample recovery. The subsurface material identification, including material strength/relative density, is by interpretation of the test results based on past experience and empirical correlations. Further details of the methods and procedures employed in the investigation, including the limitation of the EFCP testing, are presented in the attached Report Explanation Notes.

The test holes were checked for groundwater on completion.

The EFCP test results, including our interpreted subsurface profile are attached to this report.

3 RESULTS OF INVESTIGATION

3.1 Site Description

The site comprises the north-western end of Nolan Reserve, with a shallow (0.4m deep) drainage channel running along the south-eastern boundary. The site is located within gently sloping terrain that falls towards the south and the adjacent Brookvale Creek. Brookvale Creek runs along the south-western boundary of the site and eventually drains into Manly Lagoon.

The site comprises grassed sporting fields, with trees and shrubs around the perimeter. A two storey brick amenities and clubhouse building is located in the western corner of the site. This building appeared to be in fair external condition. The site is bounded to the north-east by Pittwater Road, with residential properties on the far side of Pittwater Road. To the north-west are bowling greens of the adjoining bowling club and to the south-east are more sporting fields within the remainder of Nolan Reserve. To the south-west is Brookvale Creek and then Warringah Golf Course.

3.2 Subsurface Conditions

The EFCP test results indicate a subsurface profile of alluvial soils, possibly with fill within the upper soils.

The upper 1m to 2m of the tests comprised banded sands and clays and we consider that this is likely to be fill. EFCP6 and EFCP6b refused on obstructions within the inferred fill at depths of 0.41m and 0.42m, respectively. Below this the soils were interpreted to comprise silty clay, organic clay, clayey silt and sandy silt generally of very soft to firm strength with some stiff to very stiff bands in EFCP1 and EFCP2. The clayey and silty soils extended to depths ranging from 3.2m to 5.6m.

Below depths of 3.2m to 5.6m, sand was encountered that was generally of medium dense relative density with some loose or very loose bands and occasional clay bands. However, in EFCP3 the sands were only of loose relative density. These sands extended to depths ranging from 6.9m to 9m. Below these depths silty clays, sandy silts and clayey silts of soft to firm strength were encountered to the limit of the tests.

EFCP1 was extended significantly deeper than the other EFCP tests and the clayey silt/silty clay continued with depth. This clayey silt/silty clay was initially of soft to firm strength, becoming firm to stiff with depth, until a depth of 24.5m where a banded profile of loose to medium dense sands, silty sands and stiff to very stiff silty clays was encountered. Stiff to very stiff silty clay was encountered below a depth of 27.25m and extended to the limit of the test at a depth of 30.53m.

The test holes were checked for groundwater on completion and groundwater was measured in EFCP3 and EFCP5 at depths of 1m and 0.9m, respectively. The other test holes collapsed at depths ranging from 0.9m to 1.5m and this may indicate groundwater as test holes in sandy soils tend to collapse where groundwater is encountered.

Reference should be made to the attached EFCP test results for detailed test results and our interpreted subsurface profile.

4 COMMENTS AND RECOMMENDATIONS

From the supplied drawings by Cordula Consulting Pty Ltd the light poles are to be supported on bored piers of 900mm diameter drilled to depths of 3.6m or 4m into material adequate for an allowable bearing pressure of 150kPa. We note that the upper fill and soft clays and silt would not meet this requirement and we recommend that the piled footings be specifically designed for the actual subsurface conditions at each pole location. Our recommended parameters to design the footings are given below.

We do not recommend the use of bored piers for this site as the sides of the pier holes would almost certainly collapse and difficulties with groundwater seepage would occur given the shallow groundwater at depths of 0.9m to 1.5m. Auger, grout injected (CFA) piles may be used to overcome these difficulties. Consideration could be given to the use of driven piles, but the vibration effect on the nearby structures, i.e. existing buildings, etc, would need to be considered and advice from specialist piling contractors on the suitability of such piles should be sought.

Since the vertical loads on the pole footings will be quite low the critical factor in the design of the footing system is likely to be the lateral capacity. Nevertheless, we recommend that the piles be founded within the loose or medium dense sands encountered at depths between 3.2m and 9m and not within the upper soft silts and clays due to the risk of pile settlements.

At each pole location we have provided our recommended founding depth and allowable end bearing pressure for the piles. These bearing pressures take into account any underlying weaker layers at each location. If piles need to be founded at different depths than given below (such as to satisfy lateral capacity) we should be contacted to provide specific advice. If piles are founded deeper than the depths given below the underlying weaker layers will have a greater effect and will result in lower bearing pressures being appropriate.

EFCP Location	Founding Depth	Founding Material	Allowable End Bearing Pressure
EFCP1	6m	Medium dense sand	400kPa
EFCP2	5.5m	Medium dense sand	400kPa
EFCP3	6.5m	Loose sand	150kPa
EFCP4	5m	Loose to medium dense sand	150kPa
EFCP5	4.5m	Medium dense sand	400kPa
EFCP6c	5.5m	Medium dense sand	200kPa

The above allowable end bearing pressures are based on a 900mm diameter pile and may not be appropriate for different pile diameters. Further advice is recommended where alternate pile diameters are proposed.

Allowable shaft adhesions of 5kPa within loose sands and 10kPa within medium dense sands may be used. Since the current proposed pile sizes are preliminary we should be commissioned to review the final pile design to confirm that the founding depths and allowable end bearing pressures are appropriate.

Analysis and design of the piles for lateral loads may be based on the parameters given in the table below. Parameters are given for the soils encountered within the EFCP tests and the designer will need to assess the specific subsurface conditions for each pole by reference to the EFCP test results. If required, we can complete lateral pile analysis using the computer program Wallap to estimate the lateral capacity and deflection of piles supporting the poles, if we are provided with the final design loads on the footing system.

Material	Friction Angle	Bulk Unit Weight	Undrained Shear Strength	Poissons Ratio	Elastic Modulus
Fill and very loose sands	25°	15kN/m^3	-	0.3	4MPa
Very soft to soft clays/silts	20° (c' = 0)	15kN/m^3	10kPa	0.35	3MPa
Loose sands	27°	17kN/m^3	-	0.3	15MPa
Medium dense sands	30°	20kN/m^3	-	0.3	20MPa

Due to the generally poor and somewhat variable subsurface conditions, we recommend that the lateral capacity of the piles be checked by a geotechnical engineer to confirm that the intent of our recommendations provided herein have been adopted and assess the required pile lengths and movements.

5 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and Jeffery and Katauskas Pty Ltd accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

A waste classification will need to be assigned to any soil excavated from the site prior to offsite disposal. Subject to the appropriate testing, material can be classified as Virgin Excavated Natural Material (VENM), General Solid, Restricted Solid or Hazardous Waste. If the natural soil has been stockpiled, classification of this soil as Excavated Natural Material (ENM) can also be undertaken, if requested. However, the criteria for ENM are more stringent and the cost associated with attempting to meet these criteria may be significant. Analysis takes seven to 10 working days to complete, therefore, an adequate allowance should be included in the construction program unless testing is completed prior to construction. If contamination is encountered, then substantial further testing (and associated delays) should be expected. We strongly recommend that this issue is addressed prior to the commencement of excavation on site.

If there is any change in the proposed development described in this report then all recommendations should be reviewed.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. Copyright in this report is the property of Jeffery and Katauskas Pty Ltd. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

Should you have any queries regarding this report, please do not hesitate to contact the undersigned.

For and on behalf of
JEFFERY AND KATAUSKAS PTY LTD.

Daniel Bliss
Senior Associate

Reviewed by:

Linton Speechley
Principal

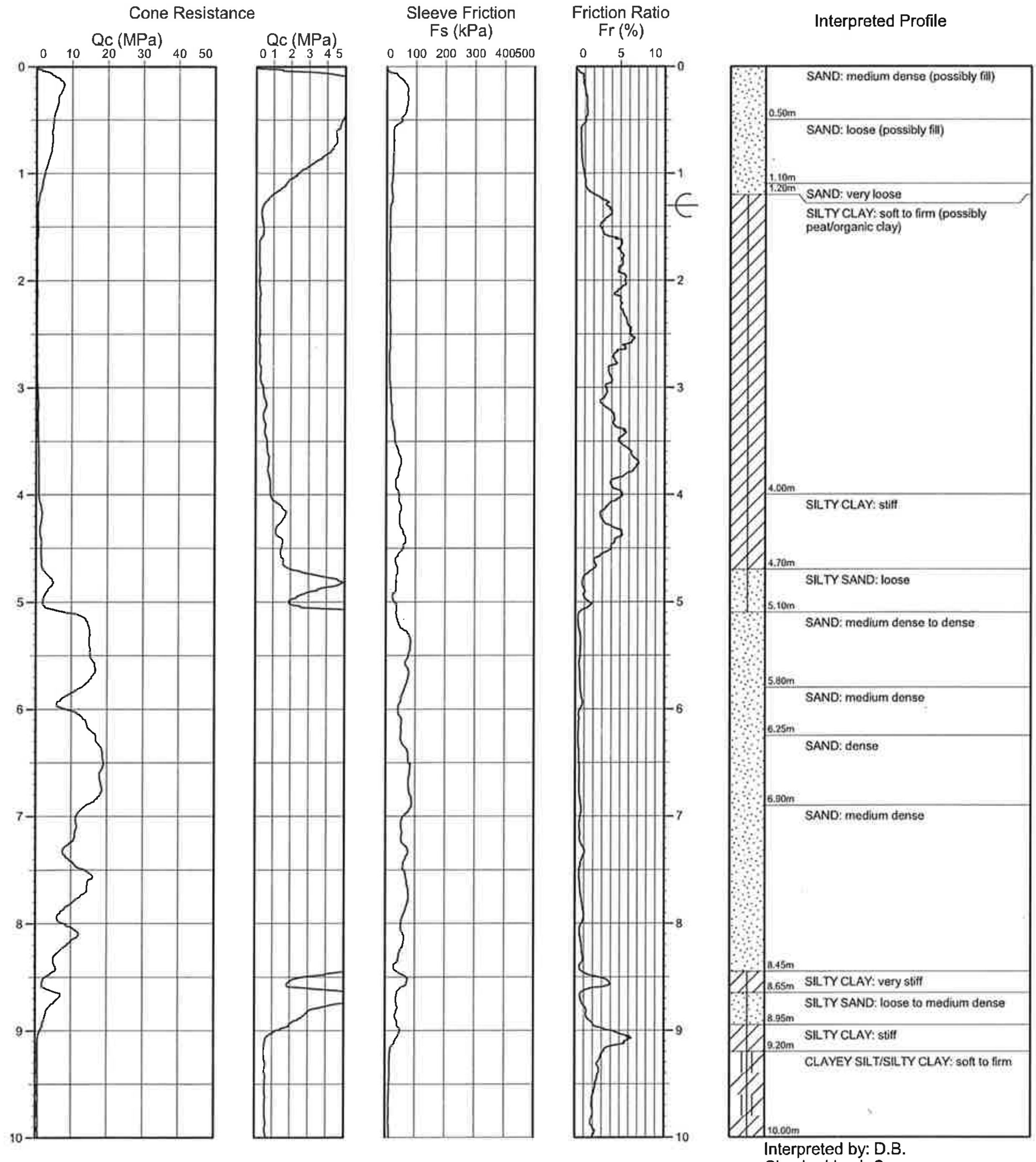
Jeffery and Katauskas Pty Ltd
CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
1
1 / 4

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL
Project: PROPOSED LIGHT POLES
Location: NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

Job No.: 24681LB	**R.L. Surface:** N/A	**Data File:** 24681B_1.GEF
Date: 15/02/11	**Datum:**	**Operator:** M.T.



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Checked by: L.S.

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EFCP No.
1
2 / 4

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client:	WARRINGAH COUNCIL		
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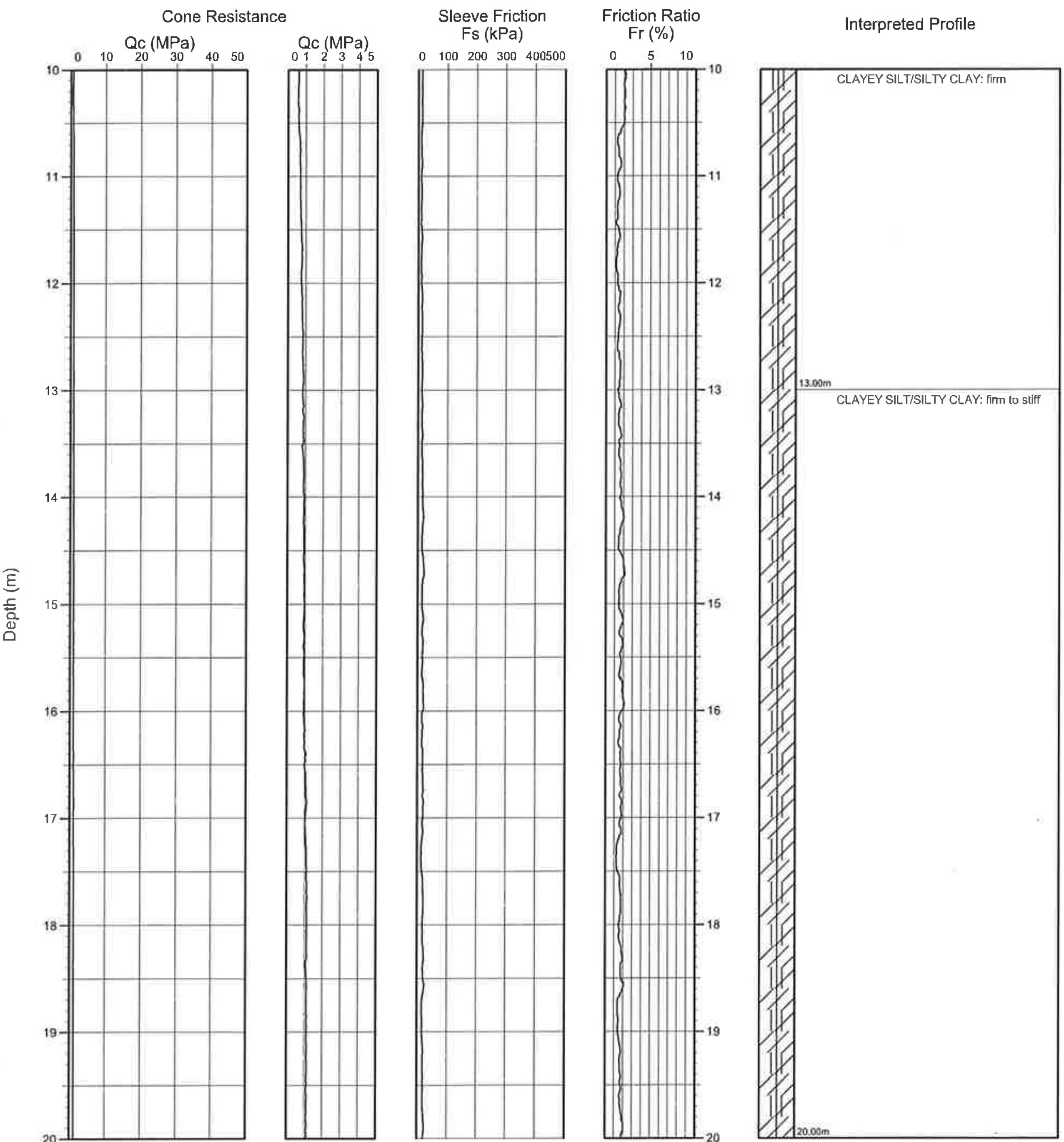

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Checked by: L.S.

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EFCP No.
1
3 / 4

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL
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Job No.: 24681LB	**R.L. Surface:** N/A	**Data File:** 24681B_1.GEF
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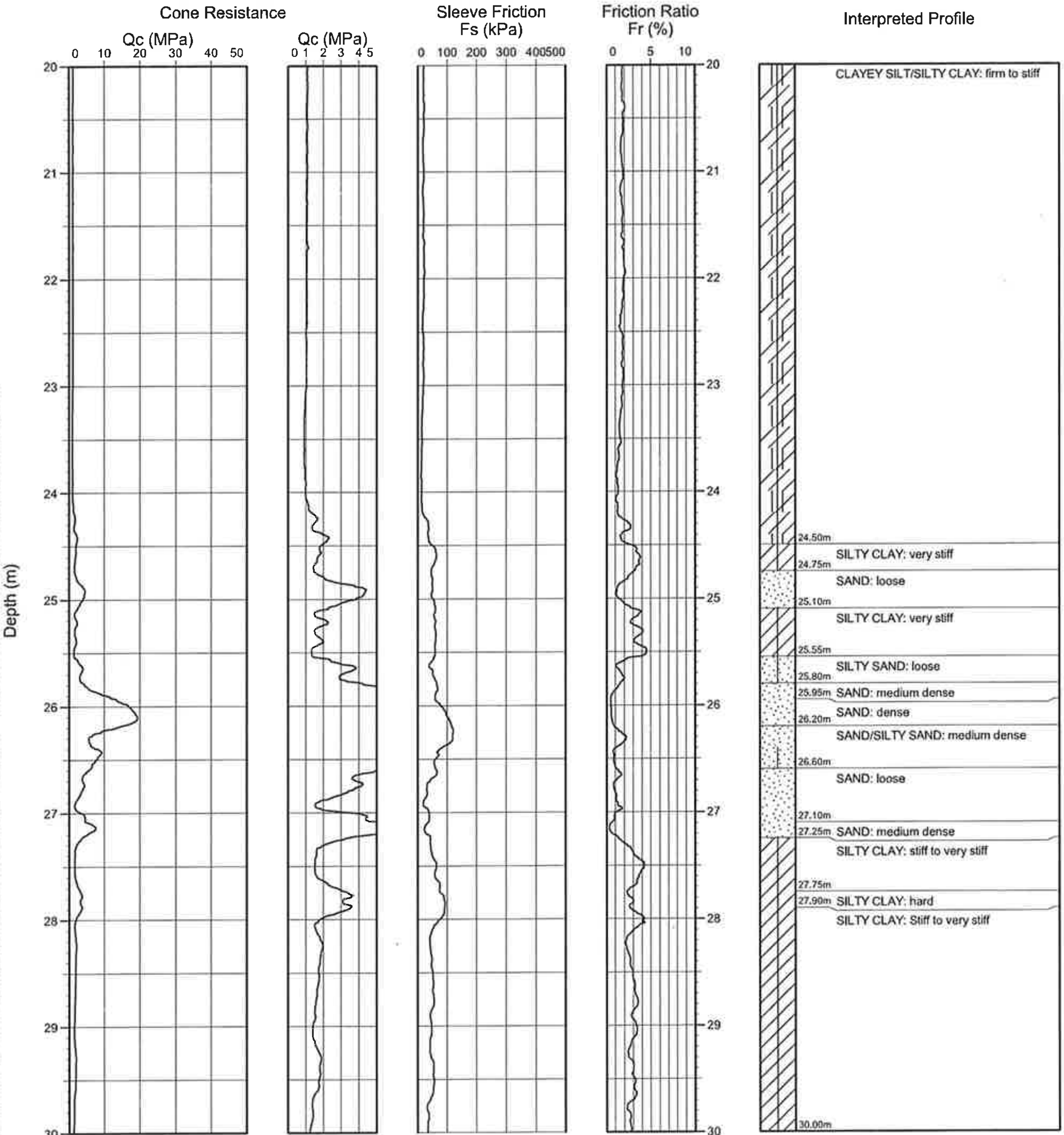

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Checked by: L.S.

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1

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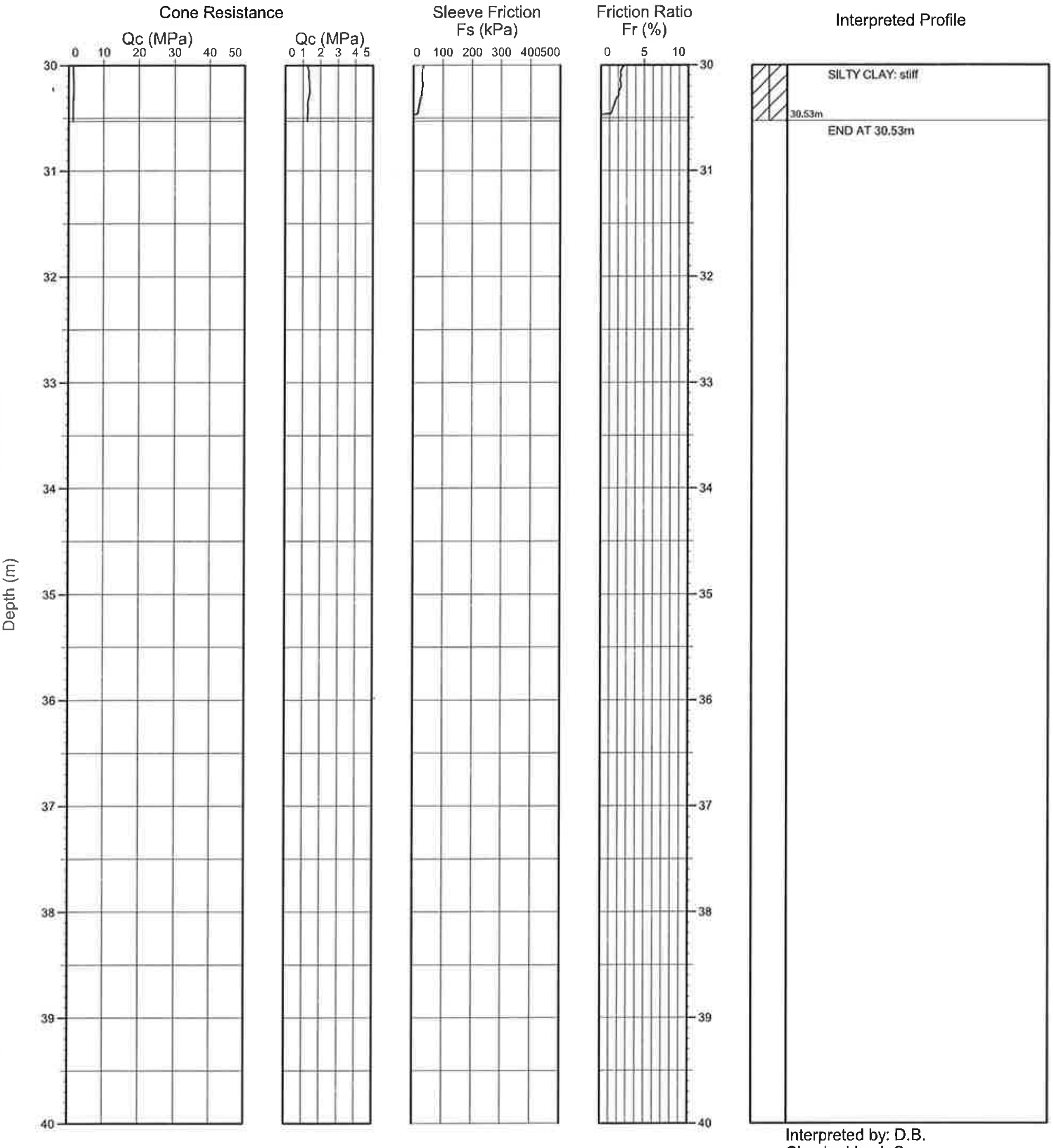

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EFCP No.
2
1 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client:	WARRINGAH COUNCIL
Project:	PROPOSED LIGHT POLES
Location:	NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

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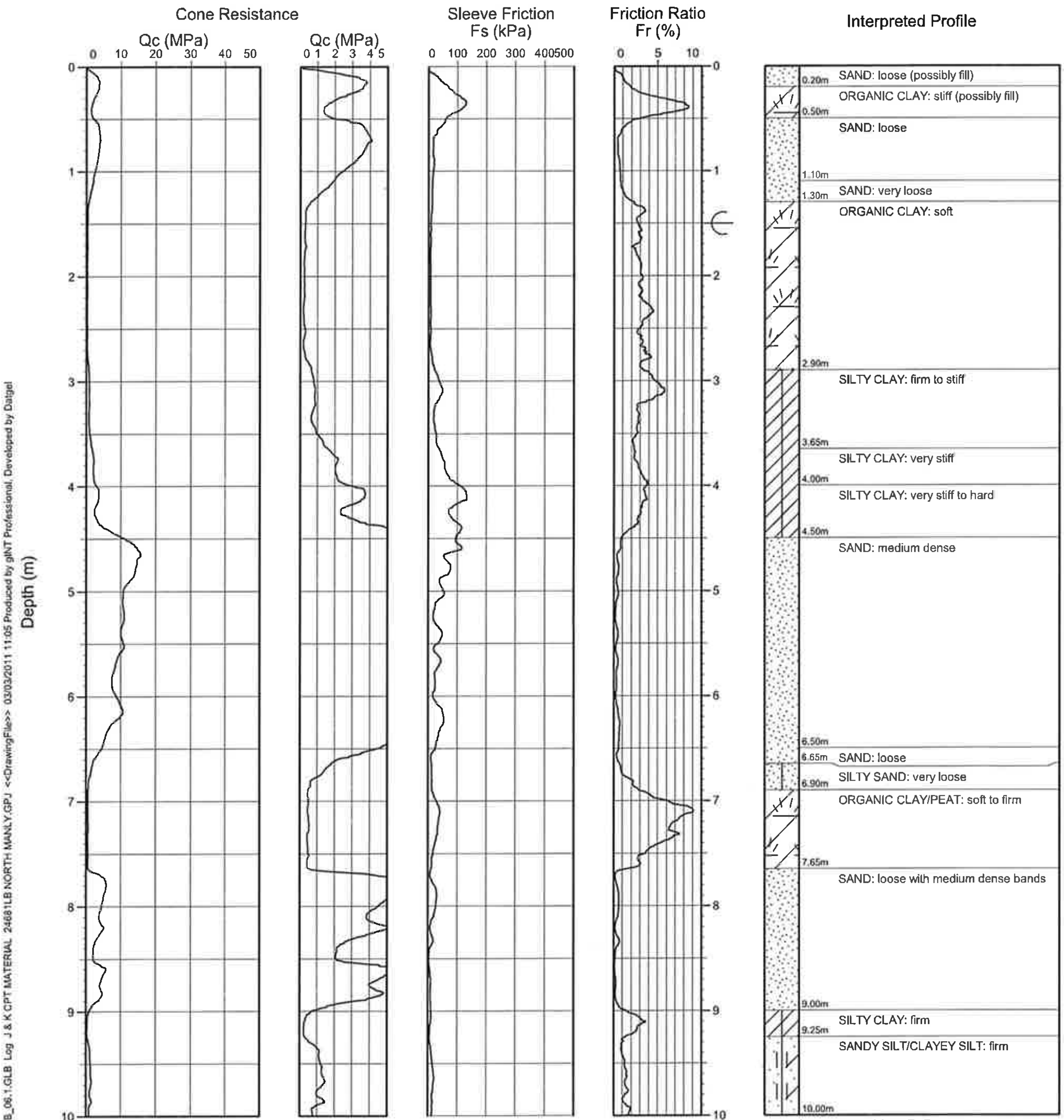

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Checked by: L.S.

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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
2
2 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL
Project: PROPOSED LIGHT POLES
Location: NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

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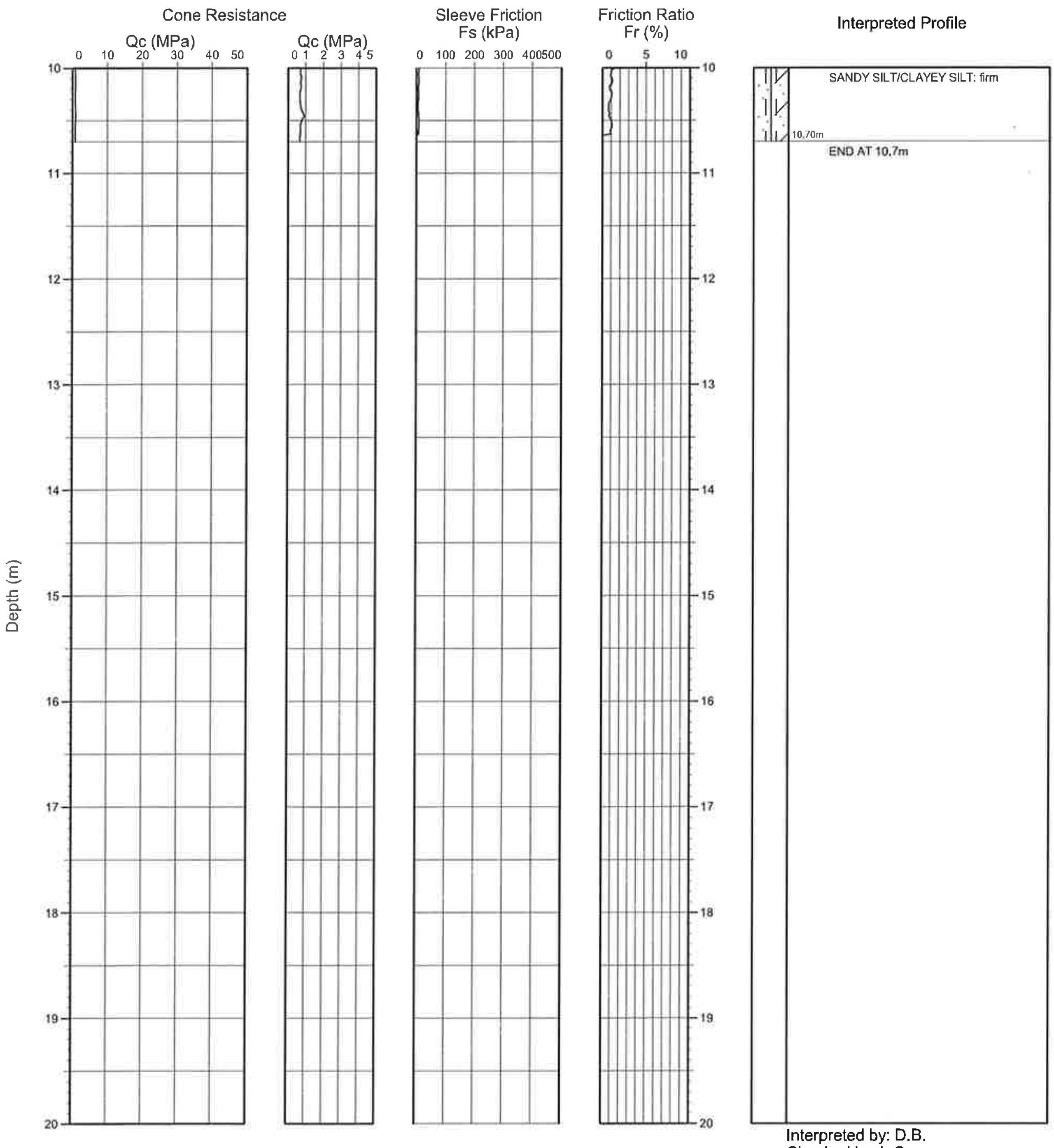

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Checked by: L.S.

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EFCP No.
3
1 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL
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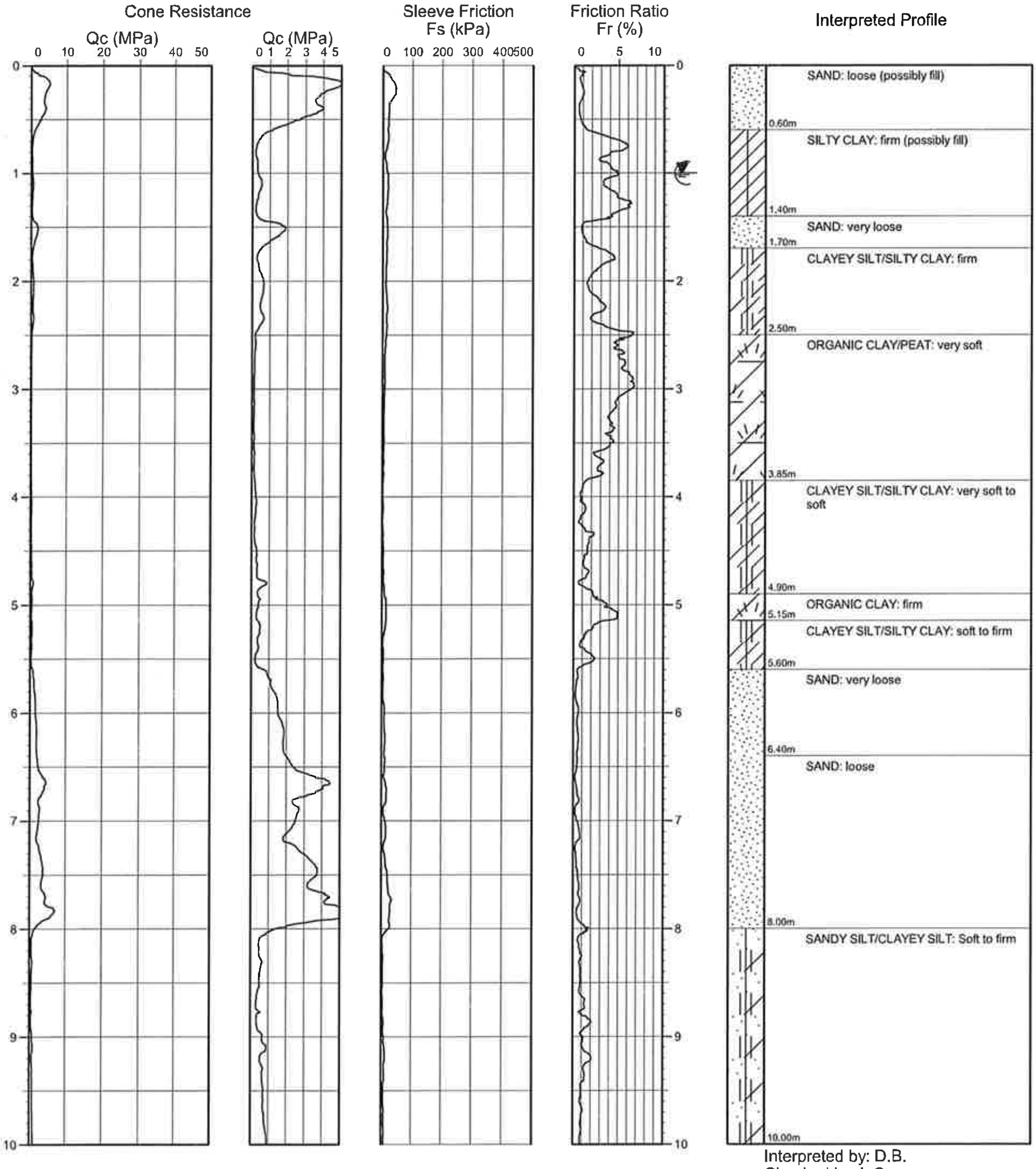

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EFCP No.
3
2 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL
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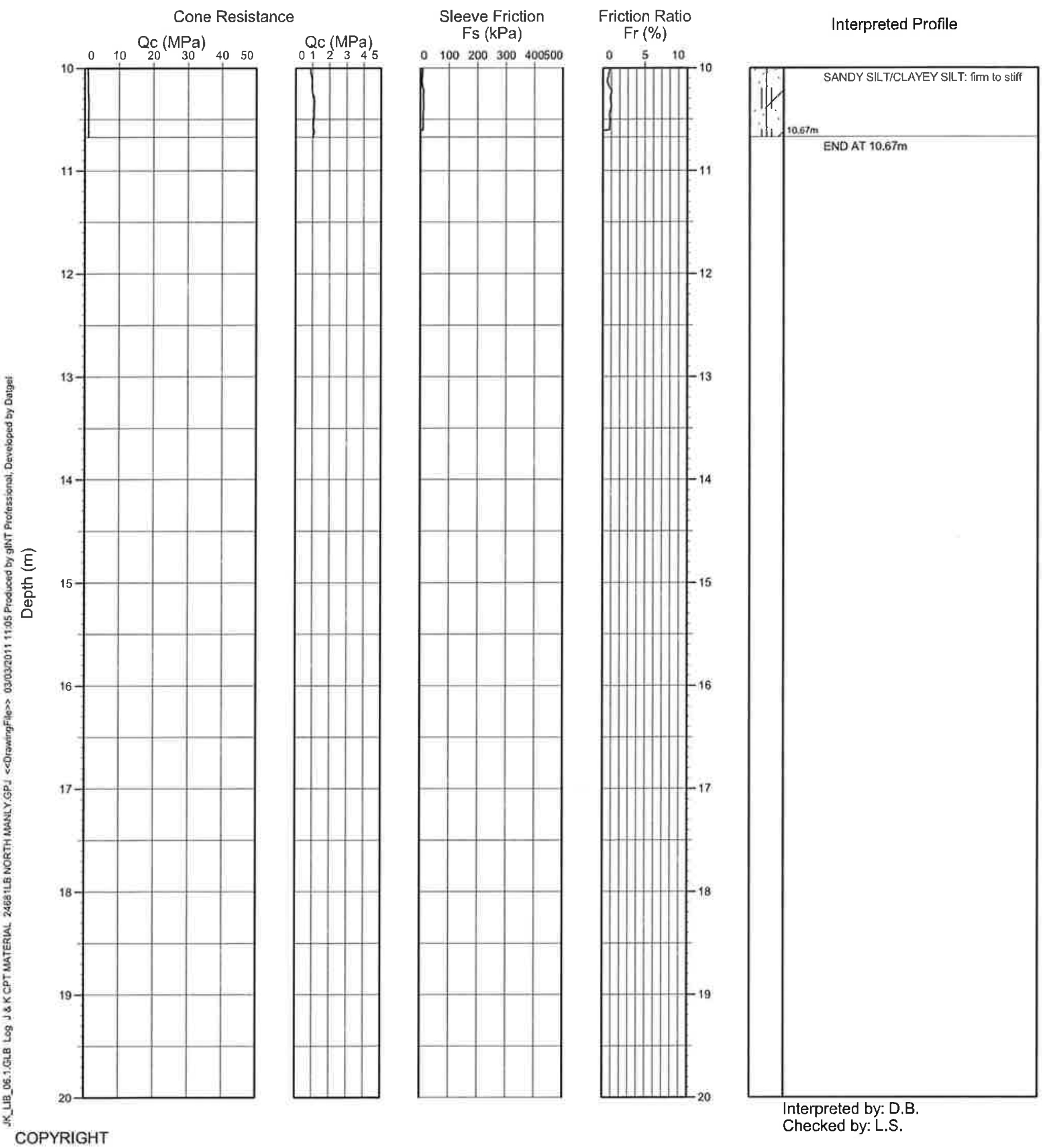

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Checked by: L.S.

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EFCP No.
4
1 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client:	WARRINGAH COUNCIL
Project:	PROPOSED LIGHT POLES
Location:	NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

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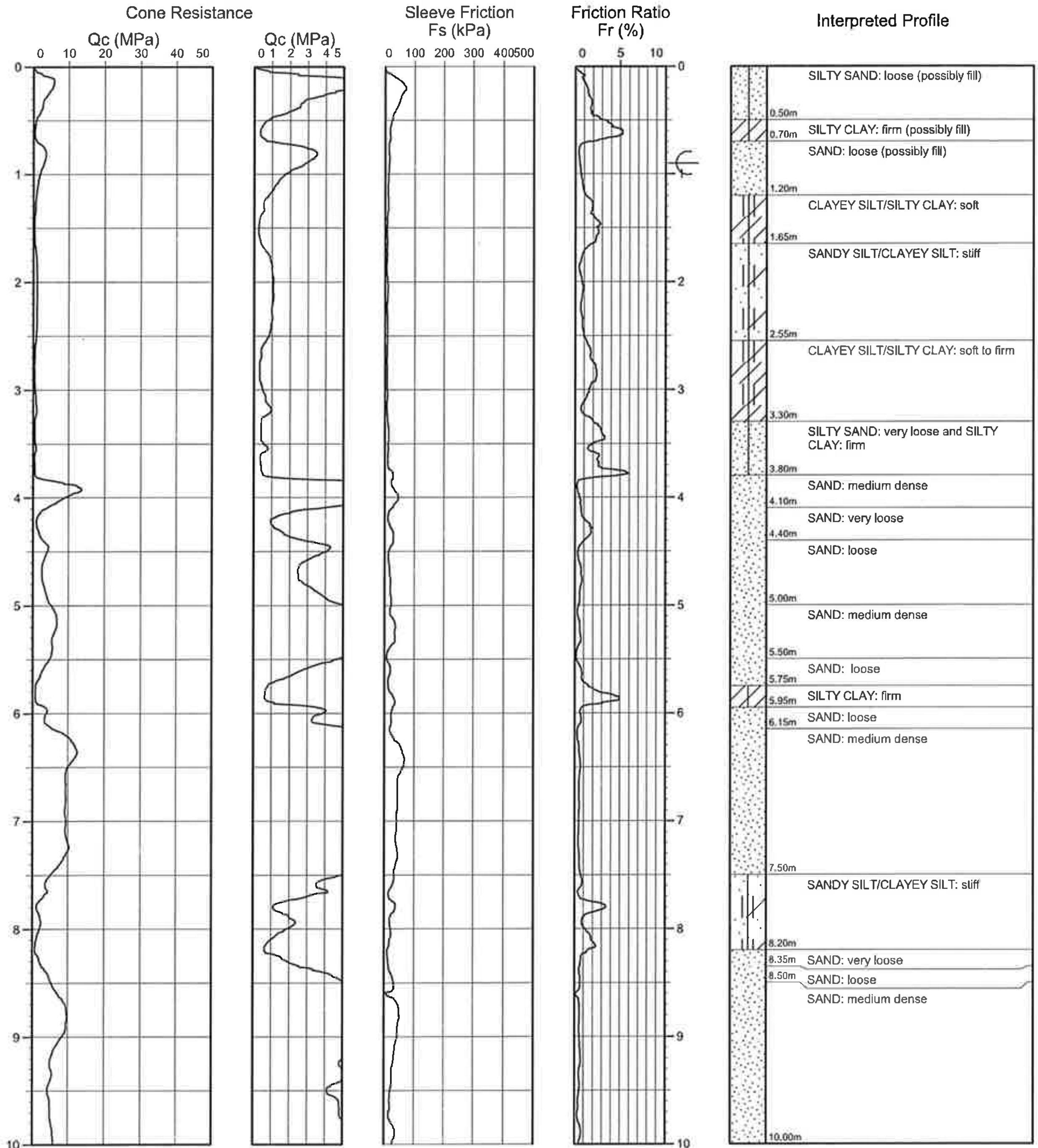

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Checked by: L.S.

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EFCP No.
4
2 / 2

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client:	WARRINGAH COUNCIL
Project:	PROPOSED LIGHT POLES
Location:	NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

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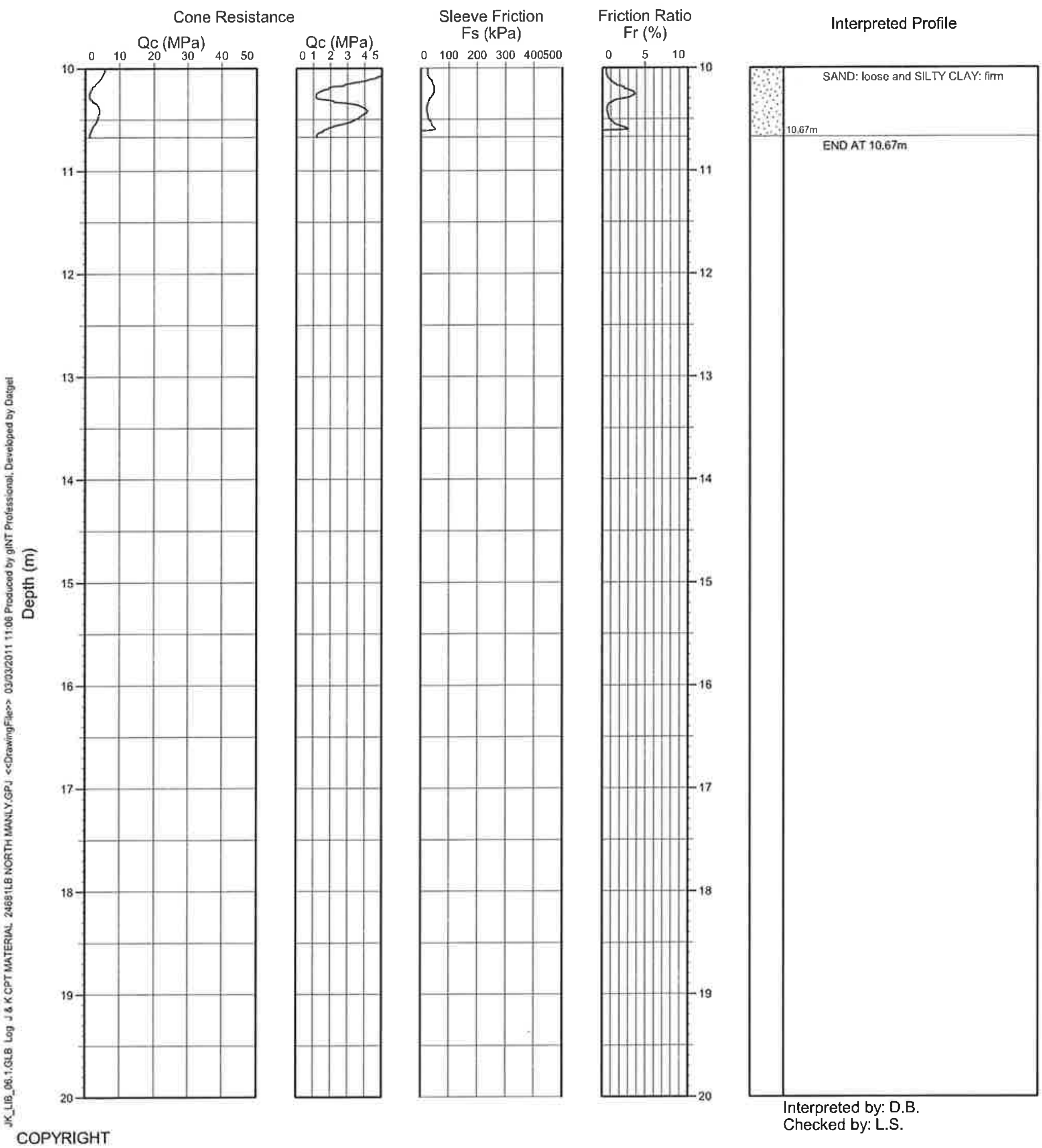

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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

EFCP No.
5
1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

Client: WARRINGAH COUNCIL

Project: PROPOSED LIGHT POLES

Location: NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

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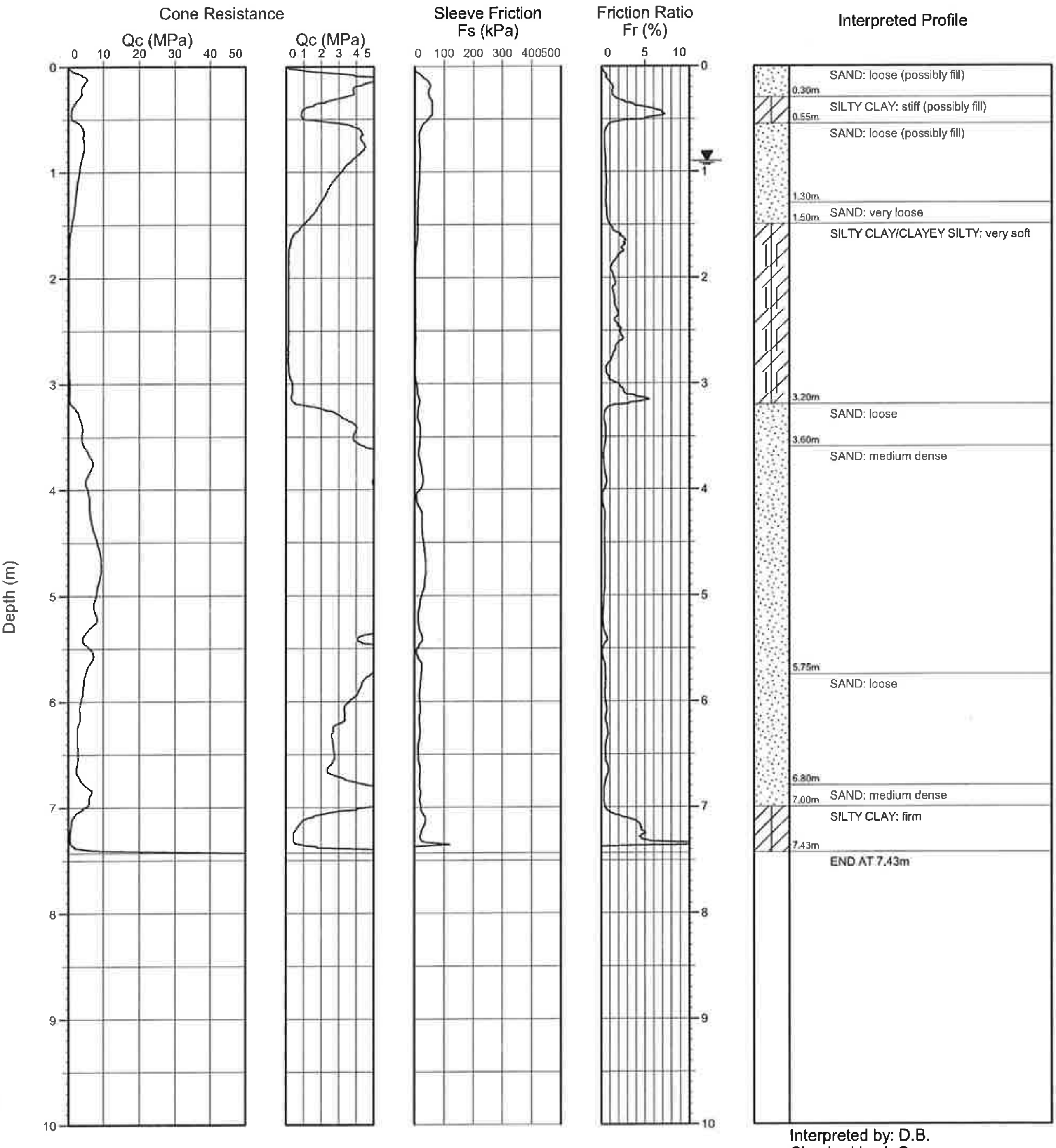

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EFCP No.
6
1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

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Location: NOLAN RESERVE, PITTWATER ROAD, NORTH MANLY, NSW

Job No.: 24681LB	**R.L. Surface:** N/A	**Data File:** 24681B_6.GEF
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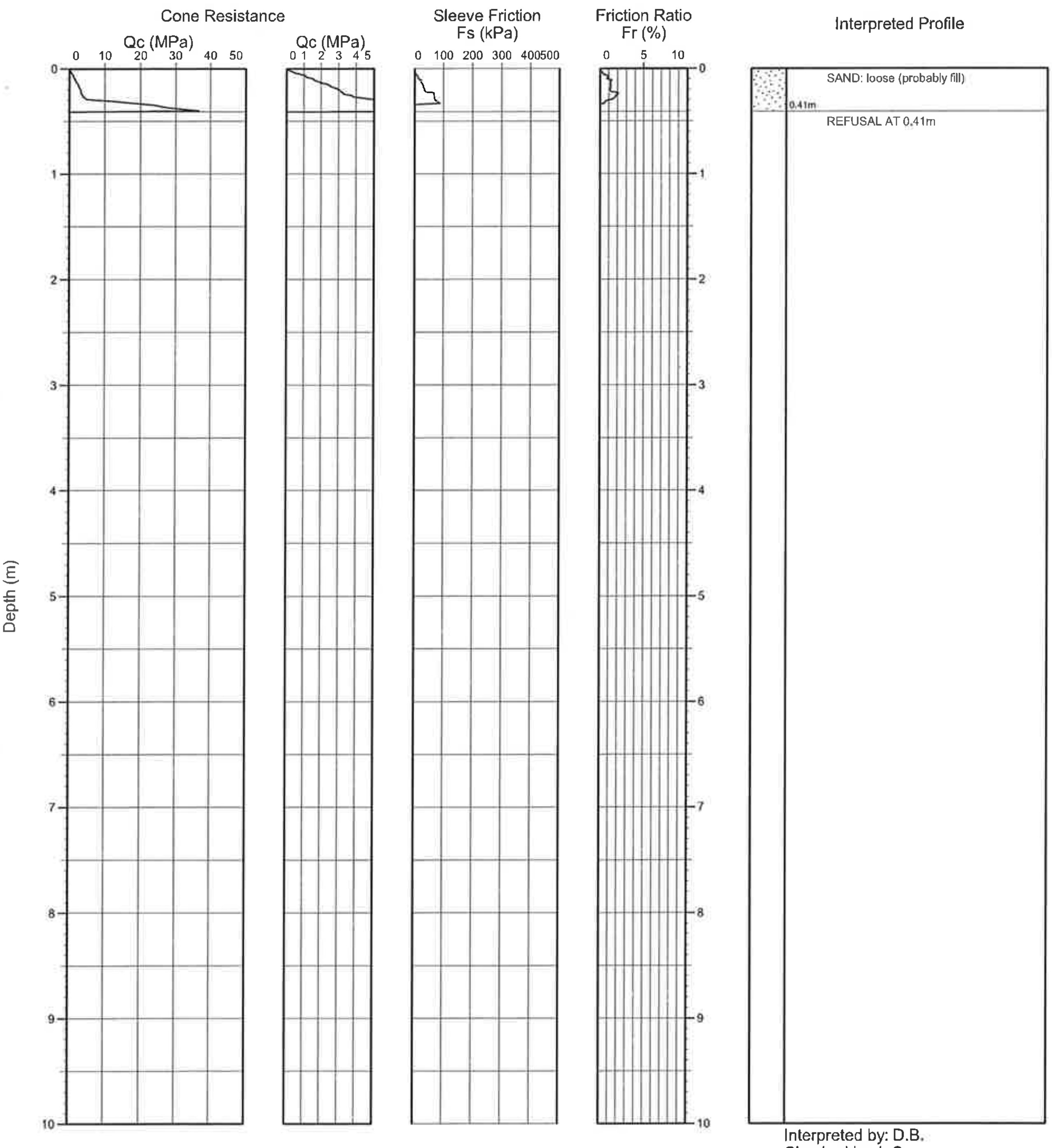

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EFCP No.
6b
1 / 1

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

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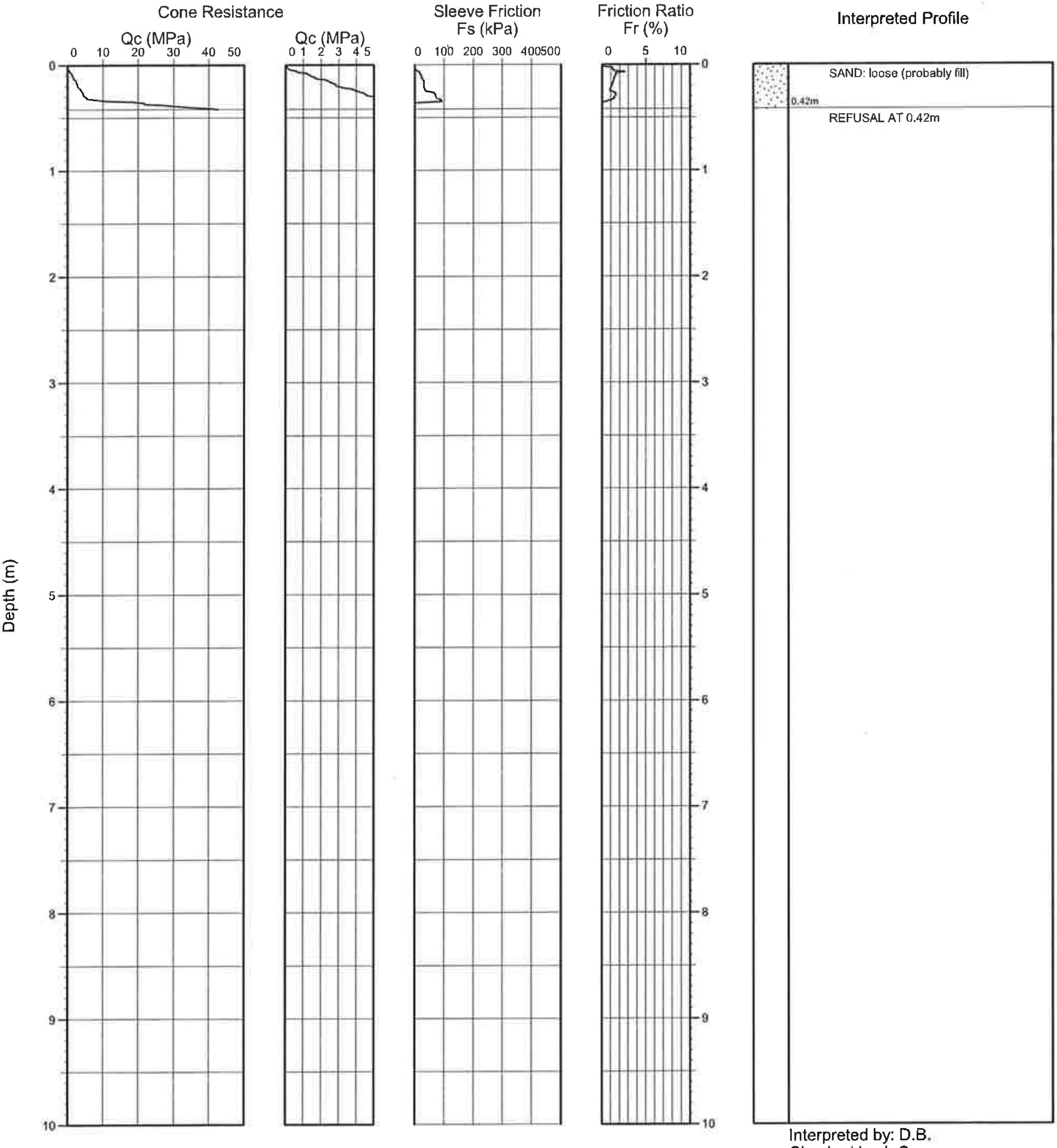
Job No.: 24681LB **R.L. Surface:** N/A **Data File:** 24681B_6b.GEF
Date: 15/02/11 **Datum:** **Operator:** M.T.



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CONSULTING GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

ELECTRICAL FRICTION CONE PENETROMETER TEST RESULTS

EFCP No.
6c
1 / 1

Client:	WARRINGAH COUNCIL
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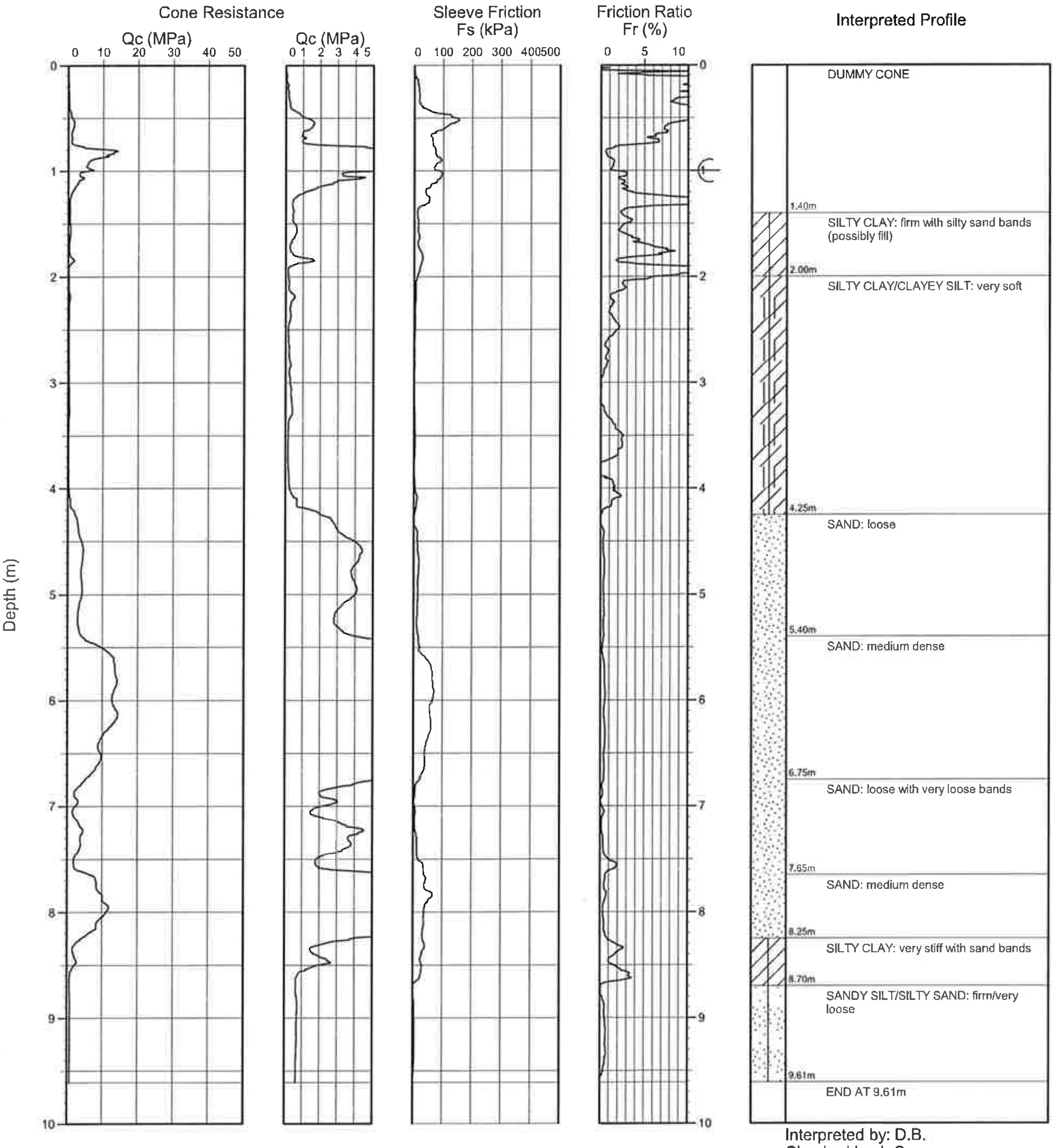

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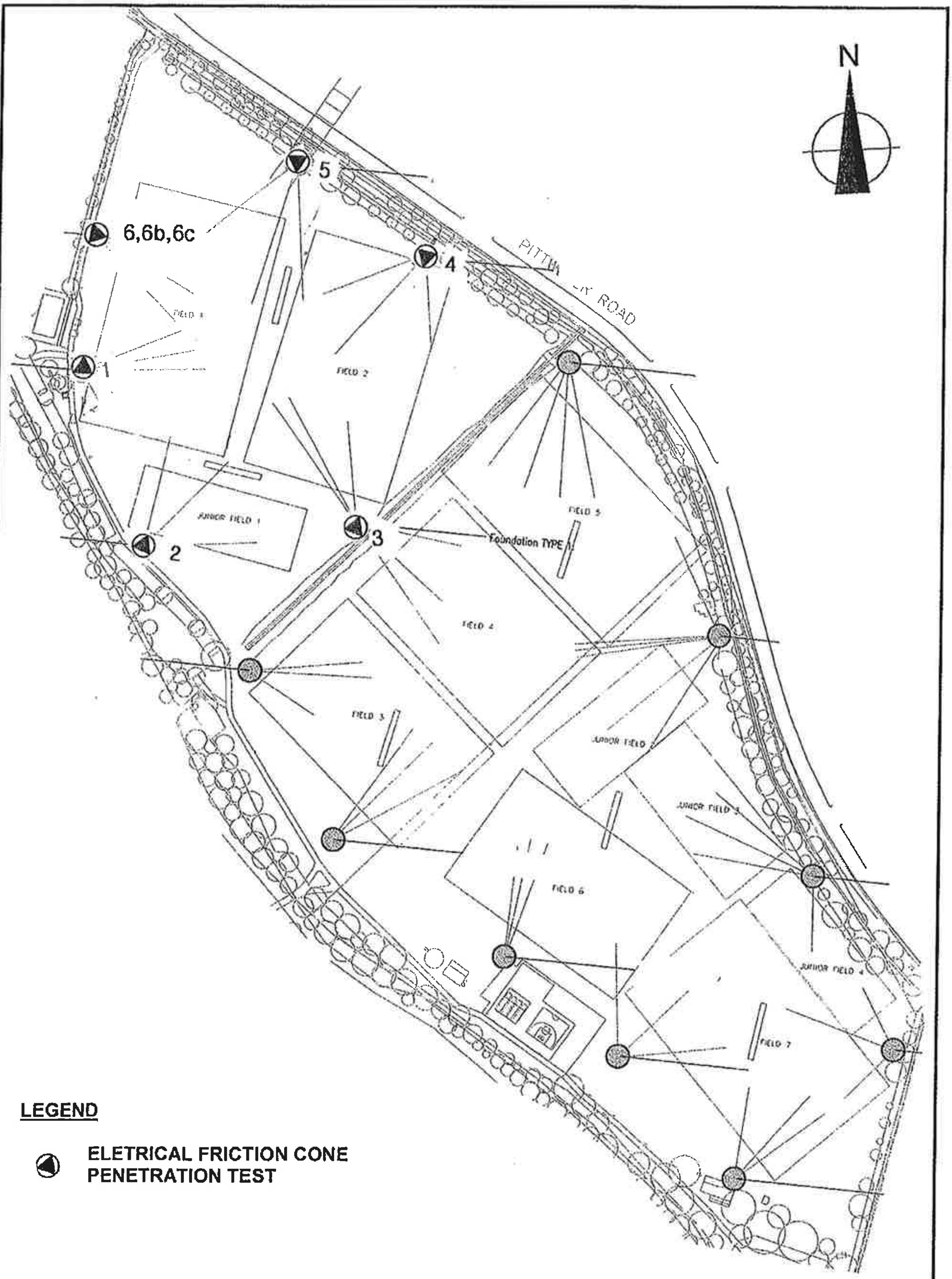

LEGEND

ELETRICAL FRICTION CONE PENETRATION TEST

SCALE (m)

0 25

INVESTIGATION LOCATION PLAN

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CONSULTING GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

Report No. 24681LB **Figure No. 1**

REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the SAA Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (eg sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2mm
Gravel	2 to 60mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose	less than 4
Loose	4 – 10
Medium dense	10 – 30
Dense	30 – 50
Very Dense	greater than 50

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength kPa
Very Soft	less than 25
Soft	25 – 50
Firm	50 – 100
Stiff	100 – 200
Very Stiff	200 – 400
Hard	Greater than 400
Friable	Strength not attainable – soil crumbles

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'Shale' is used to describe thinly bedded to laminated siltstone.

SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Premature refusal of the hand augers can occur on a variety of materials such as hard clay, gravel or ironstone, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock fragments. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from "feel" and rate of penetration.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as CORE LOSS. The location of losses are determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the top end of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

- In the case where full penetration is obtained with successive blow counts for each 150mm of, say, 4, 6 and 7 blows, as

  N = 13
  4, 6, 7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

  N>30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

Occasionally, the drop hammer is used to drive 50mm diameter thin walled sample tubes (U50) in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

A modification to the SPT test is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as "N_c" on the borehole logs, together with the number of blows per 150mm penetration.

Static Cone Penetrometer Testing and Interpretation: Cone penetrometer testing (sometimes referred to as a Dutch Cone) described in this report has been carried out using an Electronic Friction Cone Penetrometer (EFCP). The test is described in Australian Standard 1289, Test F5.1.

In the tests, a 35mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with an hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between EFCP and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of EFCP values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a rod into the ground with a sliding hammer and counting the blows for successive 100mm increments of penetration.

Two relatively similar tests are used:

- Cone penetrometer (commonly known as the Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS1289, Test F3.2). The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various Road Authorities.
- Perth sand penetrometer – a 16mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test F3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds. In any case, the boreholes or test pits represent only a very small sample of the total subsurface conditions.

The attached explanatory notes define the terms and symbols used in preparation of the logs.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than "straight line" variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems:

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg bricks, steel etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably determine the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soil for Engineering Purposes'*. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg to a twenty storey building). If this happens, the company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions – the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.

If these occur, the company will be pleased to assist with investigation or advice to resolve any problems occurring.

SITE ANOMALIES

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed that at some later stage, well after the event.

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

Attention is drawn to the document *'Guidelines for the Provision of Geotechnical Information in Tender Documents'*, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. License to use the documents may be revoked without notice if the Client is in breach of any objection to make a payment to us.

REVIEW OF DESIGN

Where major civil or structural developments are proposed <u>or</u> where only a limited investigation has been completed <u>or</u> where the geotechnical conditions/ constraints are quite complex, it is prudent to have a joint design review which involves a senior geotechnical engineer.

SITE INSPECTION

The company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

i) a site visit to confirm that conditions exposed are no worse than those interpreted, to

ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types such as appropriate footing or pier founding depths, or

iii) full time engineering presence on site.

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GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CH)
- SILT (ML, MH)
- SAND (SP, SW)
- GRAVEL (GP, GW)
- SANDY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SAND (SC)
- SILTY SAND (SM)
- GRAVELLY CLAY (CL, CH)
- CLAYEY GRAVEL (GC)
- SANDY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- BASALT, ANDESITE
- QUARTZITE

DEFECTS AND INCLUSIONS

- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

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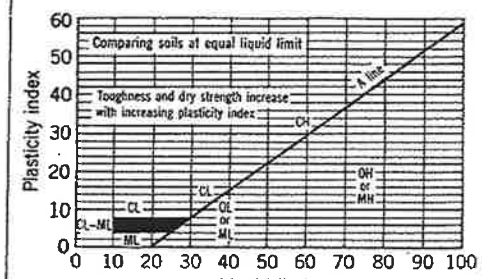
UNIFIED SOIL CLASSIFICATION TABLE

Major Divisions			Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights)	Group Symbols a	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than 4 mm sieve size	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits below "A" line, or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
	Sands More than half of coarse fraction is smaller than 4 mm sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20 % hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7

Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols

Identification Procedures on Fraction Smaller than 380 μm Sieve Size

Major Divisions		Dry Strength (crushing character-istics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Fine-grained soils More than half of material is *smaller* than 75 μm sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

NOTE: 1) Soils possessing characteristics of two groups are designated by combinations of group symbols (e.g. GW-GC, well graded gravel-sand mixture with clay fines).

2) Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

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LOG SYMBOLS

LOG COLUMN	SYMBOL	DEFINITION
Groundwater Record		Standing water level. Time delay following completion of drilling may be shown.
		Extent of borehole collapse shortly after drilling.
		Groundwater seepage into borehole or excavation noted during drilling or excavation.
Samples	ES	Soil sample taken over depth indicated, for environmental analysis.
	U50	Undisturbed 50mm diameter tube sample taken over depth indicated.
	DB	Bulk disturbed sample taken over depth indicated.
	DS	Small disturbed bag sample taken over depth indicated.
	ASB	Soil sample taken over depth indicated, for asbestos screening.
	ASS	Soil sample taken over depth indicated, for acid sulfate soil analysis.
	SAL	Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength.
	PID = 100	Photoionisation detector reading in ppm (Soil sample headspace test).
Moisture Condition (Cohesive Soils)	MC>PL	Moisture content estimated to be greater than plastic limit.
	MC≈PL	Moisture content estimated to be approximately equal to plastic limit.
	MC<PL	Moisture content estimated to be less than plastic limit.
(Cohesionless Soils)	D	DRY - runs freely through fingers.
	M	MOIST - does not run freely but no free water visible on soil surface.
	W	WET - free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS	VERY SOFT - Unconfined compressive strength less than 25kPa
	S	SOFT - Unconfined compressive strength 25-50kPa
	F	FIRM - Unconfined compressive strength 50-100kPa
	St	STIFF - Unconfined compressive strength 100-200kPa
	VSt	VERY STIFF - Unconfined compressive strength 200-400kPa
	H	HARD - Unconfined compressive strength greater than 400kPa
	( )	Bracketed symbol indicates estimated consistency based on tactile examination or other tests.
Density Index/ Relative Density (Cohesionless Soils)		**Density Index (Io) Range (%)** — **SPT 'N' Value Range (Blows/300mm)**
	VL	Very Loose <15 — 0-4
	L	Loose 15-35 — 4-10
	MD	Medium Dense 35-65 — 10-30
	D	Dense 65-85 — 30-50
	VD	Very Dense >85 — >50
	( )	Bracketed symbol indicates estimated density based on ease of drilling or other tests.
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.
Remarks	'V' bit	Hardened steel 'V' shaped bit.
	'TC' bit	Tungsten carbide wing bit.
	T 60	Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.

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LOG SYMBOLS

ROCK MATERIAL WEATHERING CLASSIFICATION

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely weathered rock	XW	Rock is weathered to such an extent that it has "soil" properties, ie it either disintegrates or can be remoulded, in water.
Distinctly weathered rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by ironstaining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Journal of Rock Mechanics, Mining, Science and Geomechanics. Abstract Volume 22, No 2, 1985.

TERM	SYMBOL	Is (50) MPa	FIELD GUIDE
Extremely Low:	EL		Easily remoulded by hand to a material with soil properties.
		0.03	
Very Low:	VL		May be crumbled in the hand. Sandstone is "sugary" and friable.
		0.1	
Low:	L		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
		0.3	
Medium Strength:	M		A piece of core 150mm long x 50mm dia. can be broken by hand with difficulty. Readily scored with knife.
		1	
High:	H		A piece of core 150mm long x 50mm dia. core cannot be broken by hand, can be slightly scratched or scored with knife; rock rings under hammer.
		3	
Very High:	VH		A piece of core 150mm long x 50mm dia. may be broken with hand-held pick after more than one blow. Cannot be scratched with pen knife; rock rings under hammer.
		10	
Extremely High:	EH		A piece of core 150mm long x 50mm dia. is very difficult to break with hand-held hammer. Rings when struck with a hammer.

ABBREVIATIONS USED IN DEFECT DESCRIPTION

ABBREVIATION	DESCRIPTION	NOTES
Be	Bedding Plane Parting	Defect orientations measured relative to the normal to the long core axis (ie relative to horizontal for vertical holes)
CS	Clay Seam	
J	Joint	
P	Planar	
Un	Undulating	
S	Smooth	
R	Rough	
IS	Ironstained	
XWS	Extremely Weathered Seam	
Cr	Crushed Seam	
60t	Thickness of defect in millimetres	