

CPS Global Pty Ltd

Geotechnical Investigation, OPTUS SITE  
S4019 MAITLAND SHOWGROUND - 50  
Louth Park Road, Maitland, NSW



ENVIRONMENTAL



WATER



WASTEWATER



GEOTECHNICAL



CIVIL



PROJECT  
MANAGEMENT



P2108245JR01V01  
May 2021

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**All enquiries regarding this project are to be directed to the Project Manager.**

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# 1 Proposed Development and Investigation Scope

Table 1 summarises proposed development details and investigation scope.

**Table 1:** Summary of proposed development details and investigation scope.

Item	Details
Property Address	OPTUS SITE S4019 MAITLAND SHOWGROUND - 50 Louth Park Road, Maitland, NSW ('the site')
Legal Identifier	Lot 13 in DP 1148282
Site Area	Approximately 72 m <sup>2</sup> across the telecommunication compound (CPS, 2021).
LGA	Maitland Council ('Council')
Proposed Development	The draft plans (CPS, 2021) indicate that the development will include a 26.65 m high monopole.
Assessment Purpose	Geotechnical investigation to assist structural design of the monopole and equipment shelter.
Investigation Scope of Work	<p>Field investigations conducted on 27 April 2021 included:</p> <ul style="list-style-type: none"> <li>○ Review of DBYD survey plans.</li> <li>○ Underground service locating.</li> <li>○ General site walkover to gain an appreciation of the site.</li> <li>○ Drilling of one borehole (BH101) up to 8.0 metres below ground level (mbgl). Refer attached borehole logs in Attachment B.</li> <li>○ Collection of soil samples for laboratory testing and future reference.</li> <li>○ One Dynamic Cone Penetrometer (DCP) tests (DCP101) up to 3.5 mbgl. DCP test results are provided in Attachment C.</li> <li>○ Conduct insitu soil resistivity testing using the Wenner 4 pin method with rod spacing at 1.5, 3.0, 4.5, 6.0, 7.5 and 9.0m as per OPTUS OSD-020 <i>Earthing Specification (May 2018)</i>.</li> </ul> <p>Investigation locations are shown in, Attachment A.</p>
Laboratory Testing	<p>Soil Aggressivity testing on one sample carried out by a National Association of Testing Authorities (NATA) accredited laboratory, Envirolab Service.</p> <p>Laboratory test certificates are provided as Attachment E.</p>

## 2 General Site Details and Subsurface Conditions

General site details and subsurface conditions based on desktop review, site walkover and site investigation findings are summarised in Table 2.

**Table 2:** Summary of general site details and subsurface conditions.

Item	Comment
Topography	Extensive alluvial plain with local relief up to 2.0 m. Slope gradients are <1% (eSPADE).
Typical Slopes	< 5 %
Site Aspect	East
Site Elevation	6 - 9 mAHD (Google Earth).
Expected Geology	Quaternary Deposit comprising Gravel, sand, silt, clay, "Waterloo Rock", marine and freshwater deposits (Newcastle 1:250 000 Geological Map).
Vegetation	Grass.
Drainage	Via overland flow towards the east.
Subsurface conditions	<p>Investigation revealed the following generalised subsurface units likely underlie the site below ground surface level:</p> <p><u>Unit A:</u> Inferred uncontrolled fill comprising silty clay encountered up to approximately 1.0 mbgl.</p> <p><u>Unit B:</u> Alluvial sand / silty sand medium dense was encountered, between 1.0 mbgl – 1.5 mbgl and from 7.0 mbgl to investigation termination depth of 8.0 mbgl.</p> <p><u>Unit C:</u> Alluvial silty sandy clay grading from very stiff to hard, encountered between the depths of 1.5 mbgl to 7.0 mbgl.</p> <p>Encountered conditions are described in more detail on the borehole logs in Attachment B and associated explanatory notes in Attachment G. For DCP test results refer to Attachment C.</p>
Groundwater	Groundwater inflow was encountered during of the boreholes at approximately 7.6 mbgl. Given the approximate site elevation and location of the Hunter river (approximately 1 km to north of the site), this groundwater level is considered to be a permanent groundwater level.

## 3 Geotechnical Assessment

### 3.1 Foundation Exposure Classification Testing

Exposure classification test results are summarised in Table 3.

**Table 3:** Exposure classification test results.

BH	Depth (mbgl)	Material	EC ( $\mu\text{S}/\text{cm}$ ) <sup>1</sup>	EC <sub>e</sub> (dS/m) <sup>2</sup>	pH	Chloride (Cl) (mg/kg)	Sulphate (SO <sub>4</sub> ) (mg/kg)	Exposure Classification		
								AS 2159 <sup>3</sup>	AS 2159 <sup>4</sup>	AS 3600 <sup>5</sup>
BH101	3.5	Silty Sandy CLAY	25	0.212	6.3	33	39	Non - aggressive	Non - aggressive	A1

**Notes:**

1. Electrical Conductivity 1:5 soil:water
2. Based on EC to EC<sub>e</sub> multiplication factors from Table 6.1 in Site Investigations for Urban Salinity (2002) guidelines.
3. Exposure classification for concrete piles in soil based on Table 6.4.2(C) of AS 2159 (2009).
4. Exposure classification for steel piles in soil based on Table 6.5.2(C) of AS 2159 (2009).
5. Exposure classification for buried reinforced concrete based on Tables 4.8.1 and 4.8.2 of AS 3600 (2009).

In accordance with AS2159 (2009), an exposure classification of 'Non-aggressive' should be adopted for buried concrete and steel piles, respectively. In accordance with AS3600 (2009), for shallow concrete footings founding in residual soil, an exposure classification of 'A1' should be adopted.

### 3.2 Preliminary Material Properties

Preliminary material properties inferred from observations during borehole drilling, such as auger penetration resistance, DCP test results as well as previous experience in similar materials are summarised in Table 4.

**Table 4:** Preliminary estimates of soil and rock strength properties.

Layer	$\gamma_{in-situ}^1$ (kN/m <sup>3</sup> )	$C_u^2$ (kPa)	$C'^3$ (kPa)	$\phi'^4$ (deg)	$E'^5$ (MPa)	$K_s^6$ (MPa)
UNCONTROLLED FILL: Silty CLAY (inferred poorly compacted)	19	30	0	24	4	4
ALLUVIUM: Silty SAND / SAND (medium dense)	18	0	0	30	6	6
ALLUVIUM: Silty Sandy CLAY (very stiff to hard)	20	100	5	26	20	20

**Notes:**

1. Material in-situ unit weight, based on visual assessment.
2. Undrained shear strength assuming normally consolidated clay.
3. Drained cohesion.
4. Effective internal friction angle estimate, assuming drained conditions.
5. Effective elastic modulus.
6. Modulus of subgrade reaction (vertical) estimate. For horizontal modulus, 1/3 vertical  $K_s$  may be adopted.
7. Not applicable.

### 3.3 Soil Resistivity

The results of in-situ soil resistivity testing are summarised in Attachment D.



## 4 Geotechnical Recommendations

General geotechnical recommendations for the proposed development are provided in Attachment F. Additional recommendations are provided below.

### 4.1 Proposed Footing Systems

We recommend adopting the following for design of foundations of proposed structures.

#### New Monopole:

- o Deepened footings, such as bored cast in-situ concrete piles embedded into very stiff to hard clay soils with a minimum depth of 4.0 mbgl, may be adopted for support of the proposed monopole. Installation of casing during piling may be required up to depth of at least 1.5 mbgl to prevent collapse of the hole.
- o Alternatively, large shallow pad footing founding with minimum depth of 2.5 mbgl on inferred very stiff to hard alluvial clay may be considered. Detail design should take into account settlement within the clay soils as a result of the structural loads applied.

Pad footing and pile / pier design for the proposed development may adopt recommended preliminary design parameters in Table 5, which are to be confirmed by a geotechnical engineer during construction stage. Note that additional foundation depth may be required to achieve lateral stability. It is recommended that all foundations are founded in consistent materials, to limit differential settlements.

Temporary excavation (e.g. for pad foundations) should be battered back at 1.5H:1V (Horizontal: Vertical). Temporary structural support would be required for excavation with zone of influence of existing nearby foundations. All earthworks should be carried out in accordance with AS 3798 (2007) and council's requirements under the guidance of a geotechnical engineer.

#### New lightly loaded high-level structures (Equipment Shelter):

- o Shallow footings, such as pad or strip footings founded on medium dense alluvial sand at minimum depth of 1.2 m. Placement of foundations on uncontrolled fill is not recommended due to possible ongoing settlements. However, a low bearing capacity of 50 kPa may be adopted to reduce the risk with minimum foundation depth of 0.7 m.

## 4.2 Preliminary Design Parameters

Foundation design should consider recommended preliminary design parameters in Table 5. Inspection should be carried out by an experienced geotechnical engineer to confirm the design bearing capacity has been achieved at foundation level.

**Table 5:** Recommended geotechnical design parameters.

Layer	Shallow Footings		Piers / Pile		K <sub>0</sub> <sup>6</sup>	K <sub>a</sub> <sup>6</sup>	K <sub>p</sub> <sup>6</sup>
	UBC <sup>2,5</sup>	ULBC <sup>3,5</sup>	UBC <sup>2,5</sup>	USF <sup>4,5</sup>			
UNCONTROLLED FILL: Silty CLAY (inferred poorly compacted)	NA <sup>7</sup>	NA <sup>7</sup>	NA <sup>7</sup>	NA <sup>7</sup>	0.59	0.42	2.37
ALLUVIUM: Silty SAND / SAND (medium dense)	300	100	NA <sup>7</sup>	NA <sup>7</sup>	0.50	0.33	3.00
ALLUVIUM: Silty Sandy CLAY (very stiff to hard)	450	150	700	NA <sup>7</sup>	0.56	0.39	2.56

**Notes:**

1. Assuming bored cast in-situ concrete pile / pier.
2. Ultimate bearing capacity (kPa) for footing embedded at least 0.5 m and piles socketed at least 1 m or 1 pile diameter (whichever is larger), into the design material.
3. Ultimate lateral bearing capacity (kPa).
4. Ultimate shaft friction (kPa) in compression. For uplift and anchor pull-out shaft resistance, we recommend reducing USF by 50% and checking against 'piston' and 'cone' pull out mechanisms in accordance with AS2159 (2009).
5. A preliminary strength reduction factor of  $\phi_g=0.45$  is recommended to calculate design geotechnical strengths.
6. K<sub>0</sub>=Earth pressure coefficient at rest; K<sub>a</sub>=Active earth pressure coefficient; K<sub>p</sub>= Passive earth pressure coefficient.
7. Not applicable

## 4.3 Preliminary Site Classification

The site is classified as a Class "P" site in accordance with AS 2870 (2011).

## 4.4 Construction Considerations

All excavation work should be completed with reference to the Code of Practice 'Excavation Work' (July 2015), by Safe Work Australia, and excavation requirements of council's Development Control Plan.

We expect that sump and pump methods will be appropriate for collection and removal of surface water infiltration and potential ephemeral perched groundwater inflow, if encountered during construction of shallow footings and piers / piles.

All surface runoff should be diverted away from excavation areas during construction works and foundations to prevent foundation material strength reduction as a result of soil saturation and limit soil erosion.

## 5 References

Australian Standard 1289.F3.2 (1984) *Determination of the Penetration Resistance of a Soil using the 9 kg Dynamic Cone Penetrometer*

Australian Standard 1796 (1993) *Geotechnical Site Investigations*.

Australian Standard 2870 (1996) *Residential Slabs and Footings*

CPS Global (2021) Draft plans, Drawing No. S4019-P1 to P2, Revision A, Dated 16.02.21 (CPS, 2021).

Land and Property Information (2020) SIX Maps Viewer, ([www.maps.six.nsw.gov.au](http://www.maps.six.nsw.gov.au)).

NSW Department of Environment & Heritage (eSPADE, NSW soil and land information), [www.environment.nsw.gov.au](http://www.environment.nsw.gov.au).

Newcastle 1:250 000 Geological Sheet S1 56-2, (1966), Geological Survey of New South Wales, Sydney.

Standards Australia Limited (1997) AS 1289.6.3.2:1997, *Determination of the penetration resistance of a soil – 9kg dynamic cone penetrometer test*, SAI Global Limited.

Standards Australia Limited (2017) AS 1726:2017, *Geotechnical site investigations*, SAI Global Limited.

Standards Australia Limited (2009) AS 2159:2009, *Piling – Design and installation*, SAI Global Limited.

Standards Australia Limited (2011) AS 2870:2011, *Residential slabs and footings*, SAI Global Limited.

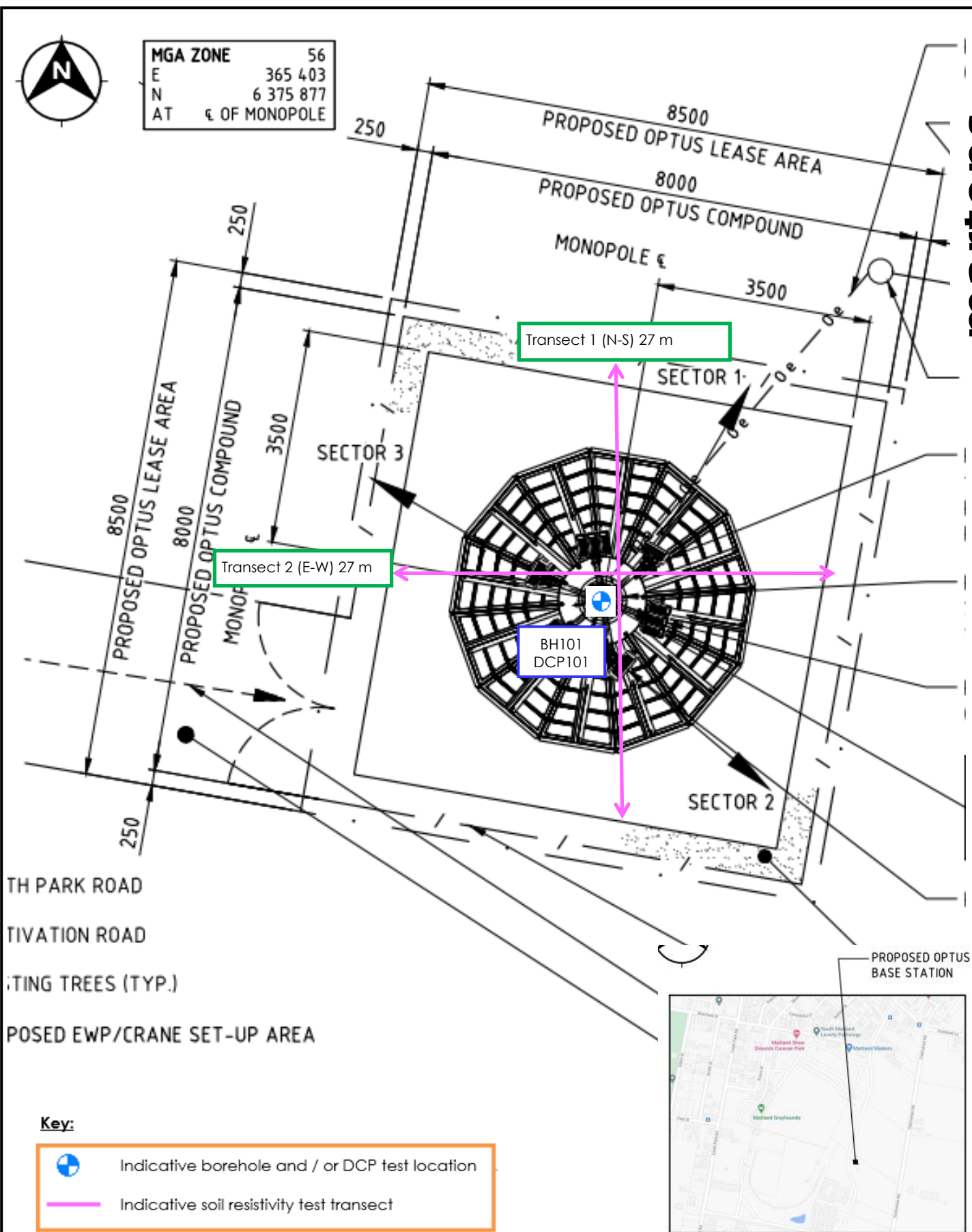
Standards Australia Limited (2007) AS 3798:2007, *Guidelines on earthworks for commercial and residential developments*, SAI Global Limited.

## Attachment A – Geotechnical Testing Plan





MGA ZONE 56  
 E 365 403  
 N 6 375 877  
 AT € OF MONOPOLE

martens



**Key:**

-  Indicative borehole and / or DCP test location
-  Indicative soil resistivity test transect

**LOCALITY MAP**

<b>Martens &amp; Associates Pty Ltd</b> ABN 85 070 240 890		<b>Environment   Water   Wastewater   Geotechnical   Civil   Management</b>	
Drawn:	AG	<b>GEOTECHNICAL TESTING PLAN</b> (CPS, 2021)	<b>FIGURE 1</b>
Approved:	KB		
Date:	10.05.2021		
Scale:	NA		
		Job No: P2108245JR01V01	

## Attachment B – Test Borehole Logs

CLIENT	CPS Global	COMMENCED	27/04/2021	COMPLETED	27/04/2021	<b>REF BH101</b>	
PROJECT	Geotechnical Investigation	LOGGED	AG	CHECKED	KB	Sheet 1 OF 1	
SITE	50 Louth Park Road, Maitland, NSW	GEOLOGY	Quaternary Deposits	VEGETATION	Grass	PROJECT NO. P2108245	
EQUIPMENT	4WD ute-mounted hydraulic drill rig	EASTING	151.5632	RL SURFACE	6 m	DATUM	AHD
EXCAVATION DIMENSIONS	ø100 mm x 8.00 m depth	NORTHING	-32.7468	ASPECT	East	SLOPE	<5%

Drilling			Sampling	Field Material Description						
METHOD	PENETRATION RESISTANCE	DEPTH (metres)	SAMPLE OR FIELD TEST	RECOVERED GRAPHIC LOG	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	
AD/V	L	11.00			CL	FILL: Silty CLAY; low plasticity; brown, dark brown; trace sand.			FILL	
		0.5/S/1 D 0.50 m								
	L-M	1.00				SP	SAND; fine grained; brown, dark brown.			ALLUVIUM
		10.00	1.2/S/1 D 1.20 m						MD	
	M	1.50				SC	Silty sandy CLAY; low plasticity; grey, pale grey, yellow, brown.			VSt
		9.50	1.9/S/1 D 1.90 m						H	
		3.40					Becoming predominantly brown, dark brown.		M (<PL)	
		7.60	3.5/S/1 D 3.50 m							
L	7.00				SM	Silty SAND; fine grained; brown, dark brown; trace clay.			M	
	4.00	7.2/S/1 D 7.20 m								
	8.00					Hole Terminated at 8.00 m (Target depth reached)			W	

EXCAVATION LOG TO BE READ IN CONJUNCTION WITH ACCOMPANYING REPORT NOTES AND ABBREVIATIONS

MARTENS 2.00 LIB.GLB Log MARTENS BOREHOLE P2108245FH01V01.GPJ ->DrawingFile- 10/05/2021 12:47 10.02.00.04 DaigelLab and In Situ Tool - DGD Lib: Martens 2.00 2016-11-13 Proj: Martens 2.00 2016-11-13



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**Engineering Log -**  
**BOREHOLE**



## Attachment C – DCP ‘N’ Counts



## Attachment D – In-situ Soil Resistivity Test Results

# Earth Resistivity Test



Method ST-57 Revision V02  
 4-point Wenner Arrangement - Method based on:  
 AEMC-4620-4630 or Sonel MRU-30 manuals;  
 IEEE Power and Energy Society (IEEE Std 81-2012);  
 Standards Australia HB 160 (2006)

Suite 201, 20 George Street, Hornsby, NSW 2077, Ph: (02) 9476 9999 Fax: (02) 9476 8767, mail@martens.com.au, www.martens.com.au

## PROJECT DETAILS Geotechnical Investigation

<b>Client:</b> CPS Globle Pty Ltd	<b>Project No.:</b> P2108245
<b>Project:</b> Geotechnical Investigation	<b>Completed by:</b> YL <b>Date:</b> 27.04.2021
<b>Site Address:</b> 50 Louth Park Road, Maitland, NSW	<b>Reviewed by:</b> KB <b>Date:</b> 27.04.2021

## SITE DETAILS

<b>Coordinates (sounding centre) Grid:</b>	<b>E:</b> 151.5632	<b>N:</b> -32.7468
<b>Weather (recent days):</b> Dry	<b>Terrain:</b>	
<b>Possible Interferences:</b>		
<b>Remarks:</b>		

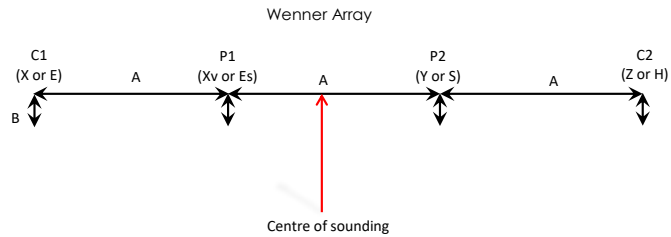
## EQUIPMENT DETAILS

<b>Equipment: (type &amp; No.):</b> Sonel MRU-30	<b>Calibration date:</b> 29/062019
--	------------------------------------

## TEST DETAILS (Enter relevant data in shaded cells)

Electrode Spacing "A" (m)	Rod Depth <sup>1</sup> "B" (B < A/20) (cm)	Resistivity Meter Readings				Average Reading "R" (Ω)	Apparent Resistivity (Ω.m) <sup>3,4</sup>	Comments
		Orientation (traverse line) <sup>2</sup>						
		NS Reading 1 (Ω)	EW Reading 2 (Ω)	Reading 3 (Ω)				
1.50	7.50	416.00	2.75		209.38	1981.91		
3.00	15.00	216.00	2.84		109.42	2071.51		
4.50	20.00	2.83	1.67		2.25	63.84		
6.00	20.00	2.57	1.19		1.88	71.01		
7.50	20.00	0.86	0.98		0.92	43.41		
9.00	20.00	0.79	0.69		0.74	41.88		

- Based on the ASTM Standard G57, electrode depth has to be 1/20 of minimum electrode spacing, typically 5 cm for "A" = 1 m.
- Refer to site plan in Attachment A for indicative traverse alignments.
- Approximate apparent resistivity to depth "A" (m).
- Will vary with changes in soil moisture, temperature and chemical composition and depth to groundwater. Values are based single material unit and assume uniform soil resistivity.



## Attachment E – Laboratory Test Certificate



Envirolab Services Pty Ltd  
ABN 37 112 535 645  
12 Ashley St Chatswood NSW 2067  
ph 02 9910 6200 fax 02 9910 6201  
customerservice@envirolab.com.au  
www.envirolab.com.au

## CERTIFICATE OF ANALYSIS 267901

### Client Details

<b>Client</b>	Martens & Associates Pty Ltd
<b>Attention</b>	K Burgess, Yiwen Li
<b>Address</b>	Suite 201, 20 George St, Hornsby, NSW, 2077

### Sample Details

<b>Your Reference</b>	<b><u>P2108245COC01V01, Maitland</u></b>
<b>Number of Samples</b>	1 Soil
<b>Date samples received</b>	29/04/2021
<b>Date completed instructions received</b>	29/04/2021

### Analysis Details

Please refer to the following pages for results, methodology summary and quality control data.  
Samples were analysed as received from the client. Results relate specifically to the samples as received.  
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

### Report Details

<b>Date results requested by</b>	06/05/2021
<b>Date of Issue</b>	03/05/2021
NATA Accreditation Number 2901. This document shall not be reproduced except in full.	
Accredited for compliance with ISO/IEC 17025 - Testing. <b>Tests not covered by NATA are denoted with *</b>	

#### Results Approved By

Diego Bigolin, Team Leader, Inorganics

#### Authorised By

Nancy Zhang, Laboratory Manager

Soil Aggressivity		
Our Reference		267901-1
Your Reference	UNITS	8245/BH101/3.5
Date Sampled		27/04/2021
Type of sample		Soil
pH 1:5 soil:water	pH Units	6.3
Electrical Conductivity 1:5 soil:water	µS/cm	25
Chloride, Cl 1:5 soil:water	mg/kg	33
Sulphate, SO4 1:5 soil:water	mg/kg	39

Method ID	Methodology Summary
<b>Inorg-001</b>	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
<b>Inorg-002</b>	Conductivity and Salinity - measured using a conductivity cell at 25°C in accordance with APHA latest edition 2510 and Rayment & Lyons.
<b>Inorg-081</b>	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Waters samples are filtered on receipt prior to analysis. Alternatively determined by colourimetry/turbidity using Discrete Analyser.



QUALITY CONTROL: Soil Aggressivity				Duplicate				Spike Recovery %		
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	[NT]	[NT]	102	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	103	[NT]
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	110	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	110	[NT]

**Result Definitions**

<b>NT</b>	Not tested
<b>NA</b>	Test not required
<b>INS</b>	Insufficient sample for this test
<b>PQL</b>	Practical Quantitation Limit
<b>&lt;</b>	Less than
<b>&gt;</b>	Greater than
<b>RPD</b>	Relative Percent Difference
<b>LCS</b>	Laboratory Control Sample
<b>NS</b>	Not specified
<b>NEPM</b>	National Environmental Protection Measure
<b>NR</b>	Not Reported

## Quality Control Definitions

<b>Blank</b>	This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.
<b>Duplicate</b>	This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.
<b>Matrix Spike</b>	A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.
<b>LCS (Laboratory Control Sample)</b>	This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.
<b>Surrogate Spike</b>	Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.
Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.	
The recommended maximums for analytes in urine are taken from "2018 TLVs and BEIs", as published by ACGIH (where available). Limit provided for Nickel is a precautionary guideline as per Position Paper prepared by AIOH Exposure Standards Committee, 2016.	
Guideline limits for Rinse Water Quality reported as per analytical requirements and specifications of AS 4187, Amdt 2 2019, Table 7.2	

## Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: >10xPQL - RPD acceptance criteria will vary depending on the analytes and the analytical techniques but is typically in the range 20%-50% – see ELN-P05 QA/QC tables for details; <10xPQL - RPD are higher as the results approach PQL and the estimated measurement uncertainty will statistically increase.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals (not SPOCAS); 60-140% for organics/SPOCAS (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.

Analysis of aqueous samples typically involves the extraction/digestion and/or analysis of the liquid phase only (i.e. NOT any settled sediment phase but inclusive of suspended particles if present), unless stipulated on the Envirolab COC and/or by correspondence. Notable exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, total recoverable metals and PFAS where solids are included by default.

Samples for Microbiological analysis (not Amoeba forms) received outside of the 2-8°C temperature range do not meet the ideal cooling conditions as stated in AS2031-2012.

## Attachment F – General Geotechnical Recommendations

# Geotechnical Recommendations

## Important Recommendations About Your Site (1 of 2)

*These general geotechnical recommendations have been prepared by Martens to help you deliver a safe work site, to comply with your obligations, and to deliver your project. Not all are necessarily relevant to this report but are included as general reference. Any specific recommendations made in the report will override these recommendations.*

### **Batter Slopes**

Excavations in soil and extremely low to very low strength rock exceeding 0.75 m depth should be battered back at grades of no greater than 1 Vertical (V) : 2 Horizontal (H) for temporary slopes (unsupported for less than 1 month) and 1 V : 3 H for longer term unsupported slopes.

Vertical excavation may be carried out in medium or higher strength rock, where encountered, subject to inspection and confirmation by a geotechnical engineer. Long term and short term unsupported batters should be protected against erosion and rock weathering due to, for example, stormwater run-off.

Batter angles may need to be revised depending on the presence of bedding partings or adversely oriented joints in the exposed rock, and are subject to on-site inspection and confirmation by a geotechnical engineer. Unsupported excavations deeper than 1.0 m should be assessed by a geotechnical engineer for slope instability risk.

Any excavated rock faces should be inspected during construction by a geotechnical engineer to determine whether any additional support, such as rock bolts or shotcrete, is required.

### **Earthworks**

Earthworks should be carried out following removal of any unsuitable materials and in accordance with AS3798 (2007). A qualified geotechnical engineer should inspect the condition of prepared surfaces to assess suitability as foundation for future fill placement or load application.

Earthworks inspections and compliance testing should be carried out in accordance with Sections 5 and 8 of AS3798 (2007), with testing to be carried out by a National Association of Testing Authorities (NATA) accredited testing laboratory.

### **Excavations**

All excavation work should be completed with reference to the *Work Health and Safety (Excavation Work) Code of Practice (2015)*, by Safe Work Australia. Excavations into rock may be undertaken as follows:

1. Extremely low to low strength rock - conventional hydraulic earthmoving equipment.
2. Medium strength or stronger rock - hydraulic earthmoving equipment with rock hammer or ripping tyne attachment.

Exposed rock faces and loose boulders should be monitored to assess risk of block / boulder movement, particularly as a result of excavation vibrations.

### **Fill**

Subject to any specific recommendations provided in this report, any fill imported to site is to comprise approved material with maximum particle size of two thirds the final layer thickness. Fill should be placed in horizontal layers of not more than 300 mm loose thickness, however, the layer thickness should be appropriate for the adopted compaction plant.

### **Foundations**

All exposed foundations should be inspected by a geotechnical engineer prior to footing construction to confirm encountered conditions satisfy design assumptions and that the base of all excavations is free from loose or softened material and water. Water that has ponded in the base of excavations and any resultant softened material is to be removed prior to footing construction.

Footings should be constructed with minimal delay following excavation. If a delay in construction is anticipated, we recommend placing a concrete blinding layer of at least 50 mm thickness in shallow footings or mass concrete in piers / piles to protect exposed foundations.

A geotechnical engineer should confirm any design bearing capacity values, by further assessment during construction, as necessary.

### **Shoring - Anchors**

Where there is a requirement for either soil or rock anchors, or soil nailing, and these structures penetrate past a property boundary, appropriate permission from the adjoining land owner must be obtained prior to the installation of these structures.

### **Shoring - Permanent**

Permanent shoring techniques may be used as an alternative to temporary shoring. The design of such structures should be in accordance with the findings of this report and any further testing recommended by this report. Permanent shoring may include [but not be limited to] reinforced block work walls, contiguous and semi contiguous pile walls, secant pile walls and soldier pile walls with or without reinforced shotcrete infill panels. The choice of shoring system will depend on the type of structure, project budget and site specific geotechnical conditions.

Permanent shoring systems are to be engineer designed and backfilled with suitable granular

## Important Recommendations About Your Site (2 of 2)

material and free-draining drainage material. Backfill should be placed in maximum 100 mm thick layers compacted using a hand operated compactor. Care should be taken to ensure excessive compaction stresses are not transferred to retaining walls.

Shoring design should consider any surcharge loading from sloping / raised ground behind shoring structures, live loads, new structures, construction equipment, backfill compaction and static water pressures. All shoring systems shall be provided with adequate foundation designs.

Suitable drainage measures, such as geotextile enclosed 100 mm agricultural pipes embedded in free-draining gravel, should be included to redirect water that may collect behind the shoring structure to a suitable discharge point.

### **Shoring - Temporary**

In the absence of providing acceptable excavation batters, excavations should be supported by suitably designed and installed temporary shoring / retaining structures to limit lateral deflection of excavation faces and associated ground surface settlements.

### **Soil Erosion Control**

Removal of any soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in any formal stormwater drainage system, on neighbouring land and in receiving waters. Where possible, this may be achieved by one or more of the following means:

1. Maintain vegetation where possible
2. Disturb minimal areas during excavation
3. Revegetate disturbed areas if possible

All spoil on site should be properly controlled by erosion control measures to prevent transportation of sediments off-site. Appropriate soil erosion control methods in accordance with Landcom (2004) shall be required.

### **Trafficability and Access**

Consideration should be given to the impact of the proposed works and site subsurface conditions on trafficability within the site e.g. wet clay soils will lead to poor trafficability by tyred plant or vehicles.

Where site access is likely to be affected by any site works, construction staging should be organised such that any impacts on adequate access are minimised as best as possible.

### **Vibration Management**

Where excavation is to be extended into medium or higher strength rock, care will be required when using a rock hammer to limit potential structural distress from excavation-induced vibrations where nearby structures may be affected by the works.

To limit vibrations, we recommend limiting rock hammer size and set frequency, and setting the hammer parallel to bedding planes and along defect planes, where possible, or as advised by a geotechnical engineer. We recommend limiting vibration peak particle velocities (PPV) caused by construction equipment or resulting from excavation at the site to 5 mm/s (AS 2187.2, 2006, Appendix J).

### **Waste – Spoil and Water**

Soil to be disposed off-site should be classified in accordance with the relevant State Authority guidelines and requirements.

Any collected waste stormwater or groundwater should also be tested prior to discharge to ensure contaminant levels (where applicable) are appropriate for the nominated discharge location.

MA can complete the necessary classification and testing if required. Time allowance should be made for such testing in the construction program.

### **Water Management - Groundwater**

If the proposed works are likely to intersect ephemeral or permanent groundwater levels, the management of any potential acid soil drainage should be considered. If groundwater tables are likely to be lowered, this should be further discussed with the relevant State Government Agency.

### **Water Management – Surface Water**

All surface runoff should be diverted away from excavation areas during construction works and prevented from accumulating in areas surrounding any retaining structures, footings or the base of excavations.

Any collected surface water should be discharged into a suitable Council approved drainage system and not adversely impact downslope surface and subsurface conditions.

All site discharges should be passed through a filter material prior to release. Sump and pump methods will generally be suitable for collection and removal of accumulated surface water within any excavations.

### **Contingency Plan**

In the event that proposed development works cause an adverse impact on geotechnical hazards, overall site stability or adjacent properties, the following actions are to be undertaken:

1. Works shall cease immediately.
2. The nature of the impact shall be documented and the reason(s) for the adverse impact investigated.
3. A qualified geotechnical engineer should be consulted to provide further advice in relation to the issue.

## Attachment G – Notes About This Report

# Information

## Important Information About Your Report (1 of 2)

*These notes have been prepared by Martens to help you interpret and understand the limitations of your report. Not all are necessarily relevant to all reports but are included as general reference.*

### **Engineering Reports - Limitations**

The recommendations presented in this report are based on limited investigations and include specific issues to be addressed during various phases of the project. If the recommendations presented in this report are not implemented in full, the general recommendations may become inapplicable and Martens & Associates accept no responsibility whatsoever for the performance of the works undertaken.

Occasionally, sub-surface conditions between and below the completed boreholes or other tests 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 Martens & Associates.

Relative ground surface levels at borehole locations may not be accurate and should be verified by on-site survey.

### **Engineering Reports – Project Specific Criteria**

Engineering reports are prepared by qualified personnel. They are based on information obtained, on current engineering standards of interpretation and analysis, and on the basis of your unique project specific requirements as understood by Martens. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the Client.

Where the report has been prepared for a specific design proposal (e.g. a three storey building), the information and interpretation may not be relevant if the design proposal is changed (e.g. to a twenty storey building). Your report should not be relied upon, if there are changes to the project, without first asking Martens to assess how factors, which changed subsequent to the date of the report, affect the report's recommendations. Martens will not accept responsibility for problems that may occur due to design changes, if not consulted.

### **Engineering Reports – Recommendations**

Your report is based on the assumption that site conditions, as may be revealed through selective point sampling, are indicative of actual conditions throughout an area. This assumption often cannot be substantiated until project implementation has commenced. Therefore your site investigation report recommendations should only be regarded as preliminary.

Only Martens, who prepared the report, are fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report, there is a risk that the report will be misinterpreted and Martens cannot be held responsible for such misinterpretation.

### **Engineering Reports – Use for Tendering Purposes**

Where information obtained from investigations is provided for tendering purposes, Martens recommend 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.

Martens would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

### **Engineering Reports – Data**

The report as a whole presents the findings of a site assessment and should not be copied in part or altered in any way.

Logs, figures, drawings etc are customarily included in a Martens report and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel), desktop studies and laboratory evaluation of field samples. These data should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

### **Engineering Reports – Other Projects**

To avoid misuse of the information contained in your report it is recommended that you confer with Martens before passing your report on to another party who may not be familiar with the background and purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

### **Subsurface Conditions - General**

Every care is taken with the report in relation to interpretation of subsurface conditions, discussion of geotechnical aspects, relevant standards 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 will depend partly on test point (eg. excavation or borehole) spacing and sampling frequency, which are often limited by project imposed budgetary constraints.



- Changes in guidelines, standards and policy or interpretation of guidelines, standards and policy by statutory authorities.
- The actions of contractors responding to commercial pressures.
- Actual conditions differing somewhat from those inferred to exist, because no professional, no matter how qualified, can reveal precisely what is hidden by earth, rock and time.

The actual interface between logged materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions.

If these conditions occur, Martens will be pleased to assist with investigation or providing advice to resolve the matter.

### **Subsurface Conditions - Changes**

Natural processes and the activity of man create subsurface conditions. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Reports are based on conditions which existed at the time of the subsurface exploration / assessment.

Decisions should not be based on a report whose adequacy may have been affected by time. If an extended period of time has elapsed since the report was prepared, consult Martens to be advised how time may have impacted on the project.

### **Subsurface Conditions - Site Anomalies**

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

### **Report Use by Other Design Professionals**

To avoid potentially costly misinterpretations when other design professionals develop their plans based on a Martens report, retain Martens to work with other project professionals affected by the report. This may involve Martens explaining the report design implications and then reviewing plans and specifications produced to see how they have incorporated the report findings.

### **Subsurface Conditions – Geo-environmental Issues**

Your report generally does not relate to any findings, conclusions, or recommendations about the potential for hazardous or contaminated materials existing at the site unless specifically required to do so as part of Martens' proposal for works.

Specific sampling guidelines and specialist equipment, techniques and personnel are typically used to perform geo-environmental or site contamination assessments. Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Martens for information relating to such matters.

### **Responsibility**

Geo-environmental reporting relies on interpretation of factual information based on professional judgment and opinion and has an inherent level of uncertainty attached to it and is typically far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded.

To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Martens to other parties but are included to identify where Martens' responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Martens closely and do not hesitate to ask any questions you may have.

### **Site Inspections**

Martens will always be pleased to provide engineering inspection services for aspects of work to which this report relates. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site. Martens is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction.

### Definitions

In engineering terms, soil includes every type of uncemented or partially cemented inorganic or organic material found in the ground. In practice, if the material does not exhibit any visible rock properties and can be remoulded or disintegrated by hand in its field condition or in water, it is described as a soil. Other materials are described using rock description terms.

The methods of description and classification of soils and rocks used in this report are typically based on Australian Standard 1726 and the Unified Soil Classification System (USCS) – refer Soil Data Explanation of Terms (2 of 3). In general, descriptions cover the following properties: strength or density, colour, moisture, structure, soil or rock type and inclusions.

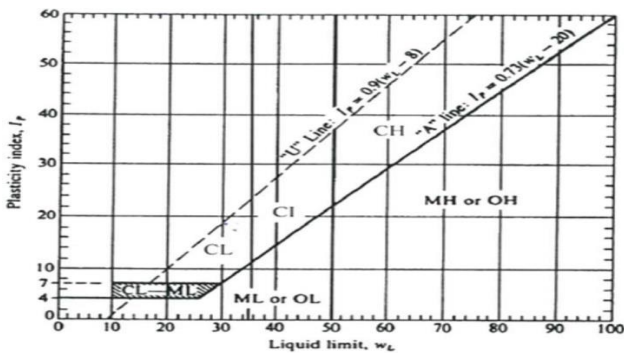
### Particle Size

Soil types are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy CLAY). Unless otherwise stated, particle size is described in accordance with the following table.

Division	Subdivision	Particle Size (mm)	
Oversized	BOULDERS	>200	
	COBBLES	63 to 200	
Coarse Grained Soil	GRAVEL	Coarse	19 to 63
		Medium	6.7 to 19
		Fine	2.36 to 6.7
	SAND	Coarse	0.6 to 2.36
		Medium	0.21 to 0.6
		Fine	0.075 to 0.21
Fine Grained Soil	SILT	0.002 to 0.075	
	CLAY	< 0.002	

### Plasticity Properties

Plasticity properties of cohesive soils can be assessed in the field by tactile properties or by laboratory procedures.



### Soil Moisture Condition

#### Coarse Grained (Granular) Soil:

Dry (D):	Looks and feels dry. Cemented soils are hard, friable or powdery. Uncemented soils run freely through fingers.
Moist (M):	Feels cool and damp and is darkened in colour. Particles tend to cohere.
Wet (W):	As for moist but with free water forming on hands when handled.

#### Fine Grained (Cohesive) Soil:

Moist, dry of plastic limit <sup>1</sup> (w < PL):	Looks and feels dry. Hard, friable or powdery.
Moist, near plastic limit (w ≈ PL):	Can be moulded, feels cool and damp, is darkened in colour, at a moisture content approximately equal to the PL.
Moist, wet of plastic limit (w > PL):	Usually weakened and free water forms on hands when handled.
Wet, near liquid limit <sup>2</sup> (w ≈ LL)	
Wet, wet of liquid limit (w > LL)	

<sup>1</sup> Plastic Limit (PL): Moisture content at which soil becomes too dry to be in a plastic condition.

<sup>2</sup> Liquid Limit (LL): Moisture content at which soil passes from plastic to liquid state.

### Consistency of Cohesive Soils

Cohesive soils refer to predominantly clay materials.

(Note: consistency is affected by soil moisture condition at time of measurement)

Term	C <sub>u</sub> (kPa)	Field Guide
Very Soft (VS)	≤12	A finger can be pushed well into the soil with little effort. Sample exudes between fingers when squeezed in fist.
Soft (S)	>12 and ≤25	A finger can be pushed into the soil to about 25mm depth. Easily moulded by light finger pressures.
Firm (F)	>25 and ≤50	The soil can be indented about 5mm with the thumb, but not penetrated. Can be moulded by strong figure pressure.
Stiff (St)	>50 and ≤100	The surface of the soil can be indented with the thumb, but not penetrated. Cannot be moulded by fingers.
Very Stiff (VSt)	>100 and ≤200	The surface of the soil can be marked, but not indented with thumb pressure. Difficult to cut with a knife. Thumbnail can readily indent.
Hard (H)	> 200	The surface of the soil can only be marked with the thumbnail. Brittle. Tends to break into fragments.
Friable (Fr)	-	Crumbles or powders when scraped by thumbnail. Can easily be crumbled or broken into small pieces by hand.

### Density of Granular Soils

Non-cohesive soils are classified on the basis of relative density, generally from standard penetration test (SPT) or Dutch cone penetrometer test (CPT) results as below:

Relative Density	%	SPT 'N' Value* (blows/300mm)	CPT Cone Value (q <sub>c</sub> MPa)
Very loose	≤15	< 5	< 2
Loose	>15 and ≤35	5 - 10	2 - 5
Medium dense	>35 and ≤65	10 - 30	5 - 15
Dense	>65 and ≤85	30 - 50	15 - 25
Very dense	> 85	> 50	> 25

\* Values may be subject to corrections for overburden pressures and equipment type and influenced by soil moisture condition at time of measurement.

### Minor Components

Minor components in soils may be present and readily detectable, but have little bearing on general geotechnical classification. Terms include:

Description of components	Proportion of component in:					
	coarse grained soil			fine grained soil		
	% Fines	Terminology	% Accessory coarse fraction	Terminology	% Sand/gravel	Terminology
Minor	≤5	Trace clay / silt, as applicable	≤15	Trace sand / gravel, as applicable	≤15	Trace sand / gravel, as applicable
	>5, ≤12	With clay / silt, as applicable	>15, ≤30	With sand / gravel, as applicable	>5, ≤30	With sand / gravel, as applicable
Secondary	>12	Prefix soil name as 'silty' or 'clayey', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable	>30	Prefix soil name as 'sandy' or 'gravelly', as applicable

### Symbols for Soils and Other

#### SOILS

	COBBLES/BOULDERS
	GRAVEL (GP or GW)
	Silty GRAVEL (GM)
	Clayey GRAVEL (GC)
	SAND (SP or SW)
	Silty SAND (SM)
	Clayey SAND (SC)

	SILT (ML or MH)
	ORGANIC SILT or CLAY (OH or OL)
	CLAY (CL, CI or CH)
	Silty CLAY
	Sandy CLAY
	PEAT (Pt)
	Gravelly CLAY

#### OTHER

	FILL
	TALUS
	ASPHALT
	CONCRETE
	TOPSOIL

### Unified Soil Classification Scheme (USCS)

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 63 mm and basing fractions on estimated mass)					USCS	Primary Name	
COARSE GRAINED SOILS More than 65 % of material less than 63 mm is larger than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than 2.36 mm.	GRAVEL and GRAVEL-SAND mixtures (±5% fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes; not enough fines to bind coarse grains; no dry strength	GW	GRAVEL	
			GRAVEL-SILT and GRAVEL-SAND mixtures (±5% fines)	Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	GP	GRAVEL	
			GRAVEL-SILT and GRAVEL-SAND mixtures (±12% fines) <sup>1</sup>	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength; may also contain sand	GM	Silty GRAVEL	
			GRAVEL-SILT and GRAVEL-SAND mixtures (±12% fines) <sup>1</sup>	With excess plastic fines (for identification procedures see CL below); medium to high dry strength; may also contain sand	GC	Clayey GRAVEL	
		SANDS More than half of coarse fraction is smaller than 2.36 mm	SAND and GRAVEL-SAND mixtures (±5% fines)	Wide range in grain sizes and substantial amounts of all intermediate sizes; not enough fines to bind coarse grains; no dry strength.	SW	SAND	
			SAND-SILT and SAND-CLAY mixtures (±12% fines) <sup>1</sup>	Predominantly one size or a range of sizes with some intermediate sizes missing; not enough fines to bind coarse grains; no dry strength	SP	SAND	
			SAND-SILT and SAND-CLAY mixtures (±12% fines) <sup>1</sup>	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength;	SM	Silty SAND	
			SAND-SILT and SAND-CLAY mixtures (±12% fines) <sup>1</sup>	With excess plastic fines (for identification procedures see CL below); medium to high dry strength	SC	Clayey SAND	
FINE GRAINED SOILS More than 35 % of material less than 63 mm is smaller than 0.075 mm	(A 0.075 mm particle is about the smallest particle visible to the naked eye)	IDENTIFICATION PROCEDURES ON FRACTIONS < 0.2 MM					
		DRY STRENGTH (Crushing Characteristics)	DILATANCY	TOUGHNESS	DESCRIPTION	USCS	Primary Name
		None to Low	Quick to Slow	Low	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or silt with low plasticity <sup>2</sup>	ML	SILT <sup>3</sup>
		Medium to High	None to Slow	Medium	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	CL (or CL <sup>+</sup> )	CLAY
		Low to Medium	Slow	Low	Organic silts and organic silty clays of low plasticity	OL	Organic SILT or CLAY
		Low to Medium	None to Slow	Low to Medium	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	SILT <sup>3</sup>
		High to Very High	None	High	Inorganic clays of high plasticity, fat clays	CH	CLAY
		Medium to High	None to Very Slow	Low to Medium	Organic clays of medium to high plasticity, organic silt of high plasticity	OH	Organic SILT or CLAY
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture				Pt	PEAT	

#### Notes:

- Between 5% and 12% - dual classification, e.g. GP-GM.
- Low Plasticity Clay - Liquid Limit  $W_L \leq 35\%$ ; Medium Plasticity Clay - Liquid limit  $W_L > 35\%$ ,  $\leq 50\%$ ; High Plasticity Clay - Liquid limit  $W_L > 50\%$ .
- Low Plasticity Silt - Liquid Limit  $W_L \leq 50\%$ ; High Plasticity Silt - Liquid limit  $W_L > 50\%$ .
- CI may be adopted for clay of medium plasticity to distinguish from clay of low plasticity.

### Soil Agricultural Classification Scheme

In some situations, such as where soils are to be used for effluent disposal purposes, soils are often more appropriately classified in terms of traditional agricultural classification schemes. Where a Martens report provides agricultural classifications, these are undertaken in accordance with descriptions by Northcote, K.H. (1979) *The factual key for the recognition of Australian Soils*, Rellim Technical Publications, NSW, p 26 - 28.

Symbol	Field Texture Grade	Behaviour of moist bolus	Ribbon length	Clay content (%)
S	Sand	Coherence nil to very slight; cannot be moulded; single grains adhere to fingers	0 mm	< 5
LS	Loamy sand	Slight coherence; discolours fingers with dark organic stain	6.35 mm	5
CLS	Clayey sand	Slight coherence; sticky when wet; many sand grains stick to fingers; discolours fingers with clay stain	6.35mm - 1.3cm	5 - 10
SL	Sandy loam	Bolus just coherent but very sandy to touch; dominant sand grains are of medium size and are readily visible	1.3 - 2.5	10 - 15
FSL	Fine sandy loam	Bolus coherent; fine sand can be felt and heard	1.3 - 2.5	10 - 20
SCL	Light sandy clay loam	Bolus strongly coherent but sandy to touch, sand grains dominantly medium size and easily visible	2.0	15 - 20
L	Loam	Bolus coherent and rather spongy; smooth feel when manipulated but no obvious sandiness or silkiness; may be somewhat greasy to the touch if much organic matter present	2.5	25
Lfsy	Loam, fine sandy	Bolus coherent and slightly spongy; fine sand can be felt and heard when manipulated	2.5	25
SiL	Silt loam	Coherent bolus, very smooth to silky when manipulated	2.5	25 + > 25 silt
SCL	Sandy clay loam	Strongly coherent bolus sandy to touch; medium size sand grains visible in a finer matrix	2.5 - 3.8	20 - 30
CL	Clay loam	Coherent plastic bolus; smooth to manipulate	3.8 - 5.0	30 - 35
SiCL	Silty clay loam	Coherent smooth bolus; plastic and silky to touch	3.8 - 5.0	30- 35 + > 25 silt
FSCL	Fine sandy clay loam	Coherent bolus; fine sand can be felt and heard	3.8 - 5.0	30 - 35
SC	Sandy clay	Plastic bolus; fine to medium sized sands can be seen, felt or heard in a clayey matrix	5.0 - 7.5	35 - 40
SiC	Silty clay	Plastic bolus; smooth and silky	5.0 - 7.5	35 - 40 + > 25 silt
LC	Light clay	Plastic bolus; smooth to touch; slight resistance to shearing	5.0 - 7.5	35 - 40
LMC	Light medium clay	Plastic bolus; smooth to touch, slightly greater resistance to shearing than LC	7.5	40 - 45
MC	Medium clay	Smooth plastic bolus, handles like plasticine and can be moulded into rods without fracture, some resistance to shearing	> 7.5	45 - 55
HC	Heavy clay	Smooth plastic bolus; handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to shearing	> 7.5	> 50

### Symbols for Rock

#### SEDIMENTARY ROCK



BRECCIA



CONGLOMERATE



CONGLOMERATIC SANDSTONE



SANDSTONE/QUARTZITE



SILTSTONE



MUDSTONE/CLAYSTONE



SHALE



COAL



LIMESTONE



LITHIC TUFF

#### IGNEOUS ROCK



GRANITE



DOLERITE/BASALT

#### METAMORPHIC ROCK



SLATE, PHYLLITE, SCHIST



GNEISS



METASANDSTONE



METASILTSTONE



METAMUDSTONE

### Definitions

Descriptive terms used for Rock by Martens are based on AS1726 and encompass rock substance, defects and mass.

**Rock Material** The intact rock that is bounded by defects.

**Rock Defect** Discontinuity, fracture, break or void in the material or minerals across which there is little or no tensile strength.

**Rock Structure** The nature and configuration of the different defects within the rock mass and their relationship to each other.

**Rock Mass** The entirety of the system formed by all of the rock material and all of the defects that are present.

### Degree of Weathering

Rock weathering is defined as the degree of decline in rock structure and grain property and can be determined in the field.

Term	Symbol	Definition
Residual soil <sup>1</sup>	RS	Material is weathered to such an extent that it has soil properties. Mass structure, material texture, and fabric of original rock are no longer visible, but the soil has not been significantly transported.
Extremely weathered <sup>1</sup>	XW	Material is weathered to such an extent that it has soil properties - i.e. it can be remoulded and can be classified according to the Unified Classification System. Mass structure and material texture and fabric of original rock are still visible.
Highly weathered <sup>2</sup>	HW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the original colour of the rock is not recognisable. Rock strength is significantly changed by weathering. Some primary minerals have weathered to clay minerals. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores.
Moderately weathered <sup>2</sup>	MW	The whole of the rock material is discoloured, usually by iron staining or bleaching to the extent that the colour of the rock is not recognisable. Rock strength shows little or no change from fresh rock.
Slightly weathered	SW	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock.
Fresh	FR	Rock substance unaffected by weathering. No sign of decomposition of individual materials or colour changes.

#### Notes:

1 RS and EW material is described using soil descriptive terms.

2. The term "Distinctly Weathered" (DW) may be used to cover the range of substance weathering between EW and SW

### 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 loading. The test procedure is described by the International Society of Rock Mechanics.

Term (Strength)	Is (50) MPa	Uniaxial Compressive Strength MPa	Field Guide	Symbol
Very low	>0.03 ≤0.1	0.6 – 2	May be crumbled in the hand. Sandstone is 'sugary' and friable.	VL
Low	>0.1 ≤0.3	2 – 6	Core 150mm long x 50mm diameter may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	L
Medium	>0.3 ≤1.0	6 – 20	Core 150mm long x 50mm diameter can be broken by hand with considerable difficulty. Readily scored with a knife.	M
High	>1 ≤3	20 – 60	Core 150mm long x 50mm diameter cannot be broken by unaided hands, can be slightly scratched or scored with a knife. Breaks with single blow from pick.	H
Very high	>3 ≤10	60 – 200	Core 150mm long x 50mm diameter, broken readily with hand held hammer. Cannot be scratched with knife. Breaks after more than one pick strike.	VH
Extremely high	>10	>200	A piece of core 150mm long x 50mm diameter is difficult to break with hand held hammer. Rings when struck with a hammer.	EH

### Degree of Fracturing

This classification applies to diamond drill cores and refers to the spacing of all types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude fractures such as drilling breaks (DB) or handling breaks (HB).

Term	Description
Fragmented	The core is comprised primarily of fragments of length less than 20 mm, and mostly of width less than core diameter.
Highly fractured	Core lengths are generally less than 20 mm to 40 mm with occasional fragments.
Fractured	Core lengths are mainly 30 mm to 100 mm with occasional shorter and longer sections.
Slightly fractured	Core lengths are generally 300 mm to 1000 mm, with occasional longer sections and sections of 100 mm to 300 mm.
Unbroken	The core does not contain any fractures.

### Rock Core Recovery

TCR = Total Core Recovery

SCR = Solid Core Recovery

RQD = Rock Quality Designation

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100\%$$

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100\%$$

$$= \frac{\sum \text{Axial lengths of core > 100 mm long}}{\text{Length of core run}} \times 100\%$$

### Rock Strength Tests

- ▼ Point load strength Index (Is50) - axial test (MPa)
- ▶ Point load strength Index (Is50) - diametral test (MPa)
- Uniaxial compressive strength (UCS) (MPa)

### Defect Type Abbreviations and Descriptions

Defect Type (with inclination given)	Planarity	Roughness
BP Bedding plane parting	PI Planar	Pol Polished
FL Foliation	Cu Curved	Sl Slickensided
CL Cleavage	Un Undulating	Sm Smooth
JT Joint	St Stepped	Ro Rough
FC Fracture	Ir Irregular	VR Very rough
SZ/SS Sheared zone/ seam (Fault)	Dis Discontinuous	
CZ/CS Crushed zone/ seam	<b>Thickness</b>	<b>Coating or Filling</b>
DZ/DS Decomposed zone/ seam	Zone > 100 mm	Cn Clean
FZ Fractured Zone	Seam > 2 mm < 100 mm	Sn Stain
IS Infilled seam	Plane < 2 mm	Ct Coating
VN Vein		Vnr Veneer
CO Contact		Fe Iron Oxide
HB Handling break		X Carbonaceous
DB Drilling break		Qz Quartzite
		MU Unidentified mineral
	<b>Inclination</b>	
	Inclination of defect is measured from perpendicular to and down the core axis. Direction of defect is measured clockwise (looking down core) from magnetic north.	

# Test, Drill and Excavation Methods

## Explanation of Terms (1 of 3)

### Sampling

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

Disturbed samples taken during drilling or excavation provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples may be taken by pushing a thin-walled sampling tube, e.g. U<sub>50</sub> (50 mm internal diameter thin walled tube), into soils and withdrawing a soil sample 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. Other sampling methods may be used. Details of the type and method of sampling are given in the report.

### Drilling / Excavation Methods

The following is a brief summary of drilling and excavation methods currently adopted by the Company and some comments on their use and application.

Hand Excavation - in some situations, excavation using hand tools, such as mattock and spade, may be required due to limited site access or shallow soil profiles.

Hand Auger - the hole is advanced by pushing and rotating either a sand or clay auger, generally 75-100 mm in diameter, into the ground. The penetration depth is usually limited to the length of the auger pole; however extender pieces can be added to lengthen this.

Test Pits - these are excavated with a backhoe or a tracked excavator, allowing close examination of the in-situ soils and, if it is safe to descend into the pit, collection of bulk disturbed samples. The depth of penetration is limited to about 3 m for a backhoe and up to 6 m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Large Diameter Auger (e.g. Pengo) - the hole is advanced by a rotating plate or short spiral auger, generally 300 mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube sampling.

Continuous Sample Drilling (Push Tube) - the hole is advanced by pushing a 50 - 100 mm diameter socket into the ground and withdrawing it at intervals to extrude the sample. This is the most reliable method of drilling in soils, since moisture content is unchanged and soil structure, strength etc. is only marginally affected.

Continuous Spiral Flight Augers - the hole is advanced using 90 - 115 mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface or, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be contaminated. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability, due to remoulding, contamination or softening of samples by ground water.

Non-core Rotary Drilling - the hole is 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.

Rotary Mud Drilling - similar to rotary drilling, but using drilling mud as a circulating fluid. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg. from SPT).

Continuous Core Drilling - a continuous core sample is obtained using a diamond tipped core barrel of usually 50 mm internal diameter. Provided full core recovery is achieved (not always possible in very weak or fractured rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation.

### In-situ Testing and Interpretation

#### Cone Penetrometer Testing (CPT)

Cone penetrometer testing (sometimes referred to as Dutch Cone) described in this report has been carried out using an electrical friction cone penetrometer.

The test is described in AS 1289.6.5.1-1999 (R2013). In the test, a 35 mm diameter rod with a cone tipped end 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 friction resistance on a separate 130 mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the push rod centre to an amplifier and recorder unit mounted on the control truck. As penetration occurs (at a rate of approximately 20 mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records. The information provided on the charts comprises:

- (i) Cone resistance ( $q_c$ ) - the actual end bearing force divided by the cross sectional area of the cone, expressed in MPa.
- (ii) Sleeve friction ( $q_f$ ) - the frictional force of the sleeve divided by the surface area, expressed in kPa.
- (iii) Friction ratio - the ratio of sleeve friction to cone resistance, expressed in percent.

There are two scales available for measurement of cone resistance. The lower (A) scale (0 - 5 MPa) is used in very soft soils where increased sensitivity is required and is shown in the graphs as a dotted line. The main (B) scale (0 - 50 MPa) is less sensitive and is shown as a full line.

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 % - 2 % are commonly encountered in sands and very soft clays rising to 4 % - 10 % in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) N \text{ (blows/300 mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:

$$q_c = (12 \text{ to } 18) C_u$$

# Test, Drill and Excavation Methods

## Explanation of Terms (2 of 3)

Interpretation of CPT values can also be made to allow estimation of modulus or compressibility values to allow calculation of foundation settlements.

Inferred stratification as shown on the attached reports is assessed from the cone and friction traces and from experience and information from nearby boreholes etc. This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties, and where precise information on soil classification is required, direct drilling and sampling may be preferable.

### Standard Penetration Testing (SPT)

Standard penetration tests are used mainly in non-cohesive soils, but occasionally also in cohesive soils as a means of determining density or strength and also of obtaining a relatively undisturbed sample.

The test procedure is described in AS 1289.6.3.1-2004. The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm penetration depth increments and the 'N' value is taken as the number of blows for the last two 150 mm depth increments (300 mm total penetration). In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued. The test results are reported in the following form:

- (i) Where full 450 mm penetration is obtained with successive blow counts for each 150 mm of say 4, 6 and 7 blows:  
as 4, 6, 7  
N = 13
- (ii) 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 15, 30/40 mm.

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally, the test method is used to obtain samples in 50 mm diameter thin walled sample tubes in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

### Dynamic Cone (Hand) Penetrometers

Hand penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows for successive 150mm increments of penetration. Normally, there is a depth limitation of 1.2m but this may be extended in certain conditions by the use of extension rods. Two relatively similar tests are used.

**Perth sand penetrometer (PSP)** - a 16 mm diameter flat ended rod is driven with a 9 kg hammer, dropping 600 mm. The test, described in AS 1289.6.3.3-1997 (R2013), was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

**Cone penetrometer (DCP)** - sometimes known as the Scala Penetrometer, a 16 mm rod with a 20 mm diameter cone end is driven with a 9 kg hammer dropping 510 mm. The test, described in AS 1289.6.3.2-1997 (R2013), was developed initially for pavement sub-grade investigations, with correlations of the test results with California Bearing Ratio published by various Road Authorities.

### Pocket Penetrometers

The pocket (hand) penetrometer (PP) is typically a light weight spring hand operated device with a stainless steel

loading piston, used to estimate unconfined compressive strength,  $q_u$ , (UCS in kPa) of a fine grained soil in field conditions. In use, the free end of the piston is pressed into the soil at a uniform penetration rate until a line, engraved near the piston tip, reaches the soil surface level. The reading is taken from a gradation scale, which is attached to the piston via a built-in spring mechanism and calibrated to kilograms per square centimetre (kPa) UCS. The UCS measurements are used to evaluate consistency of the soil in the field moisture condition. The results may be used to assess the undrained shear strength,  $C_u$ , of fine grained soil using the approximate relationship:

$$q_u = 2 \times C_u.$$

It should be noted that accuracy of the results may be influenced by condition variations at selected test surfaces. Also, the readings obtained from the PP test are based on a small area of penetration and could give misleading results. They should not replace laboratory test results. The use of the results from this test is typically limited to an assessment of consistency of the soil in the field and not used directly for design of foundations.

### Test Pit / Borehole Logs

Test pit / borehole log(s) presented herein are an engineering and / or geological interpretation of the subsurface conditions. Their reliability will depend to some extent on frequency of sampling and methods of excavation / drilling. Ideally, continuous undisturbed sampling or excavation / core drilling will provide the most reliable assessment but this is not always practicable, or possible to justify on economic grounds. In any case, the test pit / borehole logs represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of test pits / boreholes, the frequency of sampling and the possibility of other than 'straight line' variation between the test pits / boreholes.

### Laboratory Testing

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

### Ground Water

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

- In low permeability soils, ground water although present, 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 prior weather changes. They may not be the same at the time of construction as are indicated in the report.
- The use of water or mud as a drilling fluid will mask any ground water inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water observations are to be made.

More reliable measurements can be made by installing standpipes, which are read at intervals over several days, or 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 a perched water table.



# Test, Drill and Excavation Methods

## Explanation of Terms (3 of 3)

### DRILLING / EXCAVATION METHOD

HA	Hand Auger	RD	Rotary Blade or Drag Bit	NQ	Diamond Core - 47 mm
AD/V	Auger Drilling with V-bit	RT	Rotary Tricone bit	NMLC	Diamond Core – 51.9 mm
AD/T	Auger Drilling with TC-Bit	RAB	Rotary Air Blast	HQ	Diamond Core – 63.5 mm
AS	Auger Screwing	RC	Reverse Circulation	HMLC	Diamond Core – 63.5 mm
HSA	Hollow Stem Auger	CT	Cable Tool Rig	DT	Diatube Coring
S	Excavated by Hand Spade	PT	Push Tube	NDD	Non-destructive digging
BH	Tractor Mounted Backhoe	PC	Percussion	PQ	Diamond Core - 83 mm
JET	Jetting	E	Tracked Hydraulic Excavator	X	Existing Excavation

### SUPPORT

Nil	No support	S	Shotcrete	RB	Rock Bolt
C	Casing	Sh	Shoring	SN	Soil Nail
WB	Wash bore with Blade or Bailer	WR	Wash bore with Roller	T	Timbering

### WATER

- ∇ Water level at date shown
- ▷ Water inflow
- ◁ Partial water loss
- ◀ Complete water loss

GROUNDWATER NOT OBSERVED (NO) The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED (NX) The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

### PENETRATION / EXCAVATION RESISTANCE

- L Low resistance: Rapid penetration possible with little effort from the equipment used.
- M Medium resistance: Excavation possible at an acceptable rate with moderate effort from the equipment used.
- H High resistance: Further penetration possible at slow rate & requires significant effort equipment.
- R Refusal/ Practical Refusal. No further progress possible without risk of damage/ unacceptable wear to digging implement / machine.

These assessments are subjective and dependent on many factors, including equipment power, weight, condition of excavation or drilling tools, and operator experience.

### SAMPLING

D	Small disturbed sample	W	Water Sample	C	Core sample
B	Bulk disturbed sample	G	Gas Sample	CONC	Concrete Core

U63 Thin walled tube sample - number indicates nominal undisturbed sample diameter in millimetres

### TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004	CPT	Static cone penetration test
4,7,11	4,7,11 = Blows per 150mm.	CPTu	CPT with pore pressure (u) measurement
N=18	'N' = Recorded blows per 300mm penetration following 150mm seating	PP	Pocket penetrometer test expressed as instrument reading (kPa)
DCP	Dynamic Cone Penetration test to AS1289.6.3.2-1997.	FP	Field permeability test over section noted
	'n' = Recorded blows per 150mm penetration	VS	Field vane shear test expressed as uncorrected shear strength (sv = peak value, sr = residual value)
<b>Notes:</b>		PM	Pressuremeter test over section noted
RW	Penetration occurred under rod weight only	PID	Photoionisation Detector reading in ppm
HW	Penetration occurred under hammer and rod weight only	WPT	Water pressure tests
20/100mm	Where practical refusal or hammer double bouncing occurred, blows and penetration for that interval are reported (e.g. 20 blows for 100 mm penetration)		

### SOIL DESCRIPTION

Density	Consistency	Moisture
VL Very loose	VS Very soft	D Dry
L Loose	S Soft	M Moist
MD Medium dense	F Firm	W Wet
D Dense	St Stiff	Wp Plastic limit
VD Very dense	VSt Very stiff	Wl Liquid limit
	H Hard	

### ROCK DESCRIPTION

Strength	Weathering
VL Very low	EW Extremely weathered
L Low	HW Highly weathered
M Medium	MW Moderately weathered
H High	SW Slightly weathered
VH Very high	FR Fresh
EH Extremely high	