Brett Crowther

Geotechnical, Hydrogeological and Acid Sulfate Soil Assessment: 3 Gondola Road, North Narrabeen, NSW

P2108694JR02V03
May 2022

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

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MANAGEMENT

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

Contents

1 Overview

1.1 Proposed Development

Proposed development details are summarised in Table 1.

Table 1: Summary of proposed development.

Item	Details
Property address	3 Gondola Road, North Narrabeen, NSW ('the site').
Legal identifier	Lot 188 in DP 16719 (Six Maps).
LGA	Northern Beaches Council ('Council').
Site area	638.7 m^2 (TNSG, 2021).
Proposed development	We understand from the architectural plans (MAI, 2022) and client provided information that the development will include construction of a new three-storey mixed-use building comprising: o A lower ground and basement carpark level with bulk excavation level (BEL) of approximately RL -2.3 mAHD considering a typical 300 mm thick basement floor slab. This will require excavation up to approximately 4.3 metres below ground level (mbgl). o A lift well with an expected lift well base level of approximately RL -2.8 mAHD. This will likely require bulk excavations up to approximately 5.1 mbgl for the lift well, considering a typical 300 mm thick floor slab. o An upper ground level for retail purposes with a floor level of approximately 4.4 mAHD, with two levels of residential apartments above. We note that the proposed basement excavations will extend to all site boundaries and into the zone of influence of neighbouring properties and / or other infrastructure along site boundaries. The zone of influence is defined by an imaginary line drawn up at 45° away from the base of the excavation. Refer to Figure 2, Attachment A for proposed site layout.

1.2 Assessment Scope of Works

The assessment scope of works is summarised in Table 2.

Table 2: Summary of investigation scope of works.

Item	Details
Assessment purpose	Geotechnical, hydrogeological and acid sulfate soil assessment to support a development application (DA) and to assist structural design of the proposed development.
Investigation scope of work	Field investigations conducted on 2 April 2022 included: o Review of DBYD survey plans and buried service search. o General site walkover to review site topography, drainage and geology. o Concrete coring followed by mud drilling of one borehole using a truck mounted drill rig up to 9.0 mbgl. o A total of six Standard Penetration Tests (SPT) in BH101 at 1.0, 2.5, 4.0, 5.5, 7.0 and 8.5 mbgl. o One Dynamic Cone Penetrometer (DCP) test (DCP101) to a depth of 6.0 mbgl to assess soil consistency. o Collection of soil samples for laboratory testing and for future reference. Site testing locations are shown in Figure 2, Attachment A.
Laboratory testing	Testing carried out by Envirolab Services, a National Association of Testing Authorities (NATA) accredited laboratory, included soil aggressivity testing on two soil samples and sPOCAS analysis on five soil samples.

2 General Site Details and Investigation Findings

2.1 General Site Details

General site details are summarised in Table 3.

Table 3: Summary of general site details based on desktop review and site walkover.

Item	Comment
Topography	Within undulating terrain at the base of a valley between two adjacent northwest-southeast aligned ridges. The site is located approximately 40 m south of an east-west aligned man made drainage channel and 120 m west of South Creek.
Typical slopes and aspect	The site generally has a north / north easterly aspect with overall grades generally less than 2 %.
Site elevation	Site elevation ranges between approximately 1.96 mAHD in the north eastern corner and 2.13 mAHD in the south western corner of the site (TNSG, 2021).
Expected geology	Quaternary deposits (Qha) generally comprising silty to peaty quartz sand, silt and clay, with ferruginous and humic cementation in places and common shell layers (Herbert, 1983).
Soil landscape	The NSW Office of Environment and Heritage's (OEH) information system (eSPADE) indicates the site as being part of the Warriewood Soil Landscape consisting of level to gently undulating swales, depressions and infilled lagoons on Quaternary sands. This soil landscape is often associated with highly permeable soils, localised flooding hazard and high watertable (<2 mbgl).
Existing development	Existing site development includes: o A two-storey commercial building and concrete hardstands in the northern portion of the site. o A two-level carpark in the southern portion of the site with one level at ground surface level and the other over an elevated platform which is connected to the ground level via a ramp.
Neighbouring environment	At the time of the geotechnical investigation, the site was surrounded by: o Gondola Road to the north. o A single storey commercial building to the west. o A former development demolished to east (Lot 187 in DP16719). o Residential development to the south.
Drainage	Via overland flow to the north into Council's stormwater system along Gondola Road.

2.2 Subsurface Conditions

The investigation revealed the following generalised subsurface units underlie an approximately 0.15 m thick concrete pavement across the site:

Unit A: Fill comprising sand, encountered up to 1.0 mbgl, expected to have been placed under uncontrolled conditions for site raising and levelling purposes.

Unit B: Marine sands:

- Unit B1: Very loose and loose encountered below fill to approximately 4.0 mbgl.
- Unit B2: Loose to medium dense encountered to approximately 5.5 mbgl.
- Unit B3: Medium dense encountered to investigation termination depth of 9.0 mbgl.

We note that recorded DCP values at depth may overestimate soil density compared to actual site conditions due to increased skin friction of the rods. We have inferred soil strength from SPT results.

Encountered conditions are described in more detail on the borehole log in Attachment B and associated explanatory notes in Attachment G. For DCP test result refer to Attachment C.

3 Hydrogeological Assessment

3.1 NSW Department of Primary Industries Bore Search

A review of NSW Department of Primary Industries - Water (DPI-Water) groundwater bore database indicates three groundwater bores with available groundwater data are located within 500 m of the site. Bore data is summarised in Table 4.

Table 4: DPI-Water real time groundwater details for bores in the vicinity of the site.

Bore ID	Approx. Distance From Site (m) [1]	Surface Elevation (mAHD) [1]	SWL mbgl (mAHD)	Water Bearing Zone Geology
GW111041	65	2.0	2.0 (0.00)	Marine deposits
GW111042	65	2.0	2.0 (0.00)	Marine deposits
GW111043	60	2.0	2.0 (0.00)	Marine deposits

Notes:

1. From Google Earth.

3.2 Groundwater Observations

Groundwater inflow was encountered during drilling of BH101 at 1.0 mbgl (1.0 mAHD).

3.3 Conclusions

For the purpose of this report, we have adopted a permanent groundwater depth of 0.5 mbgl (approximately 1.5 mAHD), allowing for 0.5 m fluctuation due to seasonal and tidal fluctuations.

Based on our observations and groundwater level measurements as well as engineering judgements we infer and conclude the following:

- Bulk excavations to -2.3 mAHD and -3.7 mAHD for the basement car park and lift well, respectively, will intercept the adopted permanent groundwater table of 1.5 mAHD. The inflow rate into excavations is expected to be high.
- Proposed excavations into saturated soil will require dewatering to manage inflow and to provide a suitably dry working platform during the basement excavation.

- We recommend installation of groundwater wells and groundwater level monitoring to confirm permanent groundwater levels and fluctuations.

4 Geotechnical Assessment

4.1 Laboratory Test Results

Laboratory soil aggressivity test results are provided in Attachment C and summarised in Table 5 below.

Table 5: Soil aggressivity test results.

BH	Depth (mbgl)	Material	EC_e (dS/m) [1]	Resistivity (ohm/cm)	pH	Chloride (Cl) (mg/kg)	Sulphate (SO_4) (mg/kg)	Exposure Classification		
								AS 2159 [2]	AS 2159 [3]	AS 3600 [4]
BH101	1.0 – 1.2	SAND	1.29	13,000	8.7	<10	10	Mild	Non-aggressive	A2
BH101	4.0 – 4.2	SAND	1.87	9,200	8.9	21	63	Mild	Non-aggressive	A2

Notes:

1. Based on EC to ECe multiplication factor of 17 from Table 6.1 in DWLC (2002).
2. Exposure classification for concrete piles in soil based on Table 6.4.2(C) of AS 2159:2009.
3. Exposure classification for steel piles in soil based on Table 6.5.2(C) of AS 2159:2009.
4. Exposure classification for buried concrete based on Tables 4.8.1 and 4.8.2 of AS 3600:2018.

In accordance with AS3600:2018, an exposure classification of 'A2' should be adopted for buried reinforced concrete footings founding in marine soils. In accordance with AS2159:2009, an exposure classification of 'mild' and 'non-aggressive' may be adopted for design of buried concrete and steel piles, respectively.

4.2 Material Properties

Material properties inferred from observations during borehole drilling, such as auger penetration resistance, DCP / SPT test results as well as engineering judgement are summarised in Table 6.

Table 6: Material properties.

Unit	Layer	$\gamma_{in-situ}$ [1] (kN/m³)	Ø' [4] (deg)	E' [5] (MPa)	K_s [6] (MPa/m)
A	FILL (uncontrolled): SAND	16	NA [5]	NA [5]	NA [5]
B1	MARINE: SAND (very loose and loose, saturated)	18	27	5	5
B2	MARINE: SAND (loose to medium dense, saturated)	19	30	10	10
B3	MARINE: SAND (medium dense, saturated)	19	32	15	15

Notes:

1. Material in-situ unit weight, based on visual assessment.
2. Effective internal friction angle, assuming drained conditions.
3. Effective elastic modulus.
4. Vertical modulus of subgrade reaction. Horizontal modulus may be obtained by taking 1/3 K_S.
5. Not Applicable.

4.3 Risk of Slope Instability

No evidence of former or current slope movement was observed at the site. We consider the risk to property and loss of life by potential slope instability, such as landslide or soil creep, to be very low subject to the recommendations in this report, including appropriate excavation support, and adoption of relevant engineering standards and industry guidelines.

A detailed slope risk assessment in accordance with Australian Geomechanics Society's Landslide Risk Management Guidelines (2007) was not undertaken.

5 Acid Sulfate Soil Assessment

5.1 Guidelines

This assessment was undertaken in general accordance with the following guidelines:

- Acid Sulfate Soil Management Advisory Committee (1998), Acid Sulfate Soil Manual, referred to as ASSMAC (1998).
- Qld Natural Resources, Mines and Energy (2004) Acid Sulfate Soil Laboratory Methods Guidelines.

5.2 Acid Sulfate Soil Risk Map Classification

The Pittwater LEP (2014) ASS planning map indicates that the site is Class 3 land, as shown in Figure 1. ASSMAC (1998) indicates that development on Class 3 land has the potential to pose an environmental risk, if works extend more than 1 metre below the natural ground surface and / or where development is likely to lower the water table by 1 m. Proposed works trigger the need for a preliminary geomorphic ASS assessment to be undertaken.

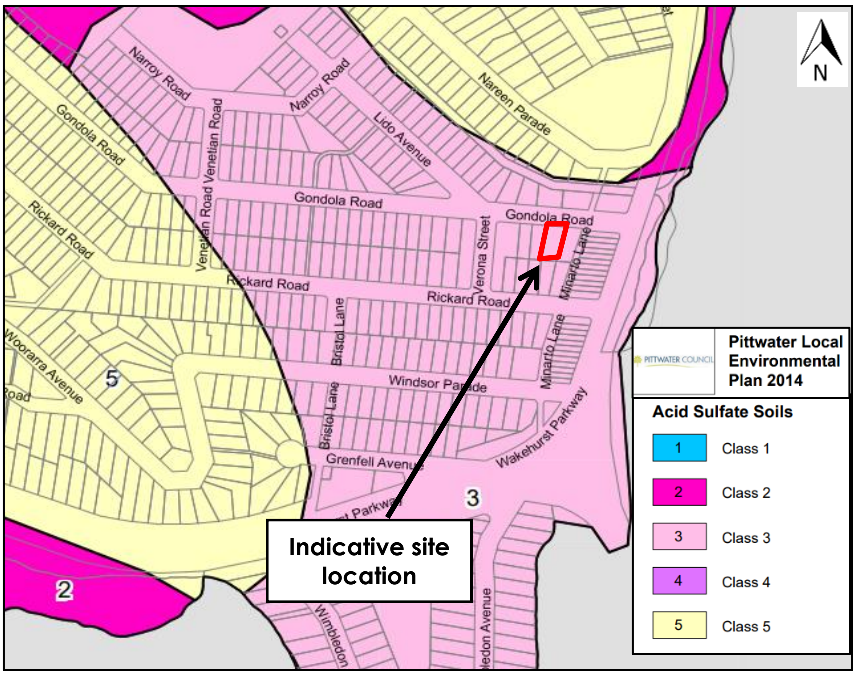

Figure 1: Pittwater LEP (2014) ASS risk map showing site location relative to risk classes.

5.3 Geomorphic Setting

The likelihood of ASS occurrence at a site is a function of various geomorphic parameters, in particular those listed in Table 7 as derived from ASSMAC (1998). Each is an indicator that ASS may be present onsite.

Table 7: Site geomorphic features indicative of ASS.

Geomorphic Feature	Present On Site?
Holocene sediments	Yes
Soil horizons less than 5 mAHD	Yes
Marine / estuarine sediments or tidal lakes	Yes
Coastal wetland; backwater swamps; waterlogged or scalded areas; inter-dune swales or coastal sand dunes	Likely [1]
Dominant vegetation is mangroves, reeds, rushes and other swamp or marine tolerant species.	Likely [1]
Geologies containing sulfide bearing material / coal deposits or former marine shales/sediments	Possible
Deep older (Holocene or Pleistocene) estuarine sediments > 10 mbgl (if deep excavation or drainage is proposed)	Possible

Notes:

1. Likely to have existed prior to development of the area.

Some of the geomorphic features that represent risk of ASS being on the site are present. Therefore, the geomorphic setting of the site indicates that actual or potential ASS may be present and laboratory testing of soils is required.

5.4 sPOCAS Assessment

5.4.1 Methodology

Five soil samples, as summarised in Table 8, were collected from boreholes and submitted for sPOCAS analysis.

Table 8: Summary of samples analysed by laboratory for sPOCAS.

Borehole ID	Approximate Surface Elevation [1] (mAHD)	Sample Depth (mbgl)	Material	Approximate Sample Elevation (mAHD)
BH101	2.0	0.5 to 0.6	(Fill)	1.4 to 1.5
		1.0 to 1.2	(Marine Sand)	0.8 to 1.0
		2.5 to 2.7		-0.7 to -0.5
		4.0 to 4.2		-2.2 to -2.0
		5.5 to 5.7		-3.7 to -3.5

Notes:

1. Surface elevation according to survey plan by GSS (2017).

5.4.2 ASS Action Criteria

It is estimated that more than 1000 tonnes of soil will be disturbed. According to Table 4.4 of ASSMAC (1998), a detailed ASS management plan (ASSMP) would be required if the soil exhibits one of the following criteria (for >1,000 tonnes disturbed soil):

- Oxidisable sulphur (S_{POS}) is ≥ 0.03%; or
- TPA or TSA is ≥18 mol H^+/tonne.

5.4.3 Results

Laboratory sPOCAS analysis are shown in Attachment D. Analytical analysis indicates the presence of potential acid sulfate soils (PASS) at the site:

- All samples returned values for $pH_{KCL} - pH_{OX}$ of > 1.
- 1 sample returned a value for pH_{OX} of < 3.5.
- 3 of the 5 samples returned S_{POS} values equal to or above the criteria of 0.03 %w/w.
- 1 of the 5 samples returned a net acidity (moles H^+/t) exceeding the TPA and TSA criteria of 18 moles H^+/t.

5.5 Discussions and Conclusions

On the basis of the ASS action criteria presented in Section 5.4.2, we conclude tested soil samples below 1.2 mbgl exceed the action criteria either for the acid trail and / or sulfur trail and therefore to be PASS. In accordance with ASSMAC (1998), an ASSMP will be required if PASS soils are to be disturbed during construction works. 1 of the 5 samples requires a liming rate of 40 kg $CaCO_3$ /t.

Should materials be identified during construction works which do not resemble materials identified in this report, Martens and Associates should be contacted to inspect the material and assess the need for further testing / advice.

6 Geotechnical Recommendations

6.1 Overview

Geotechnical recommendations for site development are provided below. Further general geotechnical recommendations are provided in Attachment F.

6.2 Excavatability

Excavations for the basement car park are expected to encounter uncontrolled fill and very loose and loose marine sands. These soils should be readily excavated using conventional tracked earthmoving equipment. Consideration should be given to groundwater induced impacts within the excavation base in developing construction methodologies, including use of appropriate plant, and designs.

All excavation work should be completed with reference to the most recent version of Code of Practice 'Excavation Work', by Safe Work Australia. Excavation method statements will need to be prepared by the excavation contractor prior to the issue of CC.

6.3 Material Disposal

Prior to any fill material being removed from site, a formal waste classification assessment shall be required in accordance with NSW EPA (2014) Waste Classification Guidelines. Removal of PASS is to be undertaken in accordance with the ASSMP.

6.4 Excavation Support

Bulk excavation will extend into the zone of influence of neighbouring properties / structures along the perimeter of the site. Excavations must be temporarily and permanently supported to maintain excavation stability and limit potential adverse impacts on neighbouring structures. Appropriate excavation support methodologies should be adopted by the excavation contractor and design engineer and approved by a geotechnical engineer. This should include assessment of foundation conditions of adjacent building footings.

As excavations will extend beyond the groundwater level, partial cut-off walls such as diaphragm walls or secant pile walls should be adopted in preventing water inflow into the excavation while also providing lateral restraint. Cut-off wall depth will need to be determined based on adopted dewatering methodologies and on groundwater recharge rates to limit upward seepage of groundwater at the excavation base.

Additional structural support may be required to minimise lateral deflections. The use of anchors is not recommended due to generally low bond resistance in sand. It is therefore recommended that internal propping be installed during a staged excavation sequence. The shoring design and propping requirements should consider surcharge loads from adjacent buildings.

Consideration should be given to the potential removal of support for existing adjacent footings during pile / diaphragm wall installation. Mitigation measures for piles could include the use of steel casing or continuous flight auger (CFA) piles. Pile installation should also avoid consecutive construction of two immediately adjacent piles. An experienced piling contractor should be engaged to ensure good verticality of piles to limit gaps between piles that could lead to loss of retained materials.

Temporary shoring walls may be designed to provide long term retention with lateral restraint provided by basement and ground floor slabs.

Shoring or retaining wall design may adopt preliminary earth pressure coefficients provided in Section 6.5.

6.5 Ground vibration and Dilapidation Assessment

Care will be required to limit structural distress to neighbouring structures and potential settlement of the foundation materials caused by construction plant-induced ground vibrations. This may be achieved by:

a. Adopting appropriate plant, such as limiting the excavator size.

b. Adopting appropriate demolition and construction methodologies, including using lowest possible gears while plant traverses the site and limiting hammering of concrete during demolition and, if considered necessary, carry out hammering as far from existing structures as possible.

c. Preparing a vibration monitoring plan and monitoring plant-induced vibrations in accordance with AS 2187.2, Appendix J (2006).

d. Dilapidation surveys of adjacent structures prior to excavation and following completion of the development to identify any damage caused by the excavation process.

6.6 Earth Pressure Coefficients

Shoring or retaining wall design may adopt active, at rest and passive earth pressure coefficients of:

- 0.4, 0.56, 2.5 for very loose and loose marine sands.
- 0.33, 0.5, 3.0 for loose to medium dense marine sands.
- 0.31, 0.47, 3.26 for medium dense marine sands.

Design should consider groundwater pressures and live and dead loads on neighbouring properties.

6.7 Foundations

Bulk excavations are likely to expose loose to medium dense sands at basement level. Suitable foundations may comprise a stiffened raft slab or shallow footings such as pad or strip footings founding in loose to medium dense marine sand. For a foundation at 4.3 mbgl, a preliminary allowable end bearing capacity (AEBC) of 100 kPa may be adopted for preliminary design purposes. However detailed foundation analysis should be carried out following further investigation, to confirm bearing capacity and determine the magnitude and distribution of settlement under working load.

Should higher bearing capacities or settlement reducing piles be required, consideration may be given to non-displacement piles (e.g., bored concrete piles or CFA piles) or displacement piles (e.g., steel screw piles). A preliminary allowable end bearing capacity of 250 kPa may be adopted for non-displacement piles embedded into medium dense sand below 6 m depth. Shaft resistance should be ignored due to loose to medium dense saturated soils. We recommend further investigations are undertaken to confirm strength vs depth profile across the building footprint.

For bored piles, a temporary steel casing should be provided to prevent soil collapse during pile excavation. Casings should extend at least 2 m below pile base to limit pile foundation weakening as a result of pile excavations in groundwater. Pumping of water from excavation for cased bored piles is not recommended due to high groundwater inflow and adverse impacts on foundation conditions. A tremie pipe will be required during concrete placement for bored cast in-situ piles. Alternately CFA piles could be adopted.

Consideration may also be given to screw piles to support foundations. The screw pile design life, length and bearing capacity will depend on the adopted pile torque and type of proprietary system adopted.

All foundations should be founded on consistent materials to limit differential settlement and should be inspected by a qualified and experienced geotechnical engineer to confirm encountered conditions satisfy design assumptions.

6.8 Groundwater Management

Proposed basement excavations will extend below the groundwater table. Dewatering will be required for construction to reduce groundwater level to at least 2 m below bulk excavation level, in order for excavation and basement construction to be completed. An aquifer interference license and approval by NSW Office of Water will be required.

Piping failures or 'quick' conditions have been known to occur during excavation in sands. Care should be taken to ensure that the critical hydraulic gradient is not reached during excavation and dewatering. This can occur when the effective stress in the sand is reduced to zero due to the upward flow of water in the base. This can be mitigated against by: adopting cut-off basement perimeter walls; increasing the groundwater flow path length (e.g., by increasing the length of the walls); and designing basement walls and slabs to be waterproof and able to withstand hydrostatic pressures.

Groundwater drawdown during temporary dewatering can lead to settlement of adjacent shallow foundations or negative friction on pile foundations. The amount of settlement would depend on a number of factors including depth of drawdown and duration as well as compressibility of the soil. The amount of drawdown may be limited by the use of a cut-off wall and groundwater recharge outside the excavation. Groundwater wells should be installed outside the excavation footprint to monitor groundwater levels during excavation.

6.9 Soil Erosion Control

Removal of soil overburden should be performed in a manner that reduces the risk of sedimentation occurring in the Council stormwater system and on neighbouring lands. 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.

6.10 Site Classification

The site is classified as a class 'P' site in accordance with AS 2870 (2011), due to presence of very loose to loose marine sands underlying uncontrolled fill across the site. A reclassification to class 'A' is possible subject to all shallow footings founding in at least loose to medium dense sand with at least 100 kPa allowable end bearing capacity or higher density marine sand.

7 Proposed Additional Works

7.1 Works Prior to Construction Certificate

We recommend the following additional geotechnical works are carried out to develop the final design and prior to construction:

1. Additional boreholes / CPT investigations including installation of monitoring wells following demolition of the existing structures at the site, to confirm recommendations in this report particularly with respect to foundation bearing capacity and groundwater levels that apply across the building footprint.

2. Geotechnical monitoring plan to provide suitable monitoring during construction including location of instrumentation and trigger levels.

3. Review of the final design by a senior geotechnical engineer to confirm adequate consideration of the geotechnical risks and adoption of the recommendations provided in this report.

4. Inspections of shoring wall and foundation excavations by an experienced geotechnical engineer to confirm expected ground conditions and design bearing capacities have been achieved.

8 References

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Pittwater Local Environment Plan (LEP, 2014) Part 7.1: Acid Sulfate Soils.

Pittwater Local Environment Plan (LEP, 2014) *Acid Sulfate Soils Map - Sheet ASS_019.*

Standards Australia Limited (2004) AS 1289.6.3.1:2004, *Determination of the penetration resistance of a soil – Standard penetration test (SPT)*, SAI Global Limited.

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

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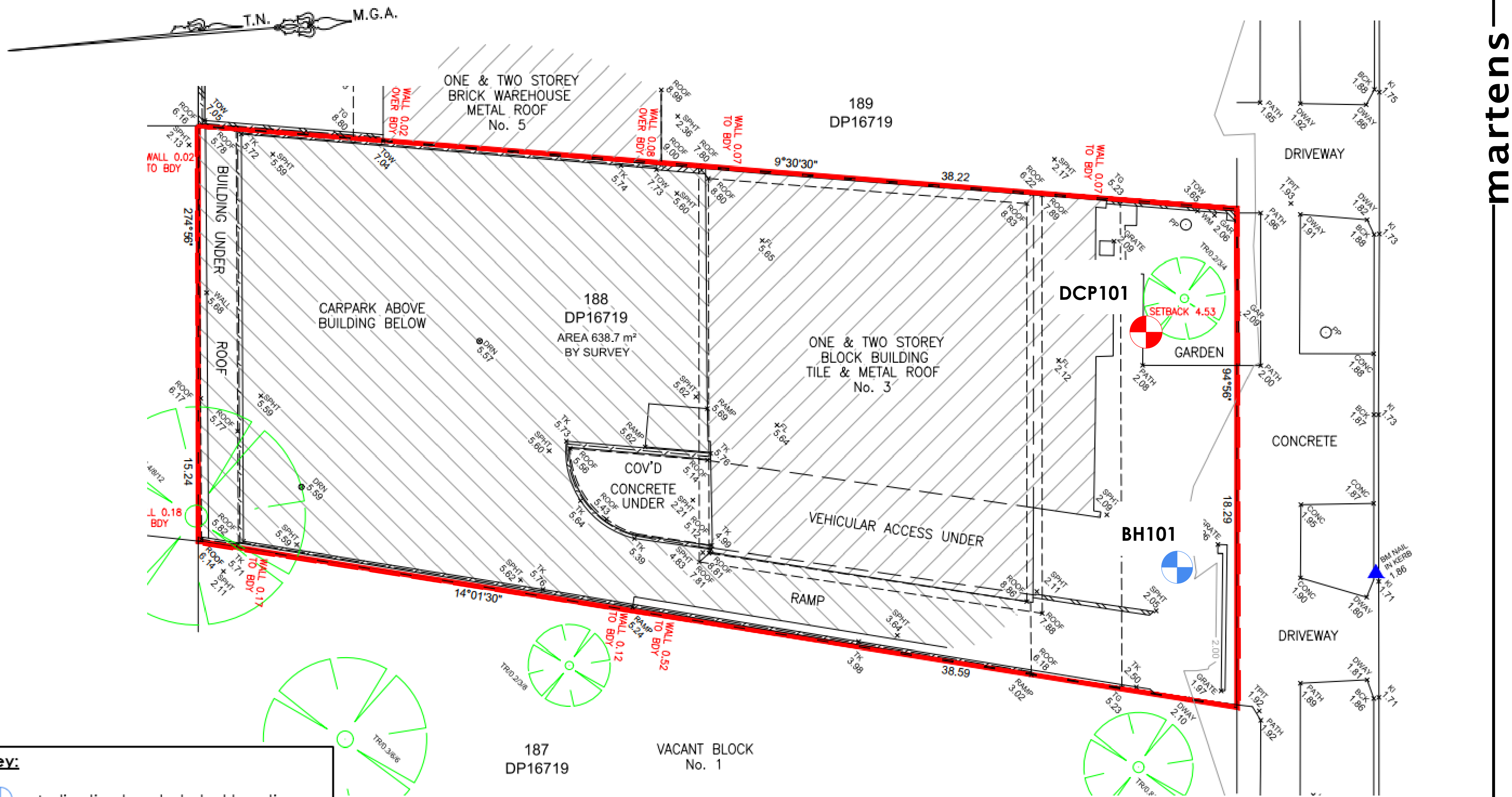
True North Survey Group (2021) Plan of Detail Over No.3 Gondola Road, North Narrabeen NSW 2101 Rev 0 Job No. 2368, dated 27/10/2021 (TNSG 2021).

9 Attachment A – Geotechnical Testing Plan



Key:

- Indicative borehole test location
- Indicative DCP test location
- Approximate site boundary

Martens & Associates Pty Ltd ABN 85 070 240 890		Environment | Water | Wastewater | Geotechnical | Civil | Management	
Drawn:	MZ	SITE LAYOUT AND GEOTECHNICAL TESTING PLAN 3 Gondola Road, North Narrabeen, NSW (Source: TNSG, 2021)	Drawing: FIGURE 2
Approved:	RE		
Date:	19.04.2022		
Scale:	NA		File No: P2108694JR02V01

10 Attachment B – Borehole Logs

CLIENT	Brett Crowther	COMMENCED	02/04/2022	COMPLETED	02/04/2022	**REF BH101**
PROJECT	Geotechnical Hydrogeological & Acid Sulfate Soil Assessment	LOGGED	MZ	CHECKED	RE	Sheet 1 OF 1
SITE	3 Gondola Road, North Narrabeen, NSW	GEOLOGY	Quaternary	VEGETATION	Nil	PROJECT NO. P2108694
EQUIPMENT	4WD ute-mounted hydraulic dril rig	LONGITUDE	151.29564	RL SURFACE	2 m	DATUM AHD
EXCAVATION DIMENSIONS	Ø100 mm x 9.00 m depth	LATITUDE	-33.70788	ASPECT	East	SLOPE 2%

Drilling					Sampling		Field Material Description				
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	USCS / ASCS CLASSIFICATION	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS
AD/T								CONCRETE SLAB;			PAVEMENT
AD/T	L			0.15 1.85	0.15-0.2/S/1 D 0.15-0.20 m 0.5-0.6/S/1 D 0.50-0.60 m		SP	SAND; fine grained; brown; trace silt; inferred; poorly compacted.	M - W	L	FILL
WB	L	▽ 02/04/22	1	1.00 1.00	SPT 1.00 m 3,2,4 N=6 1.00-1.2/S/1		SP	SAND; fine grained; dark grey to blackish grey; trace shells.	W	L	MARINE DEPOSITS
WB	L		2	2.50 -0.50	SPT 2.50 m 0,0,1 N=1 2.5-2.7/S/1		SM	Silty SAND; fine to medium grained; dark grey to blackish grey; with shells.	W	VL	
WB	L-M		3, 4	4.00 -2.00	SPT 4.00 m 3,4,5 N=9 4.00-4.2/S/1		SP	SAND; fine to medium grained; grey; with shells.	W	L - MD	
WB	M		5, 6	5.00 -3.00	SPT 5.50 m 4,7,8 N=15 5.5-5.7/S/1		SP	SAND; fine to medium grained; grey, occasional dark brown; with shells.	W	MD	
WB	M		7	7.00 -5.00	SPT 7.00 m 5,10,10 N=20 7.0-7.2/S/1			Grey with trace blackish grey.			
WB	M		8	8.40 -6.40	SPT 8.50 m 2,5,10 N=15 8.5-8.75/S/1			Grey, occasional blackish grey and brown.			
			9	9.00				Hole Terminated at 9.00 m (Target depth reached)			

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

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Engineering Log - BOREHOLE

MARTENS 2.00 LIB.GLB Log MARTENS BOREHOLE P2108694BH101V01.GPJ <<DrawingFile>> 27/04/2022 10:23 10.02.00.04 Datgel Lab and In Situ Tool - DGD | Lib: Martens 2.00 2016-11-13 Prj: Martens 2.00 2016-11-13

11 Attachment C – DCP ‘N’ Counts

Dynamic Cone Penetrometer Test Log Summary

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

Site	3 Gondola Road, North Narrabeen, NSW	**DCP Group Reference**	P2108694JS02V01
Client	Brett Crowther	**Log Date**	02.04.2022
Logged by	MZ		
Checked by	RE		
Comments	DCPs commenced at 50 mm bgl.		

TEST DATA

Depth Interval (m)	DCP101							
0.15	1							
0.30	3							
0.45	3							
0.60	4							
0.75	2							
0.90	3							
1.05	4							
1.20	4							
1.35	3							
1.50	5							
1.65	9							
1.80	13							
1.95	9							
2.10	7							
2.25	4							
2.40	4							
2.55	5							
2.70	9							
2.85	8							
3.00	8							
3.15	9							
3.30	11							
3.45	20							
3.60	17							
3.75	16							
3.90	18							
4.05	18							
4.20	20							
4.35	21							
4.50	20							
4.65	20							
4.80	16							
4.95	14							
5.10	16							
5.25	14							
5.40	15							
5.55	17							
5.70	17							
5.85	21							
6.00	22							
6.15	Terminated @ 6.05 mbgl.							
6.30								
6.45								
6.60								
6.75								
6.90								
7.05								
7.20								
7.35								
7.50								
7.65								
7.80								
7.95								
8.10								
8.25								
8.40								
8.55								
8.70								

12 Attachment D – sPOCAS Laboratory Test Results

sPOCAS Laboratory Test Results Interpretation

Method based on Acid Sulfate Soil Manual (ASSMAC, 1998)
Method ST-50 V05 Revised 30.04.2018

martens

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PROJECT DETAILS

Client	Brett Crowther	**Page No.**	1 of 1
Project	Geotechnical, Hydrogeological and ASS Assessment	**Date**	02.04.2022
Sampling Site	3 Gondola Road, North Narrabeen	**Job Number**	P2108694
Sample History	Sampled 02.04.2022	**Sampled By**	MZ

ASSUMED PARAMETERS

Gs - Specific gravity (g/cm^3)	2.7	**M - Exposed soil mass (t)**	> 1000	**ENV - Effective Neutralisation Value (%)**	90	**FOS - Factor of Safety for Liming Rate**	1.5

SAMPLE DETAILS / TEST RESULTS

Sample ID	Sample Depth (mAHD)	Material Type [1]	pH_{KCL} [2]	pH_{OX} [3]	TPA (mol H+/t) [4]	TSA (mol H+/t) [5]	S_{POS} (%S oxidisable) [6]	Assessment [7]	Liming Rate (kg $CaCO_3$/t) [8]
8694/BH101/0.5-0.6	0.50	C	9.9	8.4	< 5	< 5	0.020	PASS	<0.75
8694/BH101/1.0-1.2	1.00	C	9.8	7.7	< 5	< 5	0.020	PASS	<0.75
8694/BH101/2.5-2.7	2.50	C	9.4	**2.4**	**300**	**300**	**1.600**	PASS	<0.75
8694/BH101/4.0-4.2	4.00	C	9.9	7.8	<5	< 5	**0.080**	PASS	40.00
8694/BH101/5.5-5.7	5.50	C	9.8	7.8	< 5	< 5	**0.070**	PASS	<0.75
Assessment Criteria: (For exposed soil >1000t, use coarse textured criteria)		(F)ine textured; > 40 % clay	≤ 4 = AASS	< 3.5 = PASS pH_{KCL}-pH_{OX}>1 = PASS	62	62	0.100	TPA, TSA, S_{POS} > criteria = PASS	
		(M)edium textured; 5-40 % clay			36	36	0.060		
		(C)oarse textured; < 5 % clay			18	18	0.030		

Notes:
1. Material type based on field texture assessment or laboratory report.
2. Field pH (pH_F)or laboratory pH (pH_{KCL}). Bold (red) values indicate AASS.
3. Post peroxide oxidation pH. Bold (black) values indicate PASS.
4. Total Potential Acidity. Highlighted values exceed ASSMAC (1998) action criteria.
5. Total Sulfidic Acidity. Highlighted values exceed ASSMAC (1998) action criteria.
6. Percentage oxidisable sulphur. Highlighted values exceed ASSMAC (1998) action criteria.
7. NA = not AASS or PASS, AASS = Actual Acid Sulfate Soil, PASS = Potential Acid Sulfate Soil
8. From laboratory test results (refer to laboratory test certificates).

13 Attachment E – Laboratory Test Certificates

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CERTIFICATE OF ANALYSIS 292692

Client Details

Client	Martens & Associates Pty Ltd
Attention	M Zhang
Address	Suite 201, 20 George St, Hornsby, NSW, 2077

Sample Details

Your Reference	**P2208694:3 Gondola Road, North Narrabeen, NSW**
Number of Samples	5 Soil
Date samples received	05/04/2022
Date completed instructions received	05/04/2022

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

Date results requested by	12/04/2022
Date of Issue	13/04/2022
Reissue Details	This report replaces R00 created on 12/04/2022 due to: Prepared date amended

NATA Accreditation Number 2901. This document shall not be reproduced except in full.

Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Jenny He, Chemist
Priya Samarawickrama, Senior Chemist

Authorised By

Nancy Zhang, Laboratory Manager

sPOCAS + %S w/w						
Our Reference		292692-1	292692-2	292692-3	292692-4	292692-5
Your Reference	UNITS	8694/BH101/0.5-0.6	8694/BH101/1.0-1.2	8694/BH101/2.5-2.7	8694/BH101/4.0-4.2	8694/BH101/5.5-5.7
Date Sampled		02/04/2022	02/04/2022	02/04/2022	02/04/2022	02/04/2022
Type of sample		Soil	Soil	Soil	Soil	Soil
Date prepared	-	12/04/2022	12/04/2022	12/04/2022	12/04/2022	12/04/2022
Date analysed	-	12/04/2022	12/04/2022	12/04/2022	12/04/2022	12/04/2022
pH_{kcl}	pH units	9.9	9.8	9.4	9.9	9.8
TAA pH 6.5	moles H^+/t	<5	<5	<5	<5	<5
s-TAA pH 6.5	%w/w S	<0.01	<0.01	<0.01	<0.01	<0.01
pH_{Ox}	pH units	8.4	7.7	2.4	7.8	7.8
TPA pH 6.5	moles H^+/t	<5	<5	300	<5	<5
s-TPA pH 6.5	%w/w S	<0.01	<0.01	0.48	<0.01	<0.01
TSA pH 6.5	moles H^+/t	<5	<5	300	<5	<5
s-TSA pH 6.5	%w/w S	<0.01	<0.01	0.48	<0.01	<0.01
ANC_E	% $CaCO_3$	4.5	3.6	<0.05	5.1	3.5
a-ANC_E	moles H^+/t	900	720	<5	1,000	700
s-ANC_E	%w/w S	1.4	1.2	<0.05	1.6	1.1
S_{KCl}	%w/w S	0.006	0.007	0.11	0.01	0.01
S_P	%w/w	0.02	0.03	1.7	0.09	0.09
S_{POS}	%w/w	0.02	0.02	1.6	0.08	0.07
a-S_{POS}	moles H^+/t	12	12	1,000	49	46
Ca_{KCl}	%w/w	0.15	0.16	0.20	0.21	0.09
Ca_P	%w/w	1.6	1.3	1.1	2.2	1.3
Ca_A	%w/w	1.4	1.1	0.89	2.0	1.2
Mg_{KCl}	%w/w	0.010	0.010	0.014	0.014	0.009
Mg_P	%w/w	0.096	0.077	0.058	0.14	0.079
Mg_A	%w/w	0.086	0.066	0.044	0.13	0.071
S_{HCl}	%w/w S	<0.005	<0.005	<0.005	<0.005	<0.005
S_{NAS}	%w/w S	<0.005	<0.005	<0.005	<0.005	<0.005
a-S_{NAS}	moles H^+/t	<5	<5	<5	<5	<5
s-S_{NAS}	%w/w S	<0.01	<0.01	<0.01	<0.01	<0.01
Fineness Factor	-	1.5	1.5	1.5	1.5	1.5
a-Net Acidity	moles H^+/t	<5	<5	540	<5	<5
s-Net Acidity	%w/w S	<0.01	<0.01	0.86	<0.01	<0.01
Liming rate	kg $CaCO_3$/t	<0.75	<0.75	40	<0.75	<0.75
s-Net Acidity without -ANCE	%w/w S	0.02	0.02	0.86	0.08	0.07
a-Net Acidity without ANCE	moles H^+/t	12	12	540	49	46
Liming rate without ANCE	kg $CaCO_3$/t	0.92	0.88	40	3.7	3.5

Soil Aggressivity			
Our Reference		292692-2	292692-4
Your Reference	UNITS	8694/BH101/1.0-1.2	8694/BH101/4.0-4.2
Date Sampled		02/04/2022	02/04/2022
Type of sample		Soil	Soil
pH 1:5 soil:water	pH Units	8.7	8.9
Electrical Conductivity 1:5 soil:water	µS/cm	76	110
Chloride, Cl 1:5 soil:water	mg/kg	<10	21
Sulphate, SO4 1:5 soil:water	mg/kg	10	63
Resistivity in soil*	ohm m	130	92

Method ID	Methodology Summary
Inorg-001	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.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25°C in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA 22nd ED 2510 and Rayment & Lyons. Resistivity is calculated from Conductivity (non NATA). Resistivity (calculated) may not correlate with results otherwise obtained using Resistivity-Current method, depending on the nature of the soil being analysed.
Inorg-064	sPOCAS determined using titrimetric and ICP-AES techniques. Based on National acid sulfate soils identification and laboratory methods manual June 2018. Ideally samples should be received in the laboratory at <4oC. Please refer to SRA for sample temperature on receipt. Net acidity including ANC has a safety factor of 1.5 applied. Neutralising value (NV) of 100% is assumed for liming rate The recommendation that the SHCL concentration be multiplied by a factor of 2 to ensure retained acidity is not underestimated, has not been applied in the SHCL results reported.
Inorg-081	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: sPOCAS + %S w/w					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			12/04/2022	[NT]	[NT]	[NT]	[NT]	12/04/2022	[NT]
Date analysed	-			12/04/2022	[NT]	[NT]	[NT]	[NT]	12/04/2022	[NT]
pH $_{kcl}$	pH units		Inorg-064	[NT]	[NT]	[NT]	[NT]	[NT]	96	[NT]
TAA pH 6.5	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	97	[NT]
s-TAA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
pH $_{Ox}$	pH units		Inorg-064	[NT]	[NT]	[NT]	[NT]	[NT]	104	[NT]
TPA pH 6.5	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	83	[NT]
s-TPA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
TSA pH 6.5	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
s-TSA pH 6.5	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
ANC_E	% $CaCO_3$	0.05	Inorg-064	<0.05	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
a-ANC_E	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
s-ANC_E	%w/w S	0.05	Inorg-064	<0.05	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
S_{KCl}	%w/w S	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
S_P	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
S_{POS}	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
a-S_{POS}	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Ca_{KCl}	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Ca_P	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Ca_A	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Mg_{KCl}	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Mg_P	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Mg_A	%w/w	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
S_{HCl}	%w/w S	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
S_{NAS}	%w/w S	0.005	Inorg-064	<0.005	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
a-S_{NAS}	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
s-S_{NAS}	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Fineness Factor	-	1.5	Inorg-064	<1.5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
a-Net Acidity	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
s-Net Acidity	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Liming rate	kg $CaCO_3$/t	0.75	Inorg-064	<0.75	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
s-Net Acidity without -ANCE	%w/w S	0.01	Inorg-064	<0.01	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]

QUALITY CONTROL: sPOCAS + %S w/w					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
a-Net Acidity without ANCE	moles H^+/t	5	Inorg-064	<5	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
Liming rate without ANCE	kg $CaCO_3$/t	0.75	Inorg-064	<0.75	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]

QUALITY CONTROL: Soil Aggressivity					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	292692-4
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	2	8.7	8.8	1	100	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	2	76	79	4	105	[NT]
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	2	<10	<10	0	100	87
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	2	10	10	0	96	70
Resistivity in soil*	ohm m	1	Inorg-002	<1	2	130	130	0	[NT]	[NT]

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

Quality Control Definitions

Blank	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.
Duplicate	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.
Matrix Spike	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.
LCS (Laboratory Control Sample)	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.
Surrogate Spike	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.

14 Attachment F – General Geotechnical Recommendations

Geotechnical Recommendations

martens consulting engineers

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 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.

15 Attachment G – Notes About This Report

Information

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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.

Soil Data

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.

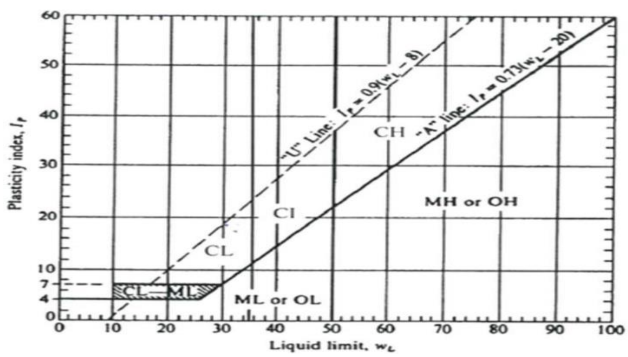
Particle Size

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[1] (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[2] (w ≈ LL)	
Wet, wet of liquid limit (w > LL)	

[1] Plastic Limit (PL): Moisture content at which soil becomes too dry to be in a plastic condition.

[2] 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_u (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_c 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
				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-SILT mixtures (≥12% fines) [1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength; may also contain sand	GM	Silty GRAVEL
				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
				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) [1]	With excess non-plastic fines (for identification procedures see ML below); zero to medium dry strength;	SM	Silty SAND
				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	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 [2]	ML	SILT [3]
	Medium to High	None to Slow	Medium	Inorganic clays of low to medium plasticity, gravely clays, sandy clays, silty clays, lean clays	CL (or CI[4])	CLAY
	Low to Medium	Slow	Low	Organic slits 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 [3]
	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:

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

Soil Data

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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

Rock Data

Explanation of Terms (1 of 2)

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[1]	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[1]	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[2]	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[2]	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)	I_s (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

Rock Data

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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

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

SCR = Solid Core Recovery

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

RQD = Rock Quality Designation

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

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)

BP	Bedding plane parting
FL	Foliation
CL	Cleavage
JT	Joint
FC	Fracture
SZ/SS	Sheared zone/ seam (Fault)
CZ/CS	Crushed zone/ seam
DZ/DS	Decomposed zone/ seam
FZ	Fractured Zone
IS	Infilled seam
VN	Vein
CO	Contact
HB	Handling break
DB	Drilling break

Planarity

Pl	Planar
Cu	Curved
Un	Undulating
St	Stepped
Ir	Irregular
Dis	Discontinuous

Roughness

Pol	Polished
Sl	Slickensided
Sm	Smooth
Ro	Rough
VR	Very rough

Thickness

Zone	> 100 mm
Seam	> 2 mm < 100 mm
Plane	< 2 mm

Coating or Filling

Cn	Clean
Sn	Stain
Ct	Coating
Vnr	Veneer
Fe	Iron Oxide
X	Carbonaceous
Qz	Quartzite
MU	Unidentified mineral

Inclination

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.

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_{50} (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:

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

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

martens consulting engineers

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
4,7,11	4,7,11 = Blows per 150mm.
N=18	'N' = Recorded blows per 300mm penetration following 150mm seating
DCP	Dynamic Cone Penetration test to AS1289.6.3.2-1997. 'n' = Recorded blows per 150mm penetration

Notes:

RW	Penetration occurred under rod weight only
HW	Penetration occurred under hammer and rod weight only
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)

CPT	Static cone penetration test
CPTu	CPT with pore pressure (u) measurement
PP	Pocket penetrometer test expressed as instrument reading (kPa)
FP	Field permeability test over section noted
VS	Field vane shear test expressed as uncorrected shear strength (sv = peak value, sr = residual value)
PM	Pressuremeter test over section noted
PID	Photoionisation Detector reading in ppm
WPT	Water pressure tests

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		