GeoEnviro Consultancy Pty Ltd
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30th April 2019

Our Reference: JG18143A-r1(rev)

Mr Tim Peterson
C/- NBRS Architecture Pty Ltd
Level 3, 4 Glen Street
MILSONS POINT NSW 2061

Attention: Mr Erin Arthur

Dear Sir,

Re Geotechnical Report
Proposed Alterations and Additions
19-23 The Corso, Manly

1. Introduction

As requested, a geotechnical investigation was carried out at the above property on the 9th April 2019. The investigation was commissioned by the property owner, My Tim Peterson of Hilrok Properties Pty Ltd by signed approval dated 28th March 2019, following our fee proposal referenced PG18650A dated 30th November 2018.

We understand that the proposed development will include alterations and additions to the existing commercial premises and this will involve removal of internal walls, installation of a new lift and construction of new floors, walls and shop front.

The purpose of the investigation was to assess the subsurface soil and groundwater condition of the site and based on the information obtained, to present comments and recommendations on the following;

- Excavation, shoring and underpinning
- Foundation design including allowable bearing capacities.

2. Site Conditions

The property is situated on the north western side of The Corso at Manly and consists of two rectangular lots (Nos 19 -21 and 23) with a total frontage of approximately 25m to The Corso by 31m deep. Market Place forms the rear property boundary.

The site is situated within an area underlain by Quaternary Marine Sands. Ground surface within the property is level. Based on the drawings provided, ground surface is at about Reduced Level (RL) 6m Australian Height Datum (AHD). The 1:100,000 geological map of Sydney, indicates the underlying bedrock to consist of Hawkesbury Sandstone expected to be present at significant depths.

The property is occupied by a four storey masonry building (Nos 19-21) and a double storey masonry building (No 23). Currently the site is occupied by a chemist and residences. Based on drawings provided, we understand that a truck sewer main about 3m wide by 5m depth runs through the length of the property with an invert level of about RL 0.39m AHD.

The immediate surrounding properties consist of single and double storey masonry mixed use building and a Hotel.

3. Foundation Investigation

The site investigation was carried out by a senior geotechnician from this company on the 9th April 2019 and consisted of;

- Drilling of two boreholes (BH 1 and 2) using a hand auger at locations nominated by the Project Architect. Borehole 1 was drilled into fill to auger refusal at a depth of 0.9m on rubble fill and this borehole was drilled immediately to the west of the sewer main at No 19-21. Borehole 2 was drilled through fill and into natural sand to a depth of 4.0m below existing ground surface and this borehole was drilled away from the sewer main at the north eastern rear corner of the property at No 23. The boreholes were observed for groundwater during and shortly after completion of the site investigation.
- Dynamic Cone Penetration (DCP) testing at two locations (DCP No 1 and 2) at the borehole locations. The DCP tests involved driving a steel probe into the ground using a standard weight sliding hammer. The DCP tests were taken to practical refusal depths of 6.9m below existing ground surface in both locations.

Reference should be made to the attached Borehole Reports for details of the subsurface profiles encountered. The DCP test results are detailed on the attached DCP Test Reports. Drawing No 1 provides information on approximate test locations.

4. Results of Investigation

4.1 Subsurface Profiles

Reference should be made to the Borehole Reports for details of the subsurface conditions encountered in each test location.

The following is a summary of the subsurface conditions encountered;

<u>Fill</u>

Fill consisting of fine to medium grained Gravelly Sand and Gravelly Silty Sand was encountered immediately beneath the approximate 110mm thick concrete slab in both boreholes.

The fill in BH 1 could not be determined due to hand auger refusal on building rubble (eg bricks), however in view of the proximity of this borehole to the sewer main and judging from the irregular DCP blow counts, we expect the fill to extend close to the invert level of the sewer main at about 6m below existing ground surface.

The fill in BH 2 was found to be about 0.6m deep.

Natural Soil

Natural fine to medium grained Sand was encountered immediately beneath the fill in BH 2 at about 0.6m below existing ground surface.

The natural sand was found to be dry to moist.

Bedrock

Bedrock was not encountered in the boreholes due to the limited penetration capacity of hand auger. We expect bedrock to consist of sandstone and the depths to bedrock is expected to be deep (ie in excess of 10m)

Groundwater

Groundwater was not encountered during and shortly after completion of the borehole investigation. Based on borehole data of nearby sites, we expect groundwater within the site to be at between 5m and 6m below existing ground surface (ie up to 1m from RL 0m AHD), noting that ground water level may fluctuate up to 1m depending on tidal condition.

4.2 DCP Test Results

The following is our assessment of the relative densities of the sandy profiles based on our DCP test results;

DCP	Depth	Relative Densities
1	0.0-2.2	Very Loose
	2.2-4.8	Loose
	4.8-5.1	Medium Dense
	5.1-6.9	Dense
2	0.0-0.7	Medium Dense
	0.7-2.9	Loose
	2.9-4.2	Very Loose
	4.2-4.8	Medium Dense
	4.8-6.9	Dense

5. Assessment and Recommendations

5.1 Shoring/Retaining and Underpinning

We understand from the drawings provided that construction of the proposed lift well will require excavation up to about 0.5m depth below existing ground surface for the lift pit.

Considerations to shore the excavation and underpin the existing footings will be required to prevent undermining of the existing footings and damage to the existing building and neighbouring buildings.

The extent of underpinning/shoring works will depend on the type and condition of the existing footings. We recommend test pits be carried out prior to excavation works to expose the footings of the existing/adjoining buildings and if the footings are found to be above the proposed excavation levels, these footings should be underpinned or the area should be adequately stabilised by shoring prior to excavation works.

In the absence of existing footing details, it is advisable to assume that continuous underpinning works will be required for the full section of the excavation. In order to control ground movements, the underpinning works should be undertaken in short alternate sections at any one time during construction.

The underpinning works should be taken to at least 0.5m below excavation level. The underpinning works may also act as a shoring/retaining system for the excavation.

As the shoring/retaining system will be propped by floor slabs and structure, an "at-rest" lateral earth pressure coefficient (K_o) of 0.5 should be adopted based on a rectangular stress block.

5.2 Footing Design

The investigation revealed the site to be generally underlain by Very Loose to Loose sand to depths of ranging from 4.2m to 4.8m below existing ground surface. The underlying sand was assessed to be Medium Dense becoming Dense at below 4.8m and 5.1m below existing ground surface.

All new building footings should be supported on Medium Dense sand or better and at least 0.5m below the zone of influence of the truck sewer main, therefore deep footings will be required. The zone of influence of the truck sewer main may be taken as the 45 degrees line (1 Vertical: 1 Horizontal) starting from the base of the sewer main up to the ground surface.

In view of the cohesionless nature of the sandy soil. suitable piers may include grout injected piers or Continuous Flight Auger (CFA) piers. Bored piers are not considered suitable as we expect the piering to intercept groundwater resulting in collapse of pier holes.

The following allowable bearing capacities may be adopted for footings founded on medium dense sand;

Depth of Embedment of Footing*1	Bearing Material	Allowable Bearing Capacity (KPa)
5.0m	Medium Dense Sand	450
6.0m	Dense Sand	600

Note: *1 Below existing ground surface

Alternatively, other proprietary piling system such as steel screw piles may be considered suitable. Should this piling option be adopted, we recommend the piling contractor be consultant to determine the working loads and expected pile depths. Adoption of this piling system would need to consider durability design (eg corrosion rate) and this may require further investigation and laboratory analysis to assess the soil aggressiveness. The certification and design compliance of this piling system should be the responsibility of the piling contractor or its representative.

6. Limitations

The interpretation and recommendations submitted in this report are based in part upon data obtained from a limited number of boreholes and DCP tests at a restricted access site. There is no investigation which is thorough enough to determine all site conditions and anomalies, no matter how comprehensive the investigation program is as site data is derived from extrapolation of limited test locations. The nature and extent of variations between test locations may not become evident until construction.

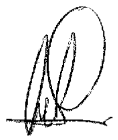
Groundwater conditions are only briefly examined in this investigation. The groundwater conditions may vary seasonally or as a consequence of construction activities on or adjacent to the site. In view of the above, the subsurface soil and rock conditions between the test locations may be found to be different or interpreted to be different from those expected. If such differences appear to exist, we recommend that this office be contacted without delay.

The statements presented in this document are intended to advise you of what should be your realistic expectations of this report and to present you with recommendations on how to minimise the risk associated with groundworks for this project. The document is not intended to reduce the level of responsibility accepted by GeoEnviro Consultancy Pty Ltd, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in to doing.

Your attention is drawn to the attached "Explanatory Notes" and this document should be read in conjunction with our report.

Should you have any queries, please contact the undersigned.

Yours faithfully
GeoEnviro Consultancy Pty Ltd



Solern Liew MIEA CPEng NER
Director

Attachment: Drawing No 1: Test Location Plan
Borehole Reports
Dynamic Cone Penetrometer Test Report
Explanatory Notes and Graphic Symbols

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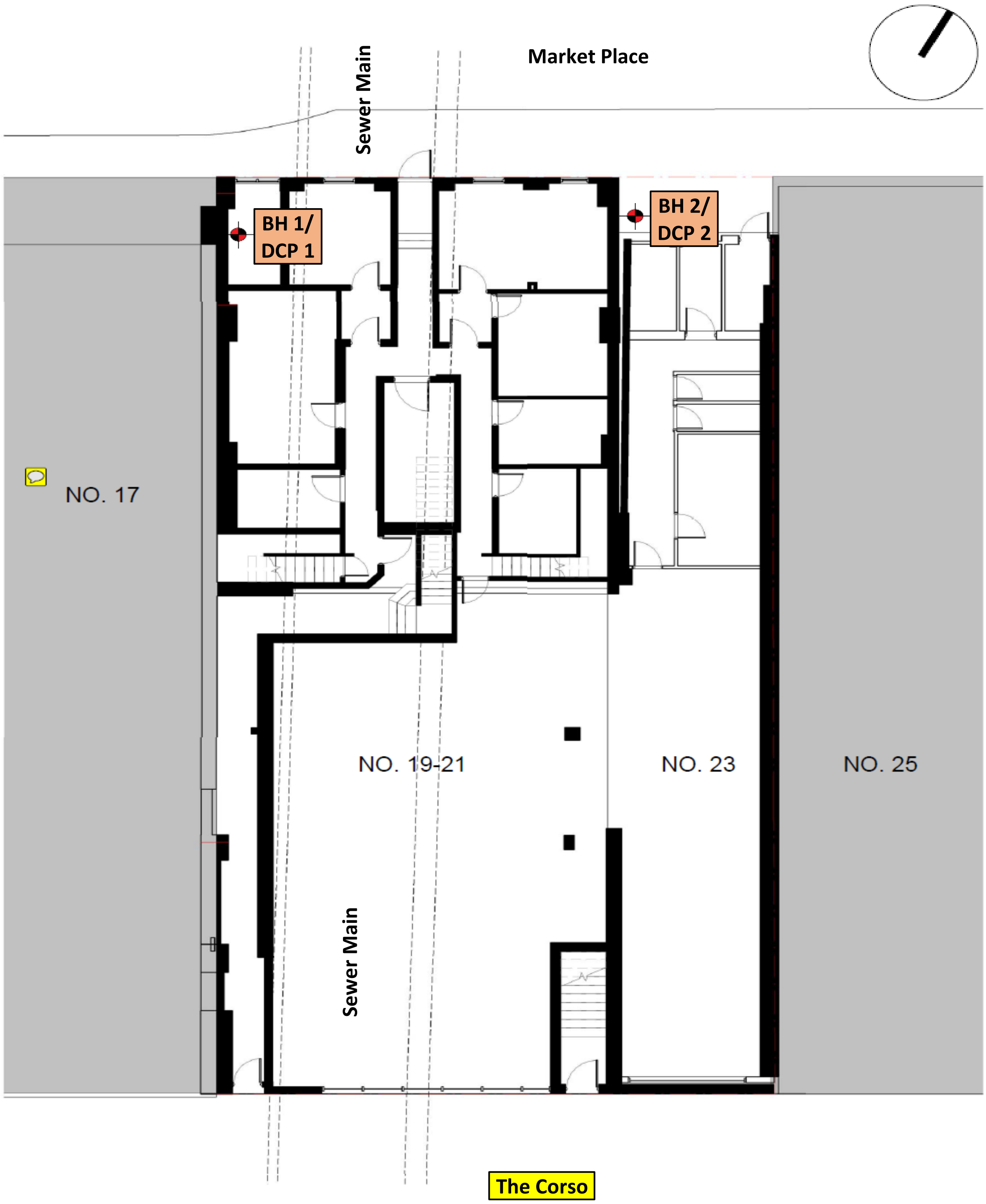

1 EXISTING GROUND FLOOR PLAN
1 : 100

Legend

BH 1/ DCP 1 — Borehole/DCP Location

GeoEnviro Consultancy Pty Ltd Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia Tel: (02) 96798733 Fax: (02) 96798744	Drawn By: SG	Date: 16/04/2019	NBRS Architecture Pty Ltd
	Checked By: SL	Date: 16/04/2019	Proposed Alterations and Additions
	Revision:	Date:	No 19-23 The Corso, Manly
	Scale: Proportional	A4	Project No: JG18143A — Drawing No: 1

GeoEnviro Consultancy Pty Ltd
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Tel: (02) 96798733 Fax: (02) 96798744

Borehole Report

Borehole no: 1

Client: NBRS Architecture Pty Ltd
Job no: JG18143A

Project: Proposed Alterations and Additions
Date: 15/04/2019

Location: No 19-23 The Corso, Manly
Logged by: SG

Drill Model and Mounting: Hand Auger
Slope: 90 degrees
R.L. Surface: 5.5m

Hole Diameter: 100 mm
Bearing: -
Datum: AHD

Method	Support	Water	Notes: Samples, Tests, etc	Depth(m)	Classification Symbol	Unified Soil Classification	Material Description Soil Type, Plasticity or Particle Characteristic, colour, secondary and minor component	Moisture Content	Consistency/Density Index	Structure and Additional Observations
HAND AUGER	NIL	DRY		0.0–0.11			Concrete Slab - 110mm			
				0.11–0.9		Fill	Gravelly Sand: Fine to medium grained, grey brown, with sandstone gravel, bricks and brick fragments	D-M		Terracotta pipe on the edge of borehole
				0.9			End of Borehole at 0.9m			Hand auger refusal on rubble
				1.0–2.3					VL	
				2.3–4.0					L	(Fill?)
				4.0						Refer to DCP test report for results below 4m

Hand Penetrometer kPa (in order printed, from top, 0.5 to 4.0 depth marks):

Hand Penetrometer kPa
-
-
-
4
8
1
6
25
2
1
1
1
1
2
1
2
2
2
2
3
4
3
4
4
4
3
3
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3
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3
3
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3
2

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Borehole Report

Borehole no: 2

Client: NBRS Architecture Pty Ltd	Job no: JG18143A
Project: Proposed Alterations and Additions	Date: 15/04/2019
Location: No 19-23 The Corso, Manly	Logged by: SG

Drill Model and Mounting: Hand Auger	Slope: 90 degrees	R.L. Surface: 5.5m
Hole Diameter: 100 mm	Bearing: -	Datum: AHD

Method	Support	Water	Notes: Samples, Tests, etc	Depth(m)	Classification Symbol	Unified Soil Classification	Material Description Soil Type, Plasticity or Particle Characteristic, colour, secondary and minor component	Moisture Content	Consistency/Density Index	Hand Penetrometer kPa	Structure and Additional Observations
HAND AUGER	NIL	DRY					Concrete slab: 100mm			-	
				0.5			Fill: Gravelly Silty Sand, fined to medium grained grey brown	D	MD	-, 3, 10, 8, 5, 4	
				1.0, 1.5, 2.0			Sand: fine to medium grained, pale yellow	D-M	L	6	
							As above but orange brown			4, 3, 2, 2, 2, 2, 2, 3, 4, 4, 4, 4, 3, 4, 3	
				2.5, 3.0, 3.5, 4.0			As above but yellow and yellow brown			3, 4, 3, 3, 4, 3	
									VL	2, 2, 2, 1, 2, 1, 2, 2, 1, 2, 1	Refer to DCP test report for results below 4m

End of Borehole at 4.0m

GeoEnviro Consultancy Pty Ltd
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Dynamic Cone Penetration Test Report

Client / Address: NBRS Architecture Pty Ltd / MILSONS POINT — Job No. JG18143A
Project: Proposed Alterations and Additions — Date: 15/04/2019
Location: No 19-23 The Corso, Manly — Report No. R01A

Test Procedure: AS 1289 1.1, 1.2.1, 6.3.2

Test Data

Test No: 1
Test Location: DCP 1
RL:
Soil Classification: Fill and Sand

Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0-0.1	-	3.0-3.1	2	6.0-6.1	12	0.0-0.1	
0.1-0.2	-	3.1-3.2	3	6.1-6.2	15	0.1-0.2	
0.2-0.3	-	3.2-3.3	4	6.2-6.3	10	0.2-0.3	
0.3-0.4	4	3.3-3.4	4	6.3-6.4	11	0.3-0.4	
0.4-0.5	8	3.4-3.5	3	6.4-6.5	13	0.4-0.5	
0.5-0.6		3.5-3.6	3	6.5-6.6	13	0.5-0.6	
0.6-0.7	1	3.6-3.7	3	6.6-6.7	15	0.6-0.7	
0.7-0.8		3.7-3.8	2	6.7-6.8	15	0.7-0.8	
0.8-0.9	6	3.8-3.9	3	6.8-6.9	17	0.8-0.9	
0.9-1.0	25	3.9-4.0	2	6.9-7.0	DCP Terminated	0.9-1.0	
1.0-1.1	2	4.0-4.1	2	7.0-7.1	at 6.90m	1.0-1.1	
1.1-1.2		4.1-4.2	2	7.1-7.2		1.1-1.2	
1.2-1.3	1	4.2-4.3	1	7.2-7.3		1.2-1.3	
1.3-1.4	1	4.3-4.4	1	7.3-7.4		1.3-1.4	
1.4-1.5	1	4.4-4.5	2	7.4-7.5		1.4-1.5	
1.5-1.6	1	4.5-4.6	2	7.5-7.6		1.5-1.6	
1.6-1.7	2	4.6-4.7	3	7.6-7.7		1.6-1.7	
1.7-1.8	1	4.7-4.8	2	7.7-7.8		1.7-1.8	
1.8-1.9	2	4.8-4.9	9	7.8-7.9		1.8-1.9	
1.9-2.0	2	4.9-5.0	6	7.9-8.0		1.9-2.0	
2.0-2.1	2	5.0-5.1	8	8.0-8.1		2.0-2.1	
2.1-2.2	2	5.1-5.2	10	8.1-8.2		2.1-2.2	
2.2-2.3	3	5.2-5.3	20	8.2-8.3		2.2-2.3	
2.3-2.4	4	5.3-5.4	13	8.3-8.4		2.3-2.4	
2.4-2.5	3	5.4-5.5	13	8.4-8.5		2.4-2.5	
2.5-2.6	4	5.5-5.6	14	8.5-8.6		2.5-2.6	
2.6-2.7	4	5.6-5.7	18	8.6-8.7		2.6-2.7	
2.7-2.8	4	5.7-5.8	13	8.7-8.8		2.7-2.8	
2.8-2.9	3	5.8-5.9	10	8.8-8.9		2.8-2.9	
2.9-3.0	3	5.9-6.0	14	8.9-9.0		2.9-3.0	

Remarks:

Weight: 9kg
Drop: 510mm
Rod Diameter: 16mm

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Authorised Signatory ______________ Solern Liew Date 15/04/2019

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Tel: (02) 96798733 Fax: (02) 96798744

Dynamic Cone Penetration Test Report

Client / Address: NBRS Architecture Pty Ltd / MILSONS POINT — Job No. JG18143A

Project: Proposed Alterations and Additions — Date: 15/04/2019

Location: No 19-23 The Corso, Manly — Report No. R02A

Test Procedure: AS 1289 1.1, 1.2.1, 6.3.2

Test Data

Test No: 2

Test Location: DCP 2

RL:

Soil Classification: Fill and Sand

Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows	Depth (m)	Blows
0.0-0.1	-	3.0-3.1	2	6.0-6.1	16	0.0-0.1	
0.1-0.2	-	3.1-3.2	2	6.1-6.2	17	0.1-0.2	
0.2-0.3	3	3.2-3.3	1	6.2-6.3	15	0.2-0.3	
0.3-0.4	10	3.3-3.4	2	6.3-6.4	14	0.3-0.4	
0.4-0.5	8	3.4-3.5	1	6.4-6.5	13	0.4-0.5	
0.5-0.6	5	3.5-3.6	2	6.5-6.6	15	0.5-0.6	
0.6-0.7	4	3.6-3.7	2	6.6-6.7	16	0.6-0.7	
0.7-0.8	6	3.7-3.8	1	6.7-6.8	17	0.7-0.8	
0.8-0.9	4	3.8-3.9	2	6.8-6.9	18	0.8-0.9	
0.9-1.0	3	3.9-4.0	1	6.9-7.0	DCP Terminated	0.9-1.0	
1.0-1.1	2	4.0-4.1	2	7.0-7.1	at 6.90m	1.0-1.1	
1.1-1.2	2	4.1-4.2	1	7.1-7.2		1.1-1.2	
1.2-1.3	2	4.2-4.3	5	7.2-7.3		1.2-1.3	
1.3-1.4	2	4.3-4.4	5	7.3-7.4		1.3-1.4	
1.4-1.5	2	4.4-4.5	5	7.4-7.5		1.4-1.5	
1.5-1.6	3	4.5-4.6	5	7.5-7.6		1.5-1.6	
1.6-1.7	4	4.6-4.7	4	7.6-7.7		1.6-1.7	
1.7-1.8	4	4.7-4.8	6	7.7-7.8		1.7-1.8	
1.8-1.9	4	4.8-4.9	18	7.8-7.9		1.8-1.9	
1.9-2.0	4	4.9-5.0	16	7.9-8.0		1.9-2.0	
2.0-2.1	3	5.0-5.1	10	8.0-8.1		2.0-2.1	
2.1-2.2	4	5.1-5.2	10	8.1-8.2		2.1-2.2	
2.2-2.3	3	5.2-5.3	14	8.2-8.3		2.2-2.3	
2.3-2.4	3	5.3-5.4	13	8.3-8.4		2.3-2.4	
2.4-2.5	4	5.4-5.5	8	8.4-8.5		2.4-2.5	
2.5-2.6	3	5.5-5.6	13	8.5-8.6		2.5-2.6	
2.6-2.7	3	5.6-5.7	14	8.6-8.7		2.6-2.7	
2.7-2.8	4	5.7-5.8	13	8.7-8.8		2.7-2.8	
2.8-2.9	3	5.8-5.9	17	8.8-8.9		2.8-2.9	
2.9-3.0	2	5.9-6.0	15	8.9-9.0		2.9-3.0	

Remarks:

Weight: 9kg
Drop: 510mm
Rod Diameter: 16mm

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Authorised Signatory ____________ Solern Liew Date 15/04/2019

GeoEnviro Consultancy Pty Ltd

EXPLANATORY NOTES

Introduction

These notes have been provided to amplify the geotechnical report with regard to investigation procedures, classification methods and certain matters relating to the Discussion and Comments sections. Not all notes are necessarily relevant to all reports.

Geotechnical reports are based on information gained from finite sub-surface probing, excavation, boring, sampling or other means of investigation, supplemented by experience and knowledge of local geology. For this reason they must be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods
The methods the description and classification of soils and rocks used in this report are based on Australian standard 1726, the SSA Site investigation Code, in general descriptions cover the following properties - strength or density, colour, structure, soil or rock type and inclusions. Identification and classification of soil and rock involves to a large extent, judgement within the acceptable level commonly adopted by current geotechnical practices.

Soil types are described according to the predominating particle size, qualified by the grading or other particles present (eg sandy clay) on the following bases:

Soil Classification	Particle Size
Clay	Less than 0.002mm
Silt	0.002 to 0.6mm
Sand	0.6 to 2.00mm
Gravel	2.00m to 60.00mm

Soil Classification	Particle size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2.00mm
Gravel	2.00mm to 60.00mm

Cohesive soils are classified on the basis of strength, either by laboratory testing or engineering examination. The strength terms are defined as follows:

Classification	**Undrained Shear Strength kPa**
Very Soft	Less than 12
Soft	12 - 25
Firm	25 - 50
Stiff	50 - 100
Very Stiff	100 - 200
Hard	Greater than 200

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

Relative Dense	**SPT 'N' Value (blows/300mm)**	**CPT Cone Value (q_c-Mpa)**
Very Loose	Less than 5	Less than 2
Loose	5 - 10	2 - 5
Medium Dense	10 - 30	5 - 15
Dense	30 - 50	15 - 25
Very Dense	> 50	> 25

Rock types are classified by their geological names, together with descriptive terms on degrees of weathering strength, defects and other minor components. Where relevant, further information regarding rock classification, is given on the following sheet.

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

Disturbed samples taken during drilling provided information on plasticity, grained size, colour, type, moisture content, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin walled sample tube (normally know as U_{50}) into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such Samples yield information on structure and strength and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils. Details of the type and method of sampling are given in the report.

Field Investigation Methods
The following is a brief summary of investigation methods currently carried out by this company and comments on their use and application.

Hand Auger Drilling
The borehole is advanced by manually operated equipment. The diameter of the borehole ranges from 50mm to 100mm. Penetration depth of hand augered boreholes may be limited by premature refusal on a variety of materials, such as hard clay, gravels or ironstone.

Test Pits
These are excavated with a tractor-mounted backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3.0m for a backhoe and up to 6.0m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Care must be taken if construction is to be carried out near, or within the test pit locations, to either adequately recompact the backfill during construction, or to design the structure or accommodate the poorly compacted backfill.

Large Diameter Auger (eg Pengo)
The hole is advanced by a rotating plate or short spiral auger generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 05m) 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 Spiral Flight Augers
The hole is advanced by using 90mm - 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the augers flights, but they are very disturbed and may be highly mixed with soil of other stratum.

Information from the drilling (as distinct from specific sampling by SPT or undisturbed samples) is of relatively low reliability due to remoulding, mixing or softening of samples by ground water, resulting in uncertainties of the original sample depth.

Continuous Spiral Flight Augers (continued)
The spiral augers are usually advanced by using a V - bit through the soil profile refusal, followed by Tungsten Carbide (TC) bit, to penetrate into bedrock. The quality and continuity of the bedrock may be assessed by examination of the recovered rock fragments and through observation of the drilling penetration resistance.

Non - core Rotary Drilling (Wash Boring)
The hole is advanced by a rotary bit, with water being pumped down the drill rod and returned up the annulus, carrying the cuttings, together with some information from the "feel" and rate of penetration.

Rotary Mud Stabilised Drilling
This is similar to rotary drilling, but uses drilling mud as a circulating fluid, which may consist of a range of products, from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (eg SPT and U_{50} samples).

Continuous Core Drilling
A continuous core sample is obtained using a diamond tipped core barrel. Providing full core recovery is achieved (which is not always possible in very weak rock and granular soils) this technique provides a very reliable (but relatively expensive) method of investigation. In rocks an NMLC triple tube core barrel which gives a core of about 50mm diameter, is usually used with water flush.

Portable Proline Drilling
This is manually operated equipment and is only used in sites which require bedrock core sampling and there is restricted site access to truck mounted drill rigs. The boreholes are usually advanced initially using a tricone roller bit and water circulation to penetrate the upper soil profile. In some instances a hand auger may be used to penetrate the soil profile. Subsequent drilling into bedrock involves the use of NMLC triple tube equipment, using water as a lubricant.

Standard Penetration Tests
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 of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289 "Methods of testing Soils for Engineering Purpose"- Test F31.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63Kg hammer with a free fall of 769mm. It is normal for the tube to be driven in three successive 150mm increments and the "N" value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rocks, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

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

as 4, 6, 7
N = 13

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

as 15,30/40mm

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

Dynamic Cone Penetration Test
A modification to the SPT test is where the same driving system is used with a solid 60^0 tipped steel cone of the same diameter as the SPT hollow sampler. The cone can be continuously driven into the borehole and is normally used in areas with thick layers of soft clays or loose sand. The results of this test are shown as 'N_c' on the bore logs, together with the number of blows per 150mm penetration.

Cone Penetrometer Testing and Interpretation
Cone penetrometer testing (sometimes referred to as Dutch Cone-CPT) described in this report, has been carried out using an electrical friction cone penetrometer and the test is described in Australian Standard 1289 test F5.1.

In the test, a 35mm diameter rod with cone tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig, which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130mm long sleeve, immediately behind the cone. Transducer in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output on continuous chart recorders. The plotted results in this report have been traced from the original records. The information provided on the charts comprises:

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

There are two scales available for measurement of cone resistance. The lower "A" scale (0-5Mpa) 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 (0-50Mpa) 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 frictions in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and very soft clays, rising to 4% to 10% in stiff clays.

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

q_c (Mpa) = (0.4 to 0.6) N (blows per 300mm)

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 estimate of modulus or compressibility values to allow calculation of foundation settlements. Inferred stratification, as shown on the attached report, is assessed from the cone and friction traces, from experience and information from nearby boreholes etc.

Cone Penetrometer Testing and Interpretation continued

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 or soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometer (AS1289)

Portable dynamic cone penetrometer tests are carried out by driving a rod in to the ground with a falling weight hammer and measuring the blows per successive 100mm increments of penetration.

There are two similar tests, Cone Penetrometer (commonly known as Scala Penetrometer) and the Perth Sand Penetrometer. Scala Penetrometer is commonly adopted by this company and consists of a 16mm rod with a 20mm diameter cone end, driven with a 9kg hammer, dropping 510mm (AS 1289 Test F3.2).

Laboratory Testing

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

Engineering Logs

The engineering logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, however, this is not always practicable or possible to justify economically. As it is, the boreholes represent only a small sample of the total sub-surface profile. Interpretation of the information and its application to design and construction should take into account the spacing of boreholes, frequency of sampling and the possibility of other than "straight line" variations between the boreholes.

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 investigation period.
- A localised perched water table may lead to a erroneous indication of the true water table.
- Water table levels will vary from time to time, due to the seasons or recent weather changes. They may not be the same at the time of construction as 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 be washed out of the hole if any water observations are to be made.

More reliable measurements can be made by installing stand pipes, which are read at intervals over several days, or weeks for low permeability soils. Piezometers sealed in a particular stratum may be interference from a perched water table or surface water.

Engineering Reports

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal is changed, say to a twenty storey building. If this occurs, the company will be pleased to review the report and sufficiency of the investigation work.

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

- Unexpected variations in ground conditions. The potential for this will depend partly on bore spacing and sampling frequency.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of contractors responding to commercial pressures.

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

Site Anomalies

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

Reproduction of Information for Contractual Purposes

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

Site Inspection

The Company will always be pleased to provide engineering inspection services for geotechnical aspect of work to which this report is related. This could range from a site visit to confirm that the conditions exposed are as expected, to full time engineering presence on site

Review of Design

Where major civil or structural developments are proposed, or where only a limited investigation has been completed, or where the geotechnical conditions are complex, it is prudent to have the design reviewed by a Senior Geotechnical Engineer.

Graphic Symbols For Soil and Rock

SOIL

- Fill
- Topsoil
- Gravel (GW , GP)
- Sand (SP, SW)
- Silt (ML, MH)
- Clay (CL, CH)
- Clayey Gravel (GC)
- Silty Sand (SM)
- Clayey Sand (SC)
- Sandy Silt (ML)
- Gravelly Clay (CL, CH)
- Silty Clay (CL, CH)
- Sandy Clay (CL, CH)
- Peat or Organic Soil

ROCK

- Shale
- Sandstone
- Siltstone,Mudstone,Claystone
- Granite, Gabbro
- Dolerite, Diorite
- Basalt, Andesite

Other Materials

- Concrete
- Bitumen, Asphaltic Concrete, Coal
- Ironstone Gravel
- Organic Material