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Report

Geotechnical Investigation, Proposed Refurbishment - Sutherland Entertainment Centre Lot 1 DP1253156, No 30 Eton Street Sutherland, NSW

Prepared for
NBRS Architecture Pty Ltd
Level 3, 4 Glen Street
MILSONS POINT, NSW 2061

Ref: JG19178A-r1
November 2019

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NBRS Architecture Pty Ltd
Level 3, 4 Glen Street
MILSONS POINT, NSW 2061

Attention: Mr Barry Flack

Dear Sir

Re Geotechnical Investigation
Proposed Refurbishment Sutherland Entertainment Centre
Lot 1 DP1253156, No 30 Eton Street, Sutherland

We are pleased to submit our geotechnical report for the proposed refurbishment of the Sutherland Entertainment Centre.

This report contains information on sub-surface conditions and our comments and recommendations on geotechnical issues for the proposed development.

Should you have any queries, please contact the undersigned.

Yours faithfully
GeoEnviro Consultancy Pty Ltd

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Director

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1. INTRODUCTION

This report presents the results of a geotechnical investigation for the proposed refurbishment of the existing Entertainment Centre located at No 30 Eton Street, Sutherland. The investigation was commissioned by Mr Barry Flack of NBRS Architecture following our fee proposal PG19678A dated 2nd September 2019.

We understand that the proposed refurbishments will include partial demolition of the south western front corner and north eastern corner of the existing building and construction of new structures. The project will include the following;

- Refurbished main theatre with reconfigured fixed seating for 700.
- Improved wings, stage and new staging system suitable for major theatrical productions.
- Improved back of house.
- New flexible teaching and rehearsal space.
- Fresh foyer and front of house
- New entry forecourt and flexible outdoor event space.
- New cafe/restaurant for 75 diners (can be expanded to 150).
- Enhanced accessibility.

The purpose of the investigation was to assess the nature of the subsurface soil, rock and groundwater conditions across the site and based upon the information obtained, to present the following;

- Building platform preparations and fill construction/earthworks specification.
- Retaining wall design parameters including lateral earth pressure coefficients, Ka, Ko and Kp.
- Slope batter design; temporary and permanent.
- Foundation design parameters including suitable footings and allowable bearing.
- Capacities and estimated settlement.
- Assessment on Earthquake site soil class to AS1170.4.
- Assessment on soil reactivity to AS2870.
- Assessment on pavement subgrade characteristics and recommendations on pavement design.
- Subgrade preparation for internal and external slab.
- Assessment on soil aggressiveness.

2. SITE INFORMATION

2.1 Site Location and Description

The Sutherland Entertainment Centre (SEC) is located at No 30 Eton Street in Sutherland between Eton Street and Merton Street approximately 50m north of Flora Street. The site is roughly rectangular in shape with an approximate 60m road frontage to Eton Street and extends 65m to Merton Street to the rear.

The SEC building occupies the southern portion of the site with the northern portion consisting of landscaped gardens. The built form of the existing SEC building comprises of a large three storey main theatre building and a smaller two-storey wing. The main theatre building occupies the eastern part of the site, while the western wing adjoins Eton Street and is flanked by an open forecourt to the north. The landscaping includes retained garden beds and lawn, water features and pedestrian pathways.

Neighbouring property to the south consists of a church premises and the south and the Sutherland Shire Council is situated immediately to the north.

2.2 Site Topography and Geological Setting

The site is situated on undulating terrain. Ground surface within the site slopes down at angles of about 1 to 3 degree sloping towards the north.

Based on the 1:100,000 Soil Landscape Map of Wollongong-Port Hacking (Reference 1); the site is underlain by Erosional soil of the Gymea Soil landscape consisting of shallow to moderately deep Yellow Earths and Earthy Sands on crests and insides of benches; shallow Siliceous Sands onleading edges of benches; localised Gleyed Podzolic Soils and Yellow Podzolic Soils on shale lenses; shallow to moderately deep Siliceous Sands and leached sands along drainage lines.

Based on the 1:100,000 Geological Map of Wollongong-Port Hacking (Reference 2); the site is underlain by Hawkesbury Sandstone (Rh and RHs), consisting of (Rh) - medium to coarse grained quartz Sandstone, very minor shale and laminate lenses and (Rhs) – Claystone, siltstone and laminate (“Shale lenses”).

3. INVESTIGATION METHODOLOGY

3.1 Fieldwork

Fieldwork for the investigation consisted of the drilling of five boreholes (BH 1 to BH 5) at locations as close as possible to the structural engineer's nominated locations as shown on Drawing No 1. The boreholes were drilled using a track mounted TCH-05 drill rig equipped for site investigation purposes on the 8th and 9th October 2019. The field investigation was supervised on a full-time basis by our geotechnical engineer.

Prior to borehole drilling, underground services checks were carried out using available drawings supplied by Dial-before-you-dig and services drawings provided. An underground service locator equipped with an electromagnetic device was engaged as an extra precautionary measure to reduce risk of damage to underground services caused by the borehole drilling.

Borehole Nos 1 and 4 were initially drilled using spiral augers attached to a V-bit to refusal followed by Tungsten Carbide (TC) bit drilling a short distance below bedrock level, followed by NMLC diamond bit coring into the bedrock to obtain bedrock core samples. These boreholes were drilled to the depths of about 7.69m and 7.20m below existing ground surface.

Borehole Nos 2 and 5 were initially drilled using hand augers followed by spiral augers attached to a TC-bit to refusal at depths of 3.6m and 5.3m below existing ground surface respectively. Borehole No 3 including three other boreholes within 700mm apart were terminated prematurely on a buried concrete slab at about 1.0m below existing ground surface.

The locations of the boreholes, which were established by off-set measurements from existing site boundaries and features are indicated on Drawing No 1.

In order to assess the strength of the subsurface soil, Standard Penetration Testing (SPT) was carried out in the boreholes. Hand penetrometer testing was carried out on the recovered SPT split-tube clayey samples to augment the SPT results.

The strength of the bedrock in the augered boreholes was subjectively assessed by examining the rock fragments from the drilling and engineering judgement. Cored bedrock samples were carefully boxed on site before returning to our laboratory for testing.

The boreholes were observed for groundwater seepage, during and upon completion of spiral augering.

The field test results, together with details of the subsurface profile encountered are presented on the Borehole and Cored Borehole Reports in Appendix A of this report and are accompanied by explanatory notes defining the terms and symbols used in their preparation.

3.2 Laboratory Testing

3.2.1 Geotechnical

One soil sample was taken to our NATA accredited laboratory for Atterberg Limits analysis in order to classify the soil to the Unified Soil Classification system and to assess the reactivity of the soil.

One subgrade bulk sample was taken from the site and tested at our NATA accredited laboratory for California Bearing Ratio (CBR) to aid assessment of pavement subgrade characteristics.

The bedrock cored samples were point load tested in our laboratory to assess the strength of the bedrock material. The point load test is an in-direct tensile strength test which provides an approximate Unconfined Compressive Strength (UCS) value of the rock core sample based on a semi-empirical formula. Prior to point load testing, the core samples were photographed for inclusion in this report.

3.2.2 Soil Aggressiveness

Four soil samples (BH 1 [2.50-2.95m], BH 2 [1.00-1.45m], BH 3 [0.6-0.8m] and BH 4 [1.00-1.45m] were taken and sent to Envirolab Services Pty Ltd to assess soil aggressiveness to buried structures. The analysis includes;

- pH
- Electrical Conductivity (EC)
- Sulphate (SO_4)
- Chlorides (CL^-)
- Resistivity

4. RESULTS OF THE INVESTIGATION

4.1 Subsurface Conditions

Reference should be made to the Borehole and Cored Borehole Reports for details of the subsurface profile encountered. A summary of the subsurface profile is as follows:

Topsoil/Fill

Topsoil/fill was encountered on the surface of BH 1 consisting of Clayey Silt of low liquid limit. Thickness of the topsoil/fill was found to be about 200mm.

Concrete Pavement

Concrete pavement was encountered in BH 2 and 4 with thickness of 110mm and 140mm respectively.

Fill

Fill was encountered beneath the topsoil/fill in BH 1, below the concrete in BH 2 and 4 and on the surface of BH 3 and 5 consisting predominantly of Gravelly Silty Clay of medium to high plasticity. Some concrete fragments were encountered in the fill in BH 1 and 3 and in BH 5 some building debris including tiles, bricks and concrete fragments were encountered. The fill was found to have thickness ranging from 0.6m to 2.2m from existing ground surface. The fill was generally assessed to be dry to moist.

Borehole 3 was terminated at 1.0m within the fill profile due to auger refusal on concrete.

Natural Soil

Natural soil was encountered beneath the fill in all boreholes except BH 3 generally consisting of medium plasticity Silty Clay.

The SPT and hand penetrometer test results indicate the natural clayey soil to generally be very stiff to hard and dry to moist (ie moisture content less than or equal to the plastic limit) except in BH 4 between 0.9m and 1.7m whereby the natural clay was assessed to be relatively weaker (ie Stiff) and moist.

Bedrock

Shale and Siltstone were encountered in all the boreholes except BH 3 at depths varying from 2.0m to 3.8m below existing ground surface.

The upper 1.8m to 2.6m of the shale was generally assessed to be extremely weathered to distinctly weathered and have extremely low to low strength.

The cored sample from BH 1 and 4 indicates the upper 2.2m of the shale to be fractured (ie defect spacing ranging from 30mm to 100mm) with clay bands and improves to slightly fractured (ie defect spacing ranging from 100mm to 300mm).

The cored samples were generally found to have extremely low to low strength with Unconfined Compressive Strength (UCS) ranging from 0.48MPa to 4.05MPa. A medium strength band was encountered in BH 4 at 3.9m below existing ground surface with UCS of 8.77MPa.

Groundwater

The boreholes were found to be dry during and shortly after completion of the spiral augering to a depth of 3.6m in BH 2 and 5.3m in BH 5. Groundwater table monitoring could not be carried out during the NMLC drilling in BH 1 and BH 4 due to water being used in the coring masking any signs of groundwater if present.

4.2 Laboratory Test Results – Geotechnical Rock Testing

The point load tests generally confirm our field classification of the rock strength. The bedrock quality may be classified to Class I (good quality) to V (poor quality) in accordance with Pells et al – 1998 (Reference 3) based on the Unconfined Compressive Strength (UCS), degree of fracturing and allowable defects. The following is a summary of the point load results and our assessment of the bedrock quality.

BH	Depth (m)		$Is_{(50)}$ (MPa)		Class	
	Start	End	Min.	Max.	Based on Strength Only	Based on Strength & Defects
1	3.80	3.99	-	-	-	V*
	3.99	6.60	0.02	0.20	IV-III	V
	6.60	7.69	0.10	0.11	III	IV-III
2	2.80	3.60	-	-	-	V*
4	2.00	3.20	-	-	-	V*
	3.20	5.50	0.03	0.44	IV-II	V
	5.50	7.20	0.04	0.14	IV-III	IV-III
5	3.00	5.30	-	-	-	V*

Note: * Subjective rock class assessment based on auger resistance and visual inspection of disturbed samples

Note that the strength of the shale was generally found to be higher than the assigned classification (ie based on Strength and Defects) and this was due to the presence of defects, therefore the overall classification of the bedrock was downgraded (ie poorer quality).

Refer to Laboratory Test Reports in Appendix B for Point Load Test results and correlated UCS of the bedrock at specific depths

4.3 Laboratory Test Results – Geotechnical Soil Testing

For details of the laboratory test results, refer to the laboratory test reports in Appendix B of this report.

The following is a summary of the Atterberg Limit test results taken from BH 4 (1.00-1.45m);

Liquid Limit %	=	57 %
Plastic Limit %	=	23 %
Plasticity Index %	=	35 %
Linear Shrinkage %	=	13.5 %
Natural Moisture Content %	=	23.0 %

Based on the laboratory test results, the liquid limit and linear shrinkage correlate to a soil with a moderate to high reactivity to moisture variation.

The following is a summary of the California Bearing Ratio test results taken from BH 1 (0.6-1.2m);

Maximum Dry Density t/m^3	=	1.76 t/m^3
Optimum Moisture Content %	=	17.5 %
Field Moisture Content %	=	17.5 %
Swell %	=	2.1 %
CBR Value %	=	3.5 %

4.4 Laboratory Test Results - Soil Aggressiveness

For details of laboratory test results, refer to laboratory test report in Appendix C.

Sample	Depth (m)	pH	ECe dS/m	Cl mg/kg	SO4 mg/kg	Resistivity ohm cm
BH1	2.50-2.95	5.5	1.36	100	190	5800
BH2	1.00-1.45	7.3	0.43	10	55	18000
BH3	0.60-0.80	8.5	0.88	22	110	9400
BH4	1.00-1.45	5.4	0.44	<10	88	18000

Note: ECe – Electrical Conductivity (dS/m)
Cl – Chloride (mg/kg)
SO4 – Sulphate (mg/kg)

5. COMMENTS AND RECOMMENDATIONS

5.1 Excavation Conditions and Vibration Issues

The borehole investigation revealed the site to be generally underlain by clayey fill and natural clay overlying bedrock consisting mainly of shale/siltstone at depths of about 2.0m to 3.8m below existing ground surface.

Excavation into the upper clayey soil and fill may be carried out using a 3 to 6 tonne mini-excavator. The upper 2.0m of the extremely low to low strength shale may be carried out using a 15 tonne excavator equipped with rock teeth bucket. A rock impact hammer will be necessary to penetrate through some stronger shale bands and we recommend an impact hammer not exceeding 200kg operating weight. A portable jack hammer may be required for trimming or excavation in confined spaces.

Excavation works using rock teeth excavator bucket and/or a portable jackhammer do not normally cause significant vibration which will result in major structural damage to the existing structures.

There is an inherent risk of excessive vibration from excavation using an impact hammer adversely impacting on existing and nearby buildings. To mitigate such risk, we recommend vibration monitoring be implemented and this should be undertaken by a specialist vibration engineer/scientists. Vibration monitoring normally includes the following;

- Establishment of ground vibration criteria based on the proximity of adjacent buildings, condition of the buildings and type of buildings.
- Installation of geophones at strategic locations to monitor vibration during excavation works and the vibration monitoring unit should be set-up to alert the excavation contractor if the vibration exceeds the recommended level.
- Vibration monitoring should be carried out by a suitably qualified person with data loggers so that daily records of vibration (measured in Peak Particle Velocity) are available if and when required
- Excavation works should be carried out by an experienced operator who is aware of factors affecting vibration and transmission of vibration such as orientation of hammer, duration of hammering, size of excavation bite and speed of vibration of the hammer.

Prior to demolition and excavation works, dilapidation surveys should be carried out on surrounding properties stating the exact conditions of the properties. Such works should be carried out by an experienced and qualified structural engineer. The dilapidation surveys should be presented to the respective property owners to ensure that the surveys presented are fair and reasonable.

Though groundwater was not encountered in the augered boreholes, groundwater seepage may still exist on the site depending on climatic conditions and therefore provision for dewatering by sump and pump should be allowed for during excavation.

5.2 Building Platform Preparation

We anticipate that some building platform preparation will be required for the proposed building extension works. Our borehole investigation revealed the site to be generally underlain by some fill with thickness ranging from 0.6m to 2.2m overlying natural Silty Clay overlying shale and siltstone bedrock at depths ranging from 2.0m to 3.8m below existing ground surface.

Typical earthworks should include the following;

- Stripping of topsoil/organic layers to expose the natural clay. The topsoil may be reused as much as possible on site in landscaping and any surplus topsoil would need to be disposed off-site.

- Excavation of insitu fill where encountered to expose natural soil. The insitu fill should be assessed by a suitably qualified NATA accredited laboratory to ensure suitability of the material for reuse as structural fill on site. Suitable structural fill should consist of compactable clays, shale and sandstone free of deleterious material (eg organic material and vegetation), silt and large oversized material with particle size greater than 75mm.

- Proof rolling of the building platform using a minimum 10 tonne roller to delineate soft and heaving areas. Any soft and heaving areas identified by the proof rolling should be further excavated and replaced with ripped sandstone having a maximum particle size of 75mm.

- If fill is required to elevate the building platform to design level, all fill should be placed in thin layers not exceeding 250mm loose thickness and the fill should be compacted to a minimum 98% Standard Maximum Dry Density (SMDD) at within 2% Optimum Moisture Content. Care should be taken to ensure fill compaction using vibration does not adversely impact on the existing buildings. Vibration monitoring using geophones may be carried out to minimise risk of damage to existing buildings and such work should be carried out by vibration scientists.

5.3 Shoring and Retaining Walls

Site excavation will not require shoring if;

- The excavation is situated at least 1.5 times the depth of excavation away from building structures.
- The excavation is situated away from underground services by at least equal distance to the depth of service trenches.
- The excavation is adequately battered to the recommended batter slopes outlined in Section 5.4.

If shoring is required, a soldier pier wall system may be adopted and this system will involve drilling of bored or CFA piles at regular spaced intervals to form a line of soldier piles and shotcreting of the area between the soldier piles after each excavation stage. For soldier pile system, shotcrete infill should be reinforced and designed to span laterally between the soldiers. It should cover the full height of the exposed excavation face to minimise the risk of potential problems associated with degradation and weathering of the face.

For excavation situated within the zone of influence of buildings or structures, a rigid wall system such as a contiguous pile wall arrangement should be adopted in order to prevent potential undermining of existing footings causing damage. Construction of the contiguous pile wall would involve drilling a continuous line of bored or continuous flight auger (CFA) piles along the length of the excavation to form a concrete wall.

Soldier piles and contiguous piles should be taken down to the full height of the excavation and should be socketed a minimum of 0.5m below proposed excavation level (including footing excavations) and into Siltstone/sandstone or to adequate depths of embedment into hard clay to provide toe restraint.

Shoring wall may be temporarily restrained by internal bracing or designed as a cantilever system for the short term before building floor slabs are constructed to provide permanent restraints.

For retaining wall which will be propped by floor slabs or fixed at the top, thus limiting deflection, an "at-rest" lateral earth pressure coefficient (K_o) should be adopted. For other retaining walls designed as "cantilevered" or gravity walls, an "active" lateral earth pressure coefficient (K_a) may be adopted. For toe resistance, an active lateral pressure coefficient (K_p) may be adopted.

We recommend the following design parameters be adopted in preliminary design;

Material	Bulk Density (kN/m^3)	K_a	K_o	K_p	Effective Cohesion, C' (kPa)	Effective Friction Angle (deg)
Compacted Fill	17.5	0.35	0.65	-	2	20
Natural clay	20.0	0.30	0.50	2.0	5	20
Shale/Siltstone	22.0	0.20	0.30	2.5	10	25

Permanent subsurface drains should be provided at the back of the retaining wall, or half hydrostatic ground water pressures should be taken into account in the design. Surcharge due to adjacent structures, construction loads and sloping backfill should be taken into account in the design

5.4 Batter Slopes

For all unretained cut and fill, the following batter slopes may be adopted for preliminary design;

Material	Temporary	Permanent
Fill and topsoil (Landscape)	1V : 1.5H	1V : 3H
Natural Clay	1V: 1H	1V : 2H
Weathered Shale/Siltstone	1V : 0.5 to 1H	1V : 1H

Steeper batter slopes may be adopted for shale batters subject to inspection and further by geotechnical engineer during excavation works.

5.5 Foundations

Our borehole investigation revealed the site to be generally underlain by fill with thickness ranging from 0.6m to 2.2m overlying natural very stiff to hard Silty Clay overlying shale and siltstone bedrock at depths ranging from 2.0m to 3.8m below existing ground surface. The natural clay in BH 4 was assessed to generally be weak (ie moist and stiff).

Subject to building platform preparation as described in the above Section 5.1, light-weight structures may be supported on footings be founded on the compacted fill or natural very stiff to hard clay. For concentrated load structures which requires higher bearing pressures or if minimal building platform preparation was carried out to redensify the insitu fill, deep footings should be adopted with footings founded on the shale/siltstone bedrock.

For shallow footings such as strip and pad or raft slab footings founded on the natural very stiff to hard clay or compacted fill, an allowable bearing capacity of 150kPa may be adopted. For deeper footings such as piers taken through fill and founded on natural very stiff to hard clay to a minimum depth of 2.0m below the existing ground surface, a higher allowable bearing capacity of 350kPa may be adopted. An allowable shaft adhesion, an allowable shaft adhesion of 20 kPa may be adopted for the section of piers below 1.0m from ground surface and in natural very stiff to hard clay. The allowable uplift capacity may be adopted as half that of the shaft adhesion.

For deep footings founded on the shale/siltstone bedrock, we recommend that the footings be designed based on the following;

BH	Depth (m)		Class	Allowable Bearing Capacity (kPa)	Allowable Shaft Adhesion* (kPa)
	Start Depth (m)	End Depth (m)			
1	3.80	3.99	V	800	50
	3.99	6.60	V	800	50
	6.60	7.69	IV-III	1200	120
2	2.80	3.60	V	800	50
4	2.00	5.50	V	800	50
	5.50	7.20	IV-III	1200	120
5	3.00	5.30	V	800	50

Note : * =No allowance for shaft adhesion should be provided for pad footings.

Footings proportioned to the above allowable loads may expect settlement to be within acceptable limits of 1% or less of the width/diameter of footings. All footings should be founded on similar geological stratum to ensure even bearing, otherwise adequate articulation should be provided to accommodate some differential settlements.

Footings should be designed to accommodate soil reactivity based on a Class 'H1' (Highly Reactive) site in accordance to AS2870 – 2011 "Residential Slabs and Footings" (Reference 9).

5.6 Earthquake Provision

Based on AS1170.4 – 2007 "Structural design actions, part 4: Earthquake actions in Australia" (Reference 10), a site sub-soil "Class C_e – Shallow soil site" may be adopted for earthquake load design.

5.7 Proposed Floor Slab and Pavements

Pavement subgrade preparation for access roads and car parks should include the following;

- Stripping of the topsoil and any "uncontrolled" fill to expose natural clay.
- Boxing of pavement subgrade to proposed design level.
- Proof rolling of the base of the excavation with a vibrating roller (minimum 10 tonne). Care should be taken to ensure that excessive vibration is not generated from the rolling resulting in damage to existing and surrounding structures. Vibration monitoring may be considered necessary and if vibration is found to be excessive, compaction may be carried out without vibration and this will require compaction in thinner layers of 100mm.
- Any soft areas identified during rolling should be further excavated and replaced with ripped sandstone fill.
- The excavated clay material may be reused as filling beneath pavements subject to moisture reconditioning. Alternatively, imported good quality fill such as ripped sandstone having a maximum particle size of 75mm may be used.

- The fill material should be compacted in layers not exceeding 250mm loose thickness compacted to a minimum 98% Standard Maximum Dry Density (SMDD) at close to Optimum Moisture Content.

- The upper 300mm of the fill material forming the pavement subgrade should be compacted to a minimum 100% SMDD.

The subgrade preparation and pavement construction should be closely monitored by a geotechnical consultant and should include field density testing of the pavement material at an appropriate frequency and level of supervision as detailed

The laboratory CBR test results indicate the natural subgrade to have a CBR value of 3.5%. In the absence of design traffic loading for the proposed roads, the following pavement design options may be adopted based on assumed design traffic loadings (ie Equivalent Standard Axle (ESA)

Material	**Assumed ESA**	
	5×10^4	**3×10^5**
Asphaltic Concrete (AC10)	25mm	50mm
Primer Seal		
DGB20 Base Course	150mm	150mm
Crushed Sandstone Subbase Course	235mm	250mm
Total	**410mm**	**450mm**

For design of internal and external concrete slabs, and concrete pavements, a modulus of subgrade reaction of 35kPa/mm may be adopted. Slab construction should include dowelled or keyed movement joints and should be underlain by compacted granular subbase layer of at least 100mm thick comprising of DGB20 of equivalent good quality crushed rock.

The pavement materials to be compacted to the following Minimum Dry Density Ratios (AS1289 5.1.1, 5.2.1);

Material	**Relative Densities**	**Compactive Effort**
Base Course	98%	Modified
Sub-Base Course	98%	Modified
Subgrade	100%	Standard

5.8 Soil Aggressiveness

The fundamental criteria for assessing soil salinity are based on Electrical Conductivity (Reference 5).

Class	EC_e (ds/m)
Non-Saline	<2
Slightly Saline	2-4
Moderately Saline	4-8
Very Saline	8-16
Highly Saline	>16

The presence of Sulphate and Chloride in the soil has the potential to cause high soil aggressivity to concrete and steel structures, in particular if the structures are in direct contact with the soil. The following is a measure of soil aggressivity to concrete based on the AS 2159-2009 “Piling – Design and Installation” (Reference 7).

Sulfates (expressed as SO_4)		pH	Chloride in Groundwater ppm	Soil Conditions A*	Soil Conditions B#
In Soil ppm	In Groundwater ppm				
<5000	<1000	>5.5	<6000	Mild	Non-aggressive
5000-10 000	1000-3000	4.5-5.5	6000-12 000	Moderate	Mild
10 000-20 000	3000-10 000	4-4.5	12 000-30 000	Severe	Moderate
>20 000	>10 000	<4	>30 000	Very Severe	Severe

Approximate 104ppm of SO4=80ppm of SO3
* Soil condition A = High permeability soils (eg sands and gravels) which is below groundwater
# Soil conditions B = Low permeability soils (eg silts and clays) and all soils above groundwater

The following is a measure of soil aggressivity to steel piles based on the AS 2159-2009 “Piling – Design and Installation” (Reference 7).

pH	Chlorides (Cl)		Resistivity ohm.cm	Soil Conditions A*	Soil Conditions B#
	In Soil ppm	In Groundwater ppm			
>5	<5000	<1000	>5000	Non-aggressive	Non-aggressive
4-5	5000-20 000	1000-10 000	2000-5000	Mild	Non-aggressive
3-4	20 000-50 000	10 000-20 000	1000-2000	Moderate	Mild
<3	>50 000	>20 000	<1000	Severe	Moderate

* Soil condition A = High permeability soils (eg sands and gravels) which is below groundwater
# Soil conditions B = Low permeability soils (eg silts and clays) and all soils above groundwater

In addition to the above, the AS 3600-2018 "Concrete Structures" (Referenced 8) outlines an exposure classification for concrete in sulfate soils as follows;

Exposure Conditions			**Exposure Classification**	
Sulphate (expressed as SO3)		**pH**	**Soil Conditions A***	**Soil conditions B#**
In Soil ppm	**In Groundwater ppm**			
<5000	<1000	>5.5	A2	A1
5000-10 000	1000-3000	4.5-5.5	B1	A2
10 000-20 000	3000-10 000	4-4.5	B2	B1
>20 000	>10 000	<4	C2	B2

Approximate 100ppm of SO_4=80ppm of SO_3
* Soil condition A = High permeability soils (eg sands and gravels) which is below groundwater
# Soil conditions B = Low permeability soils (eg silts and clays) and all soils above groundwater

The laboratory test results indicate the insitu soil to have low concentrations of Sulphate and in an environment with the lowest pH value of 5.4, the insitu soil may be classified as mildly aggressive to buried concrete structures. The laboratory test results indicate the insitu soil to have low concentrations of Chloride and in an environment with the lowest resistivity of 5800 ohm/cm, the insitu soil may be classified as Non Aggressive to buried steel structures.

6. LIMITATIONS

The interpretation and recommendations submitted in this report are based in part upon data obtained from a limited number of boreholes. The nature and extent of variations between test locations may not become evident until construction.

Groundwater conditions are only briefly examined in this investigation and though groundwater was not encountered during this investigation, groundwater may be present after prolonged wet period.

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 findings contained in this report are the results of discreet/specific sampling methodologies used in accordance with normal practices and standards. There is no investigation which is thorough enough to preclude the presence of material which presently, or in future, may be considered hazardous to the site.

As regulatory evaluation criteria are constantly updated, concentrations of contaminants presently considered low, may in the future fall short of regulatory standards that require further investigation/redemption.

Your attention is drawn to the attached “Explanatory Notes” in Appendix D. This document should be read in conjunction with our report. 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.

D:\19JOB\178\JG19178A-r1.DOC
01/11/19 2:06 PM

REFERENCE

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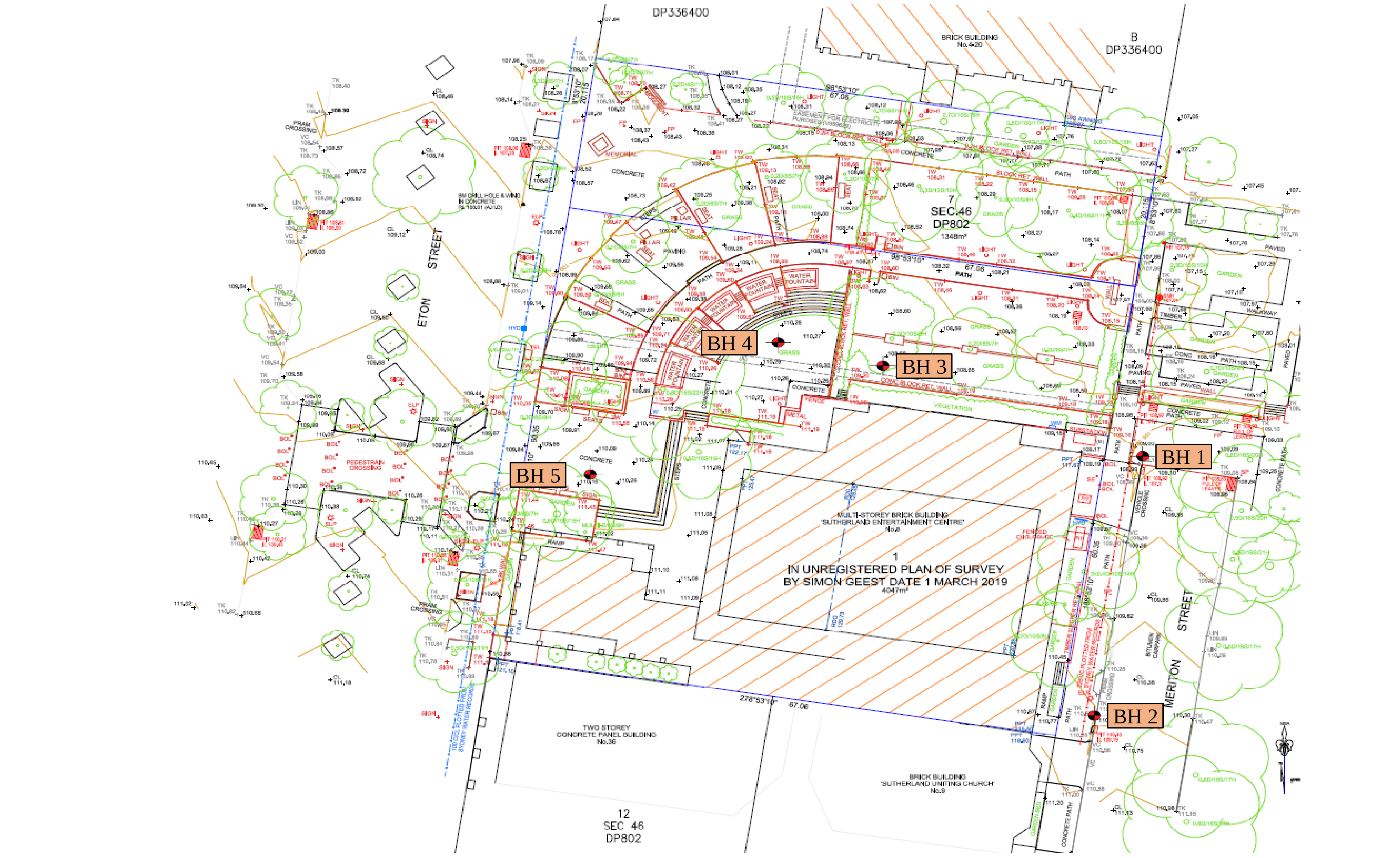
3. *Pells, PJN, Mostyn, GM. And Walker, BF (1998) Foundation on shale and sandstone in the Sydney Region.*
4. *Salinity Code of Practice – Western Sydney Regional Organisation of Councils Ltd – 2004*
5. *Department of Land and Water Conservation – "Site Investigation for Urban Salinity".2002*
6. *What do all the numbers mean? A guide for the interpretation of soil test results. – Department of Conservation and Land Management, 1992*
7. *Australian Standard, AS 2159-2009 "Piling – Design and Installation"*
8. *Australian Standard, AS 3600-2018 "Concrete Structures"*
9. *Australian Standard, AS 2870-2011 "Residential Slabs and Footings"*
10. *Australian Standard, AS 1170.4-2007 "Structural design actions, Part 4: Earthquake actions in Australia*



Legend

BH 1 Borehole

GeoEnviro Consultancy

Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia

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

Drawn By: SG	**Date: 1/11/19**	**NBRS Architecture**	
Checked By: SL	**Date: 1/11/19**	**Sutherland Entertainement Centre**	
Revision By:	**Date:**	**Borehole Location Plan**	
Scale: Proportional	**A3**	**Project No: JG19178A**	**Drawing No: 1**

APPENDIX A

Borehole and Cored Borehole Reports

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Borehole Report

Borehole no: 1

Client: NBRS Architecture
Job no: JG19178A

Project: Sutherland Entertainment Centre - Proposed Refurbishment
Date: 8-9/10/19

Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland
Logged by: SG

Drill Model and Mounting: TCH 05 | Slope: 90 deg | R.L. Surface: 109.15m

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							Topsoil/Fill: Clayey Silt: Low liquid limit, brown	D			
							Fill: Gravelly Sandy Clay: Low plasticity, brown, tree roots, 1 concrete cobble	D-M			
			DB			CH	Silty Clay: High plasticity, grey and red, trace of sand	D-M			
V-BIT			N=14 3,6,8	1.0					H	>600	
				2.0							
			N=>16 8,16	3.0		CI-CH	As above but medium to high plasticity				SPT Bouncing on ironstone gravel at 2.8m
TC-BIT				4.0			Shale/Siltstone: Grey & Brown with iron staining, distinctly weathered, extremely low to low strength				
							Start Coring BH 1 at 3.99m				
				5.0							
				6.0							
				7.0							
				8.0							

Photograph 1: Cored Borehole No 1

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Cored Borehole Report

Borehole no: 1

Client: NBRS Architecture
Job no: JG19178A

Project: Sutherland Entertainment Centre - Proposed Refurbishment
Date: 16/10/2019

Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland
Logged by: SG

Drill Model and Mounting: TCH05 | Slope: | R.L Surface: 109.15m
Hole Diameter: 49 mm | Bearing: | Datum: AHD

Method	Support	Barrel Lift	Water Loss/ Level	Depth(m)	Graphic Log	Core Description Rock type, grain characteristics, colour, structure, minor components.	Weathering	Strength	Point Load Index Strength Is(50) VL M VH EL L H EH	Defect Spacing (mm) 300 50 10 500 100 30	Defect Details: Description type, inclination, thickness, planarity, roughness, coating
				0–3.99		Start Coring BH 1 at 3.99m					
NMLC	NIL		FULL RETURN	3.99–7.69		Shale: Grey and Pale Grey, with ironstone bands	XW-DW	EL-L			4.10m, EWS, 1mm.t 4.88m, 30° Joint 5.17-5.24m, Crushed Seam 5.67m, 40° Joint 5.81-5.86m, Clay Seam 6.25m, EWS, 3mm.t, IS 6.31m, EWS, 4mm.t, IS 6.33-6.36m, Clay Seam 6.42m, EWS, 4mm.t, IS
								VL-L			6.79m, EWS, 6mm.t, IS
						Shale: Dark grey	DW				7.35m, EWS, 6mm.t, IS
				8		End BH 1 at 7.69m					

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Borehole Report

Borehole no: 2

Client: NBRS Architecture

Job no: JG19178A

Project: Sutherland Entertainment Centre - Proposed Refurbishment

Date: 8-9/10/19

Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland

Logged by: SG

Drill Model and Mounting: TCH 05 | Slope: 90 deg | R.L. Surface: 110.57m

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							Concrete 110mm with 6mm reinforcement				
							Sand - 90mm				
							Fill: Gravelly Silty Clay: Medium to high plasticity, red brown	MC <PL			
			N=15 3,7,8	1.0					H	>600	
							Gravel (Edge of Services Trench)				
TC-BIT				2.0		CH	Silty Clay: High plasticity, grey and red, with ironstone gravel	MC< PL	Vst		
			N=>13 2,13			CI-CH	As above but medium to high plasticity.		H	>600	SPT Bouncing at 2.78m
				3.0			Shale: Grey with iron staining, extremely to distinctly weathered, extremely low to low strength				
				4.0			End BH 2 at 3.6m				TC-Bit Refusal at 3.60m
				5.0							
				6.0							
				7.0							
				8.0							

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Borehole Report

Borehole no: 3

Client: NBRS Architecture

Job no: JG19178A

Project: Sutherland Entertainment Centre - Proposed Refurbishment

Date: 8-9/10/19

Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland

Logged by: SG

Drill Model and Mounting: TCH 05 | Slope: 90 deg | R.L. Surface: 108.68m

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 & V-BIT							Fill: Gravelly Clayey Silt: Low liquid limit, brown	D			
							Fill: Gravelly Silty Clay: medium plasticity, grey and brown, with gravel and concrete	D-M			
				1.0			Fill: Silty Clay: Medium plasticity, grey, with iron staining	D-M			
							End BH 3 at 1.0m on Concrete				Concrete encountered at 3 other locations within 0.7m
				2.0							
				3.0							
				4.0							
				5.0							
				6.0							
				7.0							
				8.0							

GeoEnviro Consultancy Pty Ltd
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Borehole Report

Borehole no: 4

Client: NBRS Architecture
Project: Sutherland Entertainment Centre - Proposed Refurbishment
Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland

Job no: JG19178A
Date: 8-9/10/19
Logged by: SG

Drill Model and Mounting: TCH 05
Hole Diameter: 100 mm
Slope: 90 deg
Bearing: -
R.L. Surface: 110.16m
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							Concrete 140mm with 6mm reinforcement				
							Gravelly Sand - 60mm				
						Fill	Silty Clay: Low to medium plasticity, dark grey brown	M			
				1.0							
TC-BIT			N= 6 1,3,3			CH	Silty Clay: High plasticity, grey	M	St	180	
											Harder to drill at 1.7m
				2.0		CI-CH	As above but medium to high plasticity	D	Vst		
							Shale: Grey to dark grey, extremely low to low strength extremely to distinctly weathered				
				3.0							
							Start Coring BH 4 at 3.20m				TC-BIT Refusal at 3.20m
				4.0							
				5.0							
				6.0							
				7.0							
				8.0							

Photograph 2: Cored Borehole No 4

GeoEnviro Consultancy Pty Ltd

Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Cored Borehole Report

Borehole no: 4

Client: NBRS Architecture
Job no: JG19178A

Project: Sutherland Entertainment Centre - Proposed Refurbishment
Date: 16/10/2019

Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland
Logged by: SG

Drill Model and Mounting: TCH05 | Slope: | R.L Surface: 110.16m
Hole Diameter: 49 mm | Bearing: | Datum: AHD

Method	Support	Barrel Lift	Water Loss/ Level	Depth(m)	Graphic Log	Core Description Rock type, grain characteristics, colour, structure, minor components.	Weathering	Strength	Point Load Index Strength Is(50) EL VL L M H VH EH	Defect Spacing (mm) 500 300 100 50 30 10	Defect Details: Description type, inclination, thickness, planarity, roughness, coating
				0–3.20		Start Coring BH 4 at 3.20m					
NMLC	NIL		FULL RETURN	3.20–5.10		Shale: Pale grey with iron staining	XW-DW	EL-L; L-M; EL-L-			3.65m, 80° Joint 4.25m, 70° Joint
				5.10–5.60		Shale: Grey to dark grey, with iron staining	DW				5.30m, Clay Seam, 8mm.t 5.40m, EWS, 1mm.t, IS
				5.60–7.20		Shale: Dark grey with iron staining	DW	VL-L			5.80m, EWS, 3mm.t, IS 5.99m, 30° Joint 6.27m, EWS, 1mm.t, IS 6.41m, EWS, 1mm.t, IS
				7.20–8		End BH 4 at 7.20m					

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Borehole Report

Borehole no: 5

Client: NBRS Architecture
Job no: JG19178A
Project: Sutherland Entertainment Centre - Proposed Refurbishment
Date: 8-9/10/19
Location: Lot 1 DP 1253156, No 30 Eton Street, Sutherland
Logged by: SG

Drill Model and Mounting: TCH 05
Slope: 90 deg
R.L. Surface: 110.28m
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							Fill: Sandy Silt: Low liquid limit, brown	D			
				1.0			Fill: Gravelly Silty Clay: Low plasticity, brown and grey with tile, brick and concrete fragments	D-M			
TC-BIT				2.0							
			N=20 4,8,12	3.0		CH	Silty Clay: High plasticity, grey and red	MC<PL D-M	H		
							Shale: Grey, with Clay bands, extremely to distinctly weathered, extremely low strength				
				4.0 5.0			Shale: Grey, extremely to distinctly weathered, extremely low strength				
				6.0 7.0 8.0			End BH 5 at 5.30m				TC-Bit Refusal at 5.30m

APPENDIX B

Laboratory Results – Geotechnical

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Test Results - Atterberg Limits

Client / Address: NBRS Architecture / Milsons Point — Job No: JG19178A
Project: Sutherland Entertainment Centre — Date: 1/11/19
Location: No 30 Eton Street Sutherland — Report No: R01A

Sample Identification	BH 4 1.0-1.45m)			
Sample Register No	SR13013			
Sample Date	8-Oct-19			
Test Date	14-Oct-19			
Sample Procedure	AS 1289 1.1, 1.2.1 (6.5.3)			
Test Results				
Test Procedure:	AS 1289 3.1.2			
Liquid Limit (%)	57			
Test Procedure:	AS 1289 3.2.1			
Plastic Limit (%)	23			
Test Procedure:	AS 1289 3.3.1			
Plasticity Index (%)	35			
Test Procedure:	AS 1289 3.4.1			
Linear Shrinkage (%)	13.5			
Test Procedure:	AS 1289 2.1.1			
Natural Moisture Content %	23.0			
Material Description	Silty Clay: high plasticity, grey			

Remarks

c:/lab/reports/R004 Form No. R004/Ver 08/07/13

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Authorised Signatory ____________ Solern Liew Date 1/11/19

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Test Results - California Bearing Ratio

Client / Address: NBRS Architecture / Milsons Point — Job No: JG19178A

Project: Sutherland Entertainment Centre — Date: 1/11/19

Location: No 30 Eton Street Sutherland — Report No: R02A

SAMPLE INFORMATION Test Methods							
Lab Reference No.			SR13012				
Date Sampled			08-Oct-19				
Date Tested			22-Oct-19				
Sample Identification			BH 1 (0.6-1.2m)				
Laboratory Specimen Description			Silty Clay: brown red grey with some gravel				
Preparation of the test sample							
Liquid Limit Preformed Yes / No			No				
Visual / Tactile Assessment Yes / No			Yes				
Sample Curing Time			48 h (2 days)				
TEST RESULTS							
Laboratory Compaction & Moisture Content - Test Methods AS1289 5.1.1 Mould A and AS1289 2.1.1							
Maximum Dry Density t/m3			1.76				
Optimum Moisture Content %			17.5				
Field Moisture Content %			17.5				
% Of Oversize		19mm	-				
Replacement of Oversize (See note B)			-				
California Bearing Ratio - Test Method AS1289 6.1.1							
	Dry Density t/m3	Before Soaking	1.77				
		After Soaking	1.73				
C	Density Ratio %	Before Soaking	100.5				
B		After Soaking	98.5				
R	Moisture Content %	Before Soaking	17.5				
		After Soaking	19.0				
T	Number of Days Soaked		4				
E	Surcharge kg		4.5				
S	Moisture Content After Test %	Top 30mm	22.5				
T		Whole Sample	19.0				
	Swell After Soaking %		2.1				
	Penetration mm		2.5				
	CBR Value %		3.5				

Notes: (A) Test specimen was compacted to a target dry density of 100 percent standard (AS 1289 5.1.1)

(B) If specified the percentage of oversize retained on the 19mm may be replaced by an equal portion of –19mm to +4.75mm

Remarks

C:\\Lab\report\R003 — Form No. R003/Ver08/06/18

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GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Point Load Index Test Results

Client: NBRS | Job Number: JG19178A
Project: Sutherland Entertainment Centre | Date: 1/11/19
Location: No 30 Eton Street Sutherland | Report No: R03A

Test Method : RTA T223

BH 1 Depth (m)	$I_{S(50)}$ MPa	ESTIMATED (U.C.S) MPa
4.05-4.10	0.05	0.96
4.67-4.72	0.20	4.05
5.36-5.41	0.02	0.48
5.85-5.90	0.05	1.08
6.20-6.25	0.03	0.65
6.70-6.75	0.11	2.26
7.05-7.10	0.10	2.05
7.50-7.55	0.11	2.16

BH 4 Depth (m)	$I_{S(50)}$ MPa	ESTIMATED (U.C.S) MPa
3.90-3.95	0.44	8.77
4.33-4.38	0.14	2.85
4.82-4.86	0.03	0.67
5.50-5.55	0.04	0.83
5.85-5.90	0.14	2.76
6.15-6.20	0.08	1.63
6.62-6.67	0.12	2.40
7.10-7.15	0.05	1.00

Notes:

1. In the above table testing was completed in the Axial direction
2. The Estimated Unconfined Compressive Strength (Estimated U.C.S) was calculated from the point load strength Index by the following approximate relationship and rounded off to the nearest number:

   $U.C.S = 20\ I_{S(50)}$

APPENDIX C

Laboratory Results – Soil Aggressiveness

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

CERTIFICATE OF ANALYSIS 228068

Client Details

Client	Geoenviro Consultancy Pty Ltd
Attention	Solern Liew
Address	PO Box 1543, Macquarie Centre, North Ryde, NSW, 2113

Sample Details

Your Reference	**JG19178A, Sutherland**
Number of Samples	4 Soil
Date samples received	10/10/2019
Date completed instructions received	10/10/2019

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	17/10/2019
Date of Issue	15/10/2019

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Results Approved By
Priya Samarawickrama, Senior Chemist

Authorised By

Nancy Zhang, Laboratory Manager

Misc Inorg - Soil					
Our Reference		228068-1	228068-2	228068-3	228068-4
Your Reference	UNITS	BH1	BH2	BH3	BH4
Depth		2.50-2.95	1.00-1.45	0.60-0.80	1.00-1.45
Date Sampled		08-09/10/2019	08-09/10/2019	08-09/10/2019	08-09/10/2019
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	11/10/2019	11/10/2019	11/10/2019	11/10/2019
Date analysed	-	11/10/2019	11/10/2019	11/10/2019	11/10/2019
pH 1:5 soil:water	pH Units	5.5	7.3	8.5	5.4
Electrical Conductivity 1:5 soil:water	µS/cm	170	54	110	55
Chloride, Cl 1:5 soil:water	mg/kg	100	10	22	<10
Sulphate, SO4 1:5 soil:water	mg/kg	190	55	110	88
Resistivity in soil*	ohm m	58	180	94	180

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-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: Misc Inorg - Soil					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	228068-4
Date prepared	-			11/10/2019	1	11/10/2019	11/10/2019		11/10/2019	11/10/2019
Date analysed	-			11/10/2019	1	11/10/2019	11/10/2019		11/10/2019	11/10/2019
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	1	5.5	5.8	5	105	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	1	170	180	6	95	[NT]
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	1	100	100	0	96	92
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	1	190	210	10	110	129
Resistivity in soil*	ohm m	1	Inorg-002	<1	1	58	54	7	[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.

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; 60-140% for organics (+/-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.

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

SAMPLE RECEIPT ADVICE

Client Details	
Client	Geoenviro Consultancy Pty Ltd
Attention	Solern Liew

Sample Login Details	
Your reference	JG19178A, Sutherland
Envirolab Reference	228068
Date Sample Received	10/10/2019
Date Instructions Received	10/10/2019
Date Results Expected to be Reported	17/10/2019

Sample Condition	
Samples received in appropriate condition for analysis	Yes
No. of Samples Provided	4 Soil
Turnaround Time Requested	Standard
Temperature on Receipt (°C)	12.6
Cooling Method	Ice Pack
Sampling Date Provided	YES

Comments
Nil

Please direct any queries to:

Aileen Hie	Jacinta Hurst
Phone: 02 9910 6200	**Phone: 02 9910 6200**
Fax: 02 9910 6201	**Fax: 02 9910 6201**
Email: ahie@envirolab.com.au	**Email: jhurst@envirolab.com.au**

Analysis Underway, details on the following page:

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

Sample ID	Misc Inorg - Soil
BH1-2.50-2.95	✓
BH2-1.00-1.45	✓
BH3-0.60-0.80	✓
BH4-1.00-1.45	✓

The '✓' indicates the testing you have requested. **THIS IS NOT A REPORT OF THE RESULTS.**

Additional Info
Sample storage - Waters are routinely disposed of approximately 1 month and soils approximately 2 months from receipt.
Requests for longer term sample storage must be received in writing.
Please contact the laboratory immediately if observed settled sediment present in water samples is to be included in the extraction and/or analysis (exceptions include certain Physical Tests (pH/EC/BOD/COD/Apparent Colour etc.), Solids testing, Total Recoverable metals and PFAS analysis where solids are included by default.
TAT for Micro is dependent on incubation. This varies from 3 to 6 days.

GeoEnviro Consultancy Pty Ltd
Unit 5, 39-41 Fourth Avenue, Blacktown NSW 2148, Australia
Tel: (02) 96798733 Fax: (02) 96798744

Laboratory Test Request/Chain of Custody Record

Job Details
Job Number: JG19178A
Client:
Project: Sutherland Entertainment Centre
Location: Eton Street, Sutherland

Sample Date: 8-9/10/2019
Sampled By: SG
Project Manager: SL
Store Location:

External Laboratory Details:
Laboratory name: Envirolab Services Pty Ltd
Address: 12 Ashley Street
Chatswood
Contact: Tania Notaris

Sampling Details / Sample Type / Test Required (\) / Test Performed(X)

	Location	Depth (m) From	Depth (m) To	Soil	Water	Metals (As Cd Cr Cu Pb Zn Ni Hg)	OCP / PCB	Combination 12a	Combination 5a	Combination 5	pH	EC	CEC/ESP	Cl / SO4	Resistivity	Keep Sample
1	BH 1	2.50	2.95	DG							/	/		/	/	
2	BH 2	1.00	1.45	DG							/	/		/	/	
3	BH 3	0.60	0.80	DG							/	/		/	/	
4	BH 4	1.00	1.45	DG							/	/		/	/	

ENVIROLAB
Envirolab Services
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 228068
Date Received: 10/10/2019
Time Received: 18:02
Received by: R
Temp: Cool/Ambient 12.6
Cooling: Ice/Icepack
Security: Intact/Broken/None

Relinquished by				Received By			
Laboratory	Name	Signature	Date	Laboratory En	Name	Signature	Date
GeoEnviro Consultancy	Steven Goss	SMGoss	10/10/2019		Raj	[signature]	10/10/2019

Legend
DB Disturbed Sample (Bulk, Plastic bag)
DS Disturbed Sample (Small, Plastic bag)
DG Disturbed Sample (Glass Jar)
STP Standard Penetration Test Sample
U50 Undisturbed Sample, 50mm Tube
U75 Undisturbed Sample, 75mm Tube
WG Water Sample, Amber Glass Jar
WP Water Sample, Plastic Bottle
Y Keep Sample
N Discard Sample

APPENDIX D

Explanatory Notes

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:

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

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.

GeoEnviro Consultancy Pty Ltd

Explanatory Notes – Rock Material

(In accordance with AS1726 – 1993)

Rock Material Weathering Classification

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

Rock Strength

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

Rock Material Weathering Classification

Abbreviation	Description	Notes
Be	Bedding Plan Parting	Defect orientations measured to the normal to the long core axis (is relative to horizontal for vertical holes).
CS	Clay seam	
J	Joint	
P	Planar	
Un	Undulating	
S	Smooth	
R	Rough	
IS	Ironstained	
XWS	Extremely Weathered Seam	
Cr	Crushed Seam	
600mm t	Thickness of defect in millimeters	

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