GEOTECHNIQUE®
PTY LTD

ABN 64 002 841 063

Job No: 13789/1
Our Ref: 13789/1-AA
30 August 2016

The Scots College
C/- David Fleeting Architects
18 Yanko Avenue
BRONTE NSW 2024
Email: Davidf@dfarchitects.com.au

Attention: Mr D Fleeting

Dear Sir

re: **Proposed Basement & Tennis Courts**
The Scots College, Cranbrook Road, Bellevue Hill
Geotechnical Investigation Report

This report presents the results of a geotechnical investigation carried out at the above site for the proposed multi-level basement car park. The investigation was approved by Mr Steven Adams of The Scots College Sydney in a signed confirmation of engagement dated 1 August 2016 and was carried out in accordance with the scope of work detailed in a Geotechnique Pty Ltd fee proposal Ref: ER.sf/Q7648-R1 dated 11 July 2016.

Proposed Development

We understand that the proposed development will comprise two multi-level basement car parks, one located below the existing tennis court and the other located below the playground near the main building. The basement excavation is anticipated to be varying between 5m and 8m below the existing ground surface.

A geotechnical investigation was required to assess the sub-surface conditions across the site in order to provide geotechnical recommendations on design of basement excavation, access ramp and retaining structures, floor slabs and footings.

Field Work

Field work for this investigation was carried out between 11 and 12 August 2016 and consisted of the following:

- Carry out a walk over survey to assess existing geological and geotechnical conditions within and in the vicinity of the site.
- Scan the proposed borehole locations for underground services to ensure boreholes are located away from existing services. A specialist services locator was hired for this purpose.
- Drill six boreholes to depths up to 12m, using a utility mounted drilling rig (Commachio MTC200) fully equipped for geotechnical investigation. Borehole locations are shown on the attached Drawing No 13789/1-AA1 and the borehole logs along with explanatory notes, are also attached.
- Conduct Standard Penetration Tests (SPT) in the boreholes at regular depth intervals to assess the strength characteristics of sub-surface soils.

- Recovery of representative soil samples and core samples for visual assessment and laboratory testing (point load strength index).
- Measure depths to groundwater level or seepage in the boreholes, where encountered.

The field work was supervised by a Geotechnical Engineer from this company who was responsible for locating boreholes, supervision of SPT tests, sampling and preparation of field logs.

Regional Geology

The Geological Map of Sydney (Geological Series Sheet 9130, Scale 1:100,000, 1983), published by the Department of Mineral Resources indicates the residual soils within the site is anticipated to be Quarternary Age soils consisting of medium to fine grained “marine” sand with podsols. The residual soils within the site is to be underlain by Hawkesbury Sandstone comprising medium to coarse grained quartz sandstone, very minor shale and laminite lenses.

Reference to the Soil Landscape Map of Sydney (1:100,000), the landscape at the site is likely to belong to the Newport Group, which is characterized by gently undulating plains to rolling rises of Holocene sands mantling other soil materials or bedrock. Local relief <10m, slopes <10% on lower slopes and plateau surface and up to 35% against obstacles facing prevailing winds. Very high soil erosion hazard, localised steep slopes, very low soil fertility and non-cohesive topsoils are common.

Site Description

The site consisted of existing tennis courts and part of a playground. It is bounded by Cranbrook Lane to the east, large playground to the north, The Scot College buildings and Cranbrook Road to the south and west. The ground level of tennis court is about a metre below than that of the playground. Topography of the playground is flat and generally covered with grass.

Sub-surface Conditions

Sub-surface conditions encountered at the site are detailed in the attached borehole logs and summarised in the Table below:

Table 1: Subsurface Conditions

Borehole No	Top RL (AHD m)	Termination Depth (m)	Topsoil/ Fill (m)	Natural Soil (m)	Bedrock (m)
1	≈ 54.4	12.0	0.0 - 0.5	0.5 - >12.0	NE
2	≈ 54.2	12.0	0.0 - 1.5	1.5 - >12.0	NE
3	≈ 54.0	12.0	0.0 - 0.4	0.4 - >12.0	NE
4	≈ 54.1	8.0	0.0 - 0.7	0.7 - >8.0	NE
5	≈ 54.5	8.8	0.0 - 0.5	0.5 - 5.3	5.3 - >8.8
6	≈ 53.8	8.0	0.0 - 2.5	2.5 - >8.0	NE

NE: Not encountered to the termination depths

Topsoil / Fill	Silty Sand, fine to coarse grained, dark brown to brown, with roots and gravels Asphaltic concrete pavement
Natural	Silty Sand, fine to medium grained, orange, yellow, brown and grey
Bedrock	Sandstone, fine to medium grained, yellow brown, slightly weathered to fresh, medium to high strength

Based on information presented in Table 1, the sub-surface profile within the proposed development is anticipated to comprise a sequence of topsoil / fill underlain by natural sandy soils. Sandstone bedrock was encountered only at borehole No 5 at a depth 5.3m below the surface. Depth of fill across the site varies between 0.4m and 2.5m below the existing ground surface.

Groundwater Conditions

Groundwater was not encountered to the auger drilled depths of the boreholes. Minor seepage was observed in borehole No 5 at the bedrock level (i.e., at 5.3m depth). It should be noted that the levels of groundwater/seepage might vary due to rainfall, temperature and other factors not evident during this investigation. We do not anticipate significant groundwater inflow during excavation. Groundwater inflow during excavation, if any, could be adequately managed using a conventional pump and sump system.

Laboratory Testing

Rock core obtained from borehole No 5 was photographed and tested at regular depth intervals for the determination of the Point Load Strength Index (I_{s50}). The point load strength indices for the rock cores and the assessed rock strengths, in accordance with Australian Standard AS1726-1993 (Reference 1), are summarised in the following Table 2.

Table 2: Point Load Strength Index

Borehole No	Depth (m)	Diametral $I_{s(50)}$ (MPa)	Axial $I_{s(50)}$ (MPa)	Diametral Assessed Strength*	Axial Assessed Strength*
BH5	6.2	0.29	0.37	Low	Medium
	7.2	0.35	0.52	Medium	Medium
	8.5	0.58	0.72	Medium	Medium

* Estimated strength, $I_{s(50)}$: <0.03: Extremely Low, 0.03-0.1: Very Low, 0.1-0.3: Low, 0.3-1.0: Medium, 1.0-3.0: High, 3.0-10.0 Very High
# Estimated Unconfined Compressive Strength (UCS) ≈ 20 x Axial Point Load index

Bedrock Classification for Foundation Design

Based on rock strengths (Table 2) and rock discontinuities shown in the borehole logs, bedrock from the proposed development site is classified for foundation design in accordance with Pells et al (Reference 1) in the following Table 3.

Table 3: Bedrock Classification

Borehole Number	Existing Ground Level (mAHD)	Bulk Excavation Level (mAHD)	Bulk Excavation Depth (m)	Top Depth to (m)	
				Low Strength Sandstone - Class V to IV	Medium Strength Sandstone- Class III or better
5	≈ 54.5	≈ 46.5	≈ 8	≈ 5.3	≈ 6.0

It should be noted that the depth of bedrock could vary widely across the site as it was not encountered at other borehole locations drilled up to 12m deep. Natural sand deposit (Medium dense) of considerable thickness is expected below the basement excavation level at most of the area.

DISCUSSION AND RECOMMENDATIONS

Excavation Condition

Proposed development is understood to involve 5m to 8m deep excavation depending on the number of basements. Therefore, materials to be excavated are expected to comprise topsoil, concrete pavement, and sandy fill with gravels and loose to medium dense natural sand. Low to medium strength sandstone bedrock can be found near borehole No 5 location. It is our assessment that excavation of sandy soils (natural and fill) and low strength sandstone (Class V to Class IV) can be achieved using conventional earthmoving equipment such as excavators and dozers. However, excavation of medium to high strength sandstone (Class III or better) would be considerably more difficult and require rock hammers, rock breakers, rock saw or rippers attached to Caterpillar D9/D10 dozers.

Selection of excavation equipment should be based on site access, strength of sub-surface materials and the likely impact of vibration to structures in the vicinity of the excavation (building, houses, roads, etc.). Contractors should make their own judgement using the engineering logs and core photos attached to this report and their own experience in such circumstances when tendering for excavation works.

Acceptable vibration is based on the nature and state of neighbouring structures, which will have to be established by a dilapidation survey. As a general guide, the acceptable maximum peak particle velocity in a residential area would range from about 5mm/s to 10mm/s. In order to reduce vibrations, rock saw can be used on site boundaries and then rock hammer can be used to break the cut rock into suitable sizes for removal from the site.

Groundwater was not encountered to the auger refusal / terminal depths of the boreholes. As groundwater level could change with climatic conditions, some groundwater/seepage may occur at shallower depths if excavation is carried out immediately after or during wet climatic conditions. Based on the existing subsurface conditions, we do not expect groundwater related problems. Minor groundwater, if encountered, could be readily handled using conventional pump and sump system.

Batter Slopes and Retaining Structures

Proposed development will involve up to about 8m deep basement excavation. Cut and fill slopes during and after development works should be battered for stability or retained by engineered retaining structures. Recommended batter slopes for the stability of cut and fill slopes are presented in Table 4.

Table 4: Recommended Batter Slopes

Material	Temporary (Vertical : Horizontal)		Permanent (Vertical : Horizontal)	
	Protected	Exposed	Protected	Exposed
Controlled Fill/ Residual Soil	1.0 : 1.0	1.0 : 1.5	1.0 : 2.0	1.0 : 2.5
Sandstone- Class V to IV	1.0 : 0.5	1.0 : 1.0	1.0 : 1.0	1.0 : 1.5
Sandstone- Class III or better	Sub-vertical	Sub-vertical	Sub-vertical	Sub-vertical

Surface protection of the slopes can be provided by shotcreting, which may be reinforced.

Vertical excavations in Class III sandstone bedrock, where required, will have a low risk of instability. However, some local rock bolting and shotcreting might be required depending on the relative orientation of rock discontinuities (bedding partings, fractures and joint systems) and excavation faces. The borehole log and core photograph show some rock discontinuities. Therefore, it is important that an experienced Geotechnical Engineer should inspect as excavation progresses in intervals of 1.5m and identify any signs of instability and recommended suitable stabilisation methods. It is also recommended that battered slopes and excavation faces are provided with adequate surface and sub-surface drainage.

Cut and fill slopes steeper than those recommended above would need to be retained by engineered retaining structure. Appropriate retaining structures for the proposed development would comprise either contiguous pile walls (with clear spacing less than 300mm) or secant pile walls (with no clear spacing) depending on expected seepage water flow. We recommend CFA technique to install these piers.

Earth pressure distribution on cantilevered retaining walls may be assumed to be triangular and estimated as follows:

$$p_h = k\gamma H$$

Where,

p_h = Horizontal active earth pressure (kN/m^2)
γ = Bulk density of materials to be retained (kN/m^3)
k = Coefficient of earth pressure (k_a or k_0)
k_a = Active earth pressure coefficient
k_0 = At rest earth pressure coefficient
H = Retained height (m)

For the design of flexible retaining structures where some lateral movement is acceptable an active earth pressure coefficient (k_a) is recommended. If it is critical to limit the horizontal deformation of a retaining structure use of an earth pressure coefficient at rest (k_0) should be considered. Recommended earth pressure coefficients for the design of retaining structures are presented in the following Table 5.

Table 5: Recommended Earth Pressure Coefficients

Retained Material	**Unit Weight (kN/m^3)**	**Active Earth Pressure Coefficient**	**At Rest Earth Pressure Coefficient**	**Passive Earth Pressure Coefficient**	**Passive Earth Pressure (kPa)**
Sandy Fill (Loose)	19	0.4	0.6	2.5	-
Natural Sand (Medium Dense)	20	0.3	0.5	3.0	-
Sandstone - Class V to IV	22	-	-	-	250
Sandstone - Class III or better	24	-	-	-	400

** Apply appropriate factor of safety*

The above coefficients are based on the assumption that ground level behind the retaining structure is horizontal and the retained material is effectively drained. Additional earth pressures resulting from surcharge load (buildings, infrastructures, etc) on retained materials and groundwater pressure, if any, should also be allowed for in design of retaining structures. The design of any retaining structure should also be checked for bearing capacity, overturning, sliding and overall stability of the slope.

Anchors might be required for the support of retaining structures. For anchored retaining walls, earth pressure distribution can be assumed trapezoidal with estimated peak value as 5H (8H for at rest condition) kPa, where H is the retained height (m). The pressure distribution should be nil at the surface, increasing to 5H (8H for at rest condition) at depth of 0.25H and remaining constant to 0.75H, then decreasing to nil at the base of the excavation.

Floor Slabs and Footings

Material at the base of basement excavation in most of the area is anticipated to be medium dense sand. However, medium strength sandstone bedrock can be encountered near borehole No 5. The depth of bedrock in other area is likely to be very high. Therefore, floor slabs for proposed buildings may be constructed as ground bearing slabs or suspended slabs supported by footings designed in accordance with recommendations provided in this report. For the design of ground bearing slabs, we recommend a Modulus of Subgrade Reaction Value of 30kPa/mm for medium dense sand and 50kPa/mm for low to medium strength sandstone.

Loading conditions from the proposed structure are not known at this stage. We consider that appropriate foundations would comprise shallow footings (pad and strip) founded in Class III or better sandstone as it is expected to be exposed at the base of basement excavation near borehole 5 location, or deep foundations (bored piers) socketed into sandstone bedrock below the base of excavation. The recommended allowable bearing pressures for design of shallow and deep foundations are presented in the following Table 6.

Table 6: Recommended Allowable Bearing Pressures

Founding Material	Allowable Bearing Pressure (kPa)	Allowable Shaft Adhesion (kPa)
Medium Dense Sand	250	Ignore
Sandstone - Class V to IV	1000	80
Sandstone - Class III or better	3000	250

The recommended allowable shaft adhesions against uplift pressures are half the shaft adhesions for compressive loads presented in Table 6. For footings founded in bedrock total settlements under the recommended allowable bearing pressures are estimated to be about 1% of pier diameter or minimum footing dimension. Differential settlements are estimated to be about half the estimated total settlements.

As depths to bedrock with the recommended allowable bearing pressures could vary across the site, the founding depths of footings to be constructed will also vary. As mentioned earlier that the depth of bedrock could vary widely across the site as it was only encountered at borehole No 5 location. If the depth of bedrock is too deep, screw piers in medium dense sand can be an alternative option.

Limitations

Assessments and recommendations presented in this report are based on site observation and information from six boreholes. Although we believe that the sub-surface profile presented in this report is indicative of the general profile across the site, it is possible that the sub-surface profile across the site could differ from that encountered in the boreholes. Likewise, comments on groundwater are based on observation during field work. We recommend that this company is contacted for further advice if actual site conditions encountered during basement excavation differ from those presented in this report.

If you have any questions, please do not hesitate to contact the undersigned.

Yours faithfully
GEOTECHNIQUE PTY LTD

Ariful

DR MD ARIFUL ISLAM
Senior Geotechnical Engineer

Attached	Drawing No 13789/1-AA1 (BH1-6 Borehole Location Plan) Borehole Logs (1 to 4), Core Photos and Explanatory Notes

References

1. *Pells, P J N, Mostyn, E and Walker, B F, Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, Dec 1998.*

Imagery ©2016 NearMap.com

LEGEND

● Borehole

0 10 20 30 40 50m

Scale 1:1000

PREPARED BY:

GEOTECHNIQUE®
PTY LTD

PO Box 880
Penrith NSW 2750
Tel: 02 4722 2700
Fax: 02 4722 2777
e-mail:info@geotech.com.au
www.geotech.com.au

David Fleeting Architects
Proposed Basement and Tennis Court
The Scots College
Cranbrook Road, Woollahra

Borehole Locations

Drawing No: 13789/1-AA1
Job No: 13789/1
Drawn By: MH
Date: 15 August 2016
Checked By: MT

File No: 13789-1
Layers: 0, AA1

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 1
Date : 11/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.4
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
		GP				0			Tennis Court AC Pavement 20mm				
									FILL: Silty Sand, fine to coarse grained, brown, with gravel				
		GP						SM	Silty SAND, fine to medium grained, orange to brown	M	L		Alluvial
								SM	Silty SAND, fine to medium grained, yellow brown	M	L		
				P	N=6 2,3,3	1							
						2							
				P	N=17 6,8,9					M	MD		
						3							
				P	N=23 7,11,12	4		SM	Silty SAND, fine to medium grained, yellow	M	MD		
						5							
				P	N=20 8,9,11								
						6							
				P	N= 10,15/ 100	7				M	VD		
						8							
						9							

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 1
Date : 11/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.4

hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						10							
	Dry					11							
						12			Borehole No 1 terminated at 12.0m				
						13							
						14							
						15							
						16							
						17							
						18							
						19							

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 2
Date : 11/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.2
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
		GP				0			AC 20mm FILL: Roadbase Gravel, grey				
		GP											
									FILL: Silty Sand, fine grained, grey				
		GP			N=8 3,3,5	1							
		G						SM	Silty SAND, fine grained, pale grey	M	MD		Alluvial No Sample recovered from auger
						2							
								SM	Silty SAND, fine to medium grained, brown	M	MD		
						3							
						4							
						5							
						6							
				P				SM	Silty SAND, fine to medium grained, yellow brown	M	MD		
						7							
						8							
						9							

GEOTECHNIQUE
PTY LTD

engineering log - borehole

Client :	David Fleeting Architects	**Job No. :**	13789/1
Project :	Proposed Basement and Tennis Court	**Borehole No. :**	2
Location :	The Scots College Cranbrook Road, Woollahra	**Date :**	11/08/2016
		Logged/Checked by:	MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.2

hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						10	░						
	Dry					11	░						
						12			Borehole No 2 terminated at 12.0m				
						13							
						14							
						15							
						16							
						17							
						18							
						19							

GEOTECHNIQUE
PTY LTD

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 3
Date : 11/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.0
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0			CONCRETE SLAB 170mm				
		GP							FILL: Silty Sand, fine to coarse grained, brown				
		G						SM	Silty SAND, fine to medium grained, grey	M	L		Alluvial
				P	N=9 4,4,5	1							
								SM	Silty SAND, fine to medium grained, brown	M	L		
		G				2							
								SM	Silty SAND, fine to medium grained, yellow brown	M	L		
				P	N=8 3,3,5								
						3							
						4		SM	Silty SAND, fine to medium grained, yellow	M	MD		
				P	N=21 9,9,12								
						5							
				P	N=19 7,8,11	6							
				P	N=18 5,8,10	7							
						8							
						9							

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 3
Date : 11/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted
slope : **deg.**
R.L. surface : ≅54.0
hole diameter : 125 **mm**
bearing : **deg.**
datum : AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
	Dry					10 11							
						12 13 14 15 16 17 18 19			Borehole No 3 terminated at 12.0m				

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 4
Date : 12/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.1
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0			TOPSOIL/FILL: Silty Sand, fine to medium grained, dark brown, with roots				
		G						SM	Silty SAND, fine to medium grained, pale grey	M	VL		
				P	N=3 1,1,1	1							
						2		SM	Silty SAND, fine to medium grained, brown grey	M	L		
				P	N=4 1,2,2	3							
								SM	Silty SAND, fine to medium grained, yellow brown	M	L		
				P	N=7 4,3,4	4							
						5							
				P	N=17 5,8,9	6				M	MD		
				P	N=20 7,10,10	7							
	Dry												
						8			Borehole No 4 terminated at 8.0m				
						9							

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 5
Date : 12/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.5
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	**MATERIAL DESCRIPTION** soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0	▩		TOPSOIL/FILL: Silty Sand, fine to medium grained, brown, with roots				
		GP					░	SM	Silty SAND, fine to medium grained, grey	M	L		Alluvial
				P	N=6 2,2,4	1	░						
						2	░	SM	Silty SAND, fine to medium grained, brown yellow	M	L		
				P	N=9 2,3,6		░						
						3	░						
				P	N=16 5,6,10	4	░			M	MD		
						5	░						
	▶						▒		SANDSTONE, fine to medium grained, yellow brown				Bedrock Groundwater seepage at 5.3m
				P	N= 20/100		▒						
						6			Refer to Cored Log				
						7							
						8							
						9							

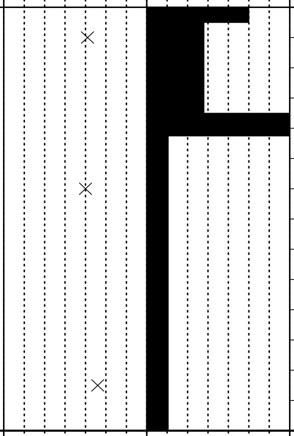
engineering log
cored borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 5
Date : 12/08/2016
Logged/Checked by : MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅54.5
core size: NMLC **bearing :** **deg.** **datum :** AHD

barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength	point load index strength $I_S(50)$ EL VL L M H VH	defect spacing (mm) 2000 1000 500 300 100 50	DEFECT DETAILS – DESCRIPTION type, inclination, thickness, planarity, roughness, coating. Specific	General
				Coring commenced at 6.0m						
		6		SANDSTONE, fine to medium grained, pale yellow	FR	H			6.1m: Be=30°, Un 6.8m: Jo=70°, St	
		7								
		8								
				Borehole No 5 terminated at 8.8m						
		9								
		10								
		11								
		12								
		13								
		14								
		15								



GEOTECHNIQUE

PTY LTD

Job No 13789/1 BH5 Started Coring at 6.0m

BH5 terminated at 8.8m

GEOTECHNIQUE
PTY LTD

engineering log - borehole

Client : David Fleeting Architects
Project : Proposed Basement and Tennis Court
Location : The Scots College
Cranbrook Road, Woollahra

Job No. : 13789/1
Borehole No. : 6
Date : 12/08/2016
Logged/Checked by: MT

drill model and mounting : Commachio Utility Mounted **slope :** **deg.** **R.L. surface :** ≅53.8

hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0	▩		TOPSOIL/FILL: Silty Sand, fine to medium grained, brown, with some roots				
		GP					▩						
				P	N=4 2,2,2	1	▩						
		GP					▩						
						2	▩						
		GP		P	N=4 2,2,2		⁙	SM	Silty SAND, fine to medium grained, brown yellow	M	VL		Alluvial
						3	⁙						
				P	N=9 3,4,5	4	⁙			M	L		
						5	⁙						
				P	N=16 6,7,9		⁙			M	MD		
						6	⁙						
				P	N=27 6,11,16	7	⁙						
	Dry						⁙						
						8			Borehole No 6 terminated at 8.0m				
						9							

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
■	Pavement (Bitumen, Concrete Slab, etc)
▩	Fill
░	Silty Sand
▩	Fill / Topsoil
▒	Sandstone
Misc. Symbols	
▶——	Seepage
Descriptions of various line types (solid, dotted, etc.)	
——	Profile change
_ _ _	Gradual profile change

Notes:

1. Exploratory borings were drilled between 12/08/2016 and 12/08/2016 using a 50, 100 and 125mm diameter continuous flight power auger.

2. These logs are subject to the limitations, conclusions and recommendations in this report.

3. Results of tests conducted on samples recovered are reported on the logs.

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
░	Sandstone
Misc. Symbols	
×	Point Load Strength
Descriptions of various line types (solid, dotted, etc.)	
——	Profile change
– – –	Gradual profile change

Notes:

1. Exploratory borings were drilled between 12/08/2016 and 12/08/2016 using a 50, 100 and 125mm diameter continuous flight power auger.

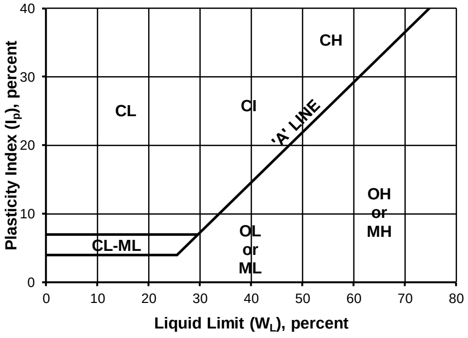
2. These logs are subject to the limitations, conclusions and recommendations in this report.

3. Results of tests conducted on samples recovered are reported on the logs.

Log Symbols & Abbreviations (Non-cored Borehole Log)

Log Column	Symbol/Value	Description		
Drilling Method	V-bit	Hardened steel 'V' shaped bit attached to auger		
	TC-bit	Tungsten Carbide bit attached to auger		
	RR	Tricone (Rock Roller) bit		
	DB	Drag bit		
	BB	Blade bit		
Groundwater	Dry	Groundwater not encountered to the drilled or auger refusal depth		
	▼	Groundwater level at depths shown on log		
	▶	Groundwater seepage at depths shown on log		
Environment Sample	GP	Glass bottle and plastic bag sample over depths shown on log		
	G	Glass bottle sample over depths shown on log		
	P	Plastic bag sample over depths shown on log		
PID Reading	100	PID reading in ppm		
Geotechnical Sample	DS	Disturbed Small bag sample over depths shown on log		
	DB	Disturbed Bulk sample over depths shown on log		
	U_{50}	Undisturbed 50mm tube sample over depths shown on log		
Field Test	N=10 3,5,5	Standard Penetration Test (SPT) 'N' value. Individual numbers indicate blows per 150mm penetration.		
	N=R 10,15/100	'R' represents refusal to penetration in hard/very dense soils or in cobbles or boulders. The first number represents10 blows for 150mm penetration whereas the second number represents 15 blows for 100mm penetration where SPT met refusal		
	DCP/PSP 5 6 R/10	Dynamic Cone Penetration (DCP) or Perth Sand Penetrometer (PSP). Each number represents blows per 100mm penetration. 'R/10' represents refusal after 10mm penetration in hard/very dense soils or in gravels or boulders.		
Classification	GP	Poorly Graded GRAVEL		
	GW	Well graded GRAVEL		
	GM	Silty GRAVEL		
	GC	Clayey GRAVEL		
	SP	Poorly graded SAND		
	SW	Well graded SAND		
	SM	Silty SAND		
	SC	Clayey SAND		
	ML	SILT / Sandy SILT / clayey SILT, low plasticity		
	MI	SILT / Sandy SILT / clayey SILT, medium plasticity		
	MH	SILT / Sandy SILT / clayey SILT, high plasticity		
	CL	CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, low plasticity		
	CI	CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, medium plasticity		
	CH	CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, high plasticity		
Moisture Condition Cohesive soils	M<PL	Moisture content less than Plastic Limit		
	M=PL	Moisture content equal to Plastic Limit		
	M>PL	Moisture content to be greater than Plastic Limit		
Cohesionless soils	D	Dry	-	Runs freely through hand
	M	Moist	-	Tends to cohere
	W	Wet	-	Tends to cohere
Consistency Cohesive soils		Term	Undrained shear strength, C_u (kPa)	Hand Penetrometer (Qu)
	VS	Very Soft	≤12	<25
	S	Soft	>12 ≤25	25 – 50
	F	Firm	>25 ≤50	50 – 100
	St	Stiff	>50 ≤100	100 – 200
	VSt	Very Stiff	>100 ≤200	200 – 400
	H	Hard	>200	>400
Density Index Cohesionless soils		Term	Density Index, I_D (%)	SPT 'N' (blows/300mm)
	VL	Very Loose	≤15	≤5
	L	Loose	>15 ≤35	>5 ≤10
	M	Medium Dense	>35 ≤65	>10 ≤30
	D	Dense	>65 ≤85	>30 ≤50
	VD	Very Dense	>85	>50
Hand Penetrometer	100 200	Unconfined compressive strength (q_u) in kPa determined using pocket penetrometer, at depths shown on log		
Remarks		Geological origin of soils		
	Residual	Residual soils above bedrock		
	Alluvium	River deposited Alluvial soils		
	Colluvial	Gravity deposited Colluvial soils		
	Aeolian	Wind deposited Aeolian soils		
	Marine	Marine Soils		

AS1726 – Unified Soil Classification System

Major Divisions		Particle size (mm)	Group Symbol	Typical Names	Field Identifications Sand and Gravels			Laboratory classification					
									% (2) < 0.075mm	Plasticity of Fine Fraction	$C_u = D_{60}/D_{10}$	$C_c = (D_{30})^2/(D_{10}D_{60})$	Notes
COARSE GRAINED SOILS (more than half of material less 63mm is larger than 0.075mm)	BOULDERS	200						Use the gradation of material passing 63mm for classification of fractions according to the criteria given in 'Major Divisions'					
	COBBLES	63											
	GRAVELS (more than half of coarse fraction is larger than 2.36mm)	Coarse 20	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength				0-5	-	>4	between 1 and 3	1. Identify lines by the method given for fine grained soils
		Medium 6	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength				0-5	-	Fails to comply with above		
			GM	Silty gravels, gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength				12-50	Below 'A' line or $I_p<4$	-	-	2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.075mm size) is greater than 5% and less than 12%. Borderline classifications require the use of dual symbols e.g. SP-SM, GW-GC
		Fine 2.36	GC	Clayey gravels, gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength				12-50	Above 'A' line or $I_p>7$	-	-	
	SANDS (more than half of coarse fraction is smaller than 2.36mm)	Coarse 0.6	SW	Well-graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength				0-5	-	>6	between 1 and 3	
		Medium 0.2	SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength				0-5	-	Fails to comply with above		
		Fine 0.075	SM	Silty sands, sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength				12-50	Below 'A' line or $I_p<4$	-	-	
			SC	Clayey sand, sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength				12-50	Above 'A' line of $I_p>7$	-	-	
FINE GRAINED SOILS (more than half of material less than 63mm is smaller than 0.075mm)	SILTS & CLAYS (liquid limit < 50%)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	**Dry Strength**	**Dilatancy**	**Toughness**						
					None to low	Quick to slow	None		More than 50% passing 0.075mm	Below 'A' line			
			CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium			Above 'A' line			
			OL	Organic silts and organic silty clays of low plasticity	Low to medium	Slow	Low			Below 'A' line			
	SILTS & CLAYS (liquid limit > 50%)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Low to medium	Slow to none	Low to medium			Below 'A' line			
			CH	Inorganic clays of medium to high plasticity, fat clays	High to very high	None	High			Above 'A' line			
			OH	Organic clays of medium to high plasticity, organic silts	Medium to high	None to very slow	Low to medium			Below 'A' line			
	HIGHLY ORGANIC SOILS		Pt	Peat and highly organic soils	Identified by colour, odour, spongy feel and generally by fibrous texture				Effervesces with H_2O_2				

Log Symbols & Abbreviations (Cored Borehole Log)

Log Column	**Symbol**	**Description**		
Core Size		Nominal Core Size (mm)		
	NQ	47		
	NMLC	52		
	HQ	63		
Water Loss	—◀	Complete water loss		
	—◁	Partial water loss		
Weathering	FR	Fresh	Rock shows no sign of decomposition or staining	
	SW	Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock	
	DW	Distinctly Weathered	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by ironstaining. Porosity may be increased by leaching, or may be decreased by deposition of weathering products in pores	
	EW	Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrate or can be remoulded, in water	
	RS	Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but soil has not been significantly transported	
Strength		Term	Point Load Strength Index (I_{s50}, MPa)	
	EL	Extremely Low	≤0.03	
	VL	Very Low	>0.03	≤0.1
	L	Low	>0.1	≤0.3
	M	Medium	>0.3	≤1
	H	High	>1	≤3
	VH	Very High	>3	≤10
	EH	Extremely High	>10	
Defect Spacing		Description	Spacing (mm)	
		Extremely closely spaced	<20	
		Very closely spaced	20 to 60	
		Closely spaced	60 to 200	
		Medium spaced	200 to 600	
		Widely spaced	600 to 2000	
		Very widely spaced	2000 to 6000	
		Extremely widely spaced	>6000	
Defect Description				
Type	Bp	Bedding parting		
	Fp	Foliation parting		
	Jo	Joint		
	Sh	Sheared zone		
	Cs	Crushed seam		
	Ds	Decomposed seam		
	Is	Infilled seam		
Macro-surface geometry	St	Stepped		
	Cu	Curved		
	Un	Undulating		
	Ir	Irregular		
	Pl	Planar		
Micro-surface geometry	Ro	Rough		
	Sm	Smooth		
	Sl	Slickensided		
Coating or infilling	cn	clean		
	sn	stained		
	vn	veneer		
	cg	coating		

AS1726 – Identification of Sedimentary Rocks for Engineering Purposes

Grain Size mm		Bedded rocks (mostly sedimentary)									
More than 20	20	Grain Size Description				At least 50% of grains are of carbonate				At least 50% of grains are of fine-grained volcanic rock	
	6	RUDACEOUS		CONGLOMERATE Rounded boulders, cobbles and gravel cemented in a finer matrix Breccia Irregular rock fragments in a finer matrix		LIMESTONE and DOLOMITE (undifferentiated)		Calcirudite		Fragments of volcanic ejecta in a finer matrix Rounded grains AGGLOMERATE Angular grains VOLCANIC BRECCIA	SALINE ROCKS Halite Anhydrite
	2										
	0.6	ARENACEOUS	Coarse	SANDSTONE Angular or rounded grains, commonly cemented by clay, calcite or iron minerals Quartzite Quartz grains and siliceous cement Arkose Many feldspar grains Greywacke Many rock chips				Calcarenite		Cemented volcanic ash TUFF	Gypsum
	0.2		Medium								
	0.06		Fine								
	0.002	ARGILLACEOUS		MUDSTONE	SILTSTONE Mostly silt	Calcareous Mudstone		Calcisiltite	**CHALK**	Fine-grained TUFF	
	Less than 0.002			SHALE Fissile	CLAYSTONE Mostly clay			Calcilutite		Very fine-grained TUFF	
Amorphous or crypto-crystalline				Flint: occurs as hands of nodules in the chalk Chert: occurs as nodules and beds in limestone and calcareous sandstone							COAL LIGNITE
				Granular cemented – except amorphous rocks							
				SILICEOUS		CALCAREOUS				SILICEOUS	CARBONACEOUS
				SEDIMENTARY ROCKS Granular cemented rocks vary greatly in strength, some sandstones are stronger than many Igneous rocks. Bedding may not show in hand specimens and is best seen in outcrop. Only sedimentary rocks, and some metamorphic rocks derived from them, contain fossils Calcareous rocks contain calcite (calcium carbonate) which effervesces with dilute hydrochloric acid							

AS1726 – Identification of Metamorphic and Igneous Rocks for Engineering Purposes

Obviously foliated rocks (mostly metamorphic)			Rocks with massive structure and crystalline texture (mostly igneous)					Grain size (mm)
Grain size description		MARBLE QUARTZITE Granulite HORNFELS Amphibolite Serpentine	Grain size description	Pegmatite			Pyrosenite	More than 20 20
COARSE	GNEISS Well developed but often widely spaced foliation sometimes with schistose bands Migmatite Irregularly foliated: mixed schists and gneisses		COARSE	GRANITE These rocks are sometimes phorphyritic and are then described, for example, as porphyritic granite	Diorite	GABBRO	Peridorite	6 2
MEDIUM	SCHIST Well developed undulose foliation; generally much mica		MEDIUM	Micorgranite These rocks are sometimes phorphyritic and are then described as porphyries	Microdiorite	Dolerite		0.6 0.2 0.06
FINE	PHYLLITE Slightly undulose foliation; sometimes 'spotted' SLATE Well developed plane cleavage (foliation)		FINE	RHYOLITE These rocks are sometimes phorphyritic and are then described as porphyries	ANDESITE	BASALT		0.002 Less than 0.002
	Mylonite Found in fault zones, mainly in igneous and metamorphic areas			Obsidian	Volcanic glass			Amorphous or cryptocrystallin e
CRYSTALLINE				Pale<--->Dark				
SILICEOUS		Mainly SILICEOUS		ACID Much quartz	INTERMEDIATE Some quartz	BASIC Little or no quartz	ULTRA BASIC	
METAMORPHIC ROCKS Most metamorphic rocks are distinguished by foliation which may impart fissility. Foliation in gneisses is best observed in outcrop. Non-foliated metamorphics are difficult to recognize except by association. Any rock baked by contact metamorphism is described as 'hornfels' and is generally somewhat stronger than the parent rock Most fresh metamorphic rocks are strong although perhaps fissile			IGNEOUS ROCKS Composed of closely interlocking mineral grains. Strong when fresh; not porous Mode of occurrence : 1 Batholith; 2 Laccoliths; 3 Sills; 4 Dykes; 5 Lava Flows; 6 Veins					