MUSEUMS DISCOVERY CENTRE EXPANSION
ENVIRONMENTAL IMPACT STATEMENT

APPENDIX R GEOTECHNICAL INVESTIGATION REPORT

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Geotechnical Investigation Report

for

Proposed Museum Discovery Centre Expansion

Building J

at

172 Showground Road Castle Hill 2154

Prepared for

Northrop Consulting Engineers

30th September 2019

Report No: 8325-GR-1-1

We give you the right information to make the right decisions

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0	30th September 2019	Issued to client	SM	DD

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APPENDICES

1. INTRODUCTION

This report presents the findings of a geotechnical investigation undertaken by Alliance Geotechnical Pty Ltd (AG) for Northrop Consulting Engineers (Client) for the proposed addition to the existing Museum located at 172 Showground Road Castle Hill 2154 (the site). The investigation was undertaken in accordance with the scope of works outlined in AG's proposal, Estimate No. 1725, dated 22nd November 2018.

It is understood that the proposed new addition to the existing Museum facilities comprises the construction of a three-storey building with a partial basement, known as Building J.

The purpose of this report is to provide recommendations regarding:

- Geotechnical subsurface conditions and groundwater;
- Geotechnical design parameters including allowable bearing capacity and lateral earth pressure for retaining structures;
- Excavation and shoring system;
- Vibrations.

In order to achieve the project objectives, the following scope of work was carried out for the geotechnical investigation:

- Review of the geological maps and the provided architectural drawings;
- A site walkover inspection;
- Six (6) boreholes to a maximum depth of 6.9m below the existing surface level (ESL);
- Point Load tests on the recovered rock core samples;
- Soil aggressivity tests.

2. SITE DESCRIPTION AND REGIONAL GEOLOGY

2.1. Site Location and Description

The site is a block of land approximately 7000 m^2 in area, located at 172 Showground Road Castle Hill. The site is located between the existing Museum Discovery Centre and Castle Hill TAFE buildings. The site is currently occupied partly by TAFE's carpark and partly by dense vegetation including mature trees with limited access for vehicles.

The site is bounded by a driveway between the site boundary and the museum's buildings to the west. To the north and east, it is bounded by TAFE's building and carpark and by Showground Road to the south.

The site location and the proposed basement layout are shown in Figure 1.

The site surface dips to the northeast with an approximate gradient of 3 degrees and ranges in elevation from RL 115.5m (AHD) at the southwestern corner to RL 110m (AHD) at the north-eastern corner.

Figure 1- General Site Location

2.2. Regional Geology

The 1:100,000 scale Penrith Geological Map (Geological Survey of NSW, Department of Minerals Resources, Sheet 9030, Edition 1, 1991) indicates that the site is underlain by Ashfield Shale (Rwa). The Ashfield Shale is described as *Laminite and dark-grey siltstone.* The geotechnical investigation has confirmed that the subject site is underlain by Ashfield Shale.

3. GEOTECHNICAL INVESTIGATION

3.1. Method

The geotechnical site investigation was carried out on 11th September 2019. Selected site photos taken during the fieldwork are presented in Appendix A.

The investigation comprised the initial scanning of underground utilities and setting out test locations, followed by the drilling of six boreholes (BH101 to BH106) to a maximum depth of 6.9m. The boreholes were drilled using a Hanjin drilling rig operated by BG drilling.

The boreholes were advanced through soil profile using a solid flight auger fitted with a Tungsten Carbide bit (TC-bit). Borehole BH101 and BH102 were cored to a depth of 6.9m.

Two of the auger boreholes were terminated upon encountering TC bit refusal and the other were terminated at a depth of 3m.

Due to the vegetations and mature trees in the middle of the site, the borehole drilling was limited to the southern and northern sides of the site, within the foot print of the proposed development.

The encountered profiles were logged by an experienced geotechnical engineer from AG and recovered samples were transported to AG's NATA accredited materials testing laboratory for further testing and storage.

The approximate locations of the boreholes are shown on the Borehole Location Plan (Drawing 8325-GR-1-A) presented in Appendix B.

The borehole log sheets and core photographs are attached in Appendix C. The log sheets should be read in conjunction with the attached Explanatory Notes, which explain the terms, abbreviations and symbols used, together with the interpretation and limitation of the logging procedure.

3.2. Results

Reference to the individual borehole log sheets attached in Appendix C should be made for a full description of the subsurface conditions encountered at each borehole location. Summarised descriptions of the encountered subsurface geotechnical profile are provided in Table 1.

Table 1 - Summary of Subsurface Profile

Borehole	**BH101**	**BH102**	**BH103**	**BH104**	**BH105**	**BH106**
Surface level (m) *	RL 113	RL 112	RL 111	RL 114	RL 115	RL 112
Geotechnical Units	Depth below the ground surface (m)					
Topsoil/ Fill: Clayey Silt/Sandy Clay	0.0 – 0.6	0.0 – 0.4	0.0 – 0.5	0.0 - 0.6	0.0 – 0.6	0.0 – 0.3
Residual Soil: Silty/gravelly clay, high plasticity, stiff to very stiff	0.6 – 1.7	0.4 – 1.4	0.5 – 1.3	0.6 – 1.9	0.6 – 1.9	0.3 – 1.6
Bedrock: Shale, very low to low strength, extremely to highly weathered	1.7 – 5.4[(a)]	1.4 – 6.6 [(b)]	1.3 – 2.5	1.9 – 3.8	1.9 – 4.0	1.6 – 3.0
Bedrock: Shale, medium strength, moderately weathered	5.4 – 6.7	6.6 – 6.9	-	-	-	-
Termination depth (m)	6.7	6.9	2.5	3.8	4.0	3.0
(a): Several clayey seams with a maximum thickness of 70mm between 2.3m and 6m; (b): Clayey seams with a maximum thickness of 90mm between 5.3m and 6.6m.						
* The levels are estimated based on the site levels indicated on Ground Floor Plan and the site's condition at the time of this investigation.						

The stratigraphy of the site comprises silty/sandy clay fill with an average thickness of 0.5m, overlying stiff to very stiff silty clay residual soils, a layer of hard residual gravelly clay overlying shale bedrock that was encountered at a 1.3m depth in the northern side, dipping to 1.9m depth at the southern

side. The bedrock comprised extremely to highly weathered, very low to low strength shale with medium strength shale encountered in the two cored boreholes below depths of 5.4m in BH101 and 6.6m in BH102.

Bedrock defects and seams are listed in the attached logs. There were several clayey seams with a maximum thickness of 90mm at 6m depth in BH102. The joints with dipping angles of 40 to 80 degrees were observed in both cored boreholes.

Groundwater seepage was not encountered during auguring. The introduction of water into the boreholes for coring precluded the indication of groundwater seepage.

4. LABORATORY TESTING

Point Load Strength Index (Is_{50}) tests (axial and diametric) were undertaken on rock core samples obtained from the boreholes and are recorded on the core log sheets presented in Appendix D. The test was carried out in AG's NATA-registered soils laboratory.

Soil aggressivity tests were performed to aid in the design of durable concrete and steel materials in contact with the site soils on selected soil samples collected from residual clay in BH101 and BH102. Table 2 presents the results of the soil aggressivity tests.

Table 2 - Aggressivity Test Results

Test	Unit	**BH101 – 0.9m** Residual silty clay	**BH4 -0.7m** Residual silty clay
Chloride	mg/kg	<10	22
pH	--	5.3	5.2
Sulfate (SO_4)	mg/kg (ppm)	67	82
Conductivity	uS/cm	42	48
Resistivity	Ohm.cm	120000	100000
Moisture	%	23	20
Results (assessed in accordance with AS 2159 – 2009, Table 6.4.2 (C) & Table 6.5.2 (C))	In relation to Concrete	Mild	Mild
	In relation to Steel	Non-aggressive	Non-aggressive

5. COMMENTS AND RECOMMENDATIONS

5.1. Proposed Development

AG was supplied with the following documents listed below by the client.

- A set of Architectural drawings, Project No. 18-14, prepared by Lahznimmo Architects, dated 25th March 2019, including:
  - Drawing No. A-SK- 1101: "Proposed Site Plan";
  - Drawing No. A-SK - 1400: "Lower Ground Floor Plan";
  - Drawing No. A-SK-3000: "Sections".

Based on the provided architectural drawings, it is understood that construction activities include:

- Construction of a new three-storey addition to the existing museum over a lower ground floor level;
- The proposed lower ground floor's finished floor level is at RL 111.75m AHD. The lower ground floor is a cut in the slope and the maximum excavation depth is 4m (assuming 200mm over-excavation) at the southwestern side (along Showground Road) reaching to the ground surface at the northern and eastern side;
- The proposed basement excavation extends to the site boundary to the west. To the south, it has an offset of 10m from the site boundary (Showground Road) and approximately more than 10m from the eastern and northern boundaries.

5.2. Groundwater Seepage Control

Although groundwater seepage was not observed during the investigation, it may still occur. Sump and pump method is expected to be feasible to control the potential groundwater seepage.

During the design life of the building, groundwater seepage should be controlled by a properly designed drainage system including a sub-floor drainage system to create a free drain layer below the base of the basement slab.

5.3. Excavation Conditions

The proposed development includes excavation of the lower ground floor to a maximum depth of 4m below ESL. To form the lower ground floor the cut is to extend in a slope toward the south. The excavation base is anticipated to be founded within very low to low strength shale at the southern side and within residual silty clay at the northern side. The soil profile and very low to low strength Shale is expected to be excavatable using conventional earthmoving equipment (such as a 10 Tonne excavator).

5.4. Vibration Monitoring

Given that the entire of the basement excavation is expected to be within the soil profile and also very low to low strength shale, issues associated with vibration attenuation are unlikely to be experienced during construction.

A dilapidation survey on nearby structures and infrastructure is recommended to be undertaken prior to the commencement of any site excavations. The report should include precise measurements of the existing defects and cracks presented with the relevant photos.

5.5. Excavation Stability

Unsupported temporary batter slopes are feasible provided that the excavations in the soil and very low to low strength shale will not extend below the 'zone of influence' of any adjacent structures, road and infrastructure (i.e. a 45° line drawn from the foundation level of any adjacent structure).

Based on the encountered soil and rock profile, and the proposed lower ground floor setbacks from the site boundaries, unsupported batter slopes are feasible for the proposed excavation along eastern,

and southern sides. Due to the space restriction, it is not practical to batter the slopes for the entire length of the western boundary. Since the excavation depth is variable and reaches to the ground surface at the northern side, it might be possible where the setbacks are adequate, unsupported batter slopes be adopted for the western side.

The recommended maximum permanent and temporary batter slopes are presented in Table 3.

Table 3 - Maximum Recommended Batter Slope Gradient

Material	Maximum Batter Slope (H: V)
	Temporary *
Fill: Clayey Silt/Sandy Clay	2: 1
Residual Soil: Silty/gravelly clay, high plasticity, stiff to very stiff	1: 1
Bedrock: Shale, very low to low strength, extremely to highly weathered	1: 2 **
* In cohesive materials the undrained shear strength of soil reduces by time following weathering and subsequently, moisture content changes (dry out). Also, following rainfall, water seepage through dry out cracks in the clayey soils may trigger localised slope instability. Therefore, it is recommended to cover the batter slopes to maintain the soil's natural moisture content and manage the construction works to provide structural retention or backfilling for the battered slopes, as soon as possible. ** Subject to inspection by a geotechnical engineer and carrying out remedial works if recommended (shotcrete, etc.).	

Benching with a maximum height of 1.5m equivalent to the above batter slopes would also be feasible.

Wherever unsupported batter slopes are not feasible (e.g. a portion of excavation along the western boundary), the sides of the proposed basement excavation will require retention. The shoring system could take the form of a soldier pile wall with reinforced shotcrete infill panels. Weep holes or drains (e.g. vertical drains) should be provided behind shotcrete to avoid build-up of hydrostatic pressure in the overburden soils and rock mass.

The shoring system piles will need to be extended below the proposed lower ground slab level. The socket depth of the shoring system should be indicated by the design engineer to assess the lateral pressures exerted and stability of the excavation.

Survey monitoring should be carried out during the construction of a shoring system to check and confirm that deflections and movements are within tolerable limits accepted in design.

5.6. Lateral Earth Pressure Coefficient

The permanent retaining wall and temporary shoring system should be designed using the parameters provided in Table 4 below.

If it is critical to limit the horizontal deformation an earth pressure coefficient 'at rest' (K_0) should be considered. Where some lateral movement is acceptable, an 'active' lateral earth pressure coefficient (K_a) is recommended.

Table 4 – Typical Material Properties for Retention Design

Geotechnical Units	Depth (m)	C' (kPa)	$\emptyset'$ (degrees)	γ (KN/m^3)	K_a	K_p	K_o	E' (MPa)	ϑ'
Residual Soil: Stiff to very stiff silty clay	0.0 – 2.0	4	26	19	0.39	2.56	0.56	20	0.35
Very low to low strength shale	2.0 – 5.5	25	25	22	0.41	2.46	0.58	100	0.3
Medium strength shale	Below 5.5	100	25	23	0.41	2.46	0.58	200	0.3

Legend:
$\emptyset'$: Effective Friction Angle
c': Effective Cohesion
γ : Bulk Unit Weight
K_a: Active earth pressure
K_o: Earth pressure at rest
Kp: Passive earth pressure
E': Elasticity Modulus
ϑ': Poisson's Ratio

The permanent retaining wall structures should be designed using a triangular earth pressure distribution and the following formula if the retaining system is designed as a cantilever wall:

$$P_h = (\gamma \cdot h + q) \cdot K_a - 2C'\sqrt{K_a}$$

where:

P_h = Horizontal active pressure (kN/m^2)
γ = Unit weight of soil (kN/m^3)
K_a = Coefficient of active earth pressure
h = Retained height (m)
q = Surcharge pressure behind retaining wall (kN/m^2)

The surcharge pressure including the pressure applied by live loads or existing structures/infrastructure footings located within the zone of influence of the excavation should be added to the above stress distribution.

5.7. Foundations

The lower floor is expected to be partially founded on bedrock and partially on soil profile with inferred a maximum 1.6m depth to bedrock. To avoid foundation differential settlement, it is recommended to found the building on bedrock. Therefore, the footings can be a combination of shallow pad footings and piers. The design parameters for the foundations are presented in Table 5. The pile footings should be designed in accordance with AS 2159-2009 Piling – Design and Installation. It is recommended to found the piles into the bedrock with a minimum socket depth of 500mm.

The bedrock quality and bearing capacity are assessed in accordance with the classification presented by Pells et al (1998) for Sydney Sandstone and Shale.

Table 5 – Geotechnical Design Parameters for Foundation (Shallow & Deep)

Description	Approximate depth (m)	Allowable End Bearing Capacity (kPa)	Allowable Shaft Adhesion (kPa)	Elastic Modulus (MPa)
Very low to low strength shale	2m below the ground surface	700	70	100
Low to medium strength shale	5.5m below the ground surface	1000	150	200

The approximate depth to the bedrock is estimated based on an indication at the drilled borehole locations and the site condition at the time of this investigation.

The borehole drilling was limited to the northern and the southern portions of the site due to the existing dense vegetation and trees in the middle of the site. The bedrock depth is generally shallower in the northern side and dips toward the south. However, conditions within the middle of the site were not determined and could differ.

Therefore, it is recommended to drill additional boreholes to confirm the bedrock depth after clearing the site. If higher bearing pressure were to be applied, additional cored boreholes would be required to assess and prove the foundation condition.

5.8. Construction Inspections

The inspections during the lower ground excavation should be undertaken at every 1.5m depth intervals. The purpose of the inspections is to assess the stability of the unsupported slope and provide recommendations for any required remedial works.

The footing excavations should be inspected before installation of the reinforcement cage and pouring concrete.

The pile footings will need to be inspected during the piles boring and before lowering the reinforcement cage and pouring concrete. An experienced geotechnical engineer is to confirm the design socket depths and also confirm that the bases of the piles are clean and free of soft, loose, wet or disturbed soils.

6. LIMITATIONS

Alliance Geotechnical Pty Ltd (AG) has prepared this report for the site located at 172 Showground Road Castle Hill 2154 in accordance with AG's fee proposal and Terms of Engagement. This geotechnical report has been prepared for Northrop Consulting Engineers for this project and for the purposes outlined in this report. This report cannot be relied upon for other projects, other parties on this site or any other site. The comments and recommendations provided in this report are based on the assumption that the geotechnical recommendations contained in this report will be fully complied with during the design and construction of the proposed site development.

The borehole investigation and laboratory testing results provided in this report are indicative of the subsurface conditions at the site only at the specific sampling and testing locations, and to the depths drilled at the time of the investigation. Subsurface conditions can change significantly due to geological and human processes. Where variations in conditions are encountered further geotechnical advice should be sought from AG.

REFERENCES

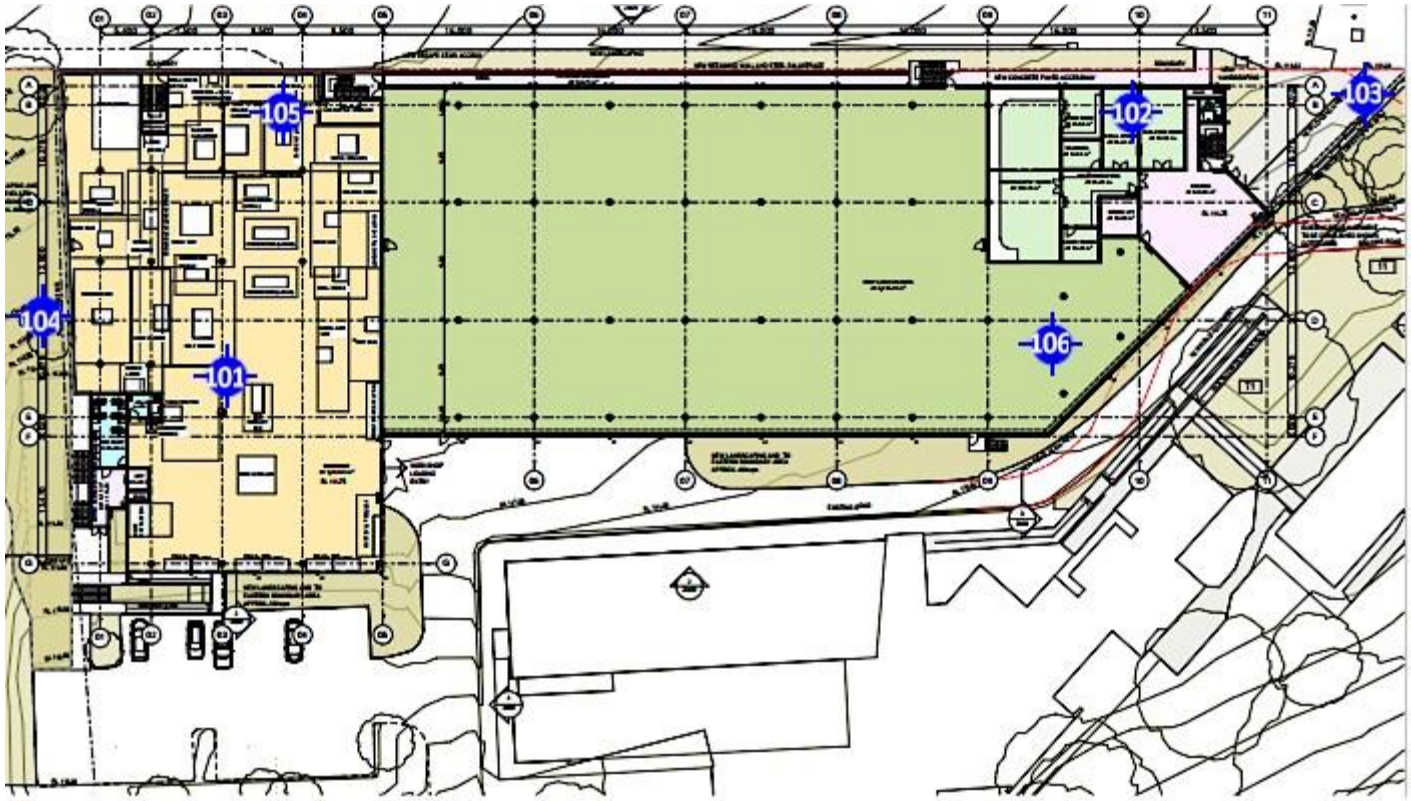
- Standards Australia, AS1726-2017 - *Geotechnical Site Investigations*
- Standards Australia, AS 1289 – 2006 - *Method of testing soils for engineering purposes*
- Standards Australia, AS 2159-2009 - *Piling - Design and Installation*
- Standards Australia, AS4678 -2002 - *Earth Retaining Structures*
- P.J.N. Pells, G. Mostyn and B. F. Walker, *Construction of Foundations on Sandstone and Shale in the Sydney Region*, Australian Geotechnics, December 1998
- The 1:100,000 NSW Department of Mineral Resources Geological Map of Penrith

APPENDIX A – Site Photographs

Photo 1 – General Site Overview – Looking North

Photo 2 – AG's Site Investigation – Drilling BH102

APPENDIX B – Borehole Location Plan (Drawing: 8325-GR-1-A)



LEGEND:

- Borehole Location

SCALE:

0 10 20 30 40 50 100 METRES

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Borehole Location Plan

Client Name:	Northrop Consulting Engineers Pty Ltd	Figure / Drawing Number:	8325-GR-1-A
Project Name:	Proposed New Building – Museum Discovery Centre	Figure / Drawing Date:	19/09/2019
Project Location:	172 Showground Road, Castle Hill NSW	Report Number:	8325-GR-1-1

APPENDIX C – Borehole Logs (BH101 to BH106) & Core Box Photos

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Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 113.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Dry Before Coring				--	FILL/TOPSOIL: Clayey Silt and Sandy Clay, brown, trace of fine to coarse ironstone gravel.		D	--	FILL/TOPSOIL
					CI-CH	Silty CLAY, high plasticity, red and brown/grey, with fine to medium ironstone gravel, MC<PL.	DS	D - M	VSt	RESIDUAL
		112	1				SPT 6, 8, 10 N=18			
					CI	Gravelly CLAY, medium plasticity, grey and brown, with some shale fragments, MC<PL.		D	H	
					--	SHALE, extremely weathered, brown and grey, extremely to very low strength.		--	--	BEDROCK
		111	2							
						Borehole BH 101 continued as cored hole				
		110	3							
		109	4							
		108	5							
		107	6							
		106	7							

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BH No: BH 101
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Job No: 8325

Cored Borehole Log

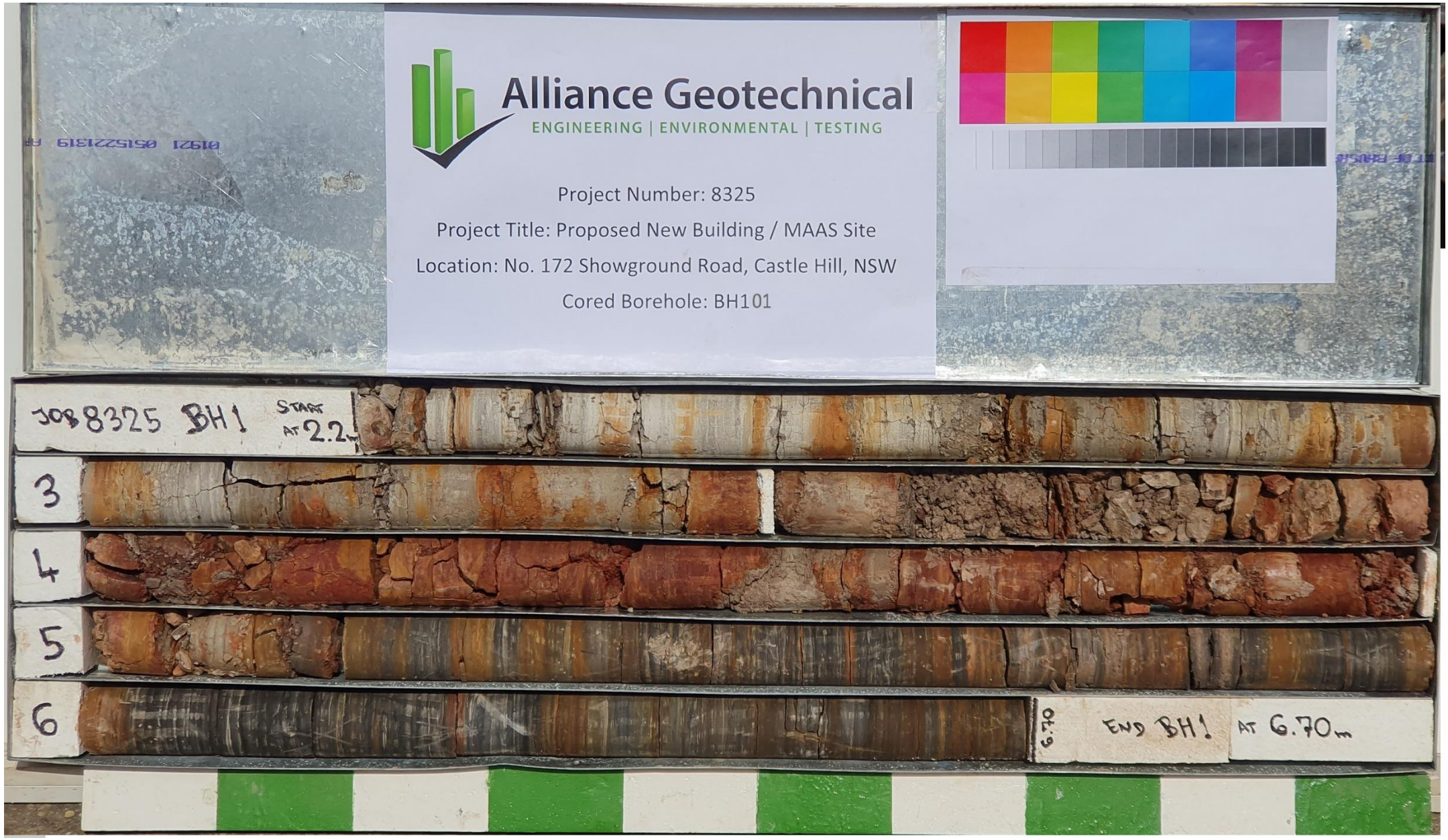
Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 113.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength (EL -0.03, VL -0.1, L -0.3, M -1, H -3, VH -10, EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm (30, 100, 300, 1000, 3000)	Additional Data
		112	1								
		111	2		Continued from non-cored borehole						
NMLC	Full Return	110	3		SHALE, grey and brown, with light grey siltstone bands and red/orange ironstained zones.	HW		D 0.18 A 0.42 D 0.45 A 0.12	52		2.32 - EW Seam, 40mm thickness. 2.41 - JT, 60°, curved. 2.65 - EW Seam, 55mm thickness. 2.79 - EW Seam, 18mm thickness. 3.11 - JT, 80°, curved. 3.22 - EW Seam, 25mm thickness.
		109	4		SHALE / IRONSTONE, dark red and yellow/orange, with hard to very hard ironstained zones.	EW/HW		D 0.63 A 0.51 D 0.61 A 0.24 D 0.53 A 0.03	21		3.40 - EW Seam, 50mm thickness. 3.53 - Clay Seam, 70mm. 3.60 - Fragmented Core 350mm. 4.00 - JT, 60°, planar. 4.06 - Fragmented Core 90mm. 4.22 - JT, 50°, planar. 4.39 - EW Seam, 30mm thickness. 4.50 - Clay Seam, 60mm. 4.65 - JT, 50°, curved. 4.82 - JT, 60°, curved.
		108	5								4.95 - Crushed Seam, 50mm. 5.06 - EW Seam, 33mm thickness. 5.15 - Clay/EW Seam, 40mm thickness.
		107	6		SHALE, dark grey, with brown/orange bands and light grey laminations.	MW		D 0.87 A 0.08 D 0.83 A 0.3 D 0.72 A 0.31 D 1.33 A 0.33	88		5.73 - HW Seam, 44mm thickness. 5.82 - HW Seam, 36mm thickness. 6.52 - HW Seam, 12mm thickness.
		106	7		BH 101 terminated at 6.7m						End BH 101



Alliance Geotechnical ENGINEERING | ENVIRONMENTAL | TESTING Manage the earth, eliminate the risk	Core Box Photo – BH101			
Client Name:	Northrop Consulting Engineers Pty Ltd		Figure / Drawing Number:	8325-GR-1-B
Project Name:	Proposed New Building – Museum Discovery Centre		Figure / Drawing Date:	19/09/2019
Project Location:	172 Showground Road, Castle Hill NSW		Report Number:	8325-GR-1-1

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BH No: BH 102
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Job No: 8325

Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 112.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Dry Before Coring				--	TOPSOIL/FILL: Clayey Silt with Sandy Clay and fine to coarse ironstone gravel, brown and grey.		D	--	TOPSOIL/FILL
					CI-CH	Silty CLAY, high plasticity, red/brown and grey, with fine to medium ironstone gravel, MC<=PL.	DS	D - M	St - VSt	RESIDUAL
		111	1				SPT 4, 4, 9 N=13			
					CI	Gravelly CLAY, medium plasticity, grey, with some shale fragments, MC<PL.		D	H	
					--	SHALE, extremely weathered, brown and grey, extremely low strength, INTERBEDDED with Gravelly Clay, medium plasticity.		--	--	BEDROCK
		110	2							
					--	SHALE, extremely to highly weathered, grey/brown and dark red, with frequent clay bands and with hard iron-indurated zones/layers.		--	--	
		109	3							
					--	SHALE / IRONSTONE, extremely weathered, dark red/brown and yellow, with hard ironstained zones.		--	--	
		108	4							
		107	5							
						Borehole BH 102 continued as cored hole				
		106	6							
		105	7							

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Cored Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
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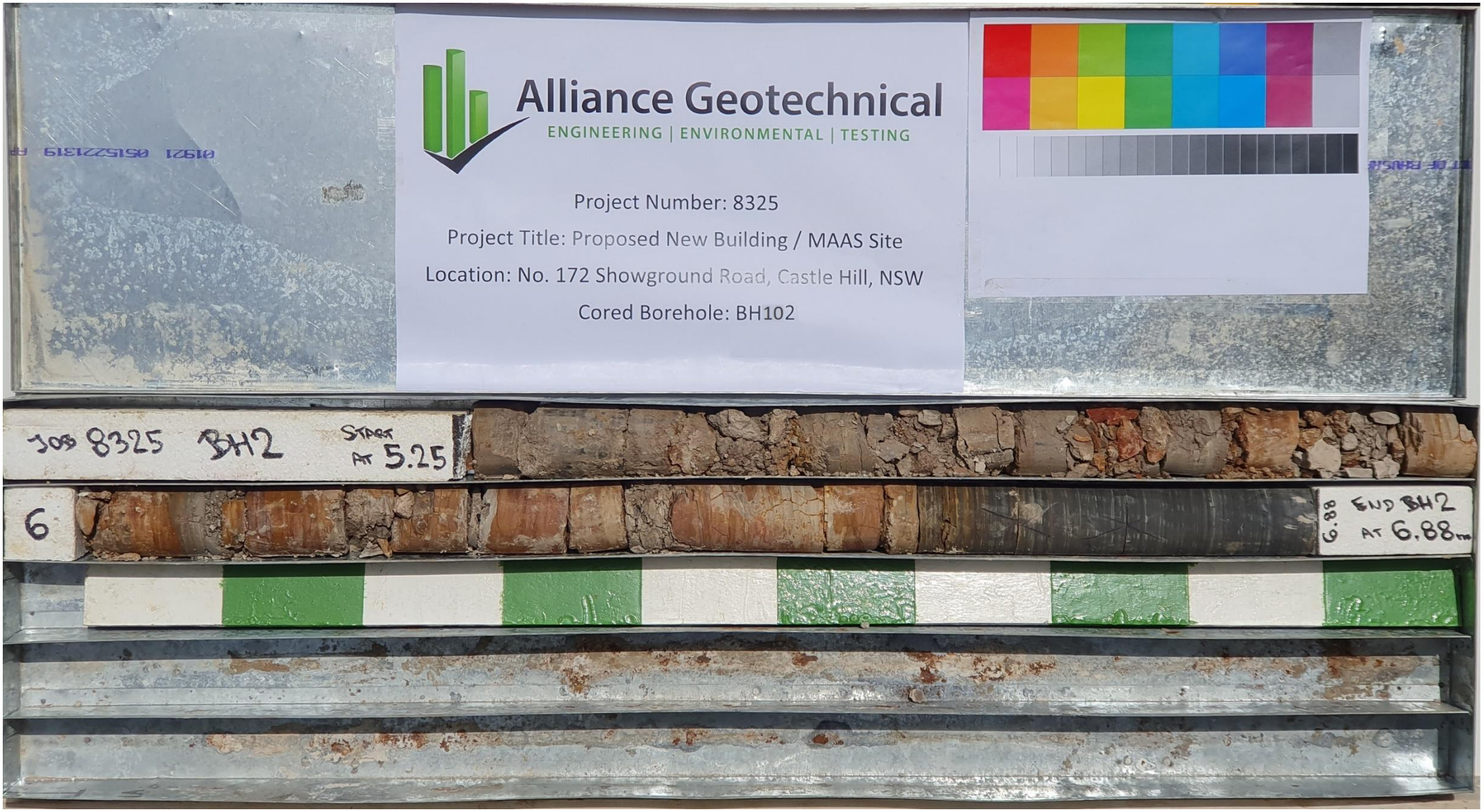
Method	Water	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength (EL -0.03, VL -0.1, L -0.3, M -1, H -3, VH -10, EH)	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm (30, 100, 300, 1000, 3000)	Additional Data
		111	1								
		110	2								
		109	3								
		108	4								
		107	5		Continued from non-cored borehole						
NMLC	Full Return	106	6		SHALE, grey and brown, interbedded with clay.	EW		D A 0.03 0.03	69		5.32 - JT, 40°, planar. 5.45 - Crushed Seam, 60mm. 5.56 - Clay Seam, 45mm.
					SHALE / IRONSTONE, dark red and brown, with very hard ironstained zones.	HW		D A 0.45 0.21 D A 0.63 0.54 D A 0.61 1.39			5.86 - Crushed Seam, 90mm. 6.09 - EW Seam, 34mm thickness. 6.19 - JT, 50°, curved. 6.28 - Clay Seam, 12mm. 6.39 - Clay/EW Seam, 40mm thickness.
					SHALE, dark grey, with light grey laminations.	MW		D A 0.53 1.12			6.57 - JT, 30°, curved.
		105	7		BH 102 terminated at 6.88m			D A 0.87 0.77			End BH 102



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Core Box Photo – BH102

Client Name:	Northrop Consulting Engineers Pty Ltd		Figure / Drawing Number:	8325-GR-1-B
Project Name:	Proposed New Building – Museum Discovery Centre		Figure / Drawing Date:	19/09/2019
Project Location:	172 Showground Road, Castle Hill NSW		Report Number:	8325-GR-1-1

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BH No: BH 103
Sheet: 1 of 1
Job No: 8325

Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 111.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Groundwater Not Encountered				--	TOPSOIL/FILL: Clayey Silt with Silty Clay and with fine to coarse ironstone gravel, brown/grey.		D	--	TOPSOIL/FILL
					CI-CH	Silty CLAY, high plasticity, red/brown and grey, with fine to medium ironstone gravel, MC<=PL.		D - M	VSt	RESIDUAL
		110	1				SPT 7, 7, 12 N=19			
					--	SHALE, extremely weathered, brown and grey/orange, extremely low strength, INTERBEDDED with Gravelly Clay, medium plasticity.		--	--	BEDROCK
		109	2							
						Borehole BH 103 terminated at 2.5m				
		108	3							
		107	4							
		106	5							
		105	6							
		104	7							

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BH No: BH 104
Sheet: 1 of 1
Job No: 8325

Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 114.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Groundwater Not Encountered				--	FILL/TOPSOIL: Mixture of Sandy/Silty Clay and Clayey Silt, brown and grey, with fine to coarse ironstone gravel and with shale fragments.		D	--	FILL/TOPSOIL
					CI-CH	Silty CLAY, high plasticity, red and grey with brown mottling, with fine to medium ironstone gravel, MC<PL.		D - M	VSt	RESIDUAL
		113	1				SPT 4, 7, 9 N=16			
					CI	Gravelly CLAY, medium plasticity, grey and red/brown, with some shale fragments, MC<PL.		D	H	
		112	2		--	SHALE, extremely weathered, brown and grey, extremely low strength.		--	--	BEDROCK
					--	SHALE, extremely to highly weathered, grey and brown, extremely low strength, with some occasional clay bands, interbedded with SILTSTONE, highly weathered, light grey, low to medium strength.		--	--	
		111	3							
		110	4			Borehole BH 104 terminated at 3.8m				
		109	5							
		108	6							
		107	7							

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BH No: BH 105
Sheet: 1 of 1
Job No: 8325

Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 115.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Groundwater Not Encountered				--	FILL/TOPSOIL: Mixture of Sandy/Silty Clay and Clayey Silt, brown and grey, with fine to coarse ironstone gravel and with shale fragments.		D	--	FILL/TOPSOIL
					CI-CH	Silty CLAY, high plasticity, red/grey and brown, with fine to medium ironstone gravel, MC<PL.		D - M	VSt	RESIDUAL
		114	1							
					CI	Gravelly CLAY, medium plasticity, grey and red/brown, with some shale fragments, MC<PL.		D	H	
		113	2		--	SHALE, extremely weathered, brown and grey, extremely low strength.		--	--	BEDROCK
					--	SHALE, extremely to highly weathered, grey and brown, extremely low strength, with some occasional clay bands, interbedded with SILTSTONE, highly weathered, light grey, low to medium strength.		--	--	
		112	3							
		111	4							
		110	5			Borehole BH 105 terminated at 4m				
		109	6							
		108	7							

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BH No: BH 106
Sheet: 1 of 1
Job No: 8325

Borehole Log

Client: Northrop Consulting Engineers Pty Ltd
Project: Proposed New Building - Museums Discovery Centre
Location: 172 Showground Road, Castle Hill NSW 2154

Started: 11/9/19
Finished: 11/9/19
Borehole Size: 100mm

Rig Type: Hanjin DB-8 Drill
Hole Location: Refer Drawing 8325-GR-1-A
Driller: JC
Logged: LM

RL Surface: 112.0
Contractor: Sytech Drilling Pty Ltd
Bearing: ---
Checked: MS

Method	Water	RL (m)	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	Moisture Condition	Consistency/ Density Index	Additional Observations
ADT	Groundwater Not Encountered				--	TOPSOIL/FILL: Clayey Silt with Silty Clay and gravel, brown.		D	--	TOPSOIL/FILL
					CI-CH	Silty CLAY, high plasticity, red/brown and grey, with fine to coarse ironstone gravel, MC<=PL.		D - M	St - VSt	RESIDUAL
		111	1							
					CI	Gravelly CLAY, medium plasticity, grey and brown/red, with some shale fragments, MC<PL.	SPT 6, 8, 14 N=22	D	VSt - H	
					--	SHALE, extremely weathered, brown and grey/red, extremely low strength, INTERBEDDED with Gravelly Clay, medium plasticity.		--	--	BEDROCK
		110	2							
					--	SHALE, extremely to highly weathered, grey and brown, with some clay bands, extremely to very low strength.		--	--	
		109	3							
						Borehole BH 106 terminated at 3m				
		108	4							
		107	5							
		106	6							
		105	7							

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EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

General

Information obtained from site investigations is recorded on log sheets. Soils and very low strength rock are commonly drilled using a combination of solid-flight augers with a Tungsten-Carbide (TC) bit. Descriptions of these materials presented on the "Borehole Log" are based on a combination of regular sampling and in-situ testing. Rock coring techniques commences once material is encountered that cannot be penetrated using a combination of solid-flight augers and Tungsten-carbide bit. The "Cored Borehole Log" presents data from drilling where a core barrel has been used to recover material - commonly rock.

The "Excavation - Geological Log" presents data and drawings from exposures of soil and rock resulting from excavation of pits or trenches.

The heading of the log sheets contains information on Project Identification, Hole or Test Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material description and structure presented as a series of columns in relation to depth below the ground surface which is plotted on the left side of the log sheet. The scale is presented in the depth column as metres below ground level.

As far as is practicable the data contained on the log sheets is factual. Some interpretation is included in the identification of material boundaries in areas of partial sampling, the location of areas of core loss, description and classification of material, estimation of strength and identification of drilling induced fractures, and geological unit. Material description and classifications are based on Australian Standard Geotechnical Site Investigations: AS 1726 - 2017 with some modifications as defined below.

These notes contain an explanation of the terms and abbreviations commonly used on the log sheets.

Drilling

Drilling, Casing and Excavating

Drilling methods deployed are abbreviated as follows

AS	Auger Screwing
ADV	Auger Drilling with V-Bit
ADT	Auger Drilling with TC Bit
BH	Backhoe
E	Excavator
HA	Hand Auger
HQ	HQ core barrel (~63.5 mm diameter core) *
HMLC	HMLC core barrel (~63.5 mm diameter core) *
NMLC	NMLC core barrel (~51.9 mm diameter core) *
NQ	NQ core barrel (~47.6 mm diameter core) *
RR	Rock Roller
WB	Wash-bore drilling

* Core diameters are approximate and vary due to the strength of material being drilled.

Drilling Fluid/Water

The drilling fluid used is identified and loss of return to the surface estimated as a percentage. It is introduced to assist with the drill process, in particular, when core drilling. The introduction of drill fluid/water does not allow for accurate identification of water seepages.

Drilling Penetration/Drill Depth

Core lifts are identified by a line and depth with core loss per run as a percentage. Ease of penetration in non-core drilling is abbreviated as follows:

VE	Very Easy
E	Easy
F	Firm
H	Hard
VH	Very Hard

Groundwater Levels

Date of measurement is shown.

Standing water level measured in completed borehole

Level taken during or immediately after drilling

Groundwater inflow water level

Samples/Tests

Samples collected and testing undertaken are abbreviated as follows

ES	Environmental Sample
DS	Disturbed Sample
BS	Bulk Sample
U50	Undisturbed (50 mm diameter)
C	Core Sample
SPT	Standard Penetration Test
N	Result of SPT (*sample taken)
VS	Vane Shear Test
IMP	Borehole Impression Device
PBT	Plate Bearing Test
PZ	Piezometer Installation
HP	Hand Penetrometer Test
HB	Hammer Bouncing

Excavation Logs

Explanatory notes are provided at the bottom of drill log sheets. Information about the origin, geology and pedology may be entered in the "Structure and other Observations" column. The depth of the base of excavation (for the logged section) at the appropriate depth in the "Material Description" column. Refusal of excavation plant is noted should it occur. A sketch of the exposure may be added.

Material Description – Soil

Material Description - In accordance with AS 1726-2017

Classification Symbol - In accordance with the Unified Classification System (AS 1726-2017).

Abbreviation	Typical Names
GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels
GM	Silty gravels, gravel-sand-silt mixtures
GC	Clayey gravels, gravel-sand-clay mixtures.
SW	Well graded sands, gravelly sands, little or no fines.
SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
SM	Silty sand, sand-silt mixtures.
SC	Clayey sands, sand-clay mixtures.
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
OL	Organic silts and organic silty clays of low plasticity. *
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts.
CH	Inorganic clays of high plasticity, fat clays
OH	Organic clays of medium to high plasticity, organic silts. *
Pt	Peat and other highly organic soils. *

* Additional details may be provided in accordance with the Von Post classification system (1922).

Organic Soils - Identification using laboratory testing:

Material	Organic Content - % of dry mass
Inorganic	<2
Organic Soil	<2 ≤ 25
Peat	> 25

Organic Soils - Descriptive terms for the degree of decomposition of peat:

Term	Decomposition	Remains	Squeeze
Fibrous	Little or none	Clearly recognizable	Only water No solid
Pseudo-fibrous	Moderate	Mixture of fibrous and amorphous	Turbid water < 50% solids
Amorphous	Full	Not recognizable	Paste > 50% solids

EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

Particle Characteristics– Definitions are as follows:

Fraction	Component (& subdivision)		Size (mm)
Oversize	Boulders		> 200
	Cobbles		> 63 ≤ 200
Coarse grained soils	Gravel	Coarse	> 19 ≤ 63
		Medium	> 6.7 ≤ 19
		Fine	> 2.36 ≤ 6.7
	Sand	Coarse	> 0.6 ≤ 2.36
		Medium	> 0.2 ≤ 0.6
		Fine	> 0.075 ≤ 0.21
Fine grained soils	Silt		0.002 ≤ 0.075
	Clay		< 0.002

Secondary and minor soil components

In coarse grained soils – The proportions of secondary and minor components are generally estimated from a visual and tactile assessment of the soils. Descriptions for secondary and minor soil components in coarse grained soils are as follows.

Designation of components	Percentage fines	Terminology (as applicable)	Percentage accessory coarse fraction	Terminology (as applicable)
Minor	≤ 5	Trace clay / silt	≤ 5	Trace sand / gravel
	> 5 ≤12	With clay / silt	> 5 ≤12	With sand / gravel
Secondary	> 12	Silty or clayey	> 30	Sandy or gravelly

Descriptions for secondary and minor soil components in fine grained soils are as follows.

Designation of components	Percentage coarse grained soils	Terminology (as applicable)
Minor	≤ 5	Trace sand / gravel / silt / clay
	> 5 ≤12	With sand / gravel / silt / clay
Secondary	> 30	Sandy / gravelly / silty / clayey

Plasticity Terms – Definitions for fine grained soils are as follows:

Descriptive Term	Range of Liquid Limit for silt	Range of Liquid Limit for clay
Low Plasticity	≤ 50	≤ 35
Medium Plasticity	N/A	> 35 ≤50
High Plasticity	> 50%	> 50

Particle Characteristics

Particle shape and angularity are estimated from a visual assessment of coarse-grained soil particle characteristics. Terminology used includes the following:

Particle shape – spherical, platy, elongated,

Particle angularity –angular, sub-angular, sub-rounded, rounded.

Moisture Condition – Abbreviations are as follows:

D	Dry, looks and feels dry
M	Moist, No free water on remoulding
W	Wet, free water on remoulding

Moisture content of fine-grained soils is based on judgement of the soils moisture content relative to the plastic and liquid limit as follows:

MC < PL	Moist, dry of plastic limit
MC ≈ PL	Moist, near plastic limit
MC > PL	Moist, wet of plastic limit
MC ≈ LL	Wet, near liquid limit
MC > LL	Wet of liquid limit

Consistency - of cohesive soils in accordance with AS 1726-2017, Table 11 are abbreviated as follows:

Consistency Term	Abbreviation	Indicative Undrained Shear Strength Range (kPa)
Very Soft	**VS**	< 12
Soft	**S**	12 ≤ 25
Firm	**F**	25 ≤ 50
Stiff	**St**	50 ≤ 100
Very Stiff	**VSt**	100 ≤ 200
Hard	**H**	≥ 200
Friable	**Fr**	-

Density Index (%) of granular soils is estimated or is based on SPT results. Abbreviations are as follows:

Description	Abbreviation	Relative Density	SPT N
Very Loose	VL	< 15%	0 - 4
Loose	L	15 - 35%	4 - 10
Medium Dense	MD	35 - 65%	10 - 30
Dense	D	65 - 85%	30 - 50
Very Dense	VD	> 85%	> 50

Structures - Fissuring and other defects are described in accordance with AS 1726-2017 using the terminology for rock defects

Origin - Where practicable an assessment is provided of the probable origin of the soil, e.g. fill, topsoil, alluvium, colluvium, residual soil.

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EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

Material Description - Rock

Material Description

Descriptions of rock for geotechnics and engineering geology in civil engineering

Identification of rock type, composition and texture based on visual features in accordance with AS 1726-2017.

Rock Naming – Where possible conventional geological names are used within the logs. Engineering properties cannot be inferred directly from the rock names in the table, but the use of a particular name provides an indicative range of characteristics to the reader. Lithological identification of rock is provided to appreciate the geology of an area, to correlate geological profiles seen in boreholes or to distinguish boulders from bedrock.

Grain Size – Grain size is done in accordance with AS1726-2017 as follows:

Coarse grained	Mainly 0.6 to 2 mm
Medium grained	0.2 – 0.6 mm
Fine grained	0.06 – 0.2 mm

Colour – Rock colour is described in the moist condition.

Texture and Fabric - Frequently used terms include:

Sedimentary Rock	Metamorphic Rock	Igneous
Bedded	Cleaved	Massive
Interbedded	Foliated	Flow banded
Laminated	Schistose	Folded
Folded	Banded	Lineated
Massive	Lineated	Porphyritic
Graded	Gneissose	Crystalline
Cross-bedded	Folded	Amorphous

Bedding and Laminated – AS 1726 – 2017 bedding and laminated rock descriptions are provided below with additional detail from BS EN ISO 14689-1 as guidance.

Description	Spacing (mm)
Very Thickly Bedded	> 2000
Thickly Bedded	> 600 ≤ 2000
Medium Bedded	> 200 ≤ 600
Thinly Bedded	> 60 ≤ 200
Very Thinly Bedded	> 20 ≤ 60
Thickly Laminated	> 6 ≤ 20
Thinly Laminated	< 6

Features, inclusions and minor components – Features, inclusions and minor components within the rock material shall be described where those features could be significant such as gas bubbles, mineral veins, carbonaceous material, salts, swelling minerals, mineral inclusions, ironstone or carbonate bands, cross-stratification or minerals the readily oxidise upon atmospheric exposure.

Moisture content – Where possible descriptions are made by the feel and appearance of the rock using one according to following terms:

Dry	Looks and feels dry.
Moist	Feels cool, darkened in colour, but no water is visible on the surface
Wet	Feels cool, darkened in colour, water film or droplets visible on the surface

The moisture content of rock cored with water may not be representative of its in-situ condition.

Durability – Descriptions of the materials durability such as tendency to develop cracks, break into smaller pieces or disintegrate upon exposure to air or in contact with water are provided where observed.

Rock Material Strength – The strength of the rock material is based on uniaxial compressive strength (UCS). The following terms are used:

Rock Strength Class	Abbreviation	UCS (MPa)	Point Load Strength Index, $I_{s\,(50)}$ (MPa)
Very Low	VL	> 0.6 ≤ 2	> 0.03 ≤ 0.1
Low	L	> 2 ≤ 6	> 0.1 ≤ 0.3
Medium	M	> 6 ≤ 20	> 0.3 ≤ 1
High	H	> 20 ≤ 60	> 1 ≤ 3
Very High	VH	> 60 ≤ 200	> 3 ≤ 10
Extremely High	EH	> 200	> 10

Strengths are estimated and where possible supported by Point Load Index Testing of representative samples. Test results are plotted on the graphical logs as follows:

D	Diametral Point Load Test
A	Axial Point Load Test

Where the estimated strength log covers more than one range it indicates the rock strength varies between the limits shown. Point Load Strength Index test results are presented as $I_{s\,(50)}$ values in MPa.

Weathering - Weathering classification assists in identification but does not imply engineering properties. Descriptions are as follows:

Term (Abbreviation)	Description
Fresh (FR)	No signs of mineral decomposition or colour change.
Slightly Weathered (SW)	partly stained or discoloured. Not or little change to strength from fresh rock.
Moderately Weathered (MW)	material is completely discoloured, little or no change of strength from fresh rock.
Highly Weathered (HW)	material is completely discoloured, significant decrease in strength from fresh rock.
Extremely Weathered (EW)	Material has soil properties. Mass structure, material texture and fabric of original rock are still visible.
Residual Soil (RS)	Material has soil properties. Mass structure and material texture and fabric of original rock not visible, but the soil has not been significantly transported.

Alteration – Physical and chemical changes of the rock material due to geological processes by fluids at depth at pressures and temperatures above atmospheric conditions. Unlike weathering, alteration shows no relationship to topography and may occur at any depth. When altered materials are recognized, the following terms are used:

Term		Abbreviation		Definition
Extremely Altered		XA		Material has soil properties. Structure, texture and fabric of original rock are still visible. The rock name is replaced with the name of the parent material, e.g. Extremely Altered basalt. Soil descriptive terms are used.
Highly Altered	Distinctly altered	HA	DA	The whole of the rock material is discoloured. Rock strength is changed by alteration. Some primary minerals are altered to clay minerals. Porosity may be higher or lower due to loss of minerals or precipitation of secondary minerals in pores.
Moderately Altered	Distinctly altered	MA	DA	The whole of the rock material is discoloured Little or no change of strength from fresh rock. The term 'Distinctly Altered' is used where it is not practicable to distinguish between 'Highly Altered' and 'Moderately Altered'. Distinctly Altered is defined as follows: The rock may be highly discoloured; Porosity may be higher due to mineral loss; or may be lower due to precipitation of secondary minerals in pores; and Some change of rock strength.
Slightly Altered		SA		Rock is slightly discoloured Little or no change of strength from fresh rock.

Alteration is only described in the context of the project where it has relevance to the civil and structural design.

Defect Descriptions

General and Detailed Descriptions – Defect descriptions are provided to suit project requirements. Generalized descriptions are used for some projects where it is unnecessary to describe each individual defect in a rock mass, or where multiple similar defects are present which are too numerous to log individually. The part of the rock mass to which this applies is delineated.

Detailed descriptions are given of defects judged to be particularly significant in the context of the project. For example, crushed seams in an apparently unstable slope. As a minimum, general descriptions outlining the number of defect sets within the rock mass and their broad characteristics are provided where it is possible to do so.

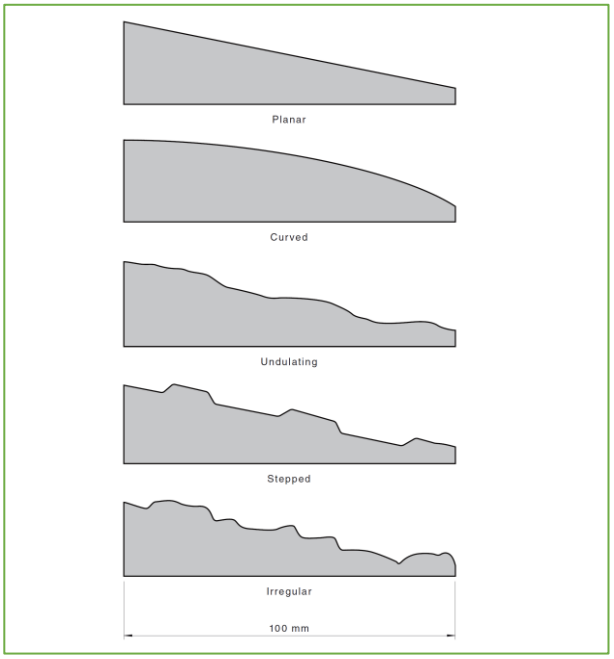
Defect Type – Defect abbreviations are as follows:

BP	Bedding Parting	FL	Foliation	SP	Shear Plane
CL	Cleavage	FZ	Fracture Zone	SZ	Shear Zone
CS	Crushed Seam	HB	Handling break	VN	Vein
DB	Drilling break	JT	Joint		
DL	Drill Lift	SM	Seam		

EXPLANATORY NOTES - DRILL & EXCAVATION LOGS

Defect Orientation – The dip and dip direction are recorded as a two-digit and three-digit number separated by a slash, e.g. 50/240 only when orientated core are collected and there is not core loss that could obscure core orientation. If alternative measurements are made, such as dip and strike or dip direction relative to magnetic north this shall be documented.

Surface Shape –At the medium scale of observation, description of the roughness of the surface shall be enhanced by description of the shape of the defect surface using the following terms, as illustrated below:



Defect Coatings and Seam Composition – Coatings are described using the following terms:

(a) *Clean* No visible coating.
(b) *Stained* No visible coating but surfaces are discoloured.
(c) *Veneer* A visible coating of soil or mineral, too thin to measure; may be patchy.
(d) *Coating* A visible coating up to 1 mm thick. Soil in-fill greater than 1 mm shall be described using defect terms (e.g. infilled seam). Defects greater than 1 mm aperture containing rock material great described as a vein.

Defect Spacing, Length, Openness and Thickness –described directly in millimetres and metres. In general descriptions, half order of magnitude categories are used, e.g. joint spacing typically 100 mm to 300 mm, sheared zones 1 m to 3 m thick.

Depending on project requirements and the scale of observation, spacing may be described as the mean spacing within a set of defects, or as the spacing between all defects within the rock mass. Where spacing is measured within a specific set of defects, measurements shall be made perpendicular to the defect set.

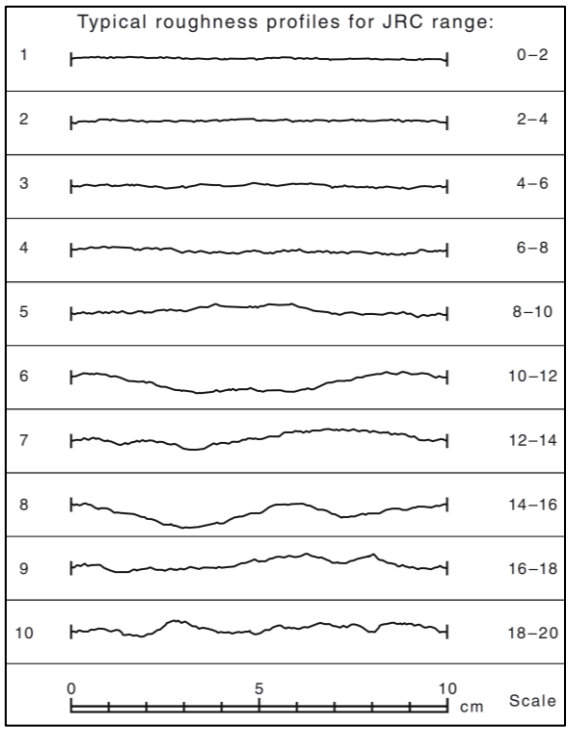
Defect spacing and length (sometimes called persistence), shall be described directly inmillimetres and metres.

Stratigraphic Unit - Geological maps related to the project are used for the designation of lithological formation name and, where possible geological unit name, e.g. Bringelly Shale, Potts Hill Sandstone Member.

Defect Roughness and Shape – Defect surface roughness is described as follows:

Very rough	Many large surface irregularities with amplitude generally more than 1 mm.
Rough	Many small surface irregularities with amplitude generally less than 1 mm.
Smooth	Smooth to touch. Few or no surface irregularities.
Polished	Shiny smooth surface
Slickensided	Grooved or striated surface, usually polished.

Where applicable Joint Roughness Range (JRC) is provided as follows:



Joint roughness profiles and corresponding JRC range based on Barton, N and Choubey, V. The Shear Strength of Rock Joints in Theory and Practice. *Rock Mechanics.* Vol. 10 (1977), pp. 1–54.

Where possible the mineralogy of the coating is identified.

Defect Infilling - abbreviated as follows:

CA	Calcite	KT	Chlorite
CN	Clean	MS	Secondary Mineral
Cy	Clay	MU	Unidentified Mineral
CS	Crushed Seam	Qz	Quartz
Fe	Iron Oxide	X	Carbonaceous

PARAMETERS RELATED TO CORE DRILLING

Total Core Recovery – T

Defect Spacing or Fracture Index – T

Rock Quality Designation – Y

Core Loss – Core loss occurs when material is lost during the drilling process It is shown at the bottom of the run unless otherwise indicated where core loss is known.

APPENDIX D– Laboratory Tests Certificate

Alliance Geotechnical
10 Welder Road
Seven Hills
NSW 2147

NATA Accredited
Accreditation Number 1261
Site Number 18217

Accredited for compliance with ISO/IEC 17025 – Testing
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

Attention: **Steven Wallace**

Report **676769-S**
Project name CASTLE HILL AGG
Project ID 8325
Received Date Sep 12, 2019

Client Sample ID			**BH1_0.5-0.9**	**BH2_0.4-0.7**
Sample Matrix			**Soil**	**Soil**
Eurofins Sample No.			**S19-Se20381**	**S19-Se20382**
Date Sampled			**Sep 11, 2019**	**Sep 11, 2019**
Test/Reference	LOR	Unit		
Chloride	10	mg/kg	< 10	< 10
Conductivity (1:5 aqueous extract at 25°C as rec.)	5	uS/cm	42	48
pH (1:5 Aqueous extract at 25°C as rec.)	0.1	pH Units	5.3	5.2
Resistivity*	0.5	ohm.m	1200	1000
Sulphate (as SO4)	10	mg/kg	67	82
% Moisture	1	%	23	20

Sample History

Where samples are submitted/analysed over several days, the last date of extraction and analysis is reported.
A recent review of our LIMS has resulted in the correction or clarification of some method identifications. Due to this, some of the method reference information on reports has changed. However, no substantive change has been made to our laboratory methods, and as such there is no change in the validity of current or previous results.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Chloride	Sydney	Sep 13, 2019	28 Days
- Method: E045 /E047 Chloride			
Conductivity (1:5 aqueous extract at 25°C as rec.)	Sydney	Sep 13, 2019	7 Days
- Method: LTM-INO-4030 Conductivity			
pH (1:5 Aqueous extract at 25°C as rec.)	Sydney	Sep 13, 2019	7 Days
- Method: LTM-GEN-7090 pH in soil by ISE			
Sulphate (as SO4)	Sydney	Sep 13, 2019	28 Days
- Method: E045 Anions by Ion Chromatography			
% Moisture	Sydney	Sep 12, 2019	14 Days
- Method: LTM-GEN-7080 Moisture			

eurofins | Environment Testing

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Site # 1254 & 14271

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NATA # 1261 Site # 18217

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Phone : +61 7 3902 4600
NATA # 1261 Site # 20794

Perth
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Phone : +61 8 9251 9600
NATA # 1261
Site # 23736

Company Name:	Alliance Geotechnical	**Order No.:**		**Received:**	Sep 12, 2019 6:00 PM
Address:	10 Welder Road Seven Hills NSW 2147	**Report #:**	676769	**Due:**	Sep 19, 2019
		Phone:	1800 288 188	**Priority:**	5 Day
		Fax:	02 9675 1888	**Contact Name:**	Steven Wallace
Project Name:	CASTLE HILL AGG				
Project ID:	8325				

Eurofins Analytical Services Manager : Andrew Black

Sample Detail						Aggressivity Soil Set	Moisture Set
Melbourne Laboratory - NATA Site # 1254 & 14271							
Sydney Laboratory - NATA Site # 18217						X	X
Brisbane Laboratory - NATA Site # 20794							
Perth Laboratory - NATA Site # 23736							
External Laboratory							
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**		
1	BH1_0.5-0.9	Sep 11, 2019		Soil	S19-Se20381	X	X
2	BH2_0.4-0.7	Sep 11, 2019		Soil	S19-Se20382	X	X
Test Counts						2	2

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follows guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013 and are included in this QC report where applicable. Additional QC data may be available on request.
2. All soil/sediment/solid results are reported on a dry basis, unless otherwise stated.
3. All biota/food results are reported on a wet weight basis on the edible portion, unless otherwise stated.
4. Actual LORs are matrix dependant. Quoted LORs may be raised where sample extracts are diluted due to interferences.
5. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds.
6. SVOC analysis on waters are performed on homogenised, unfiltered samples, unless noted otherwise.
7. Samples were analysed on an 'as received' basis.
8. Information identified on this report with blue colour, indicates data provided by customer, that may have an impact on the results.
9. This report replaces any interim results previously issued.

Holding Times

Please refer to 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours prior to sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and regardless of any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the date of sampling, therefore compliance to these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether the holding time is 7 days however for all other VOCs such as BTEX or C6-10 TRH then the holding time is 14 days.

****NOTE:** pH duplicates are reported as a range NOT as RPD

Units

mg/kg: milligrams per kilogram
mg/L: milligrams per litre
ug/L: micrograms per litre
ppm: Parts per million
ppb: Parts per billion
%: Percentage
org/100mL: Organisms per 100 millilitres
NTU: Nephelometric Turbidity Units
MPN/100mL: Most Probable Number of organisms per 100 millilitres

Terms

Dry	Where a moisture has been determined on a solid sample the result is expressed on a dry basis.
LOR	Limit of Reporting.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
LCS	Laboratory Control Sample - reported as percent recovery.
CRM	Certified Reference Material - reported as percent recovery.
Method Blank	In the case of solid samples these are performed on laboratory certified clean sands and in the case of water samples these are performed on de-ionised water.
Surr - Surrogate	The addition of a like compound to the analyte target and reported as percentage recovery.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
USEPA	United States Environmental Protection Agency
APHA	American Public Health Association
TCLP	Toxicity Characteristic Leaching Procedure
COC	Chain of Custody
SRA	Sample Receipt Advice
QSM	US Department of Defense Quality Systems Manual Version 5.3
CP	Client Parent - QC was performed on samples pertaining to this report
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC is representative of the sequence or batch that client samples were analysed within.
TEQ	Toxic Equivalency Quotient

QC - Acceptance Criteria

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is 30% however the following acceptance guidelines are equally applicable:

Results <10 times the LOR : No Limit

Results between 10-20 times the LOR : RPD must lie between 0-50%

Results >20 times the LOR : RPD must lie between 0-30%

Surrogate Recoveries: Recoveries must lie between 20-130% Phenols & 50-150% PFASs

PFAS field samples that contain surrogate recoveries in excess of the QC limit designated in QSM 5.3 where no positive PFAS results have been reported have been reviewed and no data was affected.

WA DWER (n=10): PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC Data General Comments

1. Where a result is reported as a less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch, but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown is not data from your samples.
3. Organochlorine Pesticide analysis - where reporting LCS data, Toxaphene & Chlordane are not added to the LCS.
4. Organochlorine Pesticide analysis - where reporting Spike data, Toxaphene is not added to the Spike.
5. Total Recoverable Hydrocarbons - where reporting Spike & LCS data, a single spike of commercial Hydrocarbon products in the range of C12-C30 is added and it's Total Recovery is reported in the C10-C14 cell of the Report.
6. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling.Therefore laboratory analysis is unlikely to be completed within holding time. Analysis will begin as soon as possible after sample receipt.
7. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of Recovery the term "INT" appears against that analyte.
8. Polychlorinated Biphenyls are spiked only using Aroclor 1260 in Matrix Spikes and LCS.
9. For Matrix Spikes and LCS results a dash " -" in the report means that the specific analyte was not added to the QC sample.
10. Duplicate RPDs are calculated from raw analytical data thus it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
Chloride	mg/kg	< 10			10	Pass	
Conductivity (1:5 aqueous extract at 25°C as rec.)	uS/cm	< 5			5	Pass	
Sulphate (as SO4)	mg/kg	< 10			10	Pass	
LCS - % Recovery							
Chloride	%	98			70-130	Pass	
Conductivity (1:5 aqueous extract at 25°C as rec.)	%	100			70-130	Pass	
Resistivity*	%	100			70-130	Pass	
Sulphate (as SO4)	%	100			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Spike - % Recovery									
				Result 1					
Chloride	S19-Se20382	CP	%	98			70-130	Pass	
Sulphate (as SO4)	S19-Se20382	CP	%	114			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1	Result 2	RPD	Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
				Result 1	Result 2	RPD			
Conductivity (1:5 aqueous extract at 25°C as rec.)	S19-Se20381	CP	uS/cm	42	41	4.0	30%	Pass	
pH (1:5 Aqueous extract at 25°C as rec.)	S19-Se20381	CP	pH Units	5.3	5.3	Pass	30%	Pass	
Resistivity*	S19-Se20381	CP	ohm.m	1200	1200	3.6	30%	Pass	
% Moisture	S19-Se20241	NCP	%	5.9	6.4	9.0	30%	Pass	
Duplicate									
				Result 1	Result 2	RPD			
Chloride	S19-Se20382	CP	mg/kg	< 10	< 10	<1	30%	Pass	
Sulphate (as SO4)	S19-Se20382	CP	mg/kg	82	76	7.0	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Authorised By

Andrew Black	Analytical Services Manager
Gabriele Cordero	Senior Analyst-Inorganic (NSW)

Glenn Jackson
General Manager

Final report - this Report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.