morrow

Geotechnical Investigation Report

GEOTECHNICAL REPORT FOR

118-120 STATION STREET, PENRITH NSW

Prepared for:

AUSTRALIAN GEOTECHNICAL PTY LTD

Reference: P2028_ 01

20 September 2020

Morrow Geotechnics Pty Ltd | ABN 42 605 892 126
[redacted]

1 PROJECT BACKGROUND

Morrow Geotechnics Pty Ltd has undertaken a Geotechnical Investigation to provide geotechnical advice and recommendations for the proposed development at 118-120 Station Street, Penrith NSW (the site).

1.1 Proposed Development

We understand from drawings provided by Architecture Design Studio that the proposed development will involve construction of a residential structure over two levels of basement parking requiring excavation to a depth of approximately 6 meters below ground level (mBGL).

1.2 Investigation Intent

The purpose of the investigation is to provide geotechnical advice and recommendations specific to the ground conditions observed at site for the proposed development. These recommendations include:

- Foundation advice along with relevant geotechnical design parameters;
- Excavation and shoring advice along with relevant geotechnical design parameters;
- Approaches to minimise the impact of the proposed development through vibration, ground movement or groundwater drawdown;
- Other relevant geotechnical issues which may impact construction; and
- Recommendations for further geotechnical input.

1.3 Published Geological Mapping

Information on regional sub-surface conditions, referenced from the Department of Mineral Resources Geological Map Penrith 1:100,000 Geological Series Sheet 9030 (DMR 1991), indicates that the site overlies the Cranebrook Formation of the Quaternary Period, which typically comprises gravel, sand, silt and clay.

1.4 Published Soil Landscapes

The Soil Conservation Service of NSW Penrith 1:100,000 Soil Landscapes Series Sheet 9030 (1st Edition) indicates that the alluvial landscape at the site likely comprises the Richmond Landscape. This landscape type typically includes Quaternary terraces of the Nepean and Georges Rivers, with slopes of < 1 %. It generally comprises poorly structured orange to red clay loams, clays and sands. These soils are noted to present localised seasonal waterlogging, localised flood hazard and localised water erosion hazard on terrace edges.

2 OBSERVATIONS

2.1 Investigation Methods

Fieldwork was undertaken by Morrow Geotechnics on 14 September 2020. Work carried out as part of this investigation includes:

- Review of publicly available information from previous reports in the project area, published geological and soil mapping and government agency websites;
- Site walkover inspection by an Engineering Geologist to assess topographical features, condition of surrounding structures and site conditions;
- Dial Before You Dig (DBYD) services search of proposed borehole locations;
- Drilling of two boreholes (BH1 to BH2) by a track mounted drill rig using solid flight augers equipped with a tungsten-carbide bit (TC bit). BH1 also included wash bore drilling followed by NMLC coring techniques to 15.0 m below ground level (mBGL). Rock core was boxed and photographed and point load tests were undertaken on selected core sample to assess rock strength. Borehole locations are shown on **Figure 1** and borehole logs are presented in **Appendix A**;
- Groundwater observations within boreholes during drilling.

2.2 Subsurface Conditions

The stratigraphy at the site is characterised by alluvial soils and cobble overlying interbedded sandstone and siltstone bedrock. Observations taken during the investigation have been used to produce a stratigraphic model of the site. The observed stratigraphy has been divided into four geotechnical units.

A summary of the subsurface conditions across the site, interpreted from the investigation results, is presented in **Table 1**. More detailed descriptions of subsurface conditions at the test locations are available in the borehole logs presented in **Appendix A**. The details of the method of soil and rock classification, explanatory notes and abbreviations adopted in the borehole logs are also presented in **Appendix A**.

TABLE 1 SUMMARY OF INFERRED SUBSURFACE CONDITIONS

Unit	Material	Approx. Depth Range of Unit [1] mBGL		Comments
		BH1	BH2	
1	Topsoil / Fill	0.0-0.6	0.0-0.7	Generally fine to coarse grained sand with some silt and gravels, trace clays. Unit 1 is inferred to be uncontrolled and poorly compacted.
2	Alluvial Sand and Clay	0.6-5.5	0.7-5.5	Generally low to medium plasticity sandy and silty clays along with medium grained sand. Stiff to very stiff or medium dense to dense consistency.
3	Alluvial Gravel	5.5-10.85	5.5 (EOH)	Generally gravelly cobble with fine to coarse gravel, in a fine to medium grained sand matrix, trace of silt and trace of clay.
4	High Strength Bedrock	10.85 +	-	Generally slightly weathered to fresh, medium to high strength. Defects are generally clay seams and horizontally oriented bedding partings.

Notes:

1 Depths shown are based on material observed within test locations and will vary across the site.

2.3 Groundwater Observations

Due to the introduction of drilling fluids during drilling of the boreholes, seepage water was not observed during the inspection.

3 RECOMMENDATIONS

3.1 Excavation Retention

Temporary batters may be considered for retention during basement excavation only where adequate room for full batter construction is available. Temporary batter slopes of 1V:1H will be possible for all units above the water table provided that surface water is diverted away from the batter faces and batter heights are kept to less than 4m. Where batters extend beyond 4 m height benching may be required and further advice should be sought from a qualified geotechnical engineer. Permanent batters of 2H:1V may be employed for excavation design above the water table. Permanent batters will require surface protection or revegetation to prevent erosion and slaking.

For design of flexible shoring systems a triangular pressure distribution may be employed using the parameters provided in **Table 2**. For design of rigid anchored or braced walls, a trapezoidal earth pressure distribution should be used with a maximum pressure of $0.65.K_a.\gamma.H$ (kPa), where 'H' is the effective vertical height of the wall in metres.

Morrow Geotechnics understands that the finite element software package Wallap will be used for design of shoring. Drained cohesion and friction angles for input to Wallap have been provided in **Table 2** below. Earth pressure coefficients in **Table 2** are provided for design checks only.

TABLE 2 EARTH PRESSURE PARAMETERS

Material		Unit 1 Topsoil / Fill	Unit 2 Alluvial Sand and Clay	Unit 3 Alluvial Gravel	Unit 4 High Strength Bedrock
Bulk Unit Weight (kN/m^3)		17	18	21	24
Earth Pressure Coefficients	At rest, K_o	0.58	0.50	0.36	-
	Passive, K_p	2.46	3.00	4.60	500 kPa ultimate stress block
	Active, K_a	0.41	0.33	0.22	-

Notes:

1. Unit Weight is based on visual assessment only, order of accuracy is approximately ±10%.
2. Earth pressures are provided on the assumption that the ground behind the retaining wall is flat and drained.

In addition, design of retaining walls should consider the following:

- Appropriate surcharge loading from construction equipment, vehicular traffic and neighbouring structures at finished surface level should be taken into account in the retention design. Surcharge loads on retention structures may be calculated using a rectangular stress block with an earth pressure coefficient of 0.5 applied to surcharge loads at ground surface level.

- Anchor design should ignore the contribution of any bonded length within a wedge which extends upwards at 45° from the base of the excavation to account for a failure wedge forming behind the shoring system.

3.2 Soil and Rock Excavatability

The expected ability of equipment to excavate the soil and rock encountered at the site is summarised in **Table 3**. This assessment is based on available site investigation data and guidance on the assessment of excavatability of rock by Pettifer and Fookes (1994). The presence of medium to high strength bands in lower strength rock and the discontinuity spacing may influence the excavatability of the rock mass.

TABLE 3 SOIL AND ROCK EXCAVATABILITY

Unit	Material	Excavatability
1	**Topsoil / Fill**	Easy digging by 20t Excavator
2	**Alluvial Sand and Clay**	Easy digging by 20t Excavator
3	**Alluvial Gravel**	Hard ripping by 20t Excavator
4	**High Strength Bedrock**	Hydraulic hammering will be required for excavation within Unit 5

The excavation methodology may also be affected by the following factors:

- Scale and geometry of the excavation;
- Availability of suitable construction equipment;
- Potential reuse of material on site; and
- Acceptable excavation methods, noise, ground vibration and other environmental criteria.

3.3 Excavation Vibration Considerations

As a guide, safe working distances for typical items of vibration intensive plant are listed in **Table 4**. The safe working distances are quoted for both "cosmetic" damage (refer British Standard BS 7385:1993) and human comfort (refer NSW Environmental Protection Agency Vibration Guideline).The safe working distances should be complied with at all times, unless otherwise mitigated to the satisfaction of the relevant stakeholders.

TABLE 4 RECOMMENDED SAFE WORKING DISTANCES FOR VIBRATION INTENSIVE PLANT

Plant Item	Rating/Description	Safe Working Distance	
		Cosmetic Damage (BS 7385:1993) [1]	Human Response (EPA Vibration Guideline)
Vibratory Roller	< 50 kN (typically 1-2 tonnes)	5 m	15 m to 20 m
	< 100 kN (typically 2-4 tonnes)	6 m	20 m
	< 200 kN (typically 4-6 tonnes)	12 m	40 m
	< 300 kN (typically 7-13 tonnes)	15 m	100 m
	< 300 kN (typically 13-18 tonnes)	20 m	100 m
	< 300 kN (typically >18 tonnes)	25 m	100 m
Small Hydraulic Hammer	300 kg – 5 to 12 t excavator	2 m	7 m
Medium Hydraulic Hammer	900 kg – 12 to 18 t excavator	7 m	23 m
Large Hydraulic Hammer	1600 kg – 18 to 34 t excavator	22 m	73 m
Vibratory Pile Driver	Sheet Piles	2 m to 20 m	20 m
Pile Boring	≤ 800 mm	2m (nominal)	N/A
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

Notes:

1 More stringent conditions may apply to heritage buildings or other sensitive structures.

In relation to human comfort (response), the safe working distances in **Table 4** relate to continuous vibration and apply to residential receivers. For most construction activities, vibration emissions are intermittent in nature and for this reason, higher vibration levels, occurring over shorter periods are permitted, as discussed in British Standard BS 6472-1:2008.

The safe working distances provided in **Table 4** are given for guidance only. Monitoring of vibration levels may be required to ensure vibrations levels remain below threshold values during the construction period.

3.4 Foundation Design

The parameters given in **Table 5** may be used for the design of pad footings and bored piles. Morrow Geotechnics recommends that a Preliminary Geotechnical Strength Reduction Factor (GSRF) of 0.4 is used for the design of piles in accordance with AS 2159:2009 if no allowance is made for pile testing during construction. Should pile testing be nominated, the GSRF may be reviewed and a value of 0.55 to 0.65 may be expected.

Ultimate geotechnical strengths are provided for use in limit state design. Allowable bearing pressures are provide for serviceability checks. These values have been determined to limit settlements to an acceptable level for conventional building structures, typically less than 1% of the minimum footing dimension.

TABLE 5 PAD FOOTING AND PILE DESIGN PARAMETERS

Material		Unit 1 Topsoil / Fill	Unit 2 Alluvial Sand and Clay	Unit 3 Alluvial Gravel	Unit 4 High Strength Bedrock
Allowable Bearing Pressure (kPa)		N/A	200	700	3000
Ultimate Vertical End Bearing Pressure (kPa)		N/A	500	2100	9000
Elastic Modulus (MPa)		3	15	75	200
Allowable Shaft Adhesion (kPa)	In Compression	0	20	50	300
	In Tension	0	10	25	150
Susceptibility to Liquefaction during an Earthquake		Medium	Medium	Low	Low

Notes:

1 Side adhesion values given assume there is intimate contact between the pile and foundation material. Design engineer to check both 'piston' pull-out and 'cone' pull-out mechanics in accordance with AS4678-2002 Earth Retaining Structures.

2 Susceptibility to liquefaction during an earthquake is based on the following definition:

Low - Medium to very dense sands, stiff to hard clays, and rock
Medium - Loose to medium dense sands, soft to firm clays, or uncontrolled fill below the water table
High - Very loose sands or very soft clays below the water table

To adopt these parameters we have assumed that the bases of all pile excavations are cleaned of loose debris and water and inspected by a suitably qualified Geotechnical Engineer or Engineering Geologist prior to pile construction to verify that ground conditions meet design assumptions. Where groundwater ingress is encountered during pile excavation, concrete is to be placed as soon as possible upon completion of pile excavation. Pile excavations should be pumped dry of water prior to pouring concrete, or alternatively a tremmie system could be used.

Selection of footing types and founding depth will need to consider the risk of adverse differential ground movements within the foundation footprint and between high level and deeper footings. Unless an allowance for such movement is included in the design of the proposed development we recommend that all new structures found on natural materials with comparable end bearing capacities and elastic moduli.

3.5 AS1170 Earthquake Site Risk Classification

Assessment of the material encountered during the investigation in accordance with the guidelines provided in AS1170.4-2007 indicates an earthquake subsoil class of Class B_e – Rock for the site.

3.6 Groundwater Management

No long term groundwater monitoring has been carried out as part of this investigation. Based on previous studies from neighbouring sites, groundwater is present within the Unit 3 gravels in the area. If no further groundwater studies are undertaken for the site consideration should be made for the possibility of rapid rises in groundwater level following heavy rainfall to the approximate level of the proposed basement slab on ground.

4 RECOMMENDATIONS FOR FURTHER GEOTECHNICAL SERVICES

Further geotechnical inspections should be carried out during construction to confirm the geotechnical and hydrogeological model. These should include:

- All excavated material transported off site should be classified in accordance with NSW EPA 2014 - Waste Classification Guideline Part 1; Classifying Waste.
- A suitably qualified geotechnical engineer is to assess the condition of exposed material at foundation or subgrade level to assess the ability of the prepared surface to act as a foundation or as a subgrade.
- Regular inspections of battered and unsupported excavations, where proposed, to confirm geotechnical conditions and to assess the suitability of design assumptions and to provide further advice with regards to excavation retention/ support and proposed construction methodologies, if required.

5 STATEMENT OF LIMITATIONS

The adopted investigation scope was limited by site access restrictions due to presence of structures at the site at the time of our investigation and by the investigation intent. Further geotechnical inspections should be carried out during construction to confirm both the geotechnical model and the design parameters provided in this report.

Your attention is drawn to the document “Important Information”, which is included in **Appendix B** of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Morrow Geotechnics, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

6 REFERENCES

AS1726:1993, *Geotechnical Site Investigations*, Standards Australia.

AS2159:2009, *Piling – Design and Installation*, Standards Australia.

AS2870:2011, *Residential Slabs and Footings*, Standards Australia.

AS3798:2007, *Guidelines on Earthworks for Commercial and Residential Developments*, Standards Australia.

Chapman, G.A. and Murphy, C.L. (1989), Soil Landscapes of the Sydney 1:100000 sheet. Soil Conservation Services of NSW, Sydney.

NSW Department of Finance and Service, Spatial Information Viewer, maps.six.nsw.gov.au.

NSW Department of Mineral Resources (1985) Sydney 1:100,000 Geological Series Sheet 9129 (Edition 1). Geological Survey of New South Wales, Department of Mineral Resources.

Pells (2004) Substance and Mass Properties for the Design of Engineering Structures in the Hawkesbury Sandstone, Australian Geomechanics Journal, Vol 39 No 3

7 CLOSURE

Please do not hesitate to contact Morrow Geotechnics if you have any questions about the contents of this report.

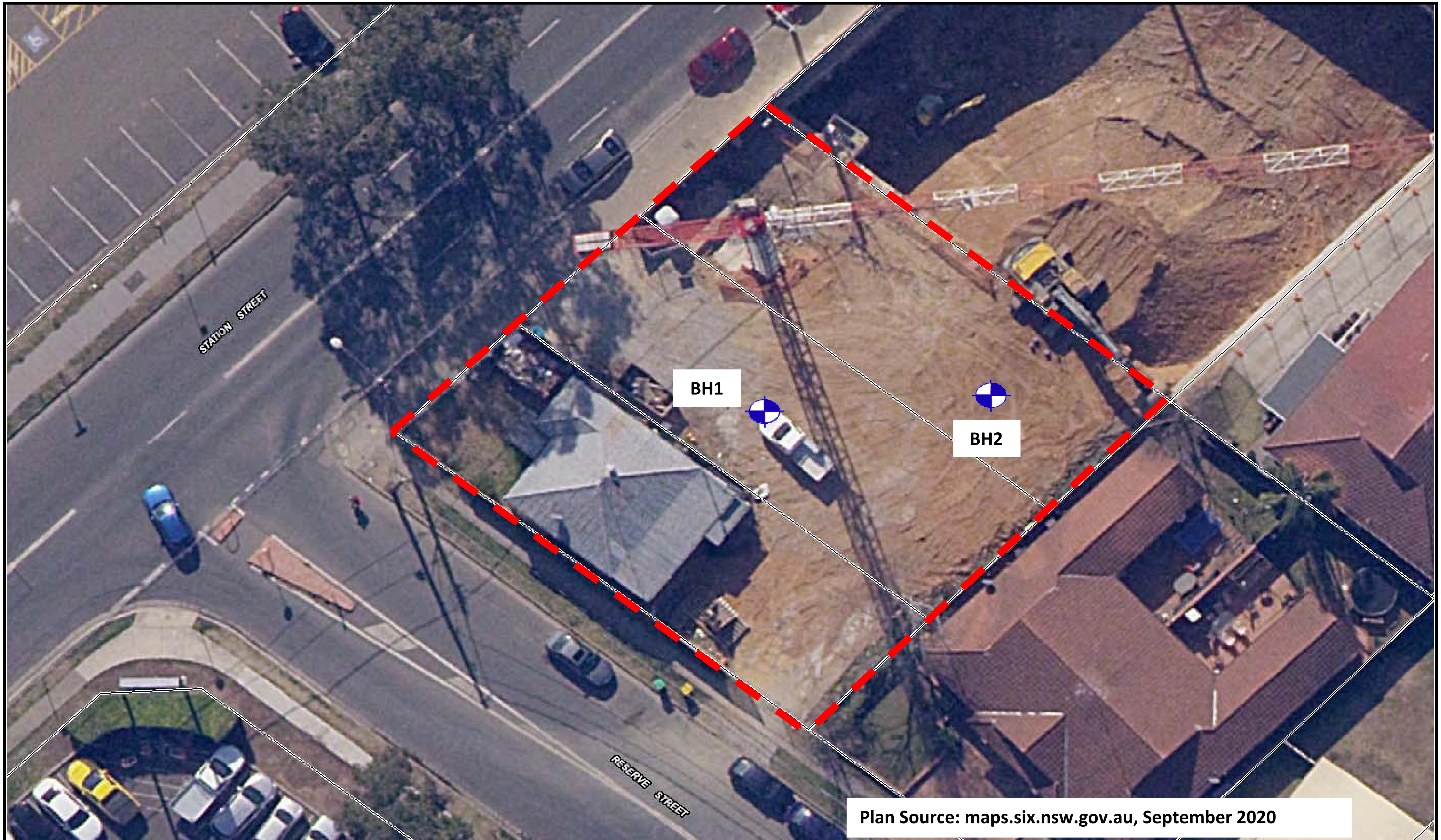
For and on behalf of Morrow Geotechnics Pty Ltd,

[redacted]

Rhiannon McKeon
Engineering Geologist

[redacted]

Alan Morrow
Principal Geotechnical Engineer



morrow PO Box 4069, Carlton NSW 2218 P: 0405 843 933 | E: info@morrowgeo.com.au	Drawn	RM	**Australian Geotechnical Pty Ltd** 118-120 Station Street, Penrith NSW Geotechnical Investigation Borehole Location Plan	Figure:	1
	Approved	AM			
	Date	15/09/2020			
	Scale	NTS		Project:	P2028

Document Set ID: 9327641
Version: 1, Version Date: 08/10/2020

Appendix A

Borehole Logs and Explanatory Notes

Project No:	P2028	Contractor:	Sytech
Client:	Austalian Geotechnical	Drill Rig:	Justin
Project:	Residential Development 118-120 Station Street, Penrith NSW	Logged:	RM
Sheet	1 of 3	Date:	14/09/2020

morrow

BH1

Drilling Method	Resistance	Water	Sampling	USCS	Depth	Stratigraphy	Consistency/ Density	Moisture	Additional Observations
ADT	H	GWNO		SP	0.5	FILL - Silty gravelly SAND fine to medium grained, black-grey, fine to coarse grained sub-angular to angular gravels, trace clay, poorly graded	D	M	
ADT	L	GWNO	SPT 2, 3, 7 N = 10	CM - CH	1.0, 1.5, 2.0	Silty CLAY moderate to high plasticity brown (Alluvial)	St	M < PL	
ADT	L	GWNO		SP	2.5, 3.0	Clayey SAND fine to medium grained, orange-brown, low plasticity, trace fine grained sub-angular to angular gravels, poorly graded (Alluvial)	MD	M	
ADT	L	GWNO	SPT 10, 12, 13 N = 25	CM - CH	3.5	Sandy CLAY moderate to high plasticity, grey-orange fine grained sand (Alluvial)	VSt	M < PL	
ADT	L	GWNO	SPT 7, 8, 10 N = 18	SP	4.0, 4.5, 5.0, 5.5	SAND fine to medium grained, red-brown-orange (Alluvials)	MD	M	
ADT	L	GWNO	SPT 33, 30, 22 N = 52	GP	6.0	GRAVELS and COBBLES in a sand matrix, orange-grey, coarse grained, sub-rounded to rounded gravels, fine to medium grained sand (Alluvial)	VD	M	
WB	H			GP	6.5, 7.0, 7.5, 8.0	Inferred continuation of above unit	VD		

Project No:	P2028	Contractor:	Sytech
Client:	Austalian Geotechnical	Drill Rig:	Justin
Project:	Residential Development 118-120 Station Street, Penrith NSW	Logged:	RM
Sheet	2 of 3	Date:	14/09/2020

BH1

Drilling Method	Resistance	Water	Sampling	USCS	Depth	Stratigraphy	Consistency/ Density	Moisture	Additional Observations
WB	H			GP	8.5 9.0 9.5 ### ###	Inferred GRAVELS and COBBLES in a sand matrix, orange-grey, coarse grained, sub-rounded to rounded gravels, fine to medium grained sand (Alluvial)	VD		
					### ### ### ### ### ### ### ### ### ### ###	Continued as cored hole from 10.85m			

Project No:	P2028	Contractor:	Sytech
Client:	Australian Geotechnical	Drill Rig:	Hanjin DB-8
Project:	Residential Development 118-120 Station Street, Penrith NSW	Logged:	RM
Sheet	3 of 3	Date:	14/09/2020

morrow

BH1

Drilling Method	Water	TCR	RQD (SCR)	Rock Strength (EL VL L M H VH EH; 0.03 0.3 3; 0 0.1 1 10)	Weathering	Depth	Stratigraphy	Defect Spacing (10 30 100 300 1000)	Defect Description
						8.5			
						9.0			
						9.5			
						###			
						###	Start Coring at 10.85m		
NMLC	0% Water Loss	100%	83% (100%)		Fr	###	LAMINITE, laminated SANDSTONE and SHALE, grey, thinly bedded (<1mm) at 0-5° angle,		10.98, HB 11.00, HB 11.16, DB 11.36, B, 5°, Un, Ro, Cn 11.38, DB 12.00, HB 12.84, DB 12.93, B, 10°, Un, Ro, Vnr Clay 13.00, HB 13.08, Sm, 2°, clay 13.14, DB 13.35, B, 5°, Pl, Ro, Cn 13.42, B, 5°, Pl, Ro, Cn 13.94, B, 5°, Un, Sm, Cn
		100%	100% (100%)			###			14.00, HB 14.13, HB 14.78, DB
						###	End of Hole at 15.0m Target Depth		
						###			
						###			

Project No:	P2028	Contractor:	Sytech
Client:	Austalian Geotechnical	Drill Rig:	Justin
Project:	Residential Development 118-120 Station Street, Penrith NSW	Logged:	RM
Sheet	1 of 1	Date:	14/09/2020

morrow

BH2

Drilling Method	Resistance	Water	Sampling	USCS	Depth	Stratigraphy	Consistency/ Density	Moisture	Additional Observations
ADT	H	GWNE		SP		FILL - Gravelly SAND, fine to medium grained, grey, f-c gr, sa-a gravels	MD	M	
				GP	0.5	FILL - Silty GRAVEL, fine to coarse grained, angular gravels, black		W	
			SPT 2, 3, 4 N = 7	CL-CM		FILL - Gravelly silty CLAY, low-medium plasticity, brown, fine to medium grained, sub-rounded to rounded gravels		M	
	L		SPT 4, 4, 6 N = 10	CL-CM	1.0, 1.5, 2.0	Sandy CLAY low to medium plasticity, fine to medium grained, mottled grey-yellow (Alluvial)	St	M < PL	
				CL	2.5, 3.0	low plasticity and orange from 2.0m			
			SPT 4, 4, 6 N = 10	SP	3.5, 4.0, 4.5	SAND fine to medium grained, orange, low plasticity clay, poorly graded (Alluvial)	L - MD	M	
			SPT 7, 9, 11 N = 20	SW	5.0	SAND fine to coarse grained, orange, well graded (Alluvial)	MD		
	H-R			GP	5.5	GRAVELS and COBBLES in a sand matrix, orange-grey, coarse grained, sub-rounded to rounded gravels, fine to medium grained sand (Alluvial)	VD		
					6.0, 6.5, 7.0, 7.5, 8.0	End BH2 at 5.5 m Refusal in Cobbles			

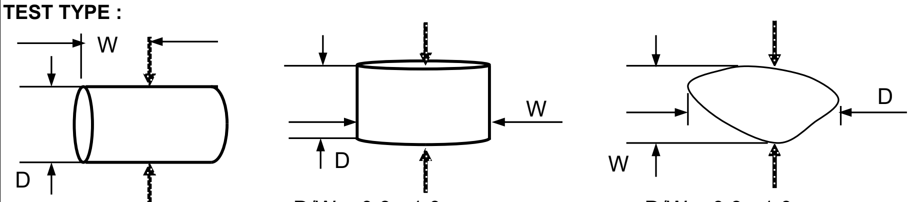
POINT LOAD STRENGTH INDEX

		Project No.	P2028
Client:	Australian Geotechnical	Date:	17-Sep-20
Project:	Geotechnical Investigation	Tested by:	JB+RM
Location:	118-120 Station Street, Penrith NSW	Data checked:	

Test Machine: GSA | Test Locality: WOL | Core Size: 52 mm

Bore/TP	Depth (m)	Rock Type	Moisture Condition	Test Type	W (mm)	D (mm)	Load kN (P)	Failure Type	Point Load Strength Index $Is_{(50)}$ (MPa)	Strength Classification
BH1	10.92	FR LAMINITE	F	D	50	50	1.63	2	0.65	M
BH1	10.92	FR LAMINITE	F	A	50	47	1.66	4	0.58	
BH1	11.30	FR LAMINITE	F	D	50	50	2.46	2	0.98	M
BH1	11.30	FR LAMINITE	F	A	50	38	2.46	1	1.01	H
BH1	12.05	FR LAMINITE	F	D	50	49	2.50	2	1.03	H
BH1	12.05	FR LAMINITE	F	A	50	46	6.40	1	2.26	H
BH1	13.05	FR LAMINITE	F	D	50	49	0.23	2	0.09	VL
BH1	13.05	FR LAMINITE	F	A	50	38	0.99	4	0.41	
BH1	13.18	FR LAMINITE	F	D	50	50	2.04	2	0.82	M
BH1	13.18	FR LAMINITE	F	A	50	50	2.39	4	0.79	
BH1	14.05	FR LAMINITE	F	D	50	48	1.85	2	0.79	M
BH1	14.05	FR LAMINITE	F	A	50	40	3.70	1	1.46	H
BH1	14.95	FR LAMINITE	F	D	50	48	1.01	2	0.43	M
BH1	14.95	FR LAMINITE	F	A	50	43	2.31	4	0.86	

TEST TYPE :



W/D > 0.5
DIAMETRAL (D)

D/W = 0.3 - 1.0
AXIAL (A)

D/W = 0.3 - 1.0
IRREGULAR LUMP (I)

MOISTURE CONDITION :
Field (F), Saturated (S), Dry (D)

FAILURE TYPE :
1. Fracture through fabric of specimen oblique to bedding, not influenced by weak planes.
2. Fracture along bedding.
3. Fracture influenced by pre-existing joint plane (J), microfracture (M), vein (V), chemical alteration (C).
4. Chip or partial fracture.

NOTES For specimens tested parallel to plane of weakness $D_e^2 = D^2$
For specimens tested perpendicular to plane of weakness $D_e^2 = 4WD/\pi$

GENERAL

Information obtained from site investigations is recorded on log sheets. The "Cored Drill Hole Log" presents data from an operation where a core barrel has been used to recover material - commonly rock. The "Non-Core Drill Hole - Geological Log" presents data from an operation where coring has not been used and information is based on a combination of regular sampling and insitu testing. The material penetrated in non-core drilling is commonly soil but may include rock. The "Excavation - Geological Log" presents data and drawings from exposures of soil and rock resulting from excavation of pits, trenches, etc.

The heading of the log sheets contains information on Project Identification, Hole or Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material substance 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 common depth scale is 8m per drill log sheet and about 3-5m for excavation logs sheets.

As far as is practicable the data contained on the log sheets is factual. Some interpretation is inevitable 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. Material description and classifications are based on SAA Site Investigation Code AS 1726 - 1993 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

ADV	Auger Drilling with V-Bit
ADT	Auger Drilling with TC Bit
WB	Wash-bore drilling
RR	Rock Roller
NMLC	NMLC core barrel
NQ	NQ core barrel
HMLC	HMLC core barrel
HQ	HQ core barrel

Drilling Fluid/Water

The drilling fluid used is identified and loss of return to the surface estimated as a percentage.

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
M	Medium
H	High
VH	Very High

Groundwater Levels

Date of measurement is shown.

Standing water level measured in completed borehole

Level taken during or immediately after drilling

D	Disturbed
B	Bulk
U	Undisturbed
SPT	Standard Penetration Test
N	Result of SPT (sample taken)
PBT	Plate Bearing Test
PZ	Piezometer Installation
HP	Hand Penetrometer Test

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

Classification Symbol - In accordance with the Unified Classification System (AS 1726-1993, Appendix A, Table A1)

Material Description - In accordance with AS 1726-1993, Appendix A2.3

Moisture Condition

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

Consistency - In accordance with AS 1726-1993, Appendix A2.5

VS	Very Soft	< 12.5 kPa
S	Soft	12.5 – 25 kPa
F	Firm	25 – 50 kPa
St	Stiff	50 – 100 kPa
VSt	Very Stiff	100 – 200 kPa
H	Hard	> 200 kPa

Strength figures quoted are the approximate range of undrained shear strength for each class.

Density Index. (%) is estimated or is based on SPT results.

VL	Very Loose	< 15 %
L	Loose	15 – 35 %
MD	Medium Dense	35 – 65 %
D	Dense	65 – 85 %
VD	Very Dense	> 85 %

MATERIAL DESCRIPTION -ROCK

Material Description

Identification of rock type, composition and texture based on visual features in accordance with AS 1726-1993, Appendix A3.1-A3.3 and Tables A6a, A6b and A7.

Core Loss

Is shown at the bottom of the run unless otherwise indicated.

Bedding

Thinly Laminated	< 6 mm
Laminated	6 - 20
Very Thinly Bedded	20 - 60
Thinly Bedded	60 - 200
Medium Bedded	200 – 600
Thickly Bedded	600 – 2000
Very Thickly Bedded	> 2000

Weathering - No distinction is made between weathering and alteration. Weathering classification assists in identification but does not imply engineering properties.

Fresh (F)	Rock substance unaffected by weathering
Slightly Weathered (SW)	Rock substance partly stained or discoloured. Colour and texture of fresh rock recognisable.
Moderately Weathered (MW)	Staining or discolouration extends throughout rock substance. Fresh rock colour not recognisable.
Highly Weathered (HW)	Stained or discoloured throughout. Signs of chemical or physical alteration. Rock texture retained.
Extremely Weathered (EW)	Rock texture evident but material has soil properties and can be remoulded.

Strength - The following terms are used to described rock strength:

Rock Strength Class	Abbreviation	Point Load Strength Index, Is(50) (MPa)
Extremely Low	EL	< 0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	≥ 10

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

° Diametral Point Load Test

Axial Point Load Test

Where the estimated strength log covers more than one range it indicates the rock strength varies between the limits shown.

MATERIALS STRUCTURE/FRACTURES

ROCK

Natural Fracture Spacing - A plot of average fracture spacing excluding defects known or suspected to be due to drilling, core boxing or testing. Closed or cemented joints, drilling breaks and handling breaks are not included in the Natural Fracture Spacing.

Visual Log - A diagrammatic plot of defects showing type, spacing and orientation in relation to core axis.

Defects	————	Defects open in-situ or clay sealed
	– – – – – –	Defects closed in-situ
	....	Breaks through rock substance

Additional Data - Description of individual defects by type, orientation, in-filling, shape and roughness in accordance with AS 1726-1993, Appendix A Table A10, notes and Figure A2.

Orientation - angle relative to the plane normal to the core axis.

Type	BP	Bedding Parting
	JT	Joint
	SM	Seam
	FZ	Fracture Zone
	SZ	Shear Zone
	VN	Vein
	FL	Foliation
	CL	Cleavage
	DL	Drill Lift
	HB	Handling Break
	DB	Drilling Break
Infilling	CN	Clean
	X	Carbonaceous
	Clay	Clay
	KT	Chlorite
	CA	Calcite
	Fe	Iron Oxide
	Qz	Quartz
	MS	Secondary Mineral
	MU	Unidentified Mineral
Shape	PR	Planar
	CU	Curved
	UN	Undulose
	ST	Stepped
	IR	Irregular
	DIS	Discontinuous
Rougness	POL	Polished
	SL	Slickensided
	S	Smooth
	RF	Rough
	VR	Very Rough

SOIL

Structures - Fissuring and other defects are described in accordance with AS 1726-1993, Appendix A2.6, using the terminology for rock defects.

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

IMPORTANT INFORMATION

Appendix A

This Document has been provided by Morrow Geotechnics Pty Ltd subject to the following limitations:

This Document has been prepared for the particular purpose outlined in Morrow Geotechnics' proposal and no responsibility is accepted for the use of this Document, in whole or in part, in other contexts or for any other purpose.

The scope and the period of Morrow Geotechnics' Services are as described in Morrow Geotechnics' proposal, and are subject to restrictions and limitations. Morrow Geotechnics did not perform a complete assessment of all possible conditions or circumstances that may exist at the site referenced in the Document. The scope of services may have been limited by such factors as time, budget, site access or other site conditions. If a service is not expressly indicated, do not assume it has been provided. If a matter is not addressed, do not assume that any determination has been made by Morrow Geotechnics in regards to it. Any advice given within this document is limited to geotechnical considerations only. Other constraints particular to the project, including but not limited to architectural, environment, heritage and planning matters may apply and should be assessed independently of this advice.

Conditions may exist which were undetectable given the limited nature of the enquiry Morrow Geotechnics was retained to undertake with respect to the site. Variations in conditions may occur between investigatory locations, and there may be special conditions pertaining to the site which have not been revealed by the investigation and which have not therefore been taken into account in the Document. Accordingly, additional studies and actions may be required. No geotechnical investigation can provide a full understanding of all possible subsurface details and anomalies at a site.

In addition, it is recognised that the passage of time affects the information and assessment provided in this Document. Morrow Geotechnics' opinions are based upon information that existed at the time of the production of the Document. It is understood that the Services provided allowed Morrow Geotechnics to form no more than an opinion of the actual conditions of the site at the time the site was visited and cannot be used to assess the effect of any subsequent changes in the quality of the site, or its surroundings, or any laws or regulations.

Any assessments made in this Document are based on the conditions indicated from published sources and the investigation described. No warranty is included, either express or implied, that the actual conditions will conform exactly to the assessments contained in this Document.

Where data supplied by the client or other external sources, including previous site investigation data, have been used, it has been assumed that the information is correct unless otherwise stated. No responsibility is accepted by Morrow Geotechnics for incomplete or inaccurate data supplied by others.

Where ground conditions encountered at the site differ significantly from those anticipated in the report, either due to natural variability of subsurface conditions or construction activities, it is a condition of the report that Morrow Geotechnics be notified of any variations and be provided with an opportunity to review the recommendations of this report.

This Document is provided for sole use by the Client and is confidential to it and its professional advisers. No responsibility whatsoever for the contents of this Document will be accepted to any person other than the Client. Any use which a third party makes of this Document, or any reliance on or decisions to be made based on it, is the responsibility of such third parties. Morrow Geotechnics accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this Document.

Important Information