GEOTECHNIQUE® PTY LTD

ABN 64 002 841 063

Job No: 14561/2
Our Ref: 14561/2-AA
18 November 2019

Australian Foundation for Disability
C/- J Wyndham Prince Pty Ltd
PO Box 4366
PENRITH WESTFIELD NSW 2750
Email: mwhite@jwprince.com.au

Attention: Mr M White

Dear Sir

re: **Proposed Multi Storey Mixed Development**
Lot 1 in DP7711927, 61-79 Henry Street, Penrith
Geotechnical Investigation Report

This report presents the results of a geotechnical investigation carried out at the above site for the proposed mixed use development. Preliminary Contamination Assessment (PCA) of the site is not included and reported separately. The investigation was approved by Mr M Bellantonio of Australian Foundation for Disability in a signed confirmation of engagement dated 8 October 2019 and was carried out in accordance with the scope of work detailed in the Geotechnique Pty Ltd proposal (Our Ref: AI.sf/Q8898) dated 22 August 2019.

Proposed Development

Based on the preliminary concept drawings received, it is understood that the proposed development at the above site involves demolition of existing commercial building structures and construction of a number of multi-storey buildings (both commercial and residential use) including a hotel building at the south-west corner. The proposed buildings are up to twenty storeys high with three levels of basement car park. The basement excavation is anticipated to be about 9.0m deep below the existing ground surface.

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

Regional Geology

The Geological Map of Penrith (Geological Series Sheet 9030, Scale 1:100,000, Edition 1, 1991), published by the Department of Minerals and Energy indicates the residual soils within the site to be underlain by Triassic Age Shale of the Wianamatta Group, comprising shale, carbonaceous claystone, claystone, laminite, fine to medium grained lithic sandstone, rare coal and tuff. Quaternary Age soils of the Cranebrook Formation, comprising of gravel, sand, silt and clay, can be expected along the western boundary line of the site.

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The Soil Landscape Map of Penrith (soil Landscape Series Sheet 9030, Scale 1:100,000, 1989), prepared by the Soil Conservation Service of NSW, indicates that the site is located within the Luddenham Landscape area and typically consists of poorly drained, relatively impermeable residual natural soils.

The Salinity Potential in Western Sydney (2002) map indicates that the site has Moderate Salinity Potential.

Field Work

Field work for this investigation was carried out between 30 October and 1 November 2019 and included the following:

- Carrying out a walk over survey to assess general site conditions and identify preferred locations for boreholes.
- Reviewing services plans obtained from “Dial Before You Dig” to determine locations of underground services across the site.
- Scanning the proposed borehole locations for underground services to ensure drilling would not damage existing services. We engaged a specialist services locator for this purpose.
- Drilling five boreholes (BH1 to BH5) within the accessible part of the site using a track mounted drilling rig fully equipped for geotechnical investigation. Boreholes were initially drilled to V / TC-bit refusal in bedrock and then continued (by rock coring) to depths beyond the proposed excavation levels for basements. Borehole locations are shown on the attached Drawing No 14561/2-AA1 and the engineering borehole logs and core photographs, are also attached.
- Conducting Standard Penetration Test (SPT) in the boreholes at regular depth interval to assess strength characteristics of sub-surface soils.
- Recovering representative soil samples and core samples for visual assessment and laboratory testing.
- Measuring depths to groundwater level or seepage in the boreholes, where encountered.
- Install two standpipes in the machine drilled borehole for future monitoring of the groundwater level.

Field work was supervised by a Geotechnical Engineer from this company who was responsible for nominating the borehole locations, supervision of drilling and field test, collection of soil and rock samples for laboratory testing and preparation of engineering logs.

Site Description

The site consisted of a large single storey commercial building to the north and two double storey commercial buildings to the east and west. The vacant portion of the site is occupied by a large car park in the middle and concrete driveways along the boundary lines. The site is of semi-rectangular shape and bounded by Great Western Highway to the north, Lawson Street to the west, Henry Street to the south and commercial property to the east. Topography of the site is generally flat with a mild slope towards west.

Sub-surface Conditions

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

Table 1: Subsurface Conditions

Borehole No	Top RL (AHD m)	Termination Depth (m)	Pavement Thickness (mm)	Fill (m)	Natural Soil (m)	Bedrock (m)
BH1	31.436	14.0	200*	0.2 – 1.2	1.2 – 7.6	7.6 - >14.0
BH2	31.989	10.5	200*	0.2 – 0.7	0.7 – 5.2	5.2 - >10.5
BH3	35.091	10.0	150**	0.15 – 1.6	NE	1.6 - >10.0
BH4	31.574	10.0	200**	NE	0.2 – 0.9	0.9 - >10.0
BH5	33.086	10.5	500**	0.5 – 3.7	3.7 – 5.7	5.7 - >10.5

NE: Not Encountered *Asphalt Concrete Pavement (car park) **Cement Concrete Pavement (drive way)

The materials encountered in the boreholes can be generally described as below:

Pavement Layers	Cement Concrete Asphalt Concrete Road-base Gravel
Fill	Sand, fine grained, yellow/grey Silty Clay, low to medium plasticity, brown, traces of gravel Silty Clay, medium plasticity, brown mottled grey, with mixed gravel and ironstone Silty Clay, medium to high plasticity, grey/brown
Natural	Silty CLAY, low to medium plasticity, red/brown, traces of ironstone gravel Silty Sandy CLAY, medium plasticity, pale brown mottled orange CLAY, medium to high plasticity, brown grey Sandy CLAY, medium to high plasticity, grey/orange, with ironstone gravel
Bedrock	SHALE, grey, extremely to distinctly weathered, low to medium strength SHALE, grey, slightly weathered to fresh, medium to high strength

Geotechnical Model

Based on the information presented in Table 1, the sub-surface profile within the proposed development is anticipated to comprise a sequence of fill and natural clayey soils underlain by weathered shale bedrock. Sandy fill encountered at borehole location BH3 is likely to be trench backfilling material from nearby stormwater pipe. The pavement profile in the car park area consisted of asphalt concrete layer (40mm) underlain by road-base gravel (160mm) over clayey subgrade. Thickness of concrete driveways along the boundary lines likely to vary between 150 to 200mm. Depth to bedrock across the site varies between 0.9m and 7.6m below the existing ground surface.

Groundwater Conditions

Groundwater/seepage was encountered at borehole location BH1 at a depth 5.0m from the existing ground surface. Other boreholes were found to be in dry condition within the auger depth. Note that water used for coring precluded measurement of groundwater level at completion of drilling. It should also be noted that fluctuations in the level of groundwater/seepage might occur due to variations in rainfall and/or other factors not evident during drilling. To monitor long term water level at site, two monitoring wells were installed during the field investigation at borehole locations BH2 and BH4.

Laboratory Testing

Rock cores obtained from the boreholes were photographed and tested at regular depth intervals for the determination of the Point Load Strength Index (I_{s50}). The point load strength indices for the rock cores and the assessed rock strengths, in accordance with Australian Standard AS1726-1993 (Reference 1), are summarised in the following Table 2.

Table 2: Point Load Strength Index

Borehole No	Depth (m)	Diametral $I_{s(50)}$ (MPa)	Axial $I_{s(50)}$ (MPa)	Diametral Assessed Strength*	Axial Assessed Strength*
BH1	9.56	0.60	1.69	Medium	High
	10.71	0.40	1.50	Medium	High
	11.90	0.67	1.30	Medium	High
	12.73	0.50	1.32	Medium	High
	13.48	0.46	1.96	Medium	High
BH2	7.73	4.16	4.61	Very High	Very High
	8.75	0.35	0.78	Medium	Medium
	9.38	0.73	1.89	Medium	High
	10.36	0.27	1.32	Low	High
BH3	7.77	0.48	0.44	Medium	Medium
	8.63	0.68	0.69	Medium	Medium
	9.66	0.60	1.78	Medium	High
BH4	6.92	1.28	2.10	High	High
	7.52	0.55	0.62	Medium	Medium
	8.73	0.45	1.23	Medium	High
	9.70	0.36	0.65	Medium	Medium

* Estimated strength, $I_{s(50)}$: <0.03: Extremely Low, 0.03-0.1: Very Low , 0.1-0.3: Low, 0.3-1.0: Medium, 1.0-3.0: High, 3.0-10.0 Very High
# Estimated Unconfined Compressive Strength (UCS) ≈ 12 x Axial Point Load index

It should be noted that Point Load Strength tests could only be carried out on intact (stronger) portions of rock cores. Therefore, strength assessments presented in Table 2 indicate the upper limits of rock strengths.

Bedrock Classification for Foundation Design

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

Table 3: Bedrock classification

Borehole No	Top RL (mAHD)	Top Depth to Bedrock (m)	
		Class V or IV	Class III or better
BH1	31.436	7.6	8.5
BH2	31.989	5.2	7.5
BH3	35.091	1.6	7.4
BH4	31.574	0.9	7.4
BH5	33.086	5.7	8.1

DISCUSSION AND RECOMMENDATIONS

Excavation Condition

Proposed development is understood to involve 9m deep basement excavation. Therefore, materials to be excavated are expected to comprise clayey fill, natural clay and weathered shale bedrock. It is considered that excavation of overburden soils and weathered shale bedrock (Class V or IV) could be achieved using conventional earthmoving equipment, such as excavators (20 tonnes or more). However, excavation into Class III or better shale would be considerably more difficult and require larger equipment (such as Caterpillar D9 or equivalent with a rock hammer or rock saw). Selection of rock cutting equipment is based on site access, desired smoothness of the excavated rock surface and acceptable ground vibration during rock excavation.

Groundwater/seepage was encountered at borehole location BH1 (middle of the site) at a depth 5.0m below the existing ground surface. Other boreholes were found to be in dry condition within TC-bit refusal depths. We do not anticipate significant groundwater inflow during proposed excavation. Minor groundwater/seepage inflow if any could be managed by a conventional sump and pump method. It should be noted that fluctuations in the level of groundwater/seepage might occur due to variations in rainfall and/or other factors and trafficability problems could arise locally during wet weather or if water is allowed to pond at the site. We suggest a specialist dewatering contractor be contacted for advice if significant groundwater inflow is encountered during basement excavation. To monitor long term water level at site, two monitoring wells were installed during the field investigation.

Batter Slopes and Retaining Structures

Proposed development will involve approximately 9m deep excavation for basement. Some minor fill placement might also be required during site preparation work. Cut and fill slopes during and after development works should be battered for stability or retained by engineered retaining structures. Recommended batter slopes for the stability of cut and fill slopes are presented in Table 4.

Table 4: Recommended batter slopes

Material	**Temporary (Vertical : Horizontal)**		**Permanent (Vertical : Horizontal)**	
	Protected	**Exposed**	**Protected**	**Exposed**
Controlled Fill/ Natural Clay	1.0 : 1.0	1.0 : 1.5	1.0 : 2.0	1.0 : 2.5
Shale - Class V to IV	1.0 : 0.75	1.0 : 1.0	1.0 : 1.0	1.0 : 1.5
Shale - Class III or better	Sub-vertical	Sub-vertical	Sub-vertical	Sub-vertical

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

Batter slopes steeper than those recommended in Table 4 need to be retained by engineered retaining structures. Appropriate retaining structures for the proposed development would comprise soldier pier walls installed before excavation is commenced. The centre to centre spacing of piers can range from 2 to 3 times pier diameter.

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

$p_h = \gamma kH$

Where,

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

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

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

Table 5: Recommended earth pressure coefficients

Retained Material	Unit Weight (kN/m^3)	Active Earth Pressure Coefficient, K_a	At Rest Earth Pressure Coefficient, K_0	Ultimate Passive Earth Pressure (kPa)
Controlled Fill/ Natural Clay	18	0.40	0.60	Ignore
Shale - Class V to IV	20	0.20	0.30	350*
Shale - Class III or better	22	Not Applicable	Not Applicable	1000*

** Apply appropriate factor of safety*

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

Rock anchors might be required for the support of retaining structures. We recommend that rock anchors are taken into Class IV or better bedrock and can be designed for a bond strength (between grout and bedrock) taken as 10% of end bearing capacity values recommended in "Footings" section of the report.

Floor Slabs and Footings

Assuming that the proposed structure will have three levels of basements, material at the base of basement excavation is anticipated to be to be Class III shale. Floor slabs for proposed buildings may be constructed as ground bearing slabs or suspended slabs supported by footings designed in accordance with recommendations provided in this report. For the design of ground bearing slabs, we recommend a Modulus of Subgrade Reaction Value of 30kPa/mm for Class V or IV shale and 50kPa/mm for Class III or better shale.

Loading conditions from the proposed structure are not known at this stage. We consider that appropriate foundations would comprise either shallow footings (pad and strip) or deep foundations (bored piers). Deep footings might be preferable if footings are required to support significant lateral and/or uplift pressures. The recommended allowable bearing pressures for design of shallow and deep foundations are presented in the following Table 6.

Table 6: Recommended allowable bearing pressures

Founding Material	Allowable Bearing Pressure (kPa)	Allowable Shaft Adhesion (kPa)
Natural Clay	150	Ignore
Shale – Class V	600	50
Shale - Class IV	1200	100
Shale - Class III	3000	250

The recommended allowable shaft adhesions against uplift pressures are half the shaft adhesions for compressive loads presented in Table 6.

As depths to bedrock with the recommended allowable bearing pressures could vary across the site, the founding depths of footings to be constructed will also vary. The depth ranges presented in Table 3 are measured from existing ground surface at borehole locations and are indicative only. Therefore, an experienced Geotechnical Engineer on the basis of assessment made during footing excavation or pier hole drilling should confirm founding levels during construction. The engineer should ensure that the design strength of bedrock is achieved.

For footings founded in bedrock total settlements under the recommended allowable bearing pressures are estimated to be about 1% of pier diameter or minimum footing dimension. Differential settlements are estimated to be about half the estimated total settlements. Although groundwater/seepage was not encountered during drilling, it might be prudent to provide sub-floor drainage for long-term conditions.

General

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

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

Yours faithfully
GEOTECHNIQUE PTY LTD

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DR MD ARIFUL ISLAM (MIEAust CPEng NER)
Senior Geotechnical Engineer

Attached	Drawing No 14561/2-AA1 Borehole Locations Borehole Logs (BH1 to BH5), Core Photographs, and Explanatory Notes

References

1. *Australian Standard, Geotechnical Site Investigation, AS1726-1993.*
2. *Pells, P J N, Mostyn, E and Walker, B F, Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, Dec 1998.*

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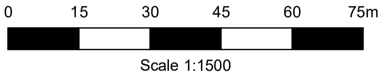
Imagery ©2019 NearMap.com

LEGEND

● Borehole



Scale 1:1500

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NOTES

1. Site features are indicative and are not to scale.
2. This drawing has been produced using a base plan provided by others to which additional information e.g test pits, borehole locations or notes have been added. Some or all of the plan may not be relevant at the time of producing this drawing

J Wyndham Prince Pty Ltd
Proposed Multi Storey Mixed Development
61-79 Henry Street
Penrith

Borehole Locations

Drawing No: 14561/2-AA1
Job No: 14561/2
Drawn By: MH
Date: 5 November 2019
Checked By: RR

File No: 14561-2
Layers: 0, AA1

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH1
Date : 30/10/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅31.436
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC Bit						0			Asphaltic Concrete (40mm)				Wearing Course
									Road base Gravel (160mm)				Base Course
		GP							FILL: Silty Clay, medium plasticity, brown grey, with mixed gravel and ironstone	M=OMC			Moderately Compacted
				DS	n=4 2,2,2	0.5							
		GP											
						1							
		G						CL-CI	Silty CLAY, low to medium plasticity, red, with ironstone	M<PL	St		Alluvial
				DS	n=8 4,4,4	1.5							
		G						CI	Silty Sandy CLAY, medium plasticity, pale brown mottled orange				
						2							
		G						CI-CH	CLAY, medium to high plasticity, brown grey		VSt		
						2.5							
				DS	n=15 5,7,8	3							
						3.5							
						4							
		G											
		G		DS	n=14 5,6,8	4.5		CI-CH	Sandy CLAY, medium to high plasticity, grey/ orange, with ironstone gravel	M>PL			Ironstone gravel band at 4.5m

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH1
Date : 30/10/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅31.436
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

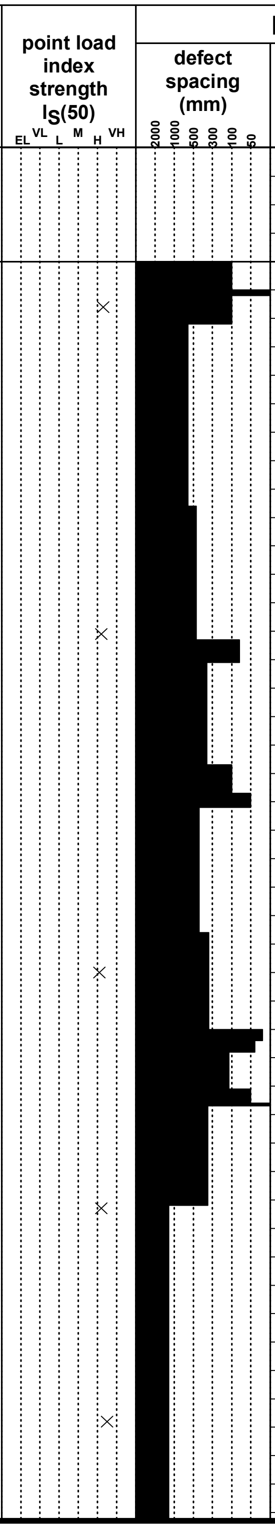
method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
	▼					5							Groundwater table at 5.0m
						5.5							
				DS	n=9 4,4,5	6							
		G											
						6.5							
						7							
					n= Refusal 20/100	7.5							
									SHALE, grey, low to medium strength, extremely to distinctly weathered				Bedrock
						8							
						8.5			SHALE, grey, medium to high strength, distinctly to slightly weathered				
						9							
									Started coring BH1 at 9.4m				
						9.5							

engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith
Job No. : 14561/2
Borehole No. : BH1
Date : 30/10/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : deg.
R.L. surface : ≅31.436
core size: NMLC
bearing : deg.
datum :

barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength	DEFECT DETAILS DESCRIPTION type, inclination, thickness, planarity, roughness, coating. Specific	General
		9		Started coring BH1 at 9.4m				
		9.5 10 10.5 11 11.5 12 12.5 13 13.5		SHALE, grey	SW- FR	M-H	Ds = 20mm, Pl, Ro, Cg Jo=0°, Pl, Sm, Cn Jo=20°, Un, Ro, Sn Bp=0°, Pl, Sm, Sn Bp=0°, Pl, Ro, Cn Jo=10°, St, Ro, Sn Jo=0°, Ir, Ro, Sn Bp=0°, Pl, Ro, Cg Jo=0°, Ir, Ro, Cn Bp=0°, Pl, Sm, Sn Jo=0°, Pl, Sm, Sn Jo=0°, Pl, Sm, Sn Bp=0°, Pl, Sm, Sn Jo=0°, Pl, Sm, Cg Is=10mm, Un, Ro, Cg Jo=0°, Pl, Ro, Cn	



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engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH1
Date : 30/10/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : **deg.**
R.L. surface : ≅31.436
core size: NMLC
bearing : **deg.**
datum :

barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength	point load index strength $I_S(50)$ EL VL L M H VH	DEFECT DETAILS defect spacing (mm) 2000 1000 500 300 100 50	DESCRIPTION type, inclination, thickness, planarity, roughness, coating. Specific	General
		14		Terminated BH1 at 14.0m						
		14.5								
		15								
		15.5								
		16								
		16.5								
		17								
		17.5								
		18								
		18.5								

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GEOTECHNIQUE

Job No 14561/2 BH1 Started Coring at 9.4m

Started Coring at 9.4m

BH1 terminated at 14.0m

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH2
Date : 31/10/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig
slope : deg.
R.L. surface : ≅31.989
hole diameter : 75 mm
bearing : deg.
datum : AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC Bit						0			Asphaltic Concrete (40mm)				Wearing Course
									Road base Gravel (160mm)				Base Course
									FILL: Silty Clay, low to medium plasticity, grey/brown	M=OMC			Well Compacted
		GP											
				DS	n=9 3,4,5	0.5							
		G						CI	Silty CLAY, medium plasticity, red/brown, traces of ironstone gravel	M<PL	St		Alluvial
						1							
				DS	n=18 6,9,9	1.5							
						2							
						2.5							
		G						CI-CH	Silty CLAY, medium to high plasticity, red/grey	M=PL	VSt		
				DS	n=8 3,3,5	3							
						3.5							
						4							
		G						CI-CH	Silty Sandy CLAY, medium to high plasticity, grey/red with yellow staining, traces of ironstone gravel				
				DS	n=13 4,5,8	4.5							

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PTY LTD

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith
Job No. : 14561/2
Borehole No. : BH2
Date : 31/10/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅31.989
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

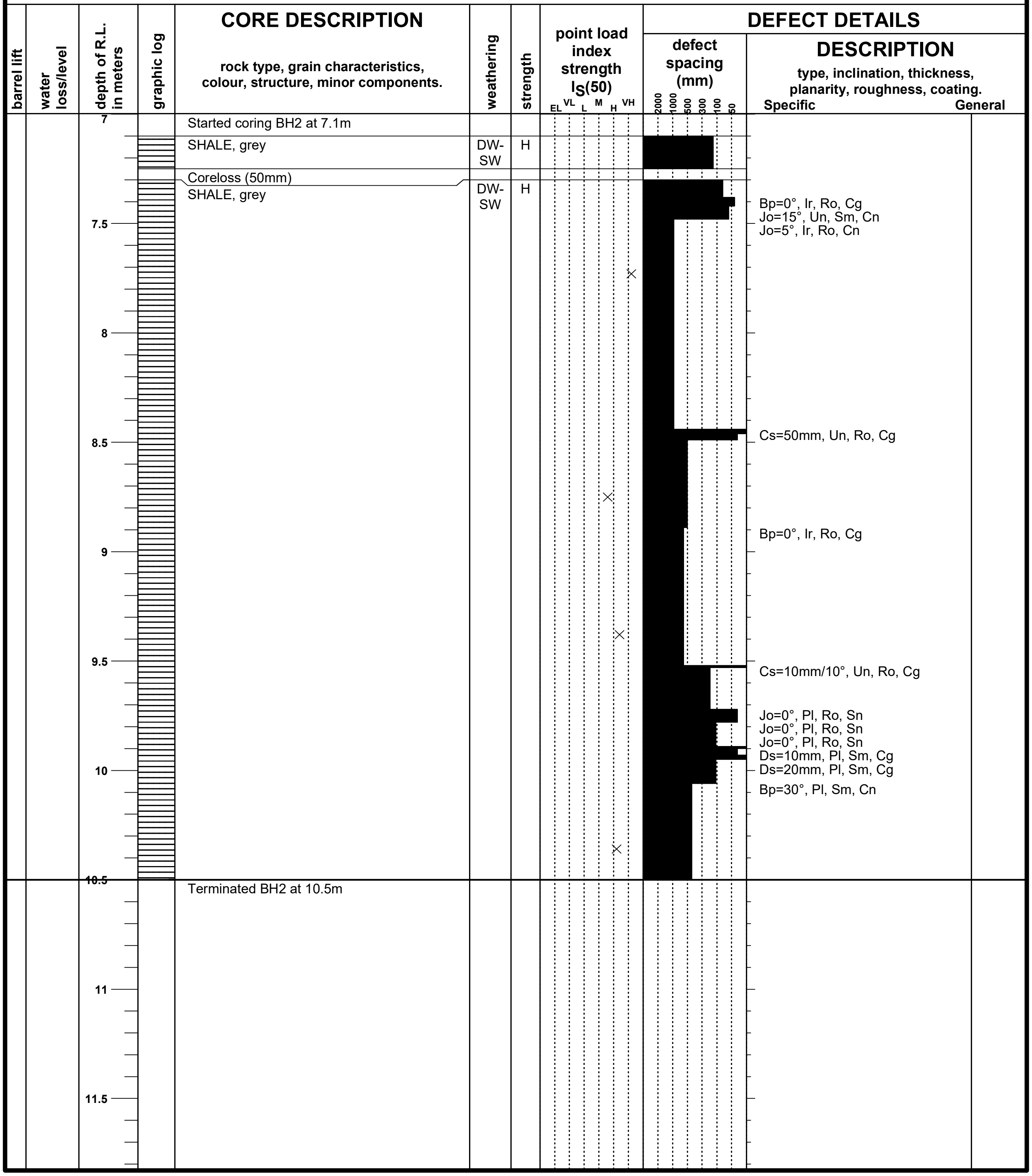
method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						5							
									SHALE, grey, extremely to distinctly weathered, low to medium strength, with clay bands				Bedrock
						5.5							
						6							
					n= Refusal 20/50	6.5							
						7							
									Started coring BH2 at 7.1m				
						7.5							
						8							
						8.5							
						9							
						9.5							

engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH2
Date : 31/10/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : deg.
R.L. surface : ≅31.989
core size: NMLC
bearing : deg.
datum :



barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength	point load index strength $I_S(50)$	defect spacing (mm)	DEFECT DETAILS DESCRIPTION type, inclination, thickness, planarity, roughness, coating. Specific	General
		7		Started coring BH2 at 7.1m						
				SHALE, grey	DW-SW	H				
				Coreloss (50mm)						
				SHALE, grey	DW-SW	H			Bp=0°, Ir, Ro, Cg Jo=15°, Un, Sm, Cn Jo=5°, Ir, Ro, Cn Cs=50mm, Un, Ro, Cg Bp=0°, Ir, Ro, Cg Cs=10mm/10°, Un, Ro, Cg Jo=0°, Pl, Ro, Sn Jo=0°, Pl, Ro, Sn Jo=0°, Pl, Ro, Sn Ds=10mm, Pl, Sm, Cg Ds=20mm, Pl, Sm, Cg Bp=30°, Pl, Sm, Cn	
		10.5		Terminated BH2 at 10.5m						


GEOTECHNIQUE
PTY LTD
Job No 14561/2 BH2 Started Coring at 7.1m
Coring at 7.1m
Coreloss 50mm
8.0m
9.0m
10.0m
BH2 terminated at 10.5m

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH3
Date : 31/10/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅35.091
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0	■		Concrete cement (150mm)				Driveway Pavement
							▩		FILL: Sand, fine grained, yellow/grey	M=OMC			Bedding sand next to stormwater pipe
		GP											
				DS	n=9 4,4,5	0.5							
		GP											
						1							
				DS	n=16 7,6,10	1.5							
							▤		SHALE, grey, very low to low strength, extremely weathered, with clay bands				Bedrock
		G											
						2							
						2.5							
							▤		SHALE, grey, low strength, extremely to distinctly weathered				
						3							
						3.5							
						4							
						4.5							

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH3
Date : 31/10/2019
Logged/Checked by: RR

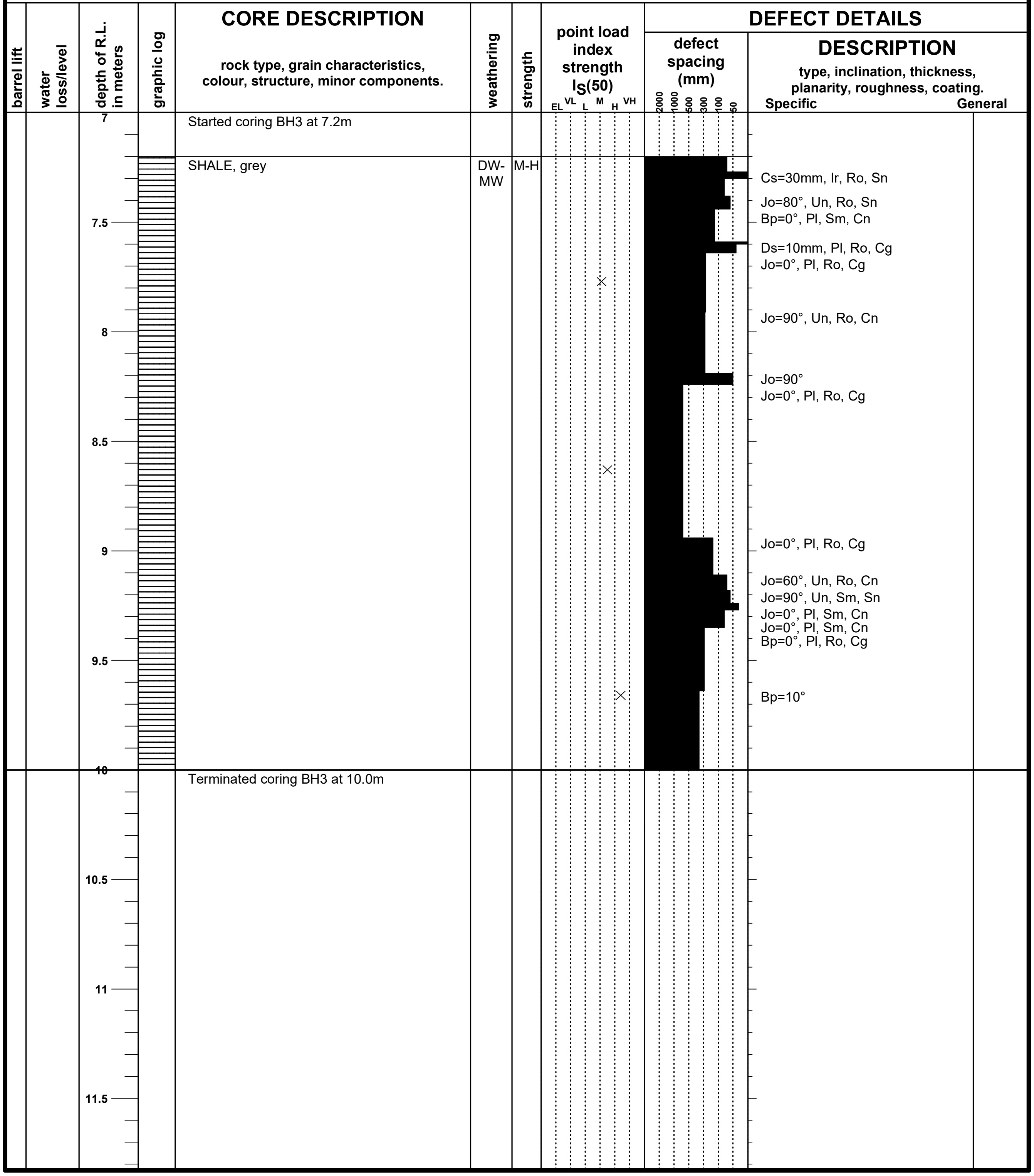
drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅35.091
hole diameter : 125 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						5							
						5.5			SHALE, grey, low to medium strength, extremely to distinctly weathered				
						6							
						6.5			SHALE, grey, medium to high strength, distinctly weathered				
						7							
									Started coring BH3 at 7.2				
						7.5							
						8							
						8.5							
						9							
						9.5							

engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith
Job No. : 14561/2
Borehole No. : BH3
Date : 01/11/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : deg.
R.L. surface : ≅35.091
core size: NMLC
bearing : deg.
datum :



CORE DESCRIPTION
rock type, grain characteristics, colour, structure, minor components.

Started coring BH3 at 7.2m

SHALE, grey — weathering: DW-MW — strength: M-H

Terminated coring BH3 at 10.0m

DEFECT DETAILS
DESCRIPTION
type, inclination, thickness, planarity, roughness, coating.
Specific / General

Cs=30mm, Ir, Ro, Sn
Jo=80°, Un, Ro, Sn
Bp=0°, Pl, Sm, Cn
Ds=10mm, Pl, Ro, Cg
Jo=0°, Pl, Ro, Cg
Jo=90°, Un, Ro, Cn
Jo=90°
Jo=0°, Pl, Ro, Cg
Jo=0°, Pl, Ro, Cg
Jo=60°, Un, Ro, Cn
Jo=90°, Un, Sm, Sn
Jo=0°, Pl, Sm, Cn
Jo=0°, Pl, Sm, Cn
Bp=0°, Pl, Ro, Cg
Bp=10°

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GEOTECHNIQUE

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Job No 14561/2 BH3 Started Coring at 7.2m

Started Coring at 7.2m

8.0m

9.0m

BH3 terminated at 10.0m

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH4
Date : 01/11/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** deg. **R.L. surface :** ≅31.574
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC Bit						0	■		Concrete Cement (200mm)				Driveway Pavement
							▨	CL-CI	Silty CLAY, low to medium plasticity, red mottled brown	M<PL	VSt		Residual
		G											
				DS	n= Refusal 4,12,15/ 100	0.5							
							☰		SHALE, grey, very low strength, residual soil to extremely weathered, with clay bands				Bedrock
						1							
					n= Refusal 9,20/100	1.5							
						2							
						2.5							
						3							
							☰		SHALE, grey, low to medium strength, extremely to distinctly weathered				
						3.5							
						4							
						4.5							

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH4
Date : 01/11/2019
Logged/Checked by: RR

drill model and mounting : Christie Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅31.574
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

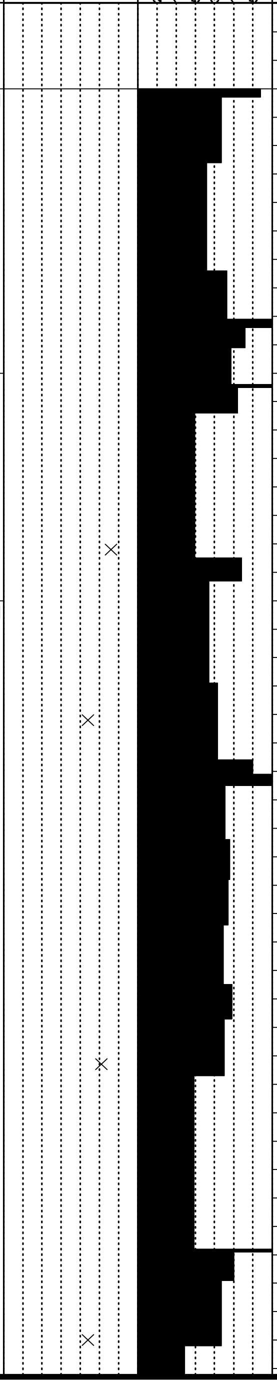
method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
	DRY					5	▤						
						5.5 6 6.5 7 7.5 8 8.5 9 9.5			Started coring BH4 at 5.3m				

engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith
Job No. : 14561/2
Borehole No. : BH4
Date : 01/11/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : deg.
R.L. surface : ≅31.574
core size: NMLC
bearing : deg.
datum :

barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength
		5		Started coring BH4 at 5.3m		
				SHALE, grey/brown	EW-DW	M-H
				SHALE, grey, with clay bands	EW-DW	L-M
				SHALE, grey	DW-MW	M-H



DEFECT DETAILS
DESCRIPTION type, inclination, thickness, planarity, roughness, coating.
Specific / General

Jo=90°, Pl, Sm, Cn
Jo=0°, St, Ro, Cn
Jo=0°, Pl, Ro, Cn
Cs=30mm, Pl, Ro, Cn
Jo=10°, Pl, Sm, Cn
Ds=10mm, Pl, Sm, Cn
Jo=0°, St, Ro, Cg
Jo=80°, Cu, Ro, Cg
Jo=70°, Un, Ro, Cn
Jo=0°, Pl, Sm, Cn
Jo=0°, Pl, Sm, Cg
Ds=40mm, Ir, Ro, Sn
Jo=0°, Pl, Sm, Cg
Jo=0°, Pl, Sm, Cg
Jo=0°, Pl, Sm, Cg
Jo=0°, Pl, Sm, Cg
Jo=0°, Pl, Sm, Cg
Jo=15°, St, Ro, Vn
Cs=10mm, Pl, Ro, Cn
Jo=0°, Pl, Sm, Cg
Jo=0°, Pl, Ro, Cn

Depth scale: 5, 5.5, 6, 6.5, 7, 7.5, 8, 8.5, 9, 9.5

engineering log
cored borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith
Job No. : 14561/2
Borehole No. : BH4
Date : 01/11/2019
Logged/Checked by : RR

drill model and mounting : Christie Hydropower Rig
slope : **deg.**
R.L. surface : ≅31.574
core size: NMLC
bearing : **deg.**
datum :

barrel lift	water loss/level	depth of R.L. in meters	graphic log	CORE DESCRIPTION rock type, grain characteristics, colour, structure, minor components.	weathering	strength	point load index strength $I_S(50)$ EL VL L M H VH	defect spacing (mm) 2000 1000 500 300 100 50	DEFECT DETAILS – DESCRIPTION type, inclination, thickness, planarity, roughness, coating. Specific	General
		10								
		10.5		Terminated BH4 at 10.5m						
		11								
		11.5								
		12								
		12.5								
		13								
		13.5								
		14								
		14.5								

GEOTECHNIQUE
PTY LTD

Job No 14561/2 BH4 Started Coring at 5.3m

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH5
Date : 01/11/2019
Logged/Checked by: RR

drill model and mounting : Chrisite Hydropower Rig
slope : deg.
R.L. surface : ≅33.086
hole diameter : 75 mm
bearing : deg.
datum : AHD

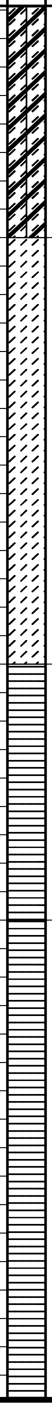
method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0	■		Concrete Cement (500mm)				Driveway Pavement
		GP		DS	n=11 5,5,6	0.5	▨		FILL: Silty Clay, low to medium plasticity, brown, traces of gravel	M=OMC			Well compacted
		GP				1	▨						
		GP		DS	n=13 5,6,7	1.5	▨		FILL: Silty Clay, medium to high plasticity, grey/ brown				
						2	▨						
		GP				2.5	▨						
					n=16 6,7,9	3	▨						
		GP				3.5	▨						
		G					▧	CI-CH	Silty CLAY, medium to high plasticity, grey/ brown	M<PL	St		Natural
						4	▧						
						4.5	▧						

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH5
Date : 01/11/2019
Logged/Checked by: RR

drill model and mounting : Chrisite Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅33.086
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD



method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC Bit						5							
						5.5							
									SHALE, grey/orange, very low strength, extremely weathered, with clay bands				Bedrock
						6							
						6.5							
						7							
									SHALE, grey, low to medium strength, distinctly weathered				
						7.5							
						8							
									SHALE, grey, medium to high strength, distinctly to slightly weathered				
						8.5							
						9							
						9.5							

engineering log - borehole

Client : J Wyndham Prince Pty Ltd
Project : Proposed Multi Storey Mixed Development
Location : 61-79 Henry Street, Penrith

Job No. : 14561/2
Borehole No. : BH5
Date : 01/11/2019
Logged/Checked by: RR

drill model and mounting : Chrisite Hydropower Rig **slope :** **deg.** **R.L. surface :** ≅33.086
hole diameter : 75 **mm** **bearing :** **deg.** **datum :** AHD

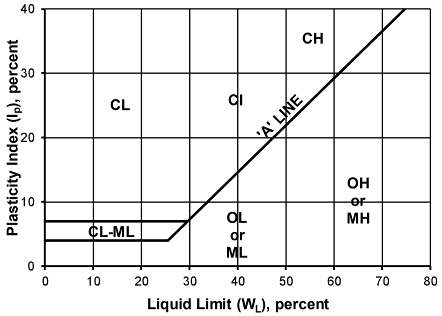
method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
	DRY					10	▤						
						10.5 11 11.5 12 12.5 13 13.5 14 14.5			Terminated BH5 at 10.5m				

Log Symbols & Abbreviations (Non-cored Borehole Log)

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

AS1726 – Unified Soil Classification System

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



Log Symbols & Abbreviations (Cored Borehole Log)

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

AS1726 – Identification of Sedimentary Rocks for Engineering Purposes

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

AS1726 – Identification of Metamorphic and Igneous Rocks for Engineering Purposes

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