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ABN 64 002 841 063

Job No: 14035/1
Our Ref: 14035/1-AA-R2
29 June 2017

Mint Holdings Pty Ltd (Julie Goh & Shane Goh)
c/- Nash Project Management Pty Ltd
Suite 3, Level 1, 8 West Street
NORTH SYDNEY NSW 2060
Email: EChin@nashmanagement.com.au

Attention: Mr E Chin

Dear Sir

re: **Proposed Townhouse Development**
Lot 176 in DP1203990 – 62 Bradley Street, Glenmore Park (Bradley Heights)
Report on Geotechnical Investigation

This report provides the results of a geotechnical investigation for the proposed townhouse development at the above site. The work was commissioned by Mr E Chin of Nash Management in an email dated 23 May 2017 and was carried out as per our proposal Q8083, dated 4 May 2017.

Proposed Development
We understand that the following will be constructed at the above site:

- Twenty-one townhouses fronting Bradley Street
- Four residential houses fronting Edgewater Drive and
- Road from Edgewater Drive to the development.

In this regard, a geotechnical investigation was required to assess existing subsurface conditions and develop geotechnical recommendations necessary for the design for the proposed structures.

Field Work
Field work for the geotechnical investigation was carried out on 29 May 2017 and the following was completed:

- OH&S risk assessment and a walk-over survey to assess existing site conditions.
- Scanning the borehole locations for underground services so that drilling would not damage the services. A specialist was hired for the purpose. Also DBYD drawings were obtained prior to going to the site.
- Drilling seven (7) boreholes to depths ranging from 3.5m to 4.5m, using a truck mounted drilling rig. The borehole locations are shown on the attached Drawing No 14035/1-AA1.
- Conducting Standard Penetration Tests (SPT) in overburden soils to assess strength characteristics of subsurface soils.
- Measuring groundwater/seepage during and at completion of drilling.
- Recovery of soil samples for visual assessment, preparation of logs.

The fieldwork was supervised by a Geotechnical Engineer from this company, who was responsible for locating boreholes, supervising drilling, in-situ testing and preparation of logs.

Regional Geology

Based on the Geological Map of Penrith (1:100,000), the bedrock at the site is anticipated to be Bringelly Shale, belonging to the Wianamatta Group of rocks and comprising shale, carbonaceous claystone, laminite, fine to medium grained lithic sandstone and rare coal.

Reference to the Soil Landscape Map (1:100,000) of Penrith indicates that the landscape of the site belongs to the Luddenham Group, which is characterised by undulating to rolling low hills on Wianamatta Group shale, often associated with Minchinbury sandstone, with local relief of 50m to 80m, ground surface slopes of 5% to 20%, narrow ridges, hillcrests and valley. Soils in this group are likely to be up to 1.5m deep, high plasticity, moderately reactive, locally impermeable and susceptible to high erosion hazards.

Site Location & Description

The site is located at the corner of Bradley Street and Edgewater Drive, Glenmore Park. The site is triangular in shape and measures about 7400m^2 in plan. The topography varies across the site. The ground levels of the edges match with that of Bradley Street and Edgewater Drive; however, the bulk centre of the site lies approximately two metres below the existing road levels. The site is covered with thick grass and a stockpile was observed in the top corner of the site.

Subsurface Conditions

The subsurface conditions encountered in the boreholes drilled across the site are detailed in the attached engineering borehole logs and summarised below:

Table 1

BH	Top RL (AHD)	Terminated depth (m)	Topsoil (m)	Fill (m)	Natural (m)	Bedrock (m)
1	71.803	4.0	0.0 – 0.1	0.1 – 4.0	NE	NE
2	70.687	4.5	0.0 – 0.1	0.1 – 4.5	NE	NE
3	69.791	3.5	NE	0.0 – 1.3	1.3 – 2.9	2.9 –> 3.5
4	70.973	4.5	0.0 – 0.1	0.1 – 0.7	0.7 – 2.0	2.0 –> 4.5
5	72.276	4.0	NE	0.0 – 2.1	2.1 –> 4.0	NE
6	73.703	4.0	NE	0.0 – 3.1	3.1 –> 4.0	NE
7	74.700	4.0	0.0 – 0.1	0.1 – 2.5	2.5 – 3.8	3.8 –> 4.0

NE : Not Encountered

Topsoil	Clayey Silt, low plasticity, brown, with root fibres
Fill	Clayey Silt, low plasticity, brown, with gravel Silty Clay, low to high plasticity, brown, grey, red with gravel and ironstones
Natural	(CI-CH) Silty CLAY, medium to high plasticity, yellow, brown, orange, grey, traces of ironstones (CI-CH) Sandy Silty CLAY, medium to high plasticity, brown with gravel
Bedrock	SHALE, black-brown, extremely weathered to distinctly weathered, low to medium strength

Based on the SPT results the natural clayey soils at the site are generally firm to very stiff in consistency.

Groundwater Conditions

Groundwater or seepage was not encountered up to the drilled depths of the boreholes. Long term water monitoring was not part of this investigation. It should be noted that groundwater levels fluctuate and are affected by many factors which fall outside of the scope present report.

Laboratory Testing

Shrink/Swell Index

Two shrink/swell index tests were conducted on the samples recovered from BH2 and BH4. Test results are detailed on the attached certificate and summarised below:

Table 2

BH	Depth	Material Description	I_{ss} %/$_p$F
2	0.5 – 0.7	FILL: Silty Clay, low plasticity , brown-grey, with gravel	1.4
4	0.5-0.7	FILL: Silty Clay, medium plasticity , brown-grey, with gravel	2.6

Discussion and Recommendations

Assessment of Existing Fill

Fill was encountered in all the boreholes from existing ground levels to varying depths ranging from 0.7m to the maximum drilled depth of 4.5m. The fill was consisted of silty clay, low to high plasticity with gravels. SPT results and visual inspection indicate that the fill is well compacted. However, it is not known how the fill was placed at the site. As the fill is undocumented, care shall be taken in supporting load bearing structure on the fill.

Site Filling

Considering the topography of the site, we expect that additional fill will be placed at the site to achieve the designed grades. The following are recommended for subgrade preparation and placement of fill:

- Strip existing topsoil and stockpile separately for possible future use. Also stockpile present at the site should be removed.
- Undertake proof rolling (using an 8 to 10 tonnes roller) of the exposed materials (existing fill or natural) to detect potentially weak spots (ground heave). Excavate areas of localised heaving to a depth of about 300mm and replace with granular fill, compacted as described below.
- Undertake proof rolling of the soft spots backfilled with granular fill, as described above. If the backfilled area shows movement during proof rolling, this office should be contacted for further recommendations.
- Place suitable fill materials on proof rolled areas. The fill should be placed in horizontal layers of 200mm to 250mm maximum loose thickness (depending on the size of equipment) and compacted to at least 98% of Standard Maximum Dry Density (SMDD), at moisture content within 2% of Standard Optimum Moisture Content (SOMC). The top 300mm of fill forming pavement subgrade should be compacted to at least 100% SMDD.
- Controlled fill should preferably comprise non-reactive fill (e.g. crushed sandstone) with a maximum particle size not exceeding 75mm, or low plasticity clay. Natural soils and bedrock obtained from excavations within the site may be used in controlled fill after removal of any unsuitable materials, crushing to sizes finer than 75mm, proper mixing and moisture conditioning.

- Fill placement should be supervised to ensure that material quality, layer thickness, testing frequency and compaction criteria conform to the specifications. We recommend "Level 2" or better supervision, in accordance with AS3798-2007 (Reference 1). It should be noted that a Geotechnical Inspection and Testing Authority will generally only provide certification on the quality of entire compacted fill if Level 1 supervision and testing is carried out.

Site Classification

The seven boreholes drilled at the site encountered fill to depths ranging from 0.7m to the maximum drilled depth of 4.5m. Based on the existing subsurface conditions, the site is classified as Class "P" (i.e. Problematic) as per AS2870-2011 "Residential slabs & footings". All footings and floor slabs shall be designed by the engineer as per engineering principles.

Footings & Floor Slabs

As the existing fill is undocumented and that additional fill will be placed at the site, we recommend that the proposed structures are supported on deep footings (bored piers or screw piles) founded in natural clays or shale bedrock. This is recommended to reduce differential settlements between the footings. Based on the borehole results, depths to natural clays are likely to range from 0.7m to deeper than 4.5m and to bedrock from 2m to deeper than 4.5m.

Deep footings (bored piers or screw piles) can be designed for the following recommended bearing pressure values:

Table 3

Founding Material	Allowable End Bearing Pressure (kPa)	Allowable Shaft Adhesion (kPa)
Stiff to very stiff natural clays	300	20
Shale bedrock	700	50

The minimum length of the bored pier or screw pile shall be 3 to 4 times its diameter.

Floor slabs can be suspended on deep footings.

Deep footings founded in natural clayey soils are likely to settle about 10mm to 15mm and deep footings founded in shale bedrock is likely to settle about 1% of pier diameter. Differential settlement is expected to be less than 50% of the total settlement provided footings are founded on similar material.

Earthquake Parameters

Based on the sub-surface materials encountered at the site and in accordance with Australian Standard AS1170.4-2007 "Structural design actions – Part 4: Earthquake actions in Australia", the following earthquake design parameters are recommended:

Table 4

Factor	Value
Probability Factor (k_p)	1.0 (based on probability of exceedance of 1/500)*
Hazard Factor (Z) for Sydney Area	0.08
Site Sub-soil	C_e

** This factor can be increased to 1.3 if the designer deems the importance level of building is Level 3 (probability of exceedance 1/1000) as per Building Code of Australia*

Road Pavement
The subgrade for the proposed road will consists of the existing and new fill.

Considering the above subgrade conditions a design California Bearing Ratio (CBR) of 4% can be adopted for pavement thickness design.

The following pavement composition is recommended for the proposed road:

Layer	Thickness (mm)
40mm	AC10 (over single coat flush seal)
135mm	Base Course (DGB20)
175mm	Sub-base Course
350mm	**Total**

In lieu of 40mm AC wearing course, two coat seal (14mm/10mm) can be provided.

The pavement depths are only valid if the subgrade and pavement materials are compacted to the following maximum dry density ratios (AS1289 5.4.1).

Basecourse	98% Modified
Sub-basecourse	95% Modified
Subgrade	100% Standard

Pavement drainage (surface and sub-surface) shall be provided as recommended by the design engineer.

Limitations
Recommendations provided in this report are based on information from seven (7) boreholes and site observation, actual sub-surface conditions across the site might differ from those expected (interpreted). If such differences are encountered during construction we recommend that this office is contacted for further advice. This can also occur with groundwater conditions, especially after climatic changes.

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

Yours faithfully
GEOTECHNIQUE PTY LTD

ZIAUDDIN AHMED
Associate Geotechnical Engineer

Attached: Drawing No 14035/1-AA1 – Borehole Location Plan
Engineering Borehole Logs & Explanatory Notes

N

LEGEND

Borehole

Imagery ©2017 NearMap.com

0 10 20 30 40 50m

Scale 1:1000

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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

Nash Project Management Pty Ltd
Lot 176 in DP1203990
62 Bradley Street
Glenmore Park (Bradley Heights)

Borehole Locations

Drawing No: 14035/1-AA1
Job No: 14035/1
Drawn By: MH
Date: 31 May 2017
Checked By: SM

File No: 14035-1
Layers: 0, AA1

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 1
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅71.803

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
TC bit						0			TOPSOIL: Clayey Silt, low plasticity, brown, with root fibres				
									FILL: Clayey Silt, low plasticity, brown, with gravel	M<OMC			Well compacted
				U_{50}	N=18 4,8,10	0.5							
									FILL: Silty Clay, low to medium plasticity, brown, with gravel	M<OMC			
						1							
						1.5							
						2							
					N=7 4,3,4								
						2.5			FILL: Silty Clay, medium to high plasticity, brown mottled grey and red, with gravel and ironstones	M≤OMC			
						3							
									FILL: Silty Clay, low to medium plasticity, brown, with gravel	M<OMC			
						3.5							
					N=11 5,4,7								
						4			Borehole No 1 terminated at 4.0m				
						4.5							

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 2
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅70.687

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
TC bit						0			TOPSOIL: Clayey Silt, low plasticity, brown, with root fibres				
									FILL: Clayey Silt, low plasticity, brown, with gravel	M<OMC			Well compacted
				U50	N=20 4,10,10	0.5			FILL: Silty Clay, low to medium plasticity, brown, with gravel	M<OMC			
						1							
						1.5							
					N=16 8,7,9	2							
						2.5			FILL: Silty Clay, medium to high plasticity, brown mottled grey and red, with gravel and ironstones	M≤OMC			
						3							
					N=14 4,6,8	3.5							
						4			FILL: Silty Clay, medium to high plasticity, brown, with gravel and root fibres	M≤OMC			Mixed with topsoil
						4.5			Borehole No 2 terminated at 4.5m				

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 3
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅69.791

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			FILL: Clayey Silt, low plasticity, brown, with gravel	M<OMC			
					N=12 6,6,6	0.5			FILL: Silty Clay, medium to high plasticity, brown mottled grey and red, with gravel and ironstones	M≤OMC			
						1							
						1.5		CI-CH	Silty CLAY, medium to high plasticity, yellow-brown mottled grey, traces of ironstones	M≤PL	St		Residual
					N=8 3,3,5	2		CH	Silty CLAY, high plasticity, mottled orange and grey, stiff, with ironstones	M≤PL	St		
						2.5							
					N=R	3			SHALE, brown-black, low to medium strength, extremely to distinctly weathered Borehole No 3 terminated at 3.5m				Bedrock
						3.5							
						4							
						4.5							

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 4
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅70.973

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
TC bit						0			TOPSOIL: Clayey Silt, low plasticity, brown, with root fibres	M<OMC			Well compacted
									FILL: Silty Clay, low to medium plasticity, brown, with gravel				
					N=8 2,3,5	0.5							
				U_{50}				CI-CH	Silty CLAY, medium to high plasticity, yellow-brown mottled grey, traces of ironstones	M<PL	St		
						1							
						1.5							
								CH	Shaley CLAY, high plasticity, grey mottled red-orange, with ironstones	M<PL	St		
					15,20 12/50	2			SHALE, brown-black, low to medium strength, extremely to distinctly weathered				Bedrock
						2.5							
						3							
								CH	Shaley CLAY, high plasticity, grey mottled red-orange, with ironstones	M<PL	St		Clay band
					N=22 5,8,14	3.5							
						4							
									SHALE, brown-black, low to medium strength, extremely to distinctly weathered				Bedrock
						4.5			Borehole No 4 terminated at 4.5m				

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 5
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅72.276

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
TC bit					N=29 5,11,18	0 0.5 1			FILL: Silty Clay, low to medium plasticity, brown, with gravel	M<OMC			Well compacted
					N=7 2,3,4	1.5 2		CI-CH	Silty CLAY, medium to high plasticity, brown-black mottled red	M≤PL	F-St		Residual
						2.5		CI	Sandy Silty CLAY, medium plasticity, brown, with gravel	M≤PL	F-St		
						3		CH	Silty CLAY, high plasticity, red, stiff, with ironstones	M≤PL	St		
						3.5		CH	Silty CLAY, high plasticity, mottled orange and grey, stiff, with ironstones				
					N=21 9,10,11	4		CH	Shaley CLAY, high plasticity, grey mottled red-orange, with ironstones	M<PL	St		
						4.5			Borehole No 5 terminated at 4.0m				

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 6
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅73.703

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			FILL: Clayey Silt, low plasticity, brown, with gravel	M<OMC			Well compacted
				U_{50}	N=13 6,6,7	0.5							
						1							
						1.5			FILL: Silty Clay, medium to high plasticity, brown mottled grey and red, with gravel and ironstones	M≤OMC			
					N=4 2,2,2	2							
						2.5							
						3		CH	Silty CLAY, high plasticity, red, stiff, with ironstones	M≤PL	St		Residual
					N=18 4,7,11	3.5			Silty CLAY, high plasticity, mottled orange and grey, stiff, with ironstones				
								CH	Shaley CLAY, high plasticity, grey mottled red-orange, with ironstones	M<PL	St-VSt		
						4			Borehole No 6 terminated at 4.0m				
						4.5							

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engineering log - borehole

Client : Nash Project Management Pty Ltd
Project : Proposed Townhouse Development
Location : 62 Bradley Street
Glenmore Park (Bradley Heights)

Job No. : 14035/1
Borehole No. : 7
Date : 29/05/2017
Logged/Checked by: SM

drill model and mounting : Hydro Powered Truck Mounted Rig **slope :** **deg.** **R.L. surface :** ≅74.700

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

method	groundwater	env samples	PID reading (ppm)	geo samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
						0			TOPSOIL: Clayey Silt, low plasticity, brown, with root fibres				
									FILL: Clayey Silt, low plasticity, brown, with gravel				Well compacted
					N=18 4,8,10	0.5			FILL: Silty Clay, low to medium plasticity, brown, with gravel				
						1							
						1.5			FILL: Silty Clay, medium to high plasticity, brown-black, with gravel and ironstones				
					N=20 5,8,12	2							
						2.5		CI	Silty CLAY, medium plasticity, yellow-brown mottled grey, traces of ironstones	M≤PL	St		Residual
						3		CH	Silty CLAY, high plasticity, mottled orange and grey, stiff, with ironstones	M≤PL	St		
						3.5		CH	Shaley CLAY, high plasticity, grey mottled red-orange, with ironstones	M<PL	St-VSt		SPT refusal at 3.5m
									SHALE, brown-black, low to medium strength, extremely to distinctly weathered				Bedrock
						4			Borehole No 7 terminated at 4.0m				
						4.5							

KEY TO SYMBOLS

Symbol Description

Strata symbols

Topsoil

Fill

Silty Clay
medium to high plasticity

Silty Clay
high plasticity

Shale

Shaley Clay
high plasticity

Silty Clay
medium plasticity

Descriptions of various line types (solid, dotted, etc.)

Profile change

Gradual profile change

Notes:

1. Exploratory borings were drilled between 29/05/2017 and 29/05/2017 using a 50, 100 and 125mm diameter continuous flight power auger.

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

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

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Log Symbols & Abbreviations (Non-cored Borehole Log)

Log Column	Symbol/Value	Description
Drilling Method	V-bit TC-bit RR DB BB	Hardened steel 'V' shaped bit attached to auger Tungsten Carbide bit attached to auger Tricone (Rock Roller) bit Drag bit 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 G P	Glass bottle and plastic bag sample over depths shown on log Glass bottle sample over depths shown on log Plastic bag sample over depths shown on log
PID Reading	100	PID reading in ppm
Geotechnical Sample	DS DB U_{50}	Disturbed Small bag sample over depths shown on log Disturbed Bulk sample over depths shown on log Undisturbed 50mm tube sample over depths shown on log
Field Test	N=10 3,5,5 N=R 10,15/100	Standard Penetration Test (SPT) 'N' value. Individual numbers indicate blows per 150mm penetration. '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 GW GM GC SP SW SM SC ML MI MH CL CI CH	Poorly Graded GRAVEL Well graded GRAVEL Silty GRAVEL Clayey GRAVEL Poorly graded SAND Well graded SAND Silty SAND Clayey SAND SILT / Sandy SILT / clayey SILT, low plasticity SILT / Sandy SILT / clayey SILT, medium plasticity SILT / Sandy SILT / clayey SILT, high plasticity CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, low plasticity CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, medium plasticity CLAY / Silty CLAY / Sandy CLAY / Gravelly CLAY, high plasticity
Moisture Condition Cohesive soils Cohesionless soils	 M<PL M=PL M>PL D M W	 Moisture content less than Plastic Limit Moisture content equal to Plastic Limit Moisture content to be greater than Plastic Limit Dry - Runs freely through hand Moist - Tends to cohere Wet - Tends to cohere
Consistency Cohesive soils	 VS S F St VSt H	Term — Undrained shear strength, C_u (kPa) — Hand Penetrometer (Qu) Very Soft — ≤12 — <25 Soft — >12 ≤25 — 25 – 50 Firm — >25 ≤50 — 50 – 100 Stiff — >50 ≤100 — 100 – 200 Very Stiff — >100 ≤200 — 200 – 400 Hard — >200 — >400
Density Index Cohesionless soils	 VL L M D VD	Term — Density Index, I_D (%) — SPT 'N' (blows/300mm) Very Loose — ≤15 — ≤5 Loose — >15 ≤35 — >5 ≤10 Medium Dense — >35 ≤65 — >10 ≤30 Dense — >65 ≤85 — >30 ≤50 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	 Residual Alluvium Colluvial Aeolian Marine	Geological origin of soils Residual soils above bedrock River deposited Alluvial soils Gravity deposited Colluvial soils Wind deposited Aeolian soils Marine Soils

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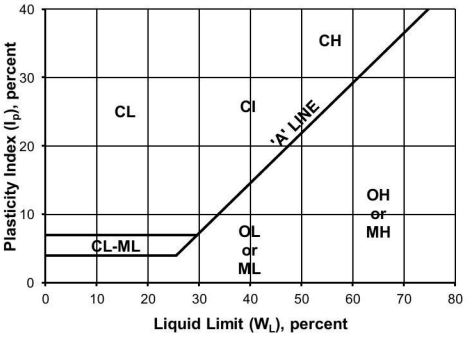
AS1726 – Unified Soil Classification System

Major Divisions		Particle size (mm)	Group Symbol	Typical Names	Field Identifications Sand and Gravels			Use the gradation of material passing 63mm for classification of fractions according to the criteria given in 'Major Divisions'	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											
	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)					**Dry Strength**	**Dilatancy**	**Toughness**						
	SILTS & CLAYS (liquid limit < 50%)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	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				



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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		

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AS1726 – Identification of Sedimentary Rocks for Engineering Purposes

Grain Size mm		Bedded rocks (mostly sedimentary)							
More than 20	20	Grain Size Description				At least 50% of grains are of carbonate		At least 50% of grains are of fine-grained volcanic rock	
	6	RUDACEOUS		CONGLOMERATE Rounded boulders, cobbles and gravel cemented in a finer matrix		LIMESTONE and DOLOMITE (undifferentiated)	Calcirudite	Fragments of volcanic ejecta in a finer matrix	SALINE ROCKS
	2			Breccia Irregular rock fragments in a finer matrix				Rounded grains AGGLOMERATE Angular grains VOLCANIC BRECCIA	Halite Anhydrite
	0.6	ARENACEOUS	Coarse	SANDSTONE Angular or rounded grains, commonly cemented by clay, calcite or iron minerals			Calcarenite	Cemented volcanic ash	Gypsum
	0.2		Medium	Quartzite Quartz grains and siliceous cement				TUFF	
	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			Grain size description	Pegmatite			Pyrosenite	More than 20
		MARBLE						20
COARSE	GNEISS Well developed but often widely spaced foliation sometimes with schistose bands	QUARTZITE	COARSE	GRANITE	Diorite	GABBRO	Peridorite	6
	Migmatite Irregularly foliated: mixed schists and gneisses	Granulite HORNFELS		These rocks are sometimes phorphyritic and are then described, for example, as porphyritic granite				2
MEDIUM	SCHIST Well developed undulose foliation; generally much mica	Amphibolite	MEDIUM	Micorgranite	Microdiorite	Dolerite		0.6
		Serpentine		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 cryptocrystalline
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					