REPORT

TO
JDH ARCHITECTS

ON
GEOTECHNICAL INVESTIGATION

FOR
PROPOSED ALTERATIONS AND ADDITIONS

AT
GREYSTANES PUBLIC SCHOOL, MERRYLANDS ROAD, GREYSTANES NSW

24 June 2017
Ref: 30431Srpt

dlcs AS/NZS ISO 9001 certified
AS/NZS 4801 certified

JK Geotechnics
GEOTECHNICAL & ENVIRONMENTAL ENGINEERS

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Report No: 30431Srpt
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Report prepared by:

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Principal I Geotechnical Engineer

For and on behalf of
JK GEOTECHNICS
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NORTH RYDE BC NSW 1670

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1 INTRODUCTION

This report presents the results of a geotechnical investigation for the proposed additions and alterations to the existing Greystanes Public School at Merrylands Road, Greystanes, NSW. The investigation was commissioned by Alison Cox of JDH Architects in an email dated 21 April 2016. The commission was on the basis of our proposal (Ref P44706S) dated 5 April 2017. The site location is shown on the attached Figure 1.

Based on the supplied concept architectural drawings prepared by JDH Architects, we understand that following the demolition of existing structures, the proposed additions will comprise separate one and three storey buildings. We have assumed that nominal site levelling will be required and that typical structural loads for this type of development apply.

The purpose of the investigation was to obtain geotechnical information on subsurface conditions as a basis for comments and recommendations on site preparation, AS2870 site classification, shrink-swell potential, footings and on grade floor slabs.

We were also commissioned to carry out a Stage 1 Contamination Assessment and preliminary salinity assessment. This work was carried out by Environmental Investigation Services (EIS) in conjunction with the geotechnical investigations. Reference should be made to the EIS report, (Ref: E30431KPrpt) for further details.

2 INVESTIGATION PROCEDURE

The fieldwork for the investigation was carried out on 3 June 2017 and comprised the drilling of five boreholes (BH1 to BH5) to depths between 5.0m and 6.0m using our track mounted JK205 drill rig. The test locations, as indicated on attached Figure 2, were set out using taped measurements from existing surface features and were electromagnetically scanned by a specialist subcontractor for buried services prior to drilling commencing. The surface reduced levels shown on the borehole logs were estimated by interpolation between spot heights shown on the provided survey plan (Ref 15920 detail, dated 11-16/01/17) prepared by C.M.S Surveyors Pty Limited. The survey plan forms the basis of Figure 2 and the survey datum is the Australian Height Datum (AHD).

The nature and composition of the subsurface soil and rock strata were assessed by logging the materials recovered during drilling. The relative compaction of the fill and the strength of the residual silty clay profile were assessed by Standard Penetration Test (SPT) ‘N’ values, which were augmented, where possible, by hand penetrometer readings on cohesive samples recovered in the SPT split tube sampler. The strength of the shale and sandstone bedrock was assessed from observation of drilling resistance using a tungsten carbide (TC) bit, examination of the recovered rock cuttings and subsequent correlation with the results of laboratory moisture contents. It should be noted that strengths assessed in this way are approximate and variances of one strength order should not be unexpected. Groundwater observations were recorded during drilling and shortly after completion of the boreholes. No long term groundwater monitoring has been carried out. Further details of the methods and procedures employed in the investigation are presented in the attached Report Explanation Notes.

Our geotechnical engineer was present full-time on site during the fieldwork to set out the test locations, direct the electromagnetic scanning, log the encountered subsurface profile and nominate insitu testing and sampling. The borehole logs are presented with this report together with a glossary of logging terms and symbols used.

Selected soil and rock chip samples were returned to our Soil Test Services Pty Ltd (STS) NATA registered laboratory, to test for moisture content, Atterberg Limits and linear shrinkage, grading and 4 day soaked California Bearing Ratio (CBR). The results of the testing are presented on the attached STS Tables A, B, C. Contamination testing of the site soils was outside the scope of this geotechnical investigation.

3 RESULTS OF INVESTIGATION

3.1 Site Description

The site lies within undulating topography on a north and west facing slope of approximately 3° to 5°. The site appears to have been regraded with cut and fill operations creating an embankment with a northern batter slope with falls of up to 20° within the northern and eastern portions of the site. The site is bound to the south by Merrylands Road and has an irregular shape with an approximate length of 330m (east-west) and 100m width (north-south).

At the time of fieldwork, the site was occupied by one and two storey brick and clad frame school buildings and several demountables. The ground surface surrounding the buildings was mainly concrete and asphaltic concrete covered pavements with garden beds and lawns extending to the site boundaries. Large lawn areas existed within the north-eastern and north-western areas of the site, and a large concrete covered sports court occupied the south-eastern corner of the site. Several medium to large trees were scattered around the site and along the boundary lines.

Surrounding the site to the north, east and west were single and double storey residential houses which appeared in a fair to good condition.

3.2 Subsurface Conditions

The 1:100,000 geological map of Penrith (Geological Survey of NSW, Geological Series Sheet 9030) indicates the site is underlain by Bringelly Shale of the Wianamatta Group. The investigation revealed a generalised subsurface profile comprising shallow to moderate depths of fill overlying residual silty clays with weathered shale bedrock at moderate depths. For detailed subsurface conditions at specific locations, reference should be made to the attached borehole logs. A summary of the subsurface conditions as encountered, is presented below:

Fill

Fill, comprising clayey and/or sandy soils, was encountered in all boreholes to depths between 0.2m (BH2) and 1.4m (BH3 and BH4). Inclusions of roots, root fibres, igneous gravel and clay/sand were found in the fill. Based on the SPT results, the fill was assessed (where possible) as being poorly to moderately compacted and dry. The fill was surfaced by asphaltic concrete at BH2 and BH5.

Residual Soils

Natural silty clays were encountered below the fill in all boreholes and were of either medium or high plasticity and of very stiff to hard strength. The residual silty clays contained inclusions of ironstone and shale gravel and root fibres.

Weathered Bedrock

Weathered shale bedrock was encountered in all boreholes at the depths and RL's tabulated below:

Borehole	Borehole RL (mAHD)	Depth to Weathered Bedrock (m)	RL of Weathered Bedrock (mAHD)
BH1	57.9	2.0	55.9
BH2	60.0	1.0	59.0
BH3	60.1	2.8	57.3
BH4	58.0	3.0	55.0
BH5	65.5	2.0	63.5

The shale on first contact was extremely weathered and of extremely low strength but improved with depth to low and medium strengths, although BH2 and BH4 encountered medium to high strength shale and BH2 reaching auger refusal at 5.0m.

3.3 Laboratory Test Results

The laboratory Atterberg limits tests correlated well with our field assessment of the plasticity of the residual clays, confirming these to be of high plasticity. The linear shrinkage tests indicated the residual clays to be highly reactive to moisture content change. The grading and hydrometer tests gave particle size distributions consistent with field logging. The moisture content tests on the recovered rock chip samples generally correlated well with our field assessment of the augered bedrock strength.

The four day soaked CBR tests carried out on the residual silty clay samples from BH1 and BH5 returned values of 1.5% and 1.0% respectively. The clay samples were compacted prior to CBR testing at close to their respective Standard Optimum Moisture Content (SOMC). During soaking, the residual clays swelled by 4.5% (BH1) and 5% (BH5) which also indicates their reactivity to moisture content changes.

4 COMMENTS AND RECOMMENDATIONS

4.1 Site Classification

Based on the results of the investigation, the areas of the proposed new buildings classify as Class ‘P’ sites in accordance with AS2870-2011. This is due to the potential for abnormal moisture conditions resulting from the presence of existing trees and covered surfaces as well as there being moderate depths of uncontrolled fill at some locations.

Notwithstanding this, where footings are founded uniformly on the underlying residual silty clays, it is likely that under ‘normal’ site conditions (where the above limitations do not occur) the soils below the buildings will undergo shrink-swell movements similar to a Class ‘H1’ site.

The designer must take into account the presence of existing trees and that some trees will be removed to allow development. The presence of trees and the removal of trees will increase the potential for problematic shrink-swell movements beyond the normal Class ‘H1’ range, probably towards the ‘H2’ range, depending upon the number, size, type and proximity of the trees.

Levelling of sites by cutting and filling also adversely affects site classification as the resulting ground has a diminished or absent cracked zone.

4.2 Subgrade Preparation and Engineered Fill

If the floor slabs will be fully suspended on the footings then no particular subgrade preparation would be necessary other than stripping all root-affected or deleterious topsoil/fill.

Alternatively, if the slab is to rely on the soil subgrade for support then the following subgrade preparation is recommended; the slab-on-ground should also be made separate from the footings on the building:

1. Stripping of top layer of root affected, deleterious fill, silty or topsoil layer; these stripped materials should be taken off site or used for landscaping as they are not suitable for reuse as engineering fill.
2. Thereafter, any remaining fill should be further excavated down to the surface of the natural clay if the fill layer exceeds about 0.3m thickness. Fill up to about 0.3m thick can be proof rolled in-situ.
3. Once the subgrade level is reached then this should be proof-rolled using about seven passes of a 7 tonne minimum deadweight non-vibratory smooth drum roller under the supervision of an experienced geotechnician or geotechnical engineer. The objectives of the proof rolling should be to improve the near surface compaction/strength of the subsoil and to detect any unstable areas. Caution is required when proof rolling near the site boundaries and existing buildings even when using a vibratory roller, so as not to damage buildings or services. Tolerable vibration thresholds are given in the attached *Vibration Emission Design Goals information* sheet.
4. Unstable subgrade detected during proof rolling should be locally excavated down to a sound base and replaced with engineered fill or further advice should be sought.
5. Any fill placed to raise site levels should be engineered fill.

Earthworks recommendations provided in this report should be complemented by reference to AS3798.

Any fill used to replace unstable areas, existing fill or raise site levels should be engineered fill. Materials preferred for use as engineered fill are well-graded granular materials, such as ripped or crushed sandstone, free of deleterious substances and having a maximum particle size not exceeding 75 millimetres (mm). Such fill should be compacted in layers not greater than 200mm loose thickness, to a density of at least 98% of Standard Maximum Dry Density (SMDD). If clay fill is approved for use then it should be compacted to a density between 98% and 102% of SMDD and have a moisture content within 2% of Standard Optimum Moisture Content (SOMC).

Soils comprising clays of medium or high plasticity should not be used as fill unless a geotechnical approval is obtained prior to use as it will affect the site classification. Density tests should be regularly carried out on the fill to confirm the above specifications are achieved. The frequency of density testing should be at least one test per layer per 500m^2 or three tests per visit whichever required the most tests. We recommend that at least Level 2 control of fill compaction, as defined in AS3798-1996, be adhered to on this site. If fill is to support footings we recommend Level 1 control.

4.3 Footings

Suitable footing systems for the proposed buildings would include high level footings or bored piles. Prior to footing construction the subgrade preparation as noted in Section 4.2 must be completed.

Where pad/strip/raft footings are adopted, these should be embedded into the natural clays of very stiff strength (or better) and can be designed on the basis of a maximum allowable bearing pressure of 200kPa. Footings founded in engineered fill can be designed for an allowable bearing pressure of 100kPa.Pad/strip footings must be sized and embedded in accordance with the requirements of AS2870 and the recommendations outlined in Section 4.1 above.

Bored piles can be founded at a minimum depth of 2m below ground level and founded in very stiff to hard clay for which an allowable end bearing pressure of 400kPa may be adopted. Shaft lengths below 2m may be designed for an allowable skin friction of 25kPa, provided the surface is not smeared (which usually requires a special cleaning tooth on the auger. Penetrating a bit deeper to shale at the first contact (plus a nominal socket of 0.3m) would allow bearing pressures of 700kPa to be adopted. Additional penetration to shale of at least very low to low strength would allow an end bearing pressure of 1000kpa to be adopted. For rock sockets an allowable shaft adhesion of 10% of the end bearing pressure may be adopted for each layer where loads are in compression and 5% for loads in tension. Where one part of a structure will be founded on rock then the whole of the structure must be similarly founded to avoid differential movement problems, whether high level or piled footings are used.

Void formers should be used below footing beams to reduce the risk of uplift pressures due to swelling clays. A nominal void thickness of 50mm would be appropriate. The need for void formers below suspended rafts should also be considered and will depend on the details of the situation at each individual building.

At least a selection of pad/strip/raft footings and bored piles should be inspected by a geotechnical engineer prior to placing steel and pouring concrete to confirm that the appropriate foundation material is being achieved. Footings should be cleaned and poured with minimum delay to avoid deterioration. Water should be prevented from ponding in the base of footing excavations as this will soften the foundation material, resulting in further excavation and cleaning being required.

4.4 Pavement Design

The soaked CBR of the two samples tested were 1.0% and 1.5% indicating a poor subgrade is present at this site. The design of any pavements supported on the natural clays should be designed for a CBR value of 1.0%. Flexible pavements supported for such low values will be relatively thick, and consequently a select granular material or a lime stabilised layer of 0.3m thickness should be nominated with a minimum CBR value of 10%. Mechanistic design using software such as CIRCLY will usually result in a more economical pavement.

Rigid pavements must have a sub-base layer comprising at least 100mm of good quality roadbase conforming to the RMS specification for DGB20.

5 SALINITY

The site is located in an area where soil and groundwater salinity may occur. Salinity can affect the longevity and appearance of structures as well as causing adverse horticultural and hydrogeological effects. The local council has guidelines relating to salinity issues which should be checked for relevance to this project.

6 GENERAL COMMENTS

The recommendations presented in this report include specific issues to be addressed during the construction phase of the project. As an example, special treatment of soft spots may be required as a result of their discovery during proof-rolling, etc. In the event that any of the construction phase recommendations presented in this report are not implemented, the general recommendations may become inapplicable and JK Geotechnics accept no responsibility whatsoever for the performance of the structure where recommendations are not implemented in full and properly tested, inspected and documented.

The long term successful performance of floor slabs and pavements is dependent on the satisfactory completion of the earthworks. In order to achieve this, the quality assurance program should not be limited to routine compaction density testing only. Other critical factors associated with the earthworks may include subgrade preparation, selection of fill materials, control of moisture content and drainage, etc. The satisfactory control and assessment of these items may require judgment from an experienced engineer. Such judgment often cannot be made by a technician who may not have formal engineering qualifications and experience. In order to identify potential problems, we recommend that a pre-construction meeting be held so that all parties involved understand the earthworks requirements and potential difficulties. This meeting should clearly define the lines of communication and responsibility.

Occasionally, the subsurface conditions between the completed boreholes may be found to be different (or may be interpreted to be different) from those expected. Variation can also occur with groundwater conditions, especially after climatic changes. If such differences appear to exist, we recommend that you immediately contact this office.

This report provides advice on geotechnical aspects for the proposed civil and structural design. As part of the documentation stage of this project, Contract Documents and Specifications may be prepared based on our report. However, there may be design features we are not aware of or have not commented on for a variety of reasons. The designers should satisfy themselves that all the necessary advice has been obtained. If required, we could be commissioned to review the geotechnical aspects of contract documents to confirm the intent of our recommendations has been correctly implemented.

A waste classification will need to be assigned to any soil excavated from the site prior to offsite disposal. Subject to the appropriate testing, material can be classified as Virgin Excavated Natural Material (VENM), General Solid, Restricted Solid or Hazardous Waste. Analysis takes seven to 10 working days to complete, therefore, an adequate allowance should be included in the construction program unless testing is completed prior to construction. If contamination is encountered, then substantial further testing (and associated delays) should be expected. We strongly recommend that this issue is addressed prior to the commencement of excavation on site.

This report has been prepared for the particular project described and no responsibility is accepted for the use of any part of this report in any other context or for any other purpose. If there is any change in the proposed development described in this report then all recommendations should be reviewed. Copyright in this report is the property of JK Geotechnics. We have used a degree of care, skill and diligence normally exercised by consulting engineers in similar circumstances and locality. No other warranty expressed or implied is made or intended. Subject to payment of all fees due for the investigation, the client alone shall have a licence to use this report. The report shall not be reproduced except in full.

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SOIL TEST SERVICES

ABN 43 002 145 173

TABLE A
MOISTURE CONTENT, ATTERBERG LIMITS AND LINEAR SHRINKAGE TEST REPORT

Client:	JK Geotechnics	**Ref No:**	30431S
Project:	Proposed Alterations and Additions	**Report:**	A
Location:	Greystanes Public School, 781 Merrylands Road, Greystanes, NSW	**Report Date:**	21/06/2017
		Page 1 of 1	

AS 1289	TEST METHOD	2.1.1	3.1.2	3.2.1	3.3.1	3.4.1
BOREHOLE NUMBER	DEPTH m	MOISTURE CONTENT %	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %	LINEAR SHRINKAGE %
1	0.50-0.95	18.0	57	21	36	15.5
1	2.50-3.00	9.5				
2	0.50-0.95	10.4	55	21	34	15.5
2	2.50-3.00	7.0				
3	1.50-1.95	25.5				
3	4.00-4.50	9.8				
4	1.50-1.95	23.2				
4	4.00-4.50	10.9				
4	5.50-6.00	8.2				
5	0.50-0.95	16.6	52	20	32	15.0

Notes:

- The test sample for liquid and plastic limit was air-dried & dry-sieved
- The linear shrinkage mould was 125mm
- Refer to appropriate notes for soil descriptions
- Date of receipt of sample: 7/06/2017

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SOIL TEST SERVICES

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TABLE B
FOUR DAY SOAKED CALIFORNIA BEARING RATIO TEST REPORT

Client:	JK Geotechnics	**Ref No:**	30431S
Project:	Proposed Alterations and Additions	**Report:**	B
Location:	Greystanes Public School, 781 Merrylands Road, Greystanes, NSW	**Report Date:**	20/06/2017
		Page 1 of 1	

BOREHOLE NUMBER	1	5
DEPTH (m)	0.50 - 1.50	0.50 - 1.50
Surcharge (kg)	4.5	4.5
Maximum Dry Density (t/m^3)	1.79 STD	1.81 STD
Optimum Moisture Content (%)	14.1	16.4
Moulded Dry Density (t/m^3)	1.74	1.78
Sample Density Ratio (%)	97	98
Sample Moisture Ratio (%)	116	97
Moisture Contents		
Insitu (%)	15.0	16.0
Moulded (%)	16.4	15.8
After soaking and		
After Test, Top 30mm(%)	29.4	28.5
Remaining Depth (%)	19.6	20.0
Material Retained on 19mm Sieve (%)	0	0
Swell (%)	4.5	5.0
C.B.R. value: @2.5mm penetration	1.5	1.0

NOTES:

- Refer to appropriate Borehole logs for soil descriptions
- Test Methods : AS 1289 6.1.1, 5.1.1 & 2.1.1.
- Date of receipt of sample: 7/06/2017.

NATA

NATA Accredited Laboratory Number:1327

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Authorised Signature / Date
(D. Treweek)

20/6/17

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SOIL TEST SERVICES
ABN 43 002 145 173

TABLE C
PARTICLE SIZE DISTRIBUTION AND HYDROMETER TEST REPORT

Client: JK Geotechnics
Project: Proposed Alterations and Additions
Location: Greystanes Public School, 781 Merrylands Road, Greystanes, NSW

Ref No: 30431S
Report No: C
Report Date: 21/06/2017
Page 1 of 2

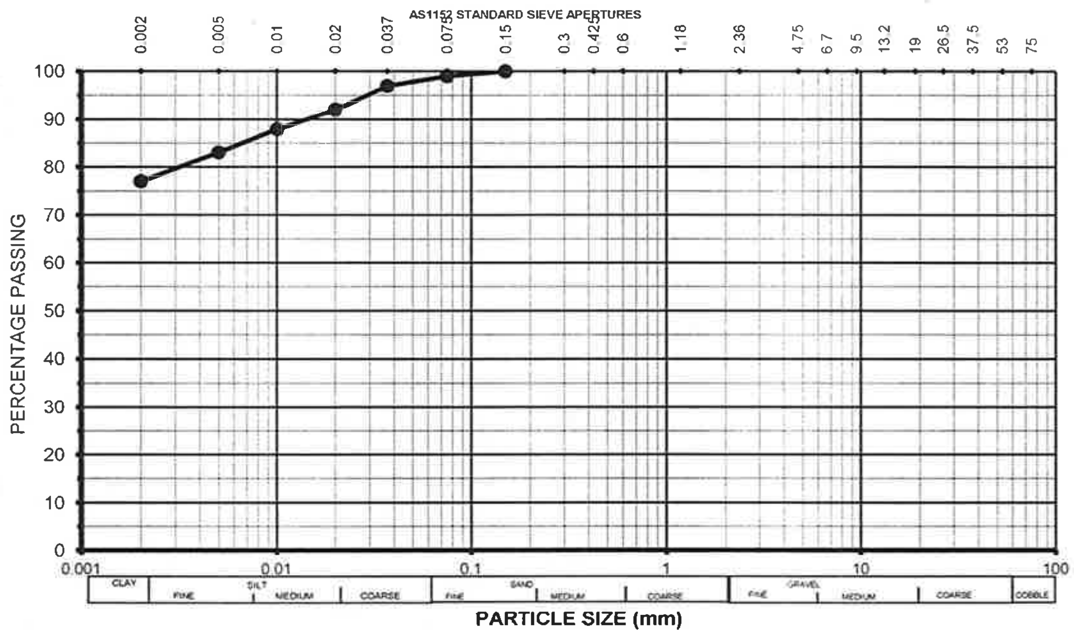
Borehole Number: 3
Depth (m): 1.50-1.95

SIEVE ANALYSIS RESULTS

SIEVE SIZE	% PASSING
150 µm	100
75 µm	99

HYDROMETER ANALYSIS

37 µm	97
20 µm	92
10 µm	88
5 µm	83
2 µm	77



Test Method: AS1289.3.6.1 & 3.6.3 Dry Sieve (washed)

• **Notes:**

• Please refer to appropriate notes for soil descriptions

NATA Accredited Laboratory
Number:1327

Approved Signatory / Date
21/6/17
(A. Tatikonda)

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SOIL TEST SERVICES
ABN 43 002 145 173

TABLE C
PARTICLE SIZE DISTRIBUTION AND HYDROMETER TEST REPORT

Client: JK Geotechnics
Project: Proposed Alterations and Additions
Location: Greystanes Public School, 781 Merrylands Road, Greystanes, NSW

Ref No: 30431S
Report No: C
Report Date: 21/06/2017
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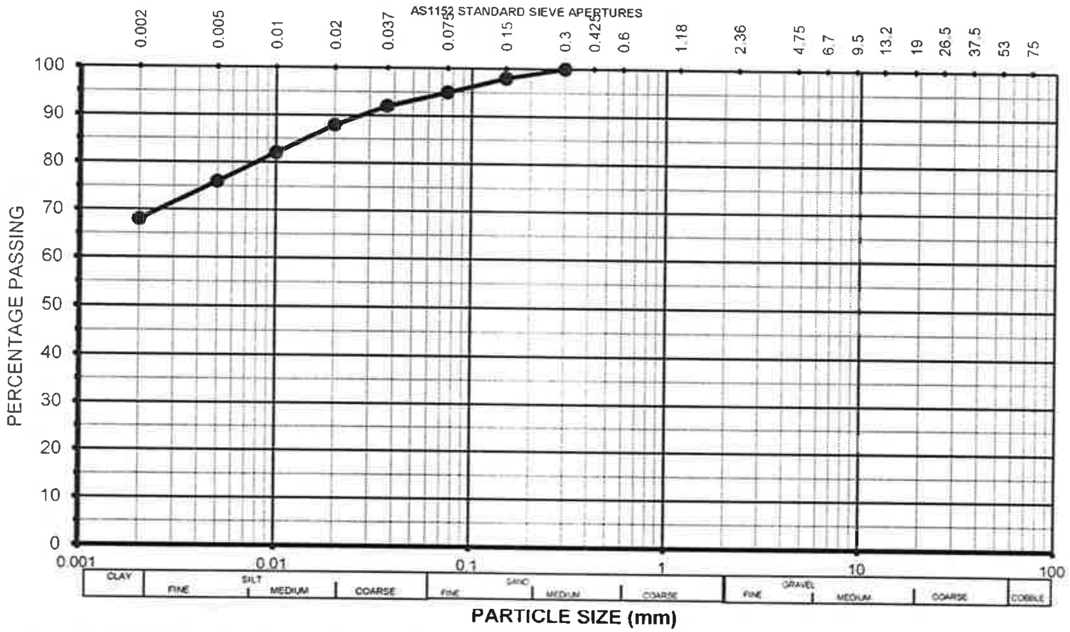

Borehole Number: 4
Depth (m): 1.50-1.95

SIEVE ANALYSIS RESULTS

SIEVE SIZE	% PASSING
300 µm	100
150 µm	98
75 µm	95
HYDROMETER ANALYSIS	
37 µm	92
20 µm	88
10 µm	82
5 µm	76
2 µm	68

Test Method: AS1289.3.6.1 & 3.6.3 Dry Sieve (washed)

• Notes:

• Please refer to appropriate notes for soil descriptions

NATA
NATA Accredited Laboratory
Number:1327

Approved Signatory / Date
21/6/17
(A. Tatikonda)

JK Geotechnics

GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
1
1/1

Client: JDH ARCHITECTS

Project: PROPOSED ALTERATIONS AND ADDITIONS

Location: GREYSTANES PUBLIC SCHOOL, 781 MERRYLANDS ROAD, GREYSTANES, NSW

Job No. 30431S **Method:** SPIRAL AUGER JK205 **R.L. Surface:** ≈ 57.9m

Date: 3/6/17 **Datum:** AHD

Logged/Checked by: K.S./P.S.

Groundwater Record	Samples (ES, U50, DB, DS)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			FILL: Silty sand, fine to coarse grained, dark brown, with roots and root fibres.	D			
		N = 18 6,8,10			CH	SILTY CLAY: high plasticity, light grey and red brown, with fine to coarse grained gravel.	MC<PL	H	>600 >600	RESIDUAL
			1							
		N = 26 7,9,17							>600 >600 580	
			2		-	SHALE: grey, with iron indurated bands.	DW	VL		VERY LOW TO LOW 'TC' BIT RESISTANCE
								VL-L		LOW TO MODERATE RESISTANCE
			3					L-M		MODERATE RESISTANCE
			4							
			5							
			6			END OF BOREHOLE AT 6.0m				
			7							

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GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
2
1/1

Client: JDH ARCHITECTS
Project: PROPOSED ALTERATIONS AND ADDITIONS
Location: GREYSTANES PUBLIC SCHOOL, 781 MERRYLANDS ROAD, GREYSTANES, NSW

Job No. 30431S
Method: SPIRAL AUGER JK205
R.L. Surface: ≈ 60.0m
Date: 3/6/17
Datum: AHD
Logged/Checked by: K.S./P.S.

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0	-	ASPHALTIC CONCRETE: 50mm.t				
			-	FILL: Gravelly sand, fine to coarse grained, brown and grey.	M			ROADBASE
	N = 21 7,9,12		CH	SILTY CLAY: high plasticity, light grey and orange brown, with fine to coarse gained ironstone and shale gravel.	MC<PL	H	>600 >600	RESIDUAL
		1	-	SHALE: grey, with iron indurated bands.	XW-DW	EL-VL		VERY LOW TO LOW 'TC' BIT RESISTANCE
					DW	L-M		LOW TO MODERATE RESISTANCE
						M-H		HIGH RESISTANCE
		5		END OF BOREHOLE AT 5.0m				'TC' BIT REFUSAL

JK Geotechnics

GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
3
1/1

Client: JDH ARCHITECTS

Project: PROPOSED ALTERATIONS AND ADDITIONS

Location: GREYSTANES PUBLIC SCHOOL, 781 MERRYLANDS ROAD, GREYSTANES, NSW

Job No. 30431S | **Method:** SPIRAL AUGER JK205 | **R.L. Surface:** ≈ 60.1m

Date: 3/6/17 | **Datum:** AHD

Logged/Checked by: K.S./P.S.

Groundwater Record	Samples (ES, U50, DB, DS)	Field Tests	Depth (m)	Graphic Log	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION			0			FILL: Silty sandy clay, low to medium plasticity, brown, with roots and root fibres, trace of ash.	MC≈PL			GRASS COVER APPEARS POORLY COMPACTED
		N = 5 2,2,3								
			1							
		N = 7 2,3,4			CL-CH	SILTY CLAY: medium to high plasticity, light grey and orange brown.	MC≈PL	VSt	260 220 270	RESIDUAL
			2							
			3		-	SHALE: grey, with iron indurated bands.	XW	EL		
							DW	VL-L		LOW 'TC' BIT RESISTANCE
			4							
			5							
								L-M		MODERATE RESISTANCE
			6			END OF BOREHOLE AT 6.0m				
			7							

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GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
4
1/1

Client: JDH ARCHITECTS
Project: PROPOSED ALTERATIONS AND ADDITIONS
Location: GREYSTANES PUBLIC SCHOOL, 781 MERRYLANDS ROAD, GREYSTANES, NSW

Job No. 30431S
Date: 3/6/17
Method: SPIRAL AUGER JK205
Logged/Checked by: K.S./P.S.
R.L. Surface: ≈ 58.0m
Datum: AHD

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0		FILL: Silty clayey sand, fine to medium grained, dark brown, with fine to coarse grained gravel.	M			GRASS COVER
	N = 13 4,7,6			FILL: Silty clay, low to medium plasticity, dark brown, with fine to coarse grained shale gravel.	MC≈PL			APPEARS WELL COMPACTED
	N = 15 5,6,9	1	CL-CH	SILTY CLAY: medium to high plasticity, light grey and orange brown, with fine to coarse grained ironstone gravel.	MC≈PL	VSt		RESIDUAL
	N > 15 11,15/ 100mm REFUSAL	3	-	SHALE: grey.	XW	EL		
				as above, but with XW seams.	DW	VL		VERY LOW TO LOW 'TC' BIT RESISTANCE
		5				L		MODERATE RESISTANCE
						M-H		HIGH RESISTANCE
		6		END OF BOREHOLE AT 6.0m				

JK Geotechnics
GEOTECHNICAL AND ENVIRONMENTAL ENGINEERS

BOREHOLE LOG

Borehole No.
5
1/1

Client: JDH ARCHITECTS
Project: PROPOSED ALTERATIONS AND ADDITIONS
Location: GREYSTANES PUBLIC SCHOOL, 781 MERRYLANDS ROAD, GREYSTANES, NSW

Job No. 30431S
Method: SPIRAL AUGER JK205
R.L. Surface: ≈ 65.5m
Date: 3/6/17
Datum: AHD
Logged/Checked by: K.S./P.S.

Groundwater Record	Field Tests	Depth (m)	Unified Classification	DESCRIPTION	Moisture Condition/ Weathering	Strength/ Rel. Density	Hand Penetrometer Readings (kPa.)	Remarks
DRY ON COMPLETION		0		ASPHALTIC CONCRETE: 50mm.t				
			-	FILL: Gravelly sand, fine to coarse grained, brown.	M			ROADBASE
	N = 17 4,8,9		CH	SILTY CLAY: high plasticity, orange brown, with fine to coarse grained ironstone and shale gravel.	MC<PL	H	>600 >600	RESIDUAL
	N = 30 9,14,16	1		SILTY CLAY: medium to high plasticity, grey, with fine to coarse grained ironstone gravel.			>600 530 560	
		2	-	SHALE: grey, with iron indurated bands.	XW	EL		
					DW	VL-L		VERY LOW TO LOW 'TC' BIT RESISTANCE
		3						
		4						
		5				L-M		MODERATE RESISTANCE
		6		END OF BOREHOLE AT 6.0m				
		7						

Samples: ES | U50 | DB | DS

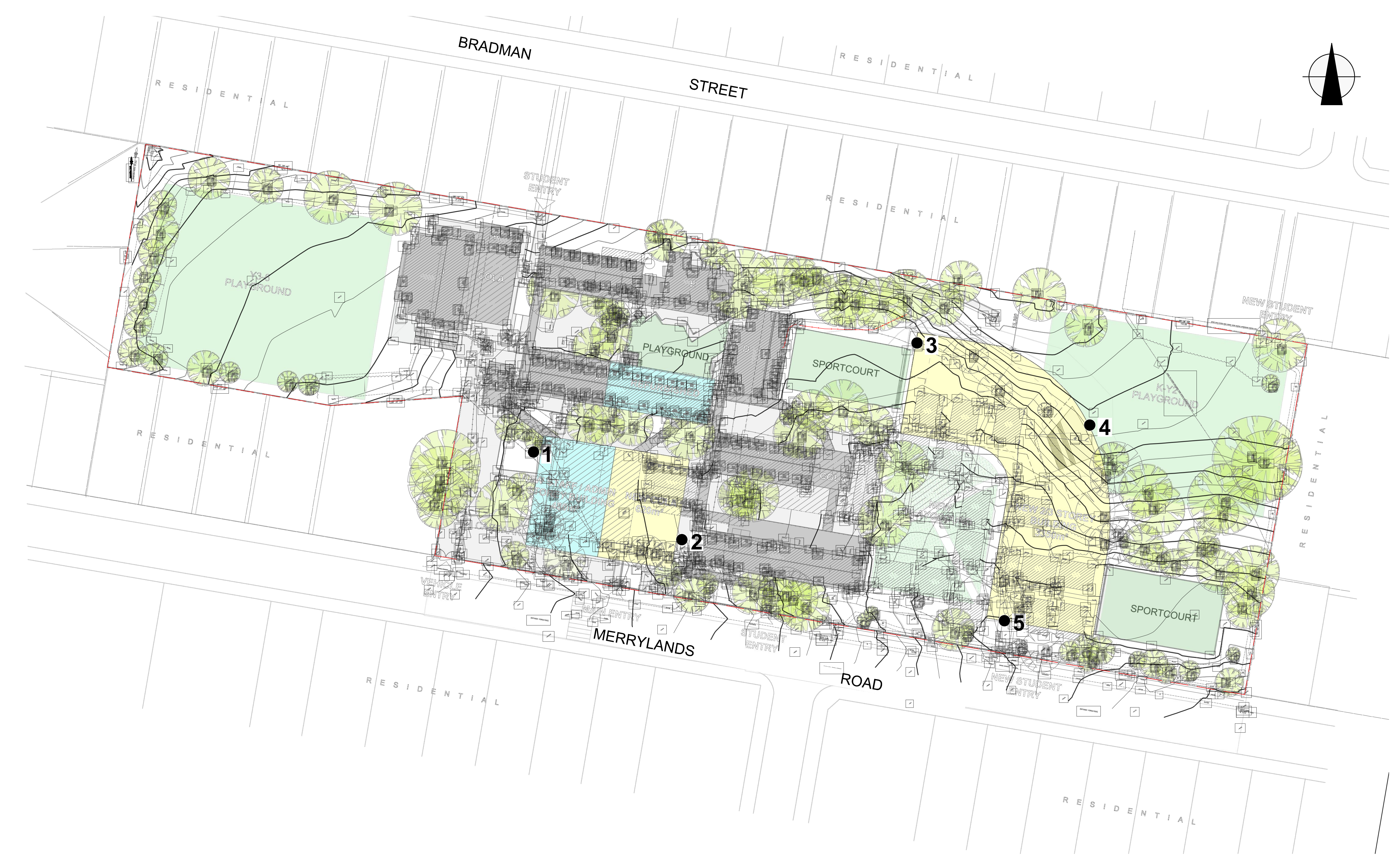
PLOT DATE: 23/06/2017 10:21:51 AM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30431S GREYSTANES\CAD\30431S.DWG

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.5.1557
AERIAL IMAGE ©: 2015 GOOGLE INC.

This plan should be read in conjunction with the JK Geotechnics report.

Title:	**SITE LOCATION PLAN**
Location:	GREYSTANES PUBLIC SCHOOL MERRYLANDS ROAD, GREYSTANES, NSW
Report No: 30431S	Figure No: 1

JK Geotechnics



0 10 20 30 40 50
SCALE 1:1000 @A3 METRES

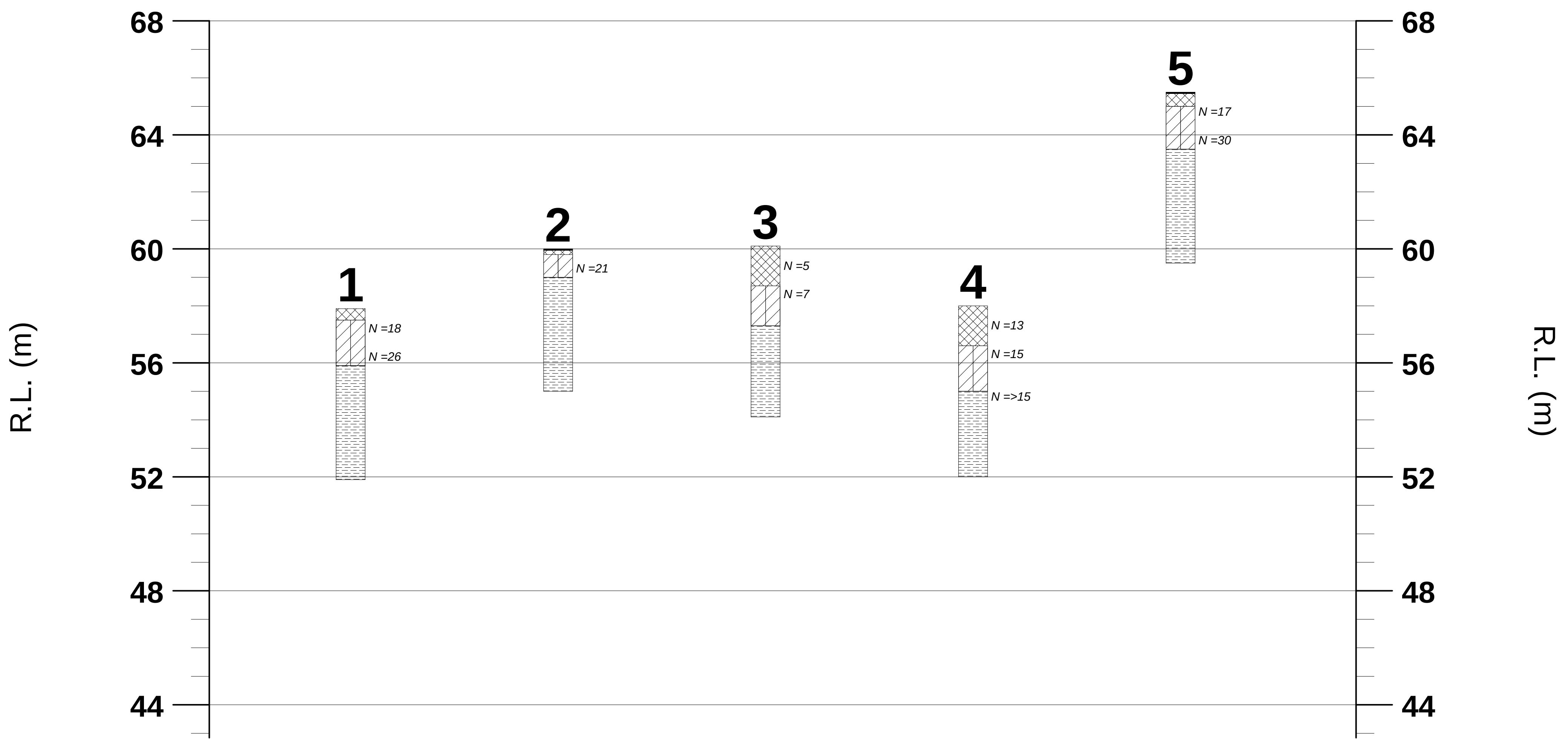
This plan should be read in conjunction with the JK Geotechnics report.

Title:	BOREHOLE LOCATION PLAN
Location:	GREYSTANES PUBLIC SCHOOL MERRYLANDS ROAD, GREYSTANES, NSW
Report No: 30431S	Figure No: 2

JK Geotechnics

PLOT DATE: 23/06/2017 10:32:04 AM DWG FILE: S:\6 GEOTECHNICAL\6F GEOTECHNICAL JOBS\30000'S\30431S GREYSTANES\CAD\30431S.DWG

GRAPHICAL BOREHOLE SUMMARY



Fill

Silty Clay

Shale

Asphaltic/ Bituminous Paving or Coal

N SPT "N" VALUE

Nc SOLID CONE BLOW COUNTS PER 150mm

NOTE: REFER TO BOREHOLE LOGS

Scale: 1 : 200 (vert) ; NTS (horiz)

JK Geotechnics

Job No.: 30431S

Figure No.: 3

VIBRATION EMISSION DESIGN GOALS

German Standard DIN 4150 – Part 3: 1999 provides guideline levels of vibration velocity for evaluating the effects of vibration in structures. The limits presented in this standard are generally recognised to be conservative.

The DIN 4150 values (maximum levels measured in any direction at the foundation, OR, maximum levels measured in (x) or (y) horizontal directions, in the plane of the uppermost floor), are summarised in Table 1 below.

It should be noted that peak vibration velocities higher than the minimum figures in Table 1 for low frequencies may be quite 'safe', depending on the frequency content of the vibration and the actual condition of the structure.

It should also be noted that these levels are 'safe limits', up to which no damage due to vibration effects has been observed for the particular class of building. 'Damage' is defined by DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls. Should damage be observed at vibration levels lower than the 'safe limits', then it may be attributed to other causes. DIN 4150 also states that when vibration levels higher than the 'safe limits' are present, it does not necessarily follow that damage will occur. Values given are only a broad guide.

Table 1: DIN 4150 – Structural Damage – Safe Limits for Building Vibration

Group	Type of Structure	Peak Vibration Velocity in mm/s			
		At Foundation Level at a Frequency of:			Plane of Floor of Uppermost Storey
		Less than 10Hz	10Hz to 50Hz	50Hz to 100Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use.	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 and 2 and have intrinsic value (eg. buildings that are under a preservation order).	3	3 to 8	8 to 10	8

Note: For frequencies above 100Hz, the higher values in the 50Hz to 100Hz column should be used.

REPORT EXPLANATION NOTES

INTRODUCTION

These notes have been provided to amplify the geotechnical report in regard to classification methods, field procedures and certain matters relating to the Comments and Recommendations section. Not all notes are necessarily relevant to all reports.

The ground is a product of continuing natural and man-made processes and therefore exhibits a variety of characteristics and properties which vary from place to place and can change with time. Geotechnical engineering involves gathering and assimilating limited facts about these characteristics and properties in order to understand or predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, excavation, probing, sampling, testing or other means of investigation. If so, they are directly relevant only to the ground at the place where and time when the investigation was carried out.

DESCRIPTION AND CLASSIFICATION METHODS

The methods of description and classification of soils and rocks used in this report are based on Australian Standard 1726, the SAA Site Investigation Code. In general, descriptions cover the following properties – soil or rock type, colour, structure, strength or density, and inclusions. Identification and classification of soil and rock involves judgement and the Company infers accuracy only to the extent that is common in current geotechnical practice.

Soil types are described according to the predominating particle size and behaviour as set out in the attached Unified Soil Classification Table qualified by the grading of other particles present (eg. sandy clay) as set out below:

Soil Classification	Particle Size
Clay	less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2mm
Gravel	2 to 60mm

Non-cohesive soils are classified on the basis of relative density, generally from the results of Standard Penetration Test (SPT) as below:

Relative Density	SPT 'N' Value (blows/300mm)
Very loose	less than 4
Loose	4 – 10
Medium dense	10 – 30
Dense	30 – 50
Very Dense	greater than 50

Cohesive soils are classified on the basis of strength (consistency) either by use of hand penetrometer, laboratory testing or engineering examination. The strength terms are defined as follows.

Classification	Unconfined Compressive Strength kPa
Very Soft	less than 25
Soft	25 – 50
Firm	50 – 100
Stiff	100 – 200
Very Stiff	200 – 400
Hard	Greater than 400
Friable	Strength not attainable – soil crumbles

Rock types are classified by their geological names, together with descriptive terms regarding weathering, strength, defects, etc. Where relevant, further information regarding rock classification is given in the text of the report. In the Sydney Basin, 'Shale' is used to describe thinly bedded to laminated siltstone.

SAMPLING

Sampling is carried out during drilling or from other excavations to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, moisture content, minor constituents and, depending upon the degree of disturbance, some information on strength and structure. Bulk samples are similar but of greater volume required for some test procedures.

Undisturbed samples are taken by pushing a thin-walled sample tube, usually 50mm diameter (known as a U50), into the soil and withdrawing it with a sample of the soil contained in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling used are given on the attached logs.

INVESTIGATION METHODS

The following is a brief summary of investigation methods currently adopted by the Company and some comments on their use and application. All except test pits, hand auger drilling and portable dynamic cone penetrometers require the use of a mechanical drilling rig which is commonly mounted on a truck chassis.

Test Pits: These are normally excavated with a backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3m for a backhoe and up to 6m for an excavator. Limitations of test pits are the problems associated with disturbance and difficulty of reinstatement and the consequent effects on close-by structures. Care must be taken if construction is to be carried out near test pit locations to either properly recompact the backfill during construction or to design and construct the structure so as not to be adversely affected by poorly compacted backfill at the test pit location.

Hand Auger Drilling: A borehole of 50mm to 100mm diameter is advanced by manually operated equipment. Premature refusal of the hand augers can occur on a variety of materials such as hard clay, gravel or ironstone, and does not necessarily indicate rock level.

Continuous Spiral Flight Augers: The borehole is advanced using 75mm to 115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling and insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface by the flights or may be collected after withdrawal of the auger flights, but they can be very disturbed and layers may become mixed. Information from the auger sampling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively lower reliability due to mixing or softening of samples by groundwater, or uncertainties as to the original depth of the samples. Augering below the groundwater table is of even lesser reliability than augering above the water table.

Rock Augering: Use can be made of a Tungsten Carbide (TC) bit for auger drilling into rock to indicate rock quality and continuity by variation in drilling resistance and from examination of recovered rock fragments. This method of investigation is quick and relatively inexpensive but provides only an indication of the likely rock strength and predicted values may be in error by a strength order. Where rock strengths may have a significant impact on construction feasibility or costs, then further investigation by means of cored boreholes may be warranted.

Wash Boring: The borehole is usually advanced by a rotary bit, with water being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from "feel" and rate of penetration.

Mud Stabilised Drilling: Either Wash Boring or Continuous Core Drilling can use drilling mud as a circulating fluid to stabilise the borehole. The term 'mud' encompasses a range of products ranging from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is only possible from intermittent intact sampling (eg. from SPT and U50 samples) or from rock coring, etc.

Continuous Core Drilling: A continuous core sample is obtained using a diamond tipped core barrel. Provided full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush. The length of core recovered is compared to the length drilled and any length not recovered is shown as CORE LOSS. The location of losses are determined on site by the supervising engineer; where the location is uncertain, the loss is placed at the top end of the drill run.

Standard Penetration Tests: Standard Penetration Tests (SPT) are used mainly in non-cohesive soils, but can also be used in cohesive soils as a means of indicating density or strength and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, "Methods of Testing Soils for Engineering Purposes" – Test F3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube with a tapered shoe, under the impact of a 63kg hammer with a free fall of 760mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

- In the case where full penetration is obtained with successive blow counts for each 150mm of, say, 4, 6 and 7 blows, as

  N = 13
  4, 6, 7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm, as

  N>30
  15, 30/40mm

The results of the test can be related empirically to the engineering properties of the soil.

Occasionally, the drop hammer is used to drive 50mm diameter thin walled sample tubes (U50) in clays. In such circumstances, the test results are shown on the borehole logs in brackets.

A modification to the SPT test is where the same driving system is used with a solid 60° tipped steel cone of the same diameter as the SPT hollow sampler. The solid cone can be continuously driven for some distance in soft clays or loose sands, or may be used where damage would otherwise occur to the SPT. The results of this Solid Cone Penetration Test (SCPT) are shown as 'N_c' on the borehole logs, together with the number of blows per 150mm penetration.

Static Cone Penetrometer Testing and Interpretation: Cone penetrometer testing (sometimes referred to as a Dutch Cone) described in this report has been carried out using a Cone Penetrometer Test (CPT). The test is described in Australian Standard 1289, Test F5.1.

In the tests, a 35mm or 44mm diameter rod with a conical tip is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the frictional resistance on a separate 134mm or 165mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are electrically connected by wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output as incremental digital records every 10mm. The results given in this report have been plotted from the digital data.

The information provided on the charts comprise:

- Cone resistance – the actual end bearing force divided by the cross sectional area of the cone – expressed in MPa.
- Sleeve friction – the frictional force on the sleeve divided by the surface area – expressed in kPa.
- Friction ratio – the ratio of sleeve friction to cone resistance, expressed as a percentage.

  The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and occasionally very soft clays, rising to 4% to 10% in stiff clays and peats. Soil descriptions based on cone resistance and friction ratios are only inferred and must not be considered as exact.

Correlations between CPT and SPT values can be developed for both sands and clays but may be site specific.

Interpretation of CPT values can be made to empirically derive modulus or compressibility values to allow calculation of foundation settlements.

Stratification can be inferred from the cone and friction traces and from experience and information from nearby boreholes etc. Where shown, this information is presented for general guidance, but must be regarded as interpretive. The test method provides a continuous profile of engineering properties but, where precise information on soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometers: Portable Dynamic Cone Penetrometer (DCP) tests are carried out by driving a rod into the ground with a sliding hammer and counting the blows for successive 100mm increments of penetration.

Two relatively similar tests are used:

- Cone penetrometer (commonly known as the Scala Penetrometer) – a 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm (AS1289, Test F3.2). The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various Road Authorities.
- Perth sand penetrometer – a 16mm diameter flat ended rod is driven with a 9kg hammer, dropping 600mm (AS1289, Test F3.3). This test was developed for testing the density of sands (originating in Perth) and is mainly used in granular soils and filling.

LOGS

The borehole or test pit logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions, and their reliability will depend to some extent on the frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will enable the most reliable assessment, but is not always practicable or possible to justify on economic grounds. In any case, the boreholes or test pits represent only a very small sample of the total subsurface conditions.

The attached explanatory notes define the terms and symbols used in preparation of the logs.

Interpretation of the information shown on the logs, and its application to design and construction, should therefore take into account the spacing of boreholes or test pits, the method of drilling or excavation, the frequency of sampling and testing and the possibility of other than 'straight line' variations between the boreholes or test pits. Subsurface conditions between boreholes or test pits may vary significantly from conditions encountered at the borehole or test pit locations.

GROUNDWATER

Where groundwater levels are measured in boreholes, there are several potential problems:

- Although groundwater may be present, in low permeability soils it may enter the hole slowly or perhaps not at all during the time it is left open.
- A localised perched water table may lead to an erroneous indication of the true water table.
- Water table levels will vary from time to time with seasons or recent weather changes and may not be the same at the time of construction.
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole or 'reverted' chemically if water observations are to be made.

More reliable measurements can be made by installing standpipes which are read after stabilising at intervals ranging from several days to perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from perched water tables or surface water.

FILL

The presence of fill materials can often be determined only by the inclusion of foreign objects (eg. bricks, steel, etc) or by distinctly unusual colour, texture or fabric. Identification of the extent of fill materials will also depend on investigation methods and frequency. Where natural soils similar to those at the site are used for fill, it may be difficult with limited testing and sampling to reliably determine the extent of the fill.

The presence of fill materials is usually regarded with caution as the possible variation in density, strength and material type is much greater than with natural soil deposits. Consequently, there is an increased risk of adverse engineering characteristics or behaviour. If the volume and quality of fill is of importance to a project, then frequent test pit excavations are preferable to boreholes.

LABORATORY TESTING

Laboratory testing is normally carried out in accordance with Australian Standard 1289 *'Methods of Testing Soil for Engineering Purposes'*. Details of the test procedure used are given on the individual report forms.

ENGINEERING REPORTS

Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal (eg. a three storey building) the information and interpretation may not be relevant if the design proposal is changed (eg. to a twenty storey building). If this happens, the company will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions – the potential for this will be partially dependent on borehole spacing and sampling frequency as well as investigation technique.
- Changes in policy or interpretation of policy by statutory authorities.
- The actions of persons or contractors responding to commercial pressures.

If these occur, the company will be pleased to assist with investigation or advice to resolve any problems occurring.

SITE ANOMALIES

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, the company requests that it immediately be notified. Most problems are much more readily resolved when conditions are exposed that at some later stage, well after the event.

REPRODUCTION OF INFORMATION FOR CONTRACTUAL PURPOSES

Attention is drawn to the document *'Guidelines for the Provision of Geotechnical Information in Tender Documents'*, published by the Institution of Engineers, Australia. Where information obtained from this investigation is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The company would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Copyright in all documents (such as drawings, borehole or test pit logs, reports and specifications) provided by the Company shall remain the property of Jeffery and Katauskas Pty Ltd. Subject to the payment of all fees due, the Client alone shall have a licence to use the documents provided for the sole purpose of completing the project to which they relate. License to use the documents may be revoked without notice if the Client is in breach of any objection to make a payment to us.

REVIEW OF DESIGN

Where major civil or structural developments are proposed <u>or</u> where only a limited investigation has been completed <u>or</u> where the geotechnical conditions/ constraints are quite complex, it is prudent to have a joint design review which involves a senior geotechnical engineer.

SITE INSPECTION

The company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related.

Requirements could range from:

i) a site visit to confirm that conditions exposed are no worse than those interpreted, to

ii) a visit to assist the contractor or other site personnel in identifying various soil/rock types such as appropriate footing or pier founding depths, or

iii) full time engineering presence on site.

GRAPHIC LOG SYMBOLS FOR SOILS AND ROCKS

SOIL

- FILL
- TOPSOIL
- CLAY (CL, CH)
- SILT (ML, MH)
- SAND (SP, SW)
- GRAVEL (GP, GW)
- SANDY CLAY (CL, CH)
- SILTY CLAY (CL, CH)
- CLAYEY SAND (SC)
- SILTY SAND (SM)
- GRAVELLY CLAY (CL, CH)
- CLAYEY GRAVEL (GC)
- SANDY SILT (ML)
- PEAT AND ORGANIC SOILS

ROCK

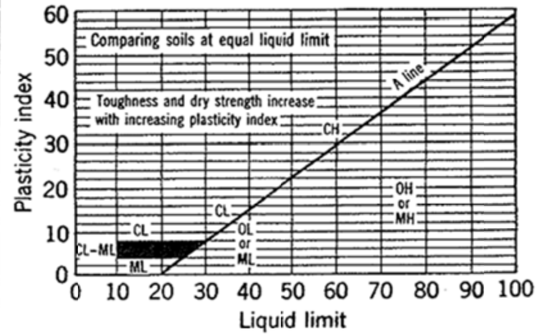
- CONGLOMERATE
- SANDSTONE
- SHALE
- SILTSTONE, MUDSTONE, CLAYSTONE
- LIMESTONE
- PHYLLITE, SCHIST
- TUFF
- GRANITE, GABBRO
- DOLERITE, DIORITE
- BASALT, ANDESITE
- QUARTZITE

DEFECTS AND INCLUSIONS

- CLAY SEAM
- SHEARED OR CRUSHED SEAM
- BRECCIATED OR SHATTERED SEAM/ZONE
- IRONSTONE GRAVEL
- ORGANIC MATERIAL

OTHER MATERIALS

- CONCRETE
- BITUMINOUS CONCRETE, COAL
- COLLUVIUM

Major divisions			Field Identification Procedures (Excluding particles larger than 75 μm and basing fractions on estimated weights)	Group Symbols a	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils More than half of material is *larger* than 75 μm sieve size[b] (The 75 μm sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than 4 mm sieve size	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles 12 mm maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than 75 μm sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols. $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or *PI* less than 4. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
	Sands More than half of coarse fraction is smaller than 4 mm sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5. Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7
Fine-grained soils More than half of material is *smaller* than 75 μm sieve size			Identification Procedures on Fraction Smaller than 380 μm Sieve Size: Dry Strength (crushing character-istics) / Dilatancy (reaction to shaking) / Toughness (consistency near plastic limit)				
	Silts and clays liquid limit less than 50		None to slight / Quick to slow / None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions. Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)	 Plasticity chart for laboratory classification of fine grained soils
			Medium to high / None to very slow / Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			Slight to medium / Slow / Slight	*OL*	Organic silts and organic silt-clays of low plasticity		
	Silts and clays liquid limit greater than 50		Slight to medium / Slow to none / Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			High to very high / None / High	*CH*	Inorganic clays of high plasticity, fat clays		
			Medium to high / None to very slow / Slight to medium	*OH*	Organic clays of medium to high plasticity		
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture	*Pt*	Peat and other highly organic soils		

Note: 1 Soils possessing characteristics of two groups are designated by combinations of group symbols (eg. GW-GC, well graded gravel-sand mixture with clay fines).
2 Soils with liquid limits of the order of 35 to 50 may be visually classified as being of medium plasticity.

LOG SYMBOLS

LOG COLUMN	SYMBOL	DEFINITION
Groundwater Record	▼	Standing water level. Time delay following completion of drilling may be shown.
	C	Extent of borehole collapse shortly after drilling.
	▶	Groundwater seepage into borehole or excavation noted during drilling or excavation.
Samples	ES U50 DB DS ASB ASS SAL	Soil sample taken over depth indicated, for environmental analysis. Undisturbed 50mm diameter tube sample taken over depth indicated. Bulk disturbed sample taken over depth indicated. Small disturbed bag sample taken over depth indicated. Soil sample taken over depth indicated, for asbestos screening. Soil sample taken over depth indicated, for acid sulfate soil analysis. Soil sample taken over depth indicated, for salinity analysis.
Field Tests	N = 17 4, 7, 10	Standard Penetration Test (SPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration. 'R' as noted below.
	N_c = 5 7 3R	Solid Cone Penetration Test (SCPT) performed between depths indicated by lines. Individual figures show blows per 150mm penetration for 60 degree solid cone driven by SPT hammer. 'R' refers to apparent hammer refusal within the corresponding 150mm depth increment.
	VNS = 25	Vane shear reading in kPa of Undrained Shear Strength.
	PID = 100	Photoionisation detector reading in ppm (Soil sample headspace test).
Moisture Condition (Cohesive Soils) (Cohesionless Soils)	MC>PL MC≈PL MC<PL D M W	Moisture content estimated to be greater than plastic limit. Moisture content estimated to be approximately equal to plastic limit. Moisture content estimated to be less than plastic limit. DRY – Runs freely through fingers. MOIST – Does not run freely but no free water visible on soil surface. WET – Free water visible on soil surface.
Strength (Consistency) Cohesive Soils	VS S F St VSt H ( )	VERY SOFT – Unconfined compressive strength less than 25kPa SOFT – Unconfined compressive strength 25-50kPa FIRM – Unconfined compressive strength 50-100kPa STIFF – Unconfined compressive strength 100-200kPa VERY STIFF – Unconfined compressive strength 200-400kPa HARD – Unconfined compressive strength greater than 400kPa Bracketed symbol indicates estimated consistency based on tactile examination or other tests.
Density Index/ Relative Density (Cohesionless Soils)	 VL L MD D VD ( )	**Density Index (I_D) Range (%)** — **SPT 'N' Value Range (Blows/300mm)** Very Loose <15 — 0-4 Loose 15-35 — 4-10 Medium Dense 35-65 — 10-30 Dense 65-85 — 30-50 Very Dense >85 — >50 Bracketed symbol indicates estimated density based on ease of drilling or other tests.
Hand Penetrometer Readings	300 250	Numbers indicate individual test results in kPa on representative undisturbed material unless noted otherwise.
Remarks	'V' bit 'TC' bit T_{60}	Hardened steel 'V' shaped bit. Tungsten carbide wing bit. Penetration of auger string in mm under static load of rig applied by drill head hydraulics without rotation of augers.

LOG SYMBOLS continued

ROCK MATERIAL WEATHERING CLASSIFICATION

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
Extremely weathered rock	XW	Rock is weathered to such an extent that it has "soil" properties, ie it either disintegrates or can be remoulded, in water.
Distinctly weathered rock	DW	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 due to deposition of weathering products in pores.
Slightly weathered rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh rock	FR	Rock shows no sign of decomposition or staining.

ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Journal of Rock Mechanics, Mining, Science and Geomechanics. Abstract Volume 22, No 2, 1985.

TERM	SYMBOL	Is (50) MPa	FIELD GUIDE
Extremely Low:	EL		Easily remoulded by hand to a material with soil properties.
----------------------	-------------	0.03	
Very Low:	VL		May be crumbled in the hand. Sandstone is "sugary" and friable.
----------------------	-------------	0.1	
Low:	L		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
----------------------	-------------	0.3	
Medium Strength:	M		A piece of core 150mm long x 50mm dia. can be broken by hand with difficulty. Readily scored with knife.
----------------------	-------------	1	
High:	H		A piece of core 150mm long x 50mm dia. core cannot be broken by hand, can be slightly scratched or scored with knife; rock rings under hammer.
----------------------	--------------	3	
Very High:	VH		A piece of core 150mm long x 50mm dia. may be broken with hand-held pick after more than one blow. Cannot be scratched with pen knife; rock rings under hammer.
----------------------	--------------	10	
Extremely High:	EH		A piece of core 150mm long x 50mm dia. is very difficult to break with hand-held hammer. Rings when struck with a hammer.

ABBREVIATIONS USED IN DEFECT DESCRIPTION

ABBREVIATION	DESCRIPTION	NOTES
Be	Bedding Plane Parting	Defect orientations measured relative to the normal to the long core axis (ie relative to horizontal for vertical holes)
CS	Clay Seam	
J	Joint	
P	Planar	
Un	Undulating	
S	Smooth	
R	Rough	
IS	Ironstained	
XWS	Extremely Weathered Seam	
Cr	Crushed Seam	
60t	Thickness of defect in millimetres	