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Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Investigation

Locomotive Shed Redevelopment
Locomotive Street, Eveleigh

Prepared for
Mirvac Projects Pty Ltd

Project 84955.04
October 2017

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

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The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author	JAM per	10 October 2017
Reviewer		10 October 2017

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Report on Geotechnical Investigation
Locomotive Shed Redevelopment
Locomotive Street, Eveleigh

1. Introduction

This report presents the results of a geotechnical investigation undertaken for the proposed Locomotive Shed Redevelopment, located on Locomotive Street, Eveleigh. The investigation was commissioned in an email dated 10 April 2017 by Belinda Aspinall of Mirvac Projects Pty Ltd (Mirvac) and was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal SYD170251 dated 3 March 2017.

The existing Locomotive Shed is located on the northern side of Locomotive Street and forms part of the Australian Technology Park district. The two storey former railway workshop building, now used as an office and conference space with a rail workshop museum, is proposed to be refurbished. The proposed works mainly comprise construction of a mezzanine floor within the existing building. The proposed mezzanine is likely to be supported by columns founded on short bored piers or similar foundation systems.

The aims of the investigation were to establish the subsurface conditions and engineering characteristics of the soil and rock, relevant for the design of the proposed structures.

The Australian Technology Park (ATP) has been continuously developed since its establishment in 1996, but has been under-utilised as a technology and business precinct for some time. UrbanGrowth NSW Development Corporation (UGDC) has actively encouraged new development and employment opportunities at the Park over the past 15 years. Mirvac intends to continue upon this and deliver on the precinct's full potential, with the construction of approximately 107,400 m^2 of floor for employment uses, which will facilitate the employment of an extra 10,000 staff within the ATP by development completion.

The geotechnical investigation comprised a review of previous DP reports for the surrounding area and fieldwork. Details of the field work are given in this report, together with comments on design and construction practice including excavation conditions, earthworks and foundations.

2. Site Description and Geology

The existing Locomotive Shed is a rectangular building of brick construction, approximately 260 m long and 95 m wide. It is separated internally into 16 north-south oriented "Bays", numbered from east to west (1, 2, 3, 4, 4a, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15). Bays 1 and 2 are used as a railway workshop museum, Bays 3 to 8 are offices, Bay 9 is occupied by a conference venue and Bays 10 to 13 form a carpark. No access was available to Bays 14 and 15, which are occupied by services rooms.

The surface elevation of the internal floor varies between RL21.5 m in the east and 21.7 m in the west, relative to Australian Height Datum.

Reference to the Sydney 1:100 000 Geological Series Sheet indicates that the site is underlain by Quaternary aged alluvial and estuarine sediments which typically comprise silty to peaty quartz sand, silt, and clay with ferruginous and humic cementation in places. The unconsolidated sediments are underlain by the Ashfield Shale of Triassic age comprising siltstone, laminite, mudstone and carbonaceous shale. Extensive filling is known to occur in the area.

The field investigation data confirmed the presence of filling in each borehole, underlain by sandy alluvial sediments, which in turn were underlain by clayey residual soil. The residual soil grades into weathered shale and laminite, consistent with the Ashfield Shale unit.

3. Field Work Methods

The field work comprised drilling of 10 boreholes, identified as BH1 to BH10 from west to east, within the existing building. Borehole BH2 was re-drilled as BH2A at an adjacent location due to the presence of a buried service pipe. All boreholes were drilled with a bobcat mounted drilling rig to depths of between 0.5 m and 10.3 m using solid flight augers and diacore drilling through concrete. Standard penetration tests (SPT) were carried out at regular intervals. The drilling cuttings and SPT samples from the boreholes were logged by a geotechnical engineer.

The borehole locations were determined relative to existing features and are shown on Drawing 1 in Appendix B.

4. Field Work Results

Using borehole data from the investigations, the subsurface profile for the Locomotive Shed can be summarised as follows:

- **CONCRETE SLABS:** The concrete floor slab was 0.15 m to 0.55 m thick and typically contained one or two layers of two dimensional reinforcing mesh. A buried steel rail track was embedded in the concrete slab in BH3. A second, approximately 0.1 m thick slab was encountered in BH1 and BH3 from a depth of about 0.6 m and asphaltic concrete, about 50 mm in thickness in boreholes BH2, 5 and 9;
- **FILLING:** Filling was encountered both between the two concrete slabs and beneath the lower slab in all boreholes to between 0.3 m and 1.3 m depth. The variably compacted filling typically comprised roadbase or gravelly clayey sand, likely to be of ripped sandstone origin;
- **SAND:** fine to medium grained sand was encountered in boreholes BH1, 2A, 4, 8 and 10. The loose to medium dense and was encountered to between 1.9 m and 2.6 m depth, except in BH10 in the east of the site, where it extended to a depth of 4.7 m;
- **CLAYEY SAND:** The sand is underlain by a thin, 0.2 to 0.6 m thick clayey sand layer in boreholes BH1 and 2A;

- **SILTY CLAY:** stiff or very stiff silty clay, grading into hard silty clay with depth, underlies the sand or clayey sand in all non-abandoned boreholes, except in BH5 where it underlies the filling; and
- **SHALE:** The top of extremely to highly weathered, extremely low to very low strength shale laminite is between RL16 m and 18 m (3.5 – 5.5 m deep), except in BH5 where it was encountered at about RL19 m (2.5 m deep) and BH10 where the top is at about RL14 m (7.9 m deep). Typically, a transition to low strength shale occurs about 3 m below the top of rock.

Groundwater was encountered only in borehole BH10 with standing levels at the completion of drilling at a depth of 7.0 m below existing ground surface (RL14.7 m). This level correlates with being near the base of the silty clay layer and is likely to be a perched groundwater.

Based on the encountered subsurface profile, it appears that the top of rock surface gently slopes towards the south, but it is also incised with roughly north to south trending depressions, which are backfilled with sandy sediments.

The detailed borehole logs are shown in Appendix C.

5. Proposed Development

The proposed works mainly comprise construction of a mezzanine floor within the existing building. The proposed mezzanine is likely to be supported by columns founded on short bored piers or similar foundation systems. The indicated likely working bearing pressures at the column foundations are between 600 and 750 kPa.

6. Comments

6.1 Excavation Characteristics

No significant excavation, other than for the foundations is expected in Bays 5 to 15. The footing excavation will encounter variable filling, including buried slabs, underground services and other bulk obstructions, in situ sand and stiff to very stiff clay, which together with the extremely to highly weathered rock should be readily achieved using conventional earthmoving equipment such as tracked excavators. However, excavation of the concrete structures and/or construction rubble will result in localised over-excavation or the use of heavy rock hammers may be required to break through the concrete and other obstructions.

It is understood that the contamination status of the filling and soil beneath the existing structure is being assessed by others.

6.2 Foundations

It is expected that all structures will be supported by piled footings bearing on rock. Typical maximum allowable pressures for the various anticipated foundation materials, based on the foundation classification methods of Pells et al. (1998), are shown in Table 1.

Note that extremely low to very low strength rock was encountered within 2.5 to 5.5 m of the existing floor, except in BH10, where it was at a depth of about 7.9 m. Variation in depth to the top of the rock in a similar range is anticipated to occur throughout the site.

For detailed design of piles, a limit state analysis should be undertaken as a more economical design is often achieved. All piling excavation should be inspected by a geotechnical engineer to confirm that foundation conditions are in accordance with the design assumptions.

Table 1: Design Parameters for Pad/Strip Footings

Rock type	Typical Allowable End Bearing Pressure (kPa)	Typical Allowable Shaft Adhesion (kPa)
Extremely low to very low strength shale (Class IV and V)	750	70
Low strength shale (Class III)	2,000	200

Foundations proportioned on the basis of the allowable parameters would be expected to experience total settlements of less than 1% of the minimum footing width (or pile diameter) under the applied working load, with differential settlement between adjacent columns expected to be less than half this value.

The pile installation should be regularly inspected by a geotechnical engineer to confirm the subsurface conditions used in the design.

Bored, fully cased or CFA piles should be considered for the foundations, as groundwater and/or collapsible filling is likely to be present locally. Excavation through obstructions with piling equipment for bored piles is typically more achievable as the drilling methods are readily exchangeable. Laboratory analytical data from the contaminated soil investigation should be used to assess the corrosion potential of the filling and groundwater.

Foundation conditions of the existing piles adjacent to the excavation will need to be confirmed prior to the excavation to assess both potential requirements for underpinning.

6.3 Design for Earthquake Loading

In accordance with AS1170-2007 “Structural Design Actions, Part 4: Earthquake Actions in Australia” a hazard factor (Z) of 0.08 and a site subsoil Class C_e is considered to be appropriate for the site, provided all structural support is founded on piles bearing on rock.

6.4 Groundwater

The available borehole data indicates that the piling will likely intercept discontinuous groundwater bearing layers. While initial inflow rates may be locally substantial, they are anticipated to be of short duration, except following rain events. Appropriate piling methods, together with corrosion protection of the piles should be adopted where perched groundwater is encountered.

7. Limitations

Douglas Partners (DP) has prepared this report for the Locomotive Shed Development project at Locomotive Street, Eveleigh in accordance with DP's proposal dated 3 March 2017 and acceptance received from Belinda Aspinall dated 10 April 2017. The work was carried out under A Consultancy Agreement, Contract No 7.759 - 001, currently under negotiation). This report is provided for the exclusive use of Mirvac Projects Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or be relied upon for other projects or purposes on the same or another site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

8. References

1. Pells P.G.N., Mostyn G. and Walker B.F., 1998. Foundation on sandstone and shale in the Sydney region, Australian Geomechanics, December 1998, p 17-29.

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Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

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

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole 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. They may not be the same at the time of construction as are indicated in the report; and
- 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 first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or 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 a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP 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 and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

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, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report 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. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

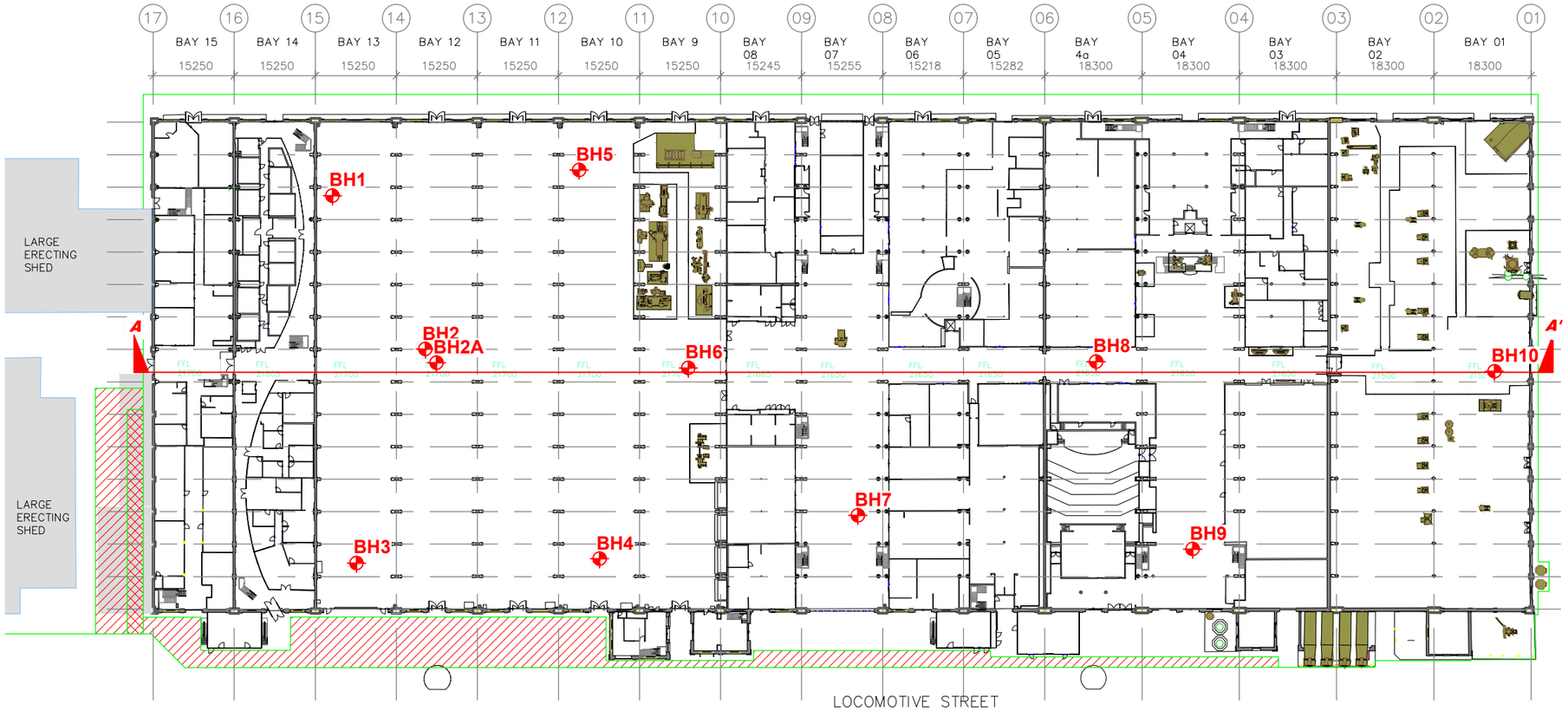
Site Inspection

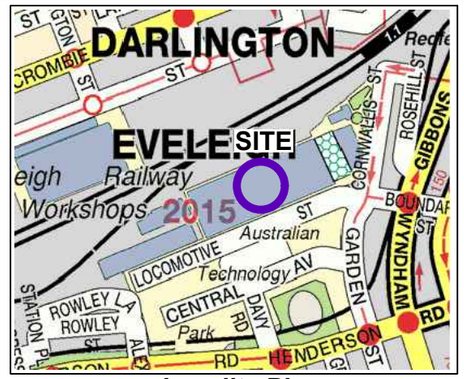
The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Location of Boreholes

Geotechnical Cross Section A-A’





Locality Plan

NOTE:
1: Base drawing from Mirvac Pty Ltd (Dwg SA-010 Rev1)
2: Test locations are approximate only and are shown with reference to existing features.

0 10 20 30 40 50 75 100m
1:1000 @ A3

LEGEND
- Borehole location
- A A' Geotechnical Cross Section A-A'

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CLIENT: Mirvac Projects Pty Ltd		TITLE: **Location of Boreholes**
OFFICE: Sydney	DRAWN BY: PSCH	**Eveleigh Locomotive Shed**
SCALE: 1:1000 @ A3	DATE: 8.5.2017	**Australian Technology Park, EVELEIGH**

N

PROJECT No:	84955.04
DRAWING No:	1
REVISION:	0

A

A'

ELEVATION (AHD)

26
24
22
20
18
16
14
12
10
8
6

1

md
md
st-vst
vst-h
EL-VL
VL
N = 17
N = 32
refusal
refusal
Bottom Depth
7.5 m

2A

md
md
st
vst-h
EL-VL
L
N = 13
N = 12
N = 29
refusal
refusal
Bottom Depth
7.5 m

5

vst
EL
VL
N = 20
N = 52
refusal
Bottom Depth
4.5 m

4

l
l
l
vst
EL
VL
N = 7
N = 5
N = 23
N = 52
refusal
Bottom Depth
7.5 m

8

l
st-vst
EL-VL
VL
N = 5
N = 13
refusal
refusal
Bottom Depth
5.7 m

10

md
vst
h
EL
VL
N = 11
N = 12
N = 6
N = 19
N = 34
N = 50
refusal
Bottom Depth
10.3 m

0
5
10
15
20
25
30
35
40
45
50

DISTANCE ALONG PROFILE (m)

NOTE: Summary logs only. Should be read in conjunction with detailed logs.

LEGEND

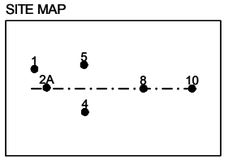
- Concrete
- Filling
- Sand
- Clayey Sand
- Silty Clay
- Shale
- Asphaltic Concrete

ROCK STRENGTH
EL - Extremely Low
VL - Very Low
L - Low
M - Medium
H - High
VH - Very High

SOIL CONSISTENCY
vs - very soft
s - soft
f - firm
st - stiff
vst - very stiff
h - hard
vl - very loose
l - loose
md - medium dense
d - dense
vd - very dense

TESTS / OTHER
N - Standard penetration test value
▽ - Water level

SITE MAP



0 3
Horizontal Scale (metres)
Vertical Exaggeration = 1.5

STANDARD CROSS-SECTION_84955.04 CROSS SECTIONS EVELEIGH LOCO SHED_DP2012_V1-1.GPJ_DPTEMPLATE2012_V1_SYDMET.GDT 9/5/17

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CLIENT: Mirvac Projects Pty Ltd		TITLE: **Geotechnical Cross Section A-A'**	PROJECT No: 84955.04
OFFICE: Sydney	DRAWN BY: JAM/LD	**ATP Locomotive Shed Upgrade**	DRAWING No: 2
SCALE: 1:150 (H) 1:100 (V) @ A3	DATE: 09.05.2017	**Locomotive Street, Eveleigh**	REVISION: 0

Appendix C

Borehole Log Results

and Descriptive Notes

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 84955.04
DATE: 19/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.28	CONCRETE 0.05m: 8mm diameter, two-way horizontal steel 0.21m: 8mm diameter, two-way horizontal steel							
	0.55	0.27m: 24mm diameter horizontal steel							
	0.64								
	0.8	FILLING - grey, coarse gravel (sandstone) filling, cement stabilised		A	0.8 0.9				
1		CONCRETE		A	1.3 1.4				1
20		FILLING - apparently poorly compacted, fine to medium sand filling with some clay and fine to medium gravel (sandstone), damp							
	1.9	SAND - apparently medium dense, brown, fine to medium sand with some silt, damp 1.1m: becoming orange-brown							
2									2
	2.55	CLAYEY SAND - apparently medium dense, brown, fine to medium clayey sand, damp		S	2.5		4,7,10 N = 17		
19		SILTY CLAY - stiff to very stiff, mottled orange red-brown and grey silty clay with some fine to medium ironstone gravel, damp			2.95				
3		3.5m: becoming very stiff to hard							3
				S	4.0		9,13,19 N = 32		
18					4.45				
4									4
	4.9	SHALE - extremely low to very low strength grey, orange and brown shale							
17				S	5.5		9,23,25/100mm refusal		
5					5.95				5
16									
6									6
15		6.8m: becoming very low strength							
				S	7.0		6,20,25/120mm refusal		
7	7.5				7.45				7
14		Bore discontinued at 7.5m - limit of investigation							
8									8
13									
9									9
12									

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.64m; Hand auger to 1.6m; Solid flight auger (TC-bit) to 7.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 84955.04
DATE: 19/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.16	CONCRETE							
	0.18	0.05m: 8mm diameter, two-way, horizontal steel							
	0.31	ASPHALTIC CONCRETE							
		CONCRETE							
		0.27m: 8mm diameter two-way horizontal steel							
		Bore discontinued at 0.31m - due to service encountered - terracotta pipe 200mm diameter							

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.31m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 84955.04
DATE: 20/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.0	CONCRETE 0.08m: 8mm diameter, two-way horizontal steel							
	0.5	0.38-0.5m: steel railway track							
	0.6	FILLING - apparently well compacted, dark grey, fine to coarse gravelly (igneous), fine to coarse sand filling, trace clay (roadbase)							
	0.9	CONCRETE		S	1.0 1.08		25/80mm refusal		
	1.3	FILLING - apparently well compacted, medium to coarse gravel (sandstone) filling, possibly cement stabilised							
20		Bore discontinued at 1.3m - auger refusal on sandstone boulder							
19									
18									
17									
16									
15									
14									
13									
12									

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.9m; Solid flight auger (TC-bit) to 1.3m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▽	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 84955.04
DATE: 20/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.3	CONCRETE 0.06m: 8mm diameter, two-way, horizontal steel		A	0.3 0.4				
		FILLING - apparently poorly compacted, dark brown, fine to coarse silty sand with some fine to medium gravel (sandstone), damp		A	0.5 0.6				
1	0.9	SAND - loose, grey, fine to medium sand, damp		A	0.9 1.0				
				S	1.45		3,3,4 N = 7		
20	2.0	SAND - loose, orange-brown, fine to medium grained sand, damp							
				S	2.5 2.95		2,2,3 N = 5		
19	3.3	SILTY CLAY - very stiff, mottled grey, orange and red-brown silty clay with some fine to medium ironstone gravel, damp							
				S	4.0 4.45		5,8,15 N = 23		
18	5.5	SHALE - extremely low strength, grey and orange-brown shale		S	5.5 5.95		14,22,30 N = 52		
17		7.2m: becoming very low strength		S	7.0 7.42		14,25,25/120mm refusal		
16	7.5	Bore discontinued at 7.5m - limit of investigation							

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.3m; Hand auger to 1.0m; Solid flight auger (TC-bit) to 7.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 84955.04
DATE: 20/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.15	CONCRETE							
	0.2	0.08m: 8mm diameter, two-way horizontal steel		A	0.2				
	0.3	ASPHALTIC CONCRETE		A	0.3				
		FILLING - apparently moderately compacted, dark brown, fine to medium gravelly (igneous), fine to coarse sand filling, damp (roadbase)			0.4				
					0.5				
				A	0.9				
1					1.0				1
		SILTY CLAY - very stiff, mottled grey, orange and purple, silty clay with some fine to medium ironstone gravel, damp		S			5,8,12 N = 20		
20					1.45				
2	2.3	SHALE - extremely low strength, grey shale							2
				S	2.5		10,22,30 N = 52		
19					2.95				
3									3
18				S	4.0		17,18,30/100mm refusal		
4	4.3	SHALE - very low strength, brown-grey shale			4.4				4
	4.5	Bore discontinued at 4.5m - limit of investigation							
17									
5									5
16									
6									6
15									
7									7
14									
8									8
13									
9									9
12									

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.15m; Solid flight auger (TC-bit) to 4.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 6
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.43	CONCRETE 0.07m: 8mm diameter, two-way, horizontal steel							
		FILLING - apparently variably compacted, dark brown, fine to coarse gravelly (igneous, sandstone and slag), fine to coarse sand filling, damp		A	0.43 0.5				
20	1.0	Bore discontinued at 1.0m - refusal on buried concrete		A	0.9 1.0				
19									
18									
17									
16									
15									
14									
13									
12									

RIG: Hand tools **DRILLER:** TJ Coring/MB **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.43m; Hand auger to 1.0m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 7
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.31	CONCRETE 0.09m: 8mm diameter, two-way, horizontal steel 0.26m: 12mm diameter, horizontal steel		A	0.4				
	0.5	FILLING - apparently variably compacted, dark brown, fine to coarse gravelly (igneous, sandstone and slag) fine to coarse sand filling, damp			0.5				
20	1	Bore discontinued at 0.5m - refusal on buried concrete							
19	2								
18	3								
17	4								
16	5								
15	6								
14	7								
13	8								
12	9								

RIG: Hand tools **DRILLER:** TJ Coring/MB **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.31m; Hand auger to 0.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 8
PROJECT No: 84955.04
DATE: 26/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		CONCRETE 0.04m: 8mm diameter, two-way, horizontal steel							
	0.45	FILLING - apparently variably compacted, dark brown, fine to coarse silty sand filling with some fine gravel (sandstone), damp		A	0.45 0.5				
				A	0.8 0.9				
	1.1	SAND - loose, orange-brown, fine to medium sand, damp		S	1.0 1.45		2,2,3 N = 5		
	2.1	SILTY CLAY - stiff to very stiff, mottled grey, orange and brown, silty clay with some fine to medium ironstone gravel, moist		S	2.5 2.95		3,5,8 N = 13		
	3.7	SHALE - extremely low to very low strength, grey shale		S	4.0 4.27		13,30/120mm refusal		
	5.5	SHALE - very low strength, grey and brown shale		S	5.5 5.64		30/140mm refusal		
	5.7	Bore discontinued at 5.7m - limit of investigation							

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.45m; Hand auger to 1.0m; Solid flight auger (TC-bit) to 5.7m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.15	CONCRETE							
	0.2	ASPHALTIC CONCRETE		A	0.4 0.5				
	0.7	FILLING - apparently variably compacted, dark brown, fine to coarse silty sand filling with some clay, brick and tile fragments, moist							
20	1	Bore discontinued at 0.7m - refusal on buried concrete							
19	2								
18	3								
17	4								
16	5								
15	6								
14	7								
13	8								
12	9								

RIG: Hand tools **DRILLER:** TJ Coring/MB **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.2m; Hand auger to 0.7m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 10
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 1 OF 2

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
21	0.2	CONCRETE							
		FILLING - apparently variably compacted, dark brown, fine to medium gravelly (sandstone and slag), fine to coarse sand filling, damp		A	0.2 0.3				
				A	0.7 0.8				
	1			S	1.0 1.45		4,4,7 N = 11		1
20	1.5	SAND - medium dense, orange-brown, fine to medium sand, humid							
	2			S	2.5 2.95		4,6,6 N = 12		2
19	3								3
18	4	4.0m; with some clay, loose		S	4.0 4.45		1,2,4 N = 6		4
17	4.7	SILTY CLAY - very stiff, mottled brown and grey silty clay with some sand and fine to medium ironstone gravel, moist							
	5			S	5.5 5.95		4,7,12 N = 19		5
16	6								6
15	7	7.0m: becoming hard		S	7.0 7.45		7,16,18 N = 34	▼	7
14	7.9	SHALE - extremely low strength, grey shale							
	8			S	8.5 8.95		14,21,29 N = 50		8
13	9								9
12	9.7	SHALE - very low strength, brown and grey shale							

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.2m; Hand auger to 1.0m; Solid flight auger (TC-bit) to 10.3m

WATER OBSERVATIONS: Free groundwater observed at 7.0m

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 10
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 2 OF 2

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		SHALE - very low strength, brown and grey shale *(continued)*		S	10.0 10.25		14,25/100mm refusal		
	10.3	Bore discontinued at 10.3m - limit of investigation							

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.2m; Hand auger to 1.0m; Solid flight auger (TC-bit) to 10.3m

WATER OBSERVATIONS: Free groundwater observed at 7.0m

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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BOREHOLE LOG

CLIENT: Mirvac Projects Pty Ltd
PROJECT: ATP Locomotive Shed Upgrade
LOCATION: Locomotive Street, Eveleigh

SURFACE LEVEL: 21.7 AHD
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 2A
PROJECT No: 84955.04
DATE: 21/4/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
		CONCRETE 0.1m: 8mm diameter, two-way, horizontal steel							
	0.56								
21	0.7	FILLING - apparently poorly compacted, brown, fine to medium sand filling with some fine to medium gravel (sandstone), damp		A	0.7 0.8				
	1	SAND - medium dense, orange-brown, fine to medium sand, damp 1.1m: becoming light brown		S	1.0 1.45		4,5,8 N = 13		1
20	2								2
	2.6				2.5				
19	2.8	CLAYEY SAND - medium dense, grey mottled orange-brown, fine to medium clayey sand with some silt, damp		S	2.95		10,7,5 N = 12		3
18	4	SILTY CLAY - stiff, brown, silty clay with some fine ironstone gravel, damp 4.0m: becoming very stiff to hard		S	4.0 4.45		6,10,19 N = 29		4
17	5								5
	5.2	SHALE - extremely low to very low strength, grey and brown shale		S	5.5 5.75		18,30/100mm refusal		
16	6								6
15	7			S	7.0 7.3		25,30/145mm refusal		7
	7.5	7.3m: becoming low strength Bore discontinued at 7.5m - limit of investigation							
14	8								8
13	9								9
12									

RIG: Bobcat **DRILLER:** GM **LOGGED:** MB **CASING:** Uncased

TYPE OF BORING: Diatube to 0.56m; Solid flight auger (TC-bit) to 7.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Sampling Methods

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Sampling

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

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil 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.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud 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 the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils 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 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm 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 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

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

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This 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.

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726-1993, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 2007. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approximate Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$. It should be noted that the UCS to $Is_{(50)}$ ratio varies significantly for different rock types and specific ratios should be determined for each site.

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and longer sections
Unbroken	Core lengths mostly > 1000 mm

Rock Descriptions

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100 \text{ mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

Symbols & Abbreviations

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

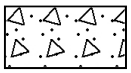
Symbols & Abbreviations

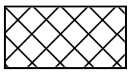
Graphic Symbols for Soil and Rock

General

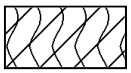

Asphalt

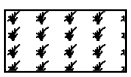

Road base

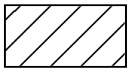

Concrete

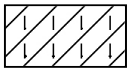

Filling

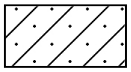
Soils


Topsoil

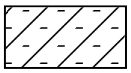

Peat

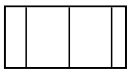

Clay

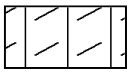

Silty clay

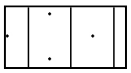

Sandy clay

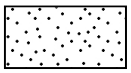

Gravelly clay

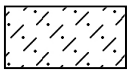

Shaly clay

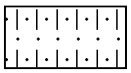

Silt


Clayey silt


Sandy silt

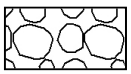

Sand

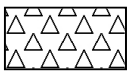

Clayey sand


Silty sand


Gravel

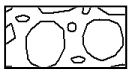

Sandy gravel


Cobbles, boulders

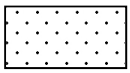

Talus

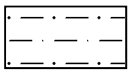
Sedimentary Rocks

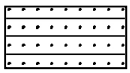

Boulder conglomerate

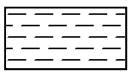

Conglomerate


Conglomeratic sandstone

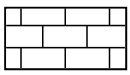

Sandstone


Siltstone

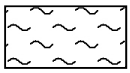

Laminite

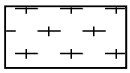

Mudstone, claystone, shale

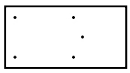

Coal


Limestone

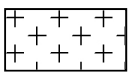
Metamorphic Rocks

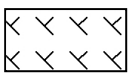

Slate, phyllite, schist

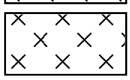

Gneiss

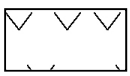

Quartzite

Igneous Rocks


Granite


Dolerite, basalt, andesite


Dacite, epidote


Tuff, breccia


Porphyry