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Report on
Geotechnical Investigation

Dubbo Health Service Redevelopment Stages 3 and 4
Myall Street, Dubbo

Prepared for
Health Infrastructure

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	Signature	Date
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Report on Geotechnical Investigation
Dubbo Health Service Redevelopment Stages 3 and 4
Myall Street, Dubbo

1. Introduction

This report presents the results of a geotechnical investigation undertaken for the proposed redevelopment works for Stages 3 and 4 at Dubbo Health Service (DHS), Myall Street, Dubbo. The work was commissioned by Health Infrastructure, in consultation with TSA Management Pty Ltd.

The DHS Redevelopment Stage 4 project scope is described as follows:

- Stage 4 – Site preparation works
  - Demolition of George Hatch and Existing Nurses Administration
  - Demolition of Existing Surgical Ward ('S' Block)
  - New Construction – Temporary Corridor Bypass Link
  - New Construction – 1 x permanent corridor bypass link south
- A new 3-storey clinical building comprising
  - Ground Level
    - Medical imaging
    - Emergency Department, including Short Stay Unit
    - A refurbished and expanded Main Entry
  - Level 1
    - Renal Dialysis Unit
    - Ambulatory Care Services
  - Level 2
    - 20 bed CCU/Cardiovascular/Stroke Unit
    - 12 bed ICU
    - Cardiovascular Suite
  - Level 3
    - Plant Area
- Other associated works
  - Expansion of on grade car parking facilities and improved access and wayfinding
  - Dedicated ambulance access off Myall Street
  - Amendments to the Cobbora Road roundabout to facilitate entry to the Hospital
  - Demolition of Playmates/Doctors Accommodation
  - Demolition of external component of existing Ambulatory Care Unit
  - Landscaping including tree removal and other public domain works
  - Upgrades of related engineering services infrastructure supporting Stage 4
  - Refurbishment of the two ICU ensuites within the medical inpatient ward (G-ward)

Geotechnical investigation was undertaken to provide information on the subsurface conditions on the site and included the drilling of boreholes at accessible locations, laboratory testing and engineering analysis. Details of the field work and comments relevant to design and construction are given in this report.

A contamination assessment was undertaken at the same time as the geotechnical investigation and is reported separately.

2. Previous Investigations

Douglas Partners undertook geotechnical investigations on the site in 1996 (Project 23882) and 2012 (Project 72811.00). These investigations included the drilling of boreholes within the hospital grounds, laboratory testing and engineering analysis. The results of these previous investigations have been used to compliment the current investigation and to develop a geotechnical model of the site.

3. Site Description and Geology

Dubbo Health Service is located to the north-east of the city centre and is bounded by Myall Street to the south, the Coonamble-Dubbo Railway line to the west, residential dwellings to the east, and vacant land to the north. The natural ground surface levels at the site appear to fall gently to the south and west.

At the time of the current investigation, the main hospital buildings were located in the southern and central portions of the site. A car park was located in the eastern portion, and the western and northern sections of the site were generally vacant.

The *Dubbo 1:250 000 Geological Series Sheet* shows that the site is close to a boundary between gravel and ferruginous sandstone, and olivine basalt and dolerite. Both of these geological units are of Cainozoic age.

4. Field Work Methods

4.1 Previous Field Work

The field work for the 1996 investigation included the drilling of fourteen boreholes (BH1 to BH14) in the southern and central portions of the site. The locations of these previous boreholes are shown on Drawing G1 in Appendix B.

The boreholes were drilled to depths of 1.2 m to 5.3 m using a Pengo boring rig fitted with 300 mm diameter augers. A senior engineering geologist logged the materials recovered from the boreholes and collected samples at regular depth intervals. Dynamic cone penetrometer (DCP) tests were also undertaken to help characterise the near-surface soils.

The ground surface levels at these borehole locations were measured to Australian Height Datum (AHD) using an automatic level, relative to a benchmark on the site.

The field work for the 2012 investigation included the drilling of three boreholes in the building works zone (BW1 to BW3), four boreholes in the civil works zone (CW1 to CW4) and three boreholes in the stormwater detention zone (SD1 to SD3). The locations of these previous boreholes are also shown on Drawing G1 in Appendix B.

The boreholes were drilled to depths of 0.9 m to 5.0 m using a Pengo boring rig fitted with 300 mm diameter augers. An experienced geotechnical engineer logged the materials recovered from the boreholes and collected samples at regular depth intervals. DCP tests were also undertaken to help characterise the near-surface soils.

The ground surface levels at these borehole locations were measured to AHD by a registered surveyor engaged by the client.

4.2 Current Field Work

The current field work included the drilling of 15 boreholes in the area of the proposed buildings (B1 to B15) and six boreholes in the proposed pavement areas (P1 to P6). The locations of these current boreholes are shown on Drawing G1 in Appendix B.

These boreholes were drilled to depths of 0.5 m to 5.0 m using a Gemco 8C7 geotechnical investigation rig fitted with 150 mm diameter augers, except for one location which was drilled using a hand-auger due to access constraints. An experienced geotechnical engineer logged the materials recovered from the boreholes and collected samples at regular depth intervals. Standard penetrometer tests (SPTs) were also undertaken within the bores.

The ground surface levels at these borehole locations were measured using a high-precision differential global positioning system (dGPS) receiver.

5. Field Work Results

The subsurface conditions encountered in the current and previous boreholes are presented in the borehole logs in Appendices C and D, respectively. Notes defining descriptive terms and classification methods are included in Appendix A. The boreholes encountered:

- PAVEMENT – bitumen/asphalt and/or roadbase gravel to depths of between 0.02 m and 0.3 m in bores B1, B3, P2, BH1, BH2, BW2, BW3, CW1 and CW4;
- FILLING – typically clayey, silty and sandy soils with gravel, roots, rootlets, building fragments, charcoal (ash) and brick to depths of between 0.1 m and 2.0 m. Filling was not encountered in B11, B12 or B15;
- NATURAL SOILS – typically clayey and sandy soils, with basalt and quartz gravel and silt in varying proportions, to depths of between 0.6 m and 5.0 m. The soils were generally very stiff or hard, although some stiff layers were also encountered. Natural soil was not observed in B4, B5, B8, P1 or P2 where auger refusal occurred either in the filling or on bedrock; and

- BEDROCK – extremely weathered rock below depths of between 1.2 m and 4.5 m which generally presents itself as hard clayey and sandy soil with gravel inclusions. It is possible that borehole refusal on particularly gravelly layers was at the surface of stronger (less weathered) rock.

Free groundwater was not observed in any of the previous or current boreholes at the time that the field work was undertaken. Minor seepage was noted in B4, B12, and B14 at the time of the field work.

A summary of subsurface conditions is provided in Tables 1A, 1B and 1C.

Table 1A: Summary of Strata Levels in Current Boreholes

Stratum	RL of Top of Stratum (m, AHD)										
	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11
Ground Surface/Filling	276.8	276.2	273.7	275	271	276	276.1	275.8	277.6	278.7	279.2
Very Stiff or Hard Clays	276.1	274.2	273.4	NE	NE	275.7	275.9	NE	277	278.2	279.2
Weathered Rock*	274.3	273.8	NE	NE	NE	273.3	273.6	NE	275.1	NE	NE
Base of Borehole	271.8	273.5	268.7	274.3	270.2	271.3	271.1	275.2	272.6	273.7	274.2

Notes: * Presents as soil; NE = not encountered

Table 1B: Summary of Strata Levels in Current Boreholes

Stratum	RL of Top of Stratum (m, AHD)									
	B12	B13	B14	B15	P1	P2	P3	P4	P5	P6
Ground Surface/Filling	280.5	278	278.7	280.2	274.8	275	273.9	278.4	277.1	275.7
Very Stiff or Hard Clays	280.5	277.8	278.1	280.2	NE	NE	273.7	278	276.9	275.5
Weathered Rock*	277.9	276	NE	NE	NE	NE	NE	NE	NE	NE
Base of Borehole	277.7	273	273.7	275.2	274.1	274.4	272.3	276.8	276.6	274.1

Notes: * Presents as soil; NE = not encountered

Table 1C: Summary of Strata Levels in Relevant Previous Boreholes

Stratum	RL of Top of Stratum (m, AHD)									
	BW1	BW2	BW3	BH1	BH2	BH3	CW1	CW2	CW3	CW4
Ground Surface/Filling	277.6	278.5	273.3	277.4	277.1	276.5	279.6	279.8	279.3	278.3
Very Stiff or Hard Clays	277.5	277.9	272.7	276.2	276.6	276.0	279.3	279.2	279.0	278.1
Weathered Rock*	275.1	274.9	269.7	273.6	275.4	275.1	NE	NE	NE	NE
Base of Borehole	272.6	274.9	269.7	273.4	275.4	274.5	274.6	274.8	277.4	273.3

Notes: BW,CW -series bores drilled in 2012; BH-series bores drilled in 1996; * Presents as soil; NE = not encountered

6. Laboratory Testing

6.1 Previous Investigations

The geotechnical laboratory testing programme for the previous investigations included the following:

- Atterberg limits and linear shrinkage to assess soil plasticity;
- Instability index to assess the shrink-swell potential of the clays;
- California bearing ratio (CBR) for pavement design purposes. These samples were compacted to dry density ratios of close to 100% relative to Standard compaction and were soaked for 4 days under a 4.5 kg surcharge load prior to testing;
- Particle-size distribution to determine soil composition;
- Emerson class testing to assess dispersion potential; and
- pH, electrical conductivity, chloride ion and sulphate ion content to assess soil aggressivity.

6.2 Current Investigation

The geotechnical laboratory testing programme for the current investigation included the following:

- Atterberg limits to assess soil plasticity;
- California bearing ratio (CBR) for pavement design purposes. These samples were compacted to dry density ratios of 100% relative to Standard compaction and were soaked for 4 days under a 4.5 kg surcharge load prior to testing;
- Emerson class testing to assess dispersion potential; and
- pH, electrical conductivity, chloride ion and sulphate ion content to assess soil aggressivity.

6.3 Summary of Results

Summaries of all the laboratory test results are provided in Tables 2 and 3. The detailed laboratory test reports for the current and previous investigations are included in Appendices E and F, respectively.

Table 2: Summary of Laboratory Test Results for Physical Parameters

Bore/Depth (m)	W_F (%)	W_L (%)	PI (%)	LS (%)	I_{SS} (%/ΔpF)	CBR (%)	Emerson (Class)
BH4/0.5	24.7	51	31	15	-	-	-
BH6/0.5-1.0	-	-	-	-	-	11	-
BH9/0.8-1.2	-	-	-	-	0.6	-	-
BH10/0.5-1.0	-	-	-	-	-	8	-
BW1/0.5	11.0	43	20	-	-	-	-
BW1/1.0	-	-	-	-	-	-	3
BW2/1.0	12.0	33	16	-	-	-	-
CW1/0.5-0.7	-	-	-	-	-	6	-
CW3/0.5	15.4	44	23	-	-	-	-
CW3/0.7-1.0	-	-	-	-	-	10	5
CW4/0.5-0.7	21.5	51	25	-	-	7	-
SD1/1.0	-	-	-	-	-	-	3
SD2/0.5	8.6	24	9	-	-	-	-
B1/2.5-2.8	-	56	23	-	-	-	-
B6/0.4-0.5	-	-	-	-	-	-	5
B6/2.5-2.95	-	63	27	-	-	-	-
B7/2.5-2.95	-	55	32	-	-	-	-
B9/0.9-1.0	-	-	-	-	-	-	5
B9/1-1.45	-	63	38	-	-	-	-
B12/1-1.45	-	40	25	-	-	-	-
B13/1-1.5	-	-	-	-	-	-	5
B14/3.5-4.5	-	57	26	-	-	-	-
B15/4.5-5.0	-	-	-	-	-	-	2
P1/0.05-0.7	-	-	-	-	-	9	-
P2/0.06-0.6	-	-	-	-	-	6	-
P3/0.2-1.2	-	-	-	-	-	5	-
P4/0.4-1.6	-	-	-	-	-	5	4
P5/0.2-0.5	-	-	-	-	-	10	-
P6/0.2-1.6	-	-	-	-	-	6	2

Notes: W_F = field moisture content; W_L = liquid limit; PI = plasticity index; LS = linear shrinkage; I_{SS} = instability index; CBR = California bearing ratio; - = not tested

Table 3: Summary of Laboratory Test Results for Chemical Parameters

Bore/Depth (m)	pH (pH units)	EC (µS/cm)	Cl^- (mg/kg)	SO_4^{2-} (mg/kg)
BW1/1.0	5.5	86	63	76
BW3/3.0	7.8	93	72	15
B1/1-1.45	7.4	69	25	46
B6/2.5-2.95	8.3	270	85	190
B10/1-1.45	8.7	280	20	51
B15/4.5-4.95	4.8	1300	1600	390

Notes: EC = electrical conductivity; Cl^- = chloride ion; SO_4^{2-} = sulphate ion

7. Geotechnical Model

The southern portion of the hospital grounds appears to be underlain by typically very stiff to hard residual clayey soils overlying extremely weathered basalt. The soils and weathered rock contain gravels in varying proportions. Basalt often weathers inconsistently such that the depth of stronger rock may vary significantly over short distances.

The northern and western portions of the hospital grounds appears to be underlain by typically very stiff to hard residual clayey soils overlying extremely weathered sandstone. Numerous gravelly layers were also encountered in this soil profile. All soils appear to be moderately to highly plastic and moderately dispersive.

Free groundwater was not observed in any of the boreholes at the time of the field work and is therefore likely to be deeper than 5 m below the ground surface.

8. Proposed Development

It is understood that the project involves the construction of new buildings and new pavement/parking areas. The geotechnical issues considered relevant to the proposed development include excavation, excavation support, site preparation, groundwater, foundations and pavements. Comments on soil aggressivity and seismicity are also provided.

9. Comments

9.1 Excavation

Excavation will be required to level the development areas on the site and is expected to be limited to maximum depths of about 2 m. Excavation will therefore be required in filling, soil and extremely weathered rock which should be readily achievable using conventional earthmoving equipment such as a hydraulic excavator with bucket attachment. Based on the information available to date, excavation in strong rock is unlikely to be required.

It should be noted that any off-site disposal of spoil will generally require assessment for re-use or classification in accordance with current *Waste Classification Guidelines* (NSW EPA, 2014).

9.2 Excavation Support

Vertical excavations in filling, soil and extremely weathered rock are not expected to be self-supporting for any extended period of time. Temporary batters may be feasible in certain areas of the site and should be cut no steeper than 1(H):1(V) in the clayey soils, up to a maximum depth of 3 m. Permanent batters should be cut no steeper than 2(H):1(V) and should include some form of erosion protection (e.g. grass) to prevent the loss of materials over time. Flatter batters may be required for maintenance purposes (i.e. mowing).

Retaining walls on the site could be designed by assuming the following:

- Coefficient of active earth pressure (K_a) in stiff to hard soils = 0.3
- Coefficient of earth pressure at rest (K_o) in stiff to hard soils = 0.5
- Coefficient of passive earth pressure (K_p) in stiff to hard soils = 3.0
- Bulk unit weight (γ) of soil and weathered rock = 20 kN/m^3
- Angle of friction (ϕ) at concrete/soil interface = 20^o
- Triangular lateral earth pressure distribution for cantilevered walls
- Trapezoidal lateral earth pressure distribution for fully propped walls where the full pressure acts over the central 60% of the wall, decreasing to zero at the top and bottom
- No hydrostatic pressure if adequate drainage is provided behind the wall

Additional surcharge loads from sloping ground surfaces, construction machinery, adjacent structures and traffic should also be considered in the design of retaining walls.

9.3 Site Preparation

The placement of filling for site regrading works could be undertaken using the following methodology:

- Strip existing vegetation, topsoil and filling from the works area;

- Proof-roll the exposed subgrade with a steel smooth-drum roller of at least 10 t weight in the presence of a geotechnical professional. Areas exhibiting unacceptable movement will require treatment to rectify the causes of the movement;
- Place filling in 250 mm thick layers and compact each layer to a dry density ratio of between 98% and 102% relative to Standard compaction;
- Condition the filling to ensure the moisture content is within 2% of optimum if it exhibits clay-like properties;
- Undertake inspections and testing in accordance with the requirements of Australian Standard AS 3798 – 2007 *Guidelines on earthworks for commercial and residential developments*.

It may be prudent to place a layer of granular material on each prepared area to provide a more trafficable surface during periods of wet weather.

9.4 Groundwater

Free groundwater was not observed in any of the boreholes at the time of the field work and is therefore likely to be deeper than 5 m below the ground surface. Seepage into excavations may occur during and following periods of rainfall, but should be able to be handled by removing the water with a pump.

9.5 Foundations

9.5.1 Site Classification

The laboratory test results suggest that the natural soils on the site are moderately reactive to changes in moisture content. Provided existing uncontrolled filling is removed or reconditioned, a site classification of M-D could be assumed for footings founded in natural soils in accordance with Australian Standard AS 2870 – 2011 *Residential slabs and footings*. A M-D site may experience unrestrained free-surface movements of 20 mm to 40 mm. The ‘D’ in this classification refers to deep-seated moisture changes that occur in western NSW. This classification also assumes tree roots are not located within the foundation soils.

Additional soil movements may occur in areas of the site that contain trees and in areas of the site from which trees will be removed to allow for construction. AS 2870 provides detailed guidance for estimating additional soil movements associated with trees. Movements could be equivalent to those expected on a Class H1-D or Class H2-D site.

Notes developed by the CSIRO regarding foundation maintenance and footing performance are included in Appendix A.

9.5.2 Spread Footings

Spread footings designed from first-principles, rather than AS 2870, could be designed on the basis of an allowable bearing pressure of 250 kPa for the very stiff to hard natural soils encountered during the investigations. Footing design should allow for unrestrained surface movements in the order of 20 mm to 40 mm as a result of soil reactivity, and possibly more if trees are located nearby.

Settlement of a spread footing is dependent on the loads applied to the footing and the foundation conditions below the footing. The total settlement of a spread footing designed using the advice provided in this report should be less than 10 mm to 15 mm upon application of the design load. Differential settlements between footings may be in the order of 50% of the value of total settlement. However, larger settlements can occur under large footings and detailed analysis should be undertaken to confirm this advice once the footings have been designed.

All spread footings should be inspected by an experienced geotechnical professional to check the adequacy of the foundation material.

Stiffened raft slabs may be suitable for supporting the proposed buildings. The modulus of subgrade reaction (k_s) of the foundation material will depend on the load applied and the area of the slab on which it is distributed. Assuming a 4,000 kN column load is transferred to very stiff to hard clayey soils over an area of 5 m by 5 m, a preliminary k_s in the order of 7 kPa/mm to 12 kPa/mm could be assumed. Detailed analysis should be undertaken to refine this preliminary value once loadings and slab efficiencies have been confirmed.

9.5.3 Piles

Piles could be used to transfer the structural loads into the underlying materials. Suitable pile types include bored piles, continuous flight auger (CFA) piles, cast in situ concrete screw-type piles, and steel screw piles for lightly loaded structures. Driven piles are unlikely to be practical for the hospital site given the noise and vibration associated with driving.

Bored piles and CFA piles could be designed using the working-stress approach by assuming an allowable end-bearing pressure of 400 kPa and an allowable shaft adhesion of 40 kPa (compression) and 30 kPa (tension) in the hard soils/extremely weathered rock. The upper 3 m of shaft length should be ignored to account for soil shrinkage away from the pile. Total settlement of a pile designed using these parameters should be less than a few millimetres upon application of the design load.

Bores piles and CFA piles could be designed using the limit-state approach by assuming an ultimate end-bearing pressure of 1000 kPa and an ultimate shaft adhesion of 100 kPa (compression) and 70 kPa (tension) in the hard soils/extremely weathered rock. The serviceability limit-state will need to be considered when using ultimate design parameters and it is likely that maximum bearing pressures close to the allowable values provided above will need to be adopted to limit settlements to acceptable magnitudes.

For pile groups, a spacing of 3 pile diameters (centre to centre) or more should result in negligible interaction effects. Piles spaced at closer centres will require analysis to determine whether the loads interact. A minimum socket of 500 mm into the end-bearing foundation material is also recommended.

An appropriate geotechnical strength reduction factor (ϕ_g) will need to be applied to the ultimate values as outlined in Australian Standard AS 2159 – 2009 *Piling – Design and installation*. The ϕ_g value depends on a number of elements outside the control of the geotechnical engineer (e.g. level of construction control, level of performance monitoring, type of testing undertaken etc.) and it is therefore inappropriate to suggest a value in this report. An appropriate value can be agreed upon by the structural and geotechnical engineers during the detailed design process. For preliminary design purposes, ϕ_g values of between 0.40 (no pile testing) and 0.60 (with dynamic load testing) can usually be justified.

It should be noted that shaft adhesion should be ignored in the case of steel screw piles. Further, the design of cast in situ concrete screw-type piles is a specialist area and is often best undertaken by the piling contractor on the basis of empirical relationships and previous load test results.

Consideration should be given to additional geotechnical investigation in areas of the site that require piles to be installed below the previous/current investigation levels. All bored piles should be inspected by an experienced geotechnical professional during construction to check the adequacy of the foundation material and to check the socket cleanliness and roughness. ‘Blind’ piling techniques (e.g. CFA piling) usually rely on contractor records rather than independent engineering inspections.

9.6 Pavements

The laboratory test results indicate that the pavement subgrade is of moderate strength, with CBR values between 5% and 11%. These results are consistent with clayey, sandy and gravelly soil. It is suggested that a design subgrade CBR of 5% be adopted for the pavements and confirmed during construction with inspections and additional testing if required. This is equivalent to a Young’s modulus of 50 MPa (for pavement design purposes only).

Pavement loadings are expected to be relatively low, with a maximum loading of 5×10^4 ESAs considered reasonable for pavements used by delivery trucks. The following unbound granular pavement thicknesses are considered appropriate for the site:

- Carparks and pavements used by passenger vehicles: 150 mm
- Pavements used by delivery trucks, garbage trucks etc.: 350 mm

These thicknesses are based on a design life of 20 years and assume maintenance is carried out over the design life as required. All granular materials should consist of a DGB20 product and should be compacted to a dry density ratio of at least 100% relative to Standard compaction. The subgrade should be prepared in accordance with Section 9.3 of this report.

Appropriate cross-fall and subsurface drainage should be provided to reduce the risk of the pavement materials becoming saturated. Good construction practice, such as installing subsurface drains around the perimeter of any garden or grassed area, will also help to reduce the chance of subgrade deterioration caused by excessive irrigation.

9.7 Soil Aggressivity

The laboratory test results suggest the soil samples tested are mild to concrete and steel elements in accordance with Australian Standard AS 2159 – 2009 *Piling – Design and installation*.

9.8 Seismicity

A Hazard Factor (*Z*) of 0.08 would be appropriate for the development site in accordance with Australian Standard AS 1170.4 – 2007 *Structural design actions – Part 4: Earthquake actions in Australia*. The site sub-soil class would be Class C_e.

10. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for a project at Dubbo Base Hospital in accordance with DP's proposal SYD151621.P.002.Rev0 dated 4 February 2016 and acceptance received from Health Infrastructure. The report is provided for the use of Health Infrastructure for this project only and for the purpose(s) described in the report. It should not be used for other projects or by a third party.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Subsurface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic 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 limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

This report must be read in conjunction with all of the attached notes 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 given 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. The contents of this report do not constitute formal design components such as are required, by Health and Safety Legislation and Regulations, to be included in a Safety Report.

Douglas Partners Pty Ltd

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.

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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.

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.

Sampling Methods

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, 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 Descriptions

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 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approx 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 $Is_{(50)}$

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 loner sections
Unbroken	Core lengths mostly > 1000 mm

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

Douglas Partners

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

July 2010

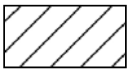
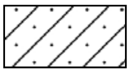
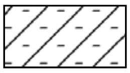
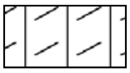
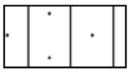
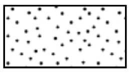
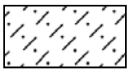
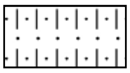
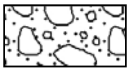
Symbols & Abbreviations

Graphic Symbols for Soil and Rock

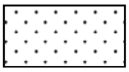
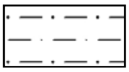
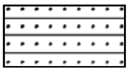
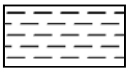
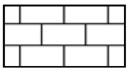
General

■	Asphalt
	Road base
	Concrete
	Filling

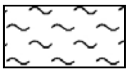
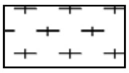
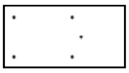
Soils

	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

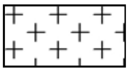
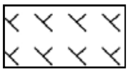
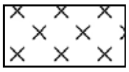
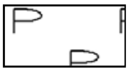
Sedimentary Rocks

	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

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction
There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation
This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil
All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure
This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth
Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation
Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots
In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself
Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures
Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

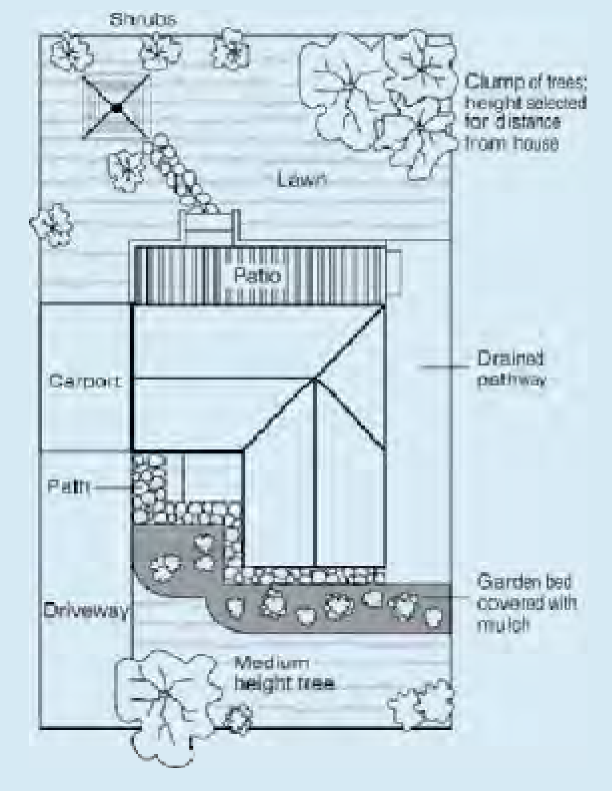
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

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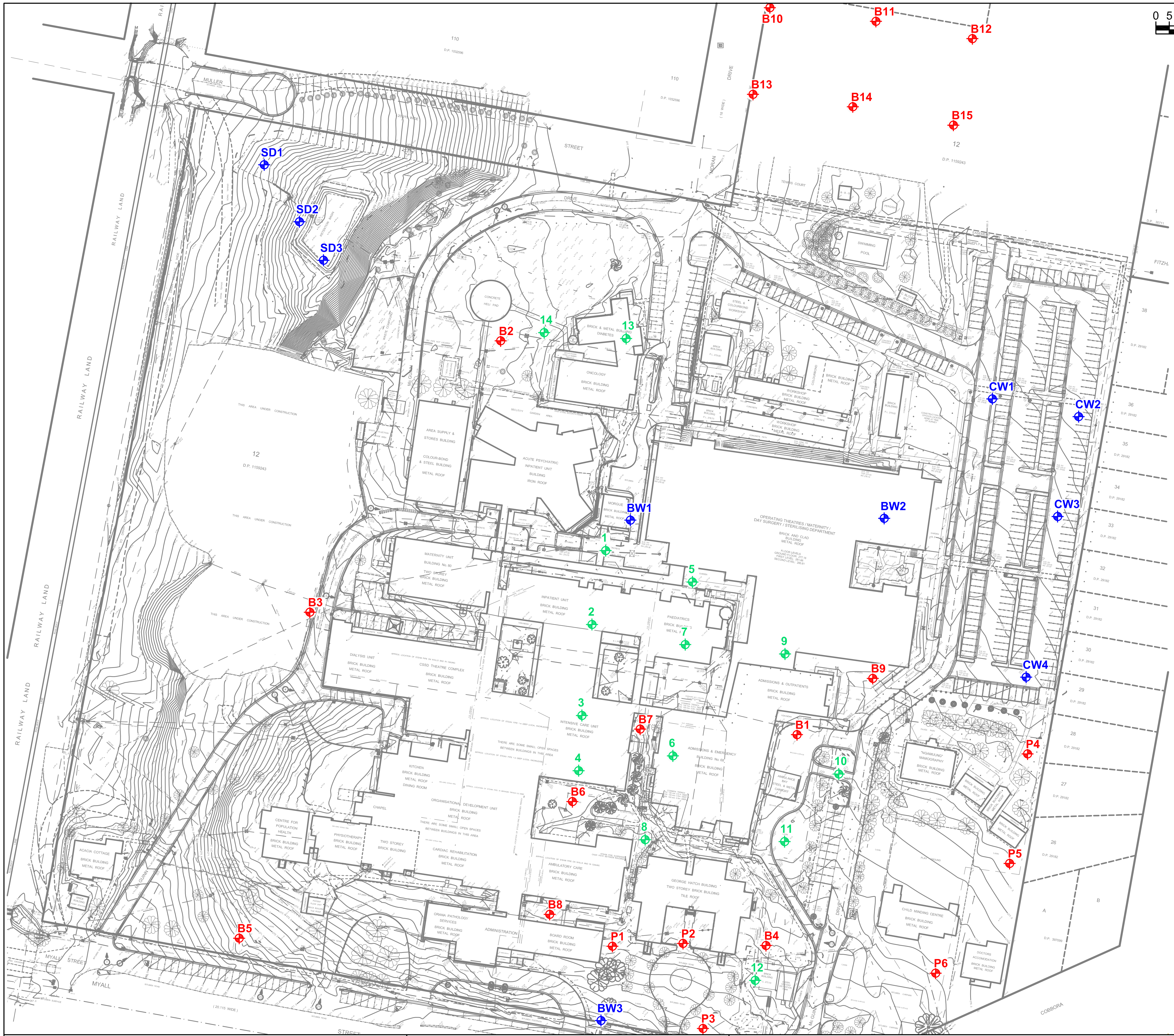
Appendix B

Drawing



0 5 10 20 30 40 50 75 100 150m

1:1500 @ A3

NOTE:

1: Base drawing provided by client.
2: Test locations are approximate only and are shown with reference to existing features.

LEGEND

⊕ Current DP Borehole
⊕ Previous DP Borehole (2012)
⊕ Previous DP Borehole (1996)

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: Health Infrastructure		TITLE: **Approximate Locations of Boreholes**	N	PROJECT No:	72811.03
OFFICE: Sydney	DRAWN BY: PSCH	**Dubbo Health Service Redevelopment Stages 3 and 4**		DRAWING No:	1
SCALE: 1:1500 @ A3	DATE: 1.12.2016	**Myall Street, Dubbo**		REVISION:	A

Appendix C

Results of Current Field Work

BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 276.8 AHD
EASTING: 652791
NORTHING: 6431793
DIP/AZIMUTH: 90°/--

BORE No: B1
PROJECT No: 72811.03
DATE: 30/3/2016
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
	0.05	ASPHALT							
		FILLING - brown, gravelly clayey sand filling (fine to coarse igneous and quartz gravel), moist		A/E	0.4 0.5				
	0.7	SILTY CLAY - hard, red-brown, silty clay with a trace of fine quartz gravel, humid							
276		0.9m: trace of fine to medium ironstone gravel		A	0.9 1.0	A/E			
	1	1.0m: yellow-brown and brown mottled, slightly sandy		S	1.0 1.45		8,12,20 N = 32		1
275									
	2								2
	2.5	SILTY CLAY - hard, grey and brown mottled, silty clay with ironstained bands and very low strength basalt bands (weathered basalt)		S	2.5 2.8		6,20 refusal		
274									
	3								3
273									
	4								4
				S	4.5 4.95		10,15,20/100mm refusal		
272									
	4.95	Bore discontinued at 4.95m- target depth reached							

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 276.2 AHD
EASTING: 652660
NORTHING: 6431950
DIP/AZIMUTH: 90°/--

BORE No: B2
PROJECT No: 72811.03
DATE: 31/3/2016
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
	0.1	FILLING (TOPSOIL) - dark brown, sandy silt and clay filling with some fine igneous gravel and rootlets, moist		A/E	0.0 0.1				
276	0.5	FILLING - brown, clayey, fine to medium sand filling with some fine igneous gravel, humid to moist		A	0.4 0.5				
275	1	FILLING - brown, silty clay filling with some fine to medium igneous gravel and a trace of charcoal, moist		A/E S	0.9 1.0 1.45		3,3,2 N = 5		1
	1.5	FILLING - stiff, brown, slightly sandy, silty clay filling with some fine to medium gravel (quartz and mudstone?), moist (possible natural)		A	1.5				
274	2 2.0	SILTY CLAY - firm to stiff, light brown, silty clay with some quartz gravel, moist (possible filling)		A	2.0				2
	2.4	SANDY CLAY - firm (?), brown and grey, sandy clay with a trace of fine to coarse igneous gravel (possible filling)		S	2.4 2.5 2.51		25/10 refusal bouncing		
273 272	2.7 3 4	Bore discontinued at 2.7m - auger refusal (possible bedrock)							3 4

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Solid flight auger to 2.7m

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 273.7 AHD
EASTING: 652610
NORTHING: 6431841
DIP/AZIMUTH: 90°/--

BORE No: B3
PROJECT No: 72811.03
DATE: 31/3/2016
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
	0.03	ASPHALT							
	0.3	FILLING (ROADBASE) - grey, sandy clayey gravel filling (fine to coarse igneous gravel), humid to moist							
273 272 271	1 2 3 3.6	GRAVELLY SANDY CLAY/CLAYEY SAND - dense, brown, gravelly sandy clay/clayey sand (fine to coarse quartz gravel), moist 2.5m: medium dense 2.9m: slightly more clayey with a trace of charcoal		A/E A/E S S	0.4-0.6 0.9-1.0 1.0-1.45 2.5-2.95		 9,11,18 N = 29 6,9,6 N = 15		1 2 3
270 269	4 4.95	SILTY CLAY - stiff, dark brown, slightly sandy, silty clay, moist 4.2m: very stiff, brown with a trace of fine gravel (ironstone and igneous) and charcoal		S	4.5-4.95		6,6,12 N = 18		4

Bore discontinued at 4.95m- target depth reached

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 275.0 AHD
EASTING: 652765
NORTHING: 6431722
DIP/AZIMUTH: 90°/--

BORE No: B4
PROJECT No: 72811.03
DATE: 30/3/2016
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
275	0.1	FILLING (TOPSOIL) - brown, clayey silt filling with some rootlets, moist	▨	A	0.0 0.1				
	0.7	FILLING - brown, gravelly, clayey, medium to coarse grained sand filling (fine to coarse igneous and quartz gravel), with a trace of glass, wet	▨	A/E	0.4 0.5			▷	
		Bore discontinued at 0.7m - auger refusal (possible basalt bedrock)							
274	1								1
273	2								2
272	3								3
271	4								4

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 0.7m
WATER OBSERVATIONS: Seepage observed at 0.3m
REMARKS: B4A drilled 0.4m away achieved refusal at similar depth

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 271.0 AHD
EASTING: 652581
NORTHING: 6431723
DIP/AZIMUTH: 90°/--

BORE No: B5
PROJECT No: 72811.03
DATE: 31/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
271		FILLING (TOPSOIL) - brown, slightly sandy, silty clay filling with some rootlets and fine quartz gravel and a trace of roots, moist	▨	A/E	0.3 0.4				
	0.4	FILLING - brown, silty clay filling with some rootlets and medium to coarse gravel (quartz and igneous), moist 0.6m: band of igneous/basalt cobbles and coarse gravel 0.7m: grey	▨						
	0.75	Bore discontinued at 0.75m - auger refusal on igneous gravel/cobbles (possible basalt bedrock)							
270	1								1
269	2								2
268	3								3
267	4								4

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 0.75m
WATER OBSERVATIONS: No free groundwater observed
REMARKS: B5A drilled 0.6m away achieved refusal at similar depth

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 276.0 AHD
EASTING: 652698
NORTHING: 6431779
DIP/AZIMUTH: 90°/--

BORE No: B6
PROJECT No: 72811.03
DATE: 30/3/2016
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
276		FILLING (TOPSOIL) - brown, silty, fine to medium grained sand filling, moist		A/E	0.0 0.2				
	0.3	SILTY CLAY - hard, red-brown, silty clay with a trace of fine ironstone and quartz gravel, humid		A/E	0.4 0.5				
275	1	1.0m: very stiff, brown with some fine grained sand		S	1.0 1.45		3,9,11 N = 20		1
274	2 2.0	SILTY CLAY - hard, grey-brown, silty clay with some fine siltstone gravel, humid			2.0				2
		2.5m: very stiff, more silty		A	2.5				
	2.7	SILTY CLAY - very stiff, brown and yellow, silty clay with some fine to medium gravel (weathered conglomerate (?))		S	2.95		6,10,12 N = 22		
273	3				3.0				3
272	4 4.0	SILTY CLAY- hard, light grey and brown mottled, silty clay (weathered siltstone)							4
		4.4m: orange-brown with some very low to low strength siltstone/ironstone bands		S	4.5 4.66		20,25/5mm refusal		
	4.66	Bore discontinued at 4.66m - target depth reached							

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 276.1 AHD
EASTING: 652727
NORTHING: 6431799
DIP/AZIMUTH: 90°/--

BORE No: B7
PROJECT No: 72811.03
DATE: 31/3/2016
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
276		FILLING (TOPSOIL) - brown, sandy silty clay filling with some rootlets and charcoal, moist		A/E	0.0 0.1				
	0.2	SILTY CLAY - stiff, red-brown, silty clay with some charcoal, moist		A/E	0.2 0.4				
		0.6m: very stiff, brown							
				A	0.9 1.0				
275	1			S	1.0 1.45		3,7,10 N = 17		1
		1.4m: trace of siltstone gravel							
274	2								2
		2.2m: firm to stiff, grey-brown with some fine sand							
	2.5	SILTY CLAY - hard, brown, yellow and grey mottled, silty clay with a trace of shaly bands		S	2.5 2.95		7,14,18 N = 32		
273	3								3
272	4								4
		4.5m: increasing shaly bands (siltstone)		S	4.5 4.95		6,11,15 N = 26		
	4.95								

Bore discontinued at 4.95m- target depth reached

RIG: Hand tools & Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Hand auger to 0.4m; Solid flight auger to 4.95m

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 275.8 AHD
EASTING: 652687
NORTHING: 6431736
DIP/AZIMUTH: 90°/--

BORE No: B8
PROJECT No: 72811.03
DATE: 31/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
		FILLING - brown, silty, fine to medium grained sand filling with some rootlets - cobbly/gravelly from 0.1m (igneous/basalt)	▨	A/E	0.0 0.1				
	0.6	Bore discontinued at 0.6m - refusal on igneous cobbles (possible basalt bedrock)							
275									
	1								1
274									
	2								2
273									
	3								3
272									
	4								4
271									

RIG: Hand tools **DRILLER:** KM **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Hand auger to 0.6m
WATER OBSERVATIONS: No free groundwater observed
REMARKS: B8A drilled 5m away achieved refusal at 0.4m

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 277.6 AHD
EASTING: 652814
NORTHING: 6431815
DIP/AZIMUTH: 90°/--

BORE No: B9
PROJECT No: 72811.03
DATE: 30/3/2016
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
		FILLING - brown and grey, sandy clay filling with some charcoal and a trace of fine quartz gravel, geofabric and medium igneous gravel, moist		A/E	0.4 0.5				
277	0.6	GRAVELLY CLAY - stiff, brown, gravelly silty clay (fine to coarse ironstone & quartz), moist		A/E	0.9 1.0				
	1 1.0	SILTY CLAY - stiff to very stiff, red-brown and yellow-brown mottled, silty clay, moist		S	1.0 1.45		3,4,4 N = 8		1
276		1.7m: very stiff, yellow-brown							
	2 2.0	SILTY CLAY - firm to stiff, yellow-brown, silty clay with some fine to medium gravel (quartz and ironstone), moist							2
275	2.5	BASALT - extremely low strength, grey and brown, laminated basalt		S	2.5 2.95		12,25 refusal		
	3								3
274	4								4
273		- very low strength, grey		S	4.5 4.95		5,14,25 N = 39		
	4.95	Bore discontinued at 4.95m- target depth reached							

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 278.7 AHD
EASTING: 652788
NORTHING: 6432061
DIP/AZIMUTH: 90°/--

BORE No: B10
PROJECT No: 72811.03
DATE: 30/3/2016
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
		FILLING - brown, sandy silty clay filling with some fine to coarse gravel (siltstone, igneous, quartz) and rootlets with a trace of steel and charcoal, dry 0.1m: brown and grey		A/E	0.0 0.1				
	0.2	SILTY CLAY - very stiff to hard, brown, silty clay with a trace of fine gravel (ironstone and quartz) and charcoal, humid (possible filling)		A/E	0.4 0.5				
278				A	0.9 1.0				
	1			S	1.0 1.45		2,3,10 N = 13		1
277									
	2								2
	2.2	SILTY CLAY - very stiff, red-brown, silty clay with a trace of fine to medium quartz gravel, humid							
276				S	2.5 2.95		4,8,8 N = 16		
	3								3
275									
	4								4
		4.2m: red-brown and light grey mottled							
274				S	4.5 4.95		6,6,10 N = 16		
	4.95	Bore discontinued at 4.95m- target depth reached							

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 279.2 AHD
EASTING: 652811
NORTHING: 6432055
DIP/AZIMUTH: 90°/--

BORE No: B11
PROJECT No: 72811.03
DATE: 30/3/2016
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
279		GRAVELLY CLAY - red-brown, gravelly silty clay (fine to coarse quartz gravel), humid		A/E	0.4 0.5				
	1			A	0.9 1.0				1
278	1.1	GRAVELLY CLAY - orange-brown, gravelly silty clay (fine to coarse siltstone gravel), humid		S	1.0 1.3		6,25 refusal		
				A	1.5 2.0				
277	2 2.0	SILTY CLAY - firm to stiff, orange-brown, silty clay, moist		A	2.0 2.5				2
		2.5m: very stiff		S	2.5 2.95		6,8,14 N = 22		
276	3	2.9m: gravelly band (siltstone/ironstone)							3
275	4 4.0	SILTY CLAY - stiff, light grey and orange-brown mottled, silty clay							4
		4.5m: stiff to very stiff		S	4.5 4.95		4,8,9 N = 17		
	4.95	4.9m: gravelly band (siltstone/ironstone)							

Bore discontinued at 4.95m- target depth reached

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 280.5 AHD
EASTING: 652850
NORTHING: 6432052
DIP/AZIMUTH: 90°/--

BORE No: B12
PROJECT No: 72811.03
DATE: 30/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
280		GRAVELLY CLAY - brown, silty gravelly clay (fine to coarse quartz gravel) with a trace of fine ironstone gravel, humid	A/E	0.4 0.5				
	1		A/E	0.9 1.0				1
279			S	1.0 1.45		3,12,15 N = 27		
	2 2.0	1.9m: band of quartz						2
		SILTY CLAY - firm to stiff, yellow-brown with some light grey mottling, silty clay with a trace of fine ironstone gravel, moist						
278		2.5m: very stiff, orange-brown with a trace of carbonaceous material	S	2.5 2.64		25/140mm refusal		
	2.6	SILTSTONE - very low strength, orange-brown siltstone						
	2.8	Bore discontinued at 2.8m - auger refusal					▷	
	3							3
277								
	4							4
276								

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 2.8m
WATER OBSERVATIONS: Seepage observed at 2.8m
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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 278.0 AHD
EASTING: 652780
NORTHING: 6432028
DIP/AZIMUTH: 90°/--

BORE No: B13
PROJECT No: 72811.03
DATE: 30/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Well Construction Details
278		FILLING - orange-brown, silty clay filling, humid (possible natural)							
	0.2	SILTY CLAY - hard, orange-brown, silty clay with some fine to medium ironstone gravel, humid							
277	1				1.0				1
				S/E			6,17,22 N = 39		
					1.45				
		1.7m: slightly sandy							
276	2 2.0	SANDY CLAY - hard, yellow-brown, silty sandy clay		A	2.0 2.1				2
					2.5				
		2.7m: some grey mottling and a trace of roots		S			7,20,25 N = 45		
					2.95				
275	3								3
274	4								4
					4.5				
				S			8,15,19 N = 34		
	4.95				4.95				

Bore discontinued at 4.95m- target depth reached

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 278.7 AHD
EASTING: 652803
NORTHING: 6432026
DIP/AZIMUTH: 90°/--

BORE No: B14
PROJECT No: 72811.03
DATE: 30/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
	0.03	FILLING - coarse igneous gravel filling						
		FILLING - brown, silty clay filling with a trace of coarse ironstone gravel, moist	A/E	0.4 0.5				
278	0.6	SILTY CLAY - stiff then very stiff, orange-brown, silty clay with a trace of fine gravel (ironstone and quartz) and charcoal, moist	A/E	0.9 1.0				
	1 1.1	SILTY CLAY - hard, yellow-brown, slightly sandy, silty clay with some fine to medium ironstone gravel, humid to moist	S	1.45		3,3,4 N = 7		1
277	2							2
		2.3m: some light grey mottling and a trace of fine quartz gravel	S	2.5 2.82		5,7,25/20mm refusal		
276	3 3.0	SILTY CLAY - stiff, orange-brown, silty clay with some gravelly bands (fine to coarse ironstone)						3
275	4		A	3.5				4
		4.3m: very stiff with some light grey mottled bands and a trace of fine quartz gravel	S	4.5		6,7,10 N = 17		
274		4.8m: coarse gravel band						
	4.95			4.95				

Bore discontinued at 4.95m- target depth reached

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Solid flight auger to 4.5m

WATER OBSERVATIONS: Seepage at 4.95m (base of SPT)

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 280.2 AHD
EASTING: 652840
NORTHING: 6432011
DIP/AZIMUTH: 90°/--

BORE No: B15
PROJECT No: 72811.03
DATE: 30/3/2016
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
280		SILTY CLAY - very stiff to hard, red-brown, silty clay with some fine gravel (ironstone, quartz) and a trace of charcoal and roots, humid (possible filling)							
				A/E	0.4 0.5				
				A/E	0.9 1.0				
	1								1
279				S	1.45		6,12,15 N = 27		
	2								2
	2.0	SILTY CLAY - stiff, orange-brown, silty clay with some fine to medium ironstone gravel, moist then humid							
278									
		2.5m: trace of light grey bands, fine quartz gravel and coarse ironstone gravel		S	2.5 2.95		4,5,6 N = 11		
	3								3
277									
	4								4
	4.0	SILTY CLAY - firm to stiff, light grey and orange mottled, silty clay with a trace of fine quartz gravel, moist		A	4.0 4.5				
276									
				S	4.95		2,4,4 N = 8		
	4.95								

Bore discontinued at 4.95m- target depth reached

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger 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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BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 274.8 AHD
EASTING: 652720
NORTHING: 6431721
DIP/AZIMUTH: 90°/--

BORE No: P1
PROJECT No: 72811.03
DATE: 31/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
		FILLING - brown, silty, fine to medium grained sand filling with some rootlets 0.1m: cobbly/gravelly from 0.1m (igneous/basalt)	▨	B	0.05 0.7				
	0.7	Bore discontinued at 0.7m - auger refusal on igneous cobbles (possible basalt bedrock)							
274									
	1								1
273									
	2								2
272									
	3								3
271									
	4								4
270									

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight 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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 275.0 AHD
EASTING: 652740
NORTHING: 6431720
DIP/AZIMUTH: 90°/--

BORE No: P2
PROJECT No: 72811.03
DATE: 1/4/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Well Construction Details
275	0.02	FILLING - grey, medium igneous gravel filling overlaying 10mm bitumen layer	▨						
	0.06	FILLING - hard, brown, silty clay with some fine to medium quartz gravel, humid	▨	B	0.06				
		FILLING - brown, slightly sandy, gravelly silty clay filling (fine to coarse igneous/basalt gravel) with some igneous/basalt cobbles and a trace of cement	▨						
	0.6	Bore discontinued at 0.6m - auger refusal on igneous cobbles (possible basalt bedrock)			0.6				
274	1								1
273	2								2
272	3								3
271	4								4

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 0.6m
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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 273.9 AHD
EASTING: 652747
NORTHING: 6431691
DIP/AZIMUTH: 90°/--

BORE No: P3
PROJECT No: 72811.03
DATE: 31/3/2016
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
		FILLING (TOPSOIL) - brown, sandy silty clay filling with some rootlets, moist to wet							
	0.2	SILTY CLAY - firm to stiff, brown, silty clay, moist to wet			0.2				
		0.5m: stiff to very stiff, with some red-brown mottling and a trace of medium igneous gravel		B					
		0.8m: very stiff with a trace of igneous cobbles							
273	1								1
					1.2				
		1.4m: some medium siltstone gravel and a trace of fine quartz gravel							
	1.6	Bore discontinued at 1.6m - target depth reached							
272	2								2
271	3								3
270	4								4
269									

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 1.6m
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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 278.4 AHD
EASTING: 652866
NORTHING: 6431805
DIP/AZIMUTH: 90°/--

BORE No: P4
PROJECT No: 72811.03
DATE: 31/3/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Well Construction Details
	0.1	FILLING - brown, silty, fine to medium grained sand filling with some rootlets, moist							
278	0.4	FILLING - brown, sandy, fine to coarse gravel filling (igneous, quartz, sandstone), humid to moist							
277	1.6	SILTY CLAY - very stiff to hard, red-brown, silty clay, humid 1.2m: approximately 200mm to 300mm gravelly band (fine to medium quartz)		B	0.4 1.6				
		Bore discontinued at 1.6m - target depth reached							

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased
TYPE OF BORING: Solid flight auger to 1.6m
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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 277.1 AHD
EASTING: 652863
NORTHING: 6431748
DIP/AZIMUTH: 90°/--

BORE No: P5
PROJECT No: 72811.03
DATE: 1/4/2016
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
277	0.2	FILLING (TOPSOIL) - brown, sandy silty clay with some rootlets, moist	⊠						
	0.5	GRAVELLY SANDY CLAY - brown, gravelly sandy clay (fine to coarse igneous gravel and cobbles), humid to moist	░	B	0.2 0.5				
		Bore discontinued at 0.5m - refusal on igneous cobbles (possible basalt bedrock)							
276	1								1
275	2								2
274	3								3
273	4								4

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Solid flight auger to 0.5m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: P5A, B, C drilled up to 1.5m away refused at same depth

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: Health Infrastructure
PROJECT: Dubbo Base Hospital - Stages 3 & 4
LOCATION: Myall Road, Dubbo

SURFACE LEVEL: 275.7 AHD
EASTING: 652832
NORTHING: 6431704
DIP/AZIMUTH: 90°/--

BORE No: P6
PROJECT No: 72811.03
DATE: 1/4/2016
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
	0.2	FILLING - brown, clayey, fine to medium sand filling with some fine to medium gravel (igneous and quartz) and rootlets and roots, humid							
275	1.6	SILTY CLAY - very stiff to hard, silty clay with some fine sand and a trace of fine to medium gravel (igneous and quartz)		B	0.2 1.6				
274		Bore discontinued at 1.6m - target depth reached							
273									
272									
271									

RIG: Gemco 8C7 **DRILLER:** A Briton **LOGGED:** KM **CASING:** Uncased

TYPE OF BORING: Solid flight auger to 1.6m

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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Appendix D

Results of Previous Field Work

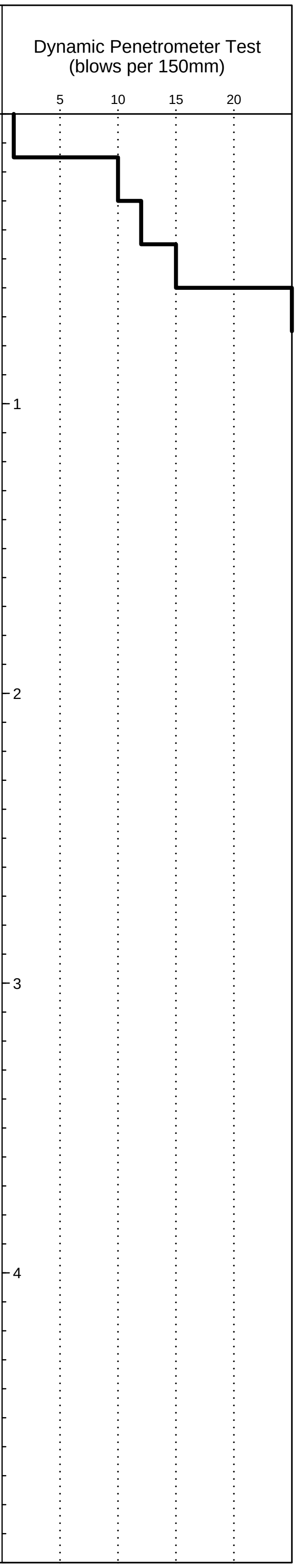
BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital Redevelopment
LOCATION: Myall Street, Dubbo

SURFACE LEVEL: 277.6 m AHD
EASTING: 652730
NORTHING: 6431875
DIP/AZIMUTH: 90°/--

BORE No: BW1
PROJECT No: 72811
DATE: 9/2/2012
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Sampling & In Situ Testing Depth	Sample	Results & Comments	Water
	0.1	FILLING - dark brown, gravelly clay filling, damp (topsoil)		E	0.1			
	0.8	SILTY CLAY - hard, red brown silty clay, medium to high plasticity		A	0.5			
	1.5	SILTY CLAY - hard, orange brown, silty clay with some rounded gravel, medium plasticity		A	1.0			
	2.5	GRAVELLY CLAY - very stiff, orange brown, subrounded to angular, fine gravelly clay						
	3.2	CLAYEY SAND - very stiff to hard, light grey and grey brown clayey sand (decomposed basalt)		A	3.0			
	5.0	CLAYEY SAND - very stiff to hard, light yellow brown, clayey sand (decomposed basalt)		A A	3.3 4.5			



Bore discontinued at 5.0m - target depth reached

RIG: Terrazo Pengo **DRILLER:** G Miles **LOGGED:** A Podnar **CASING:** Uncased

TYPE OF BORING: 300mm diameter solid flight auger

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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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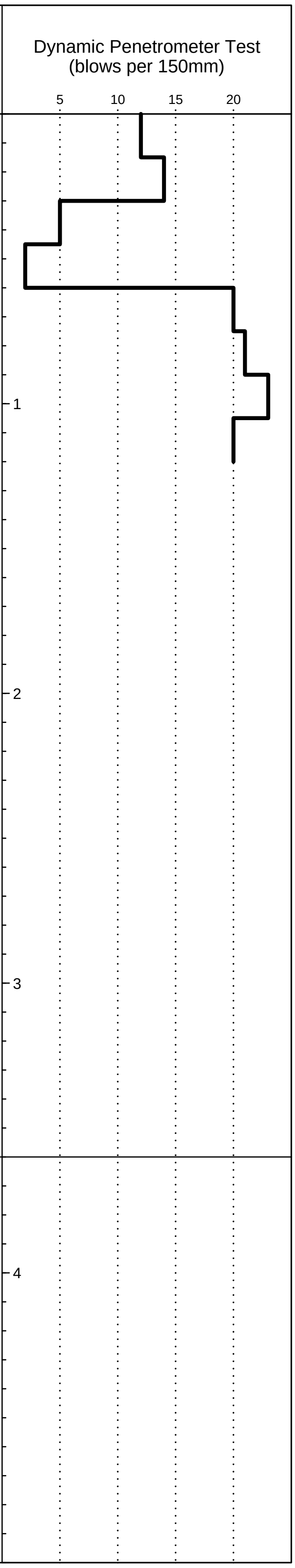
BOREHOLE LOG

CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital Redevelopment
LOCATION: Myall Street, Dubbo

SURFACE LEVEL: 278.5 m AHD
EASTING: 652817
NORTHING: 6431869
DIP/AZIMUTH: 90°/--

BORE No: BW2
PROJECT No: 72811
DATE: 9/2/2012
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.05	ASPHALT						
		FILLING - dark orange brown grey, sandy gravel filling (roadbase), damp		E	0.1			
	0.2	FILLING - dark red brown, clayey sand filling, damp		E	0.4			
	0.6	SILTY CLAY - hard, orange brown, silty clay with some fine subangular gravel		A	1.0			
		1.5m: band of subrounded gravel						
		2.5m: red brown, increasing gravel content		A	3.0			
	3.6	Bore discontinued at 3.6m - practical refusal on subrounded gravel in silty clay matrix (possibly weathered rock)		A	3.6			



RIG: Terrazo Pengo **DRILLER:** G Miles **LOGGED:** A Podnar **CASING:** Uncased
TYPE OF BORING: 300mm diameter solid flight auger
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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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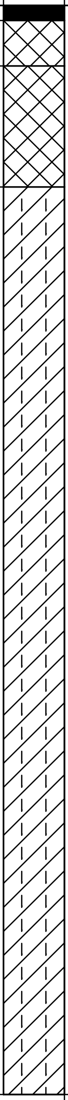
BOREHOLE LOG

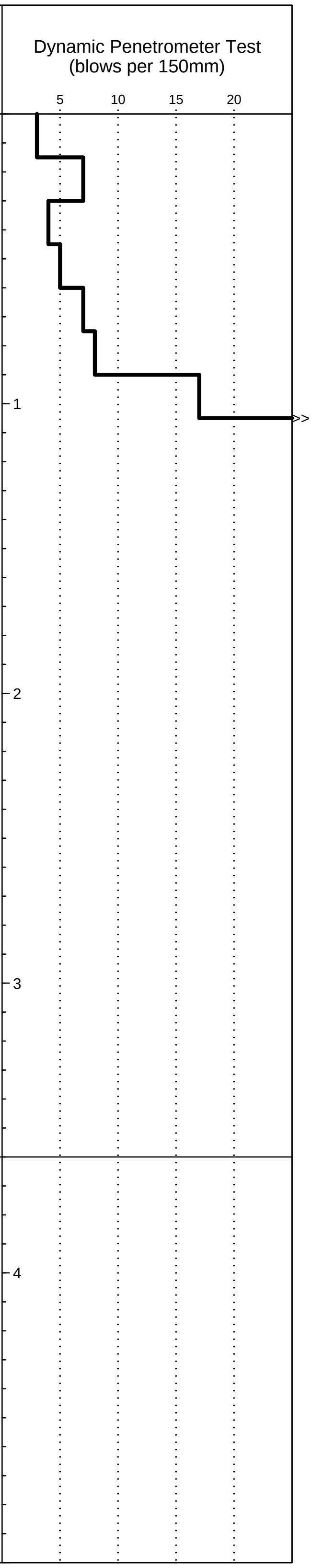
CLIENT: Health Infrastructure
PROJECT: Dubbo Base Hospital Redevelopment
LOCATION: Myall Street, Dubbo

SURFACE LEVEL: 273.3 m AHD
EASTING: 652716
NORTHING: 6431697
DIP/AZIMUTH: 90°/--

BORE No: BW3
PROJECT No: 72811
DATE: 9/2/2012
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.05	ASPHALT					
	0.2	FILLING - dark orange brown grey, sandy gravel filling (roadbase), damp	E	0.1			
	0.6	FILLING - dark red brown, clayey sand filling, damp	E	0.4			
		SILTY CLAY - hard, orange brown, silty clay with some fine subangular gravel	E	1.0			
		1.5m: band of subrounded gravel					
		2.5m: red brown, increasing gravel content	A	3.0			
	3.6	Bore discontinued at 3.6m - practical refusal on subrounded gravel in silty clay matrix (possibly weathered rock)	A	3.6			





RIG: Terrazo Pengo **DRILLER:** G Miles **LOGGED:** A Podnar **CASING:** Uncased
TYPE OF BORING: 300mm diameter solid flight auger
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

☐ Sand Penetrometer AS1289.6.3.3
☒ Cone Penetrometer AS1289.6.3.2

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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