Geotechnical Investigation Report

Farnell Street, Forbes NSW

Prepared for: Land and Housing Corporation c/- ADW Johnson Pty Ltd
EP3269.003v1 15 May 2025

Geotechnical Investigation Report

Farnell Street, Forbes NSW

Land and Housing Corporation c/- ADW Johnson Pty Ltd
7/335 Hillsborough Road,
Warners Bay NSW 2282

15 May 2025

Our Ref: EP3269.003v1

LIMITATIONS

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v01	*15/05/2025*	*EP3269.003*	*Land and Housing Corporation c/- ADW Johnson Pty Ltd*

Brisbane
310 Edward Street
Brisbane QLD 4000
T 07 3506 0233

Newcastle
3/19 Bolton Street
Newcastle NSW 2300
T 02 4048 2845

Sydney
L13, 80 Mount Street
North Sydney NSW 2060
T 02 9922 5021

Melbourne
Unit 22/1 Ricketts Road
Mount Waverley VIC 3149
T 03 7504 3610

W www.eprisk.com.au
ABN 81 147 147 591

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1 Introduction

EP Risk Management Pty Ltd (EP Risk) was engaged by Land and Housing Corporation c/- ADW Johnson Pty Ltd (ADWJ) to undertake a Geotechnical Investigation at Farnell Street, Forbes NSW.

The engagement was carried out in line with the conditions of engagement and the investigation scope as outlined in our proposal EP17912 dated 22 April 2024. The extent of the proposed residential development is shown in **Appendix A – Farnell Street- Forbes Residential Development.**

The investigation is supplementary and supersedes advice provided in Preliminary Geotechnical Investigation (desktop) Report EP3269.001 dated 17 January 2024.

1.1 Objectives and Scope

It is understood that the geotechnical investigation is required for the development of the proposed residential subdivision at Farnell Street, Forbes NSW.

EP Risk carried out the following scope of works for the geotechnical investigation:

- Prepared all the work health and safety documentation and procured Before You Dig Australia plans for the site.
- Advanced twelve (12) test pits (TP) across the site to a maximum depth of 3.0m below ground level (BGL), or prior bedrock refusal to assess the subgrade conditions.
- Advanced an additional two (2) test pits at proposed locations for lightning poles.
- Dynamic Cone Penetrometer (DCP) was conducted adjacent to test pits to assess the consistency of the subsurface.
- Collected representative soil/rock core samples for further laboratory testing. Upon completion the test pits were filled with spoil and light compaction by excavator bucket, mounded and tracked over.
- Preparation of a Geotechnical Investigation report including investigation findings, laboratory test results, pavement design and site classification.

2 Site Location and Description

The Site is located on Farnell Street, Forbes NSW legally defined as Lot 7332/DP1166365 and Lot 7025/DP1020631 and is approximately 10.05ha in size. The topography of the Site is relatively flat with elevations ranging from approximately Reduced Level (R.L.) of 262m Australian Height Datum (AHD) in the northern section of the Site to approximately R.L. 249m AHD in the southern section of the Site.

Site vegetation comprises of short to tall grass and mature trees scattered across the northern section and along the west boundary of the Site. Several informal unsealed access tracks were also observed on Site. Site drainage is assumed to be overland flow via surface gradient flowing from the northern section of the Site to the southern section of the Site and into the underground stormwater drainage infrastructure. Photos collected during the site investigation are presented in **Appendix B– Photolog**.

An excerpt from NearMap with the indicative site location is shown in Figure 1.

Indicative
Site Location

Figure 1 - Indicative Site Location

3 Desktop Study

3.1 Regional Geology

Based on geological data sourced from NSW Government website (www.minview.geoscience.nsw.gov.au), the Site is underlain by:

- Quaternary Aged (2.58 – 0.0117 Ma) – Colluvial and Residual Deposits (Q_cr) of Colluvium known to contain undifferentiated colluvial and residual deposits underlain at depth by
- Ludlow Aged (427.4-423.0 Ma) – Calarie Sandstone of Derriwong Group comprising of sandstone.

An excerpt of the geological map is shown in Figure 2.

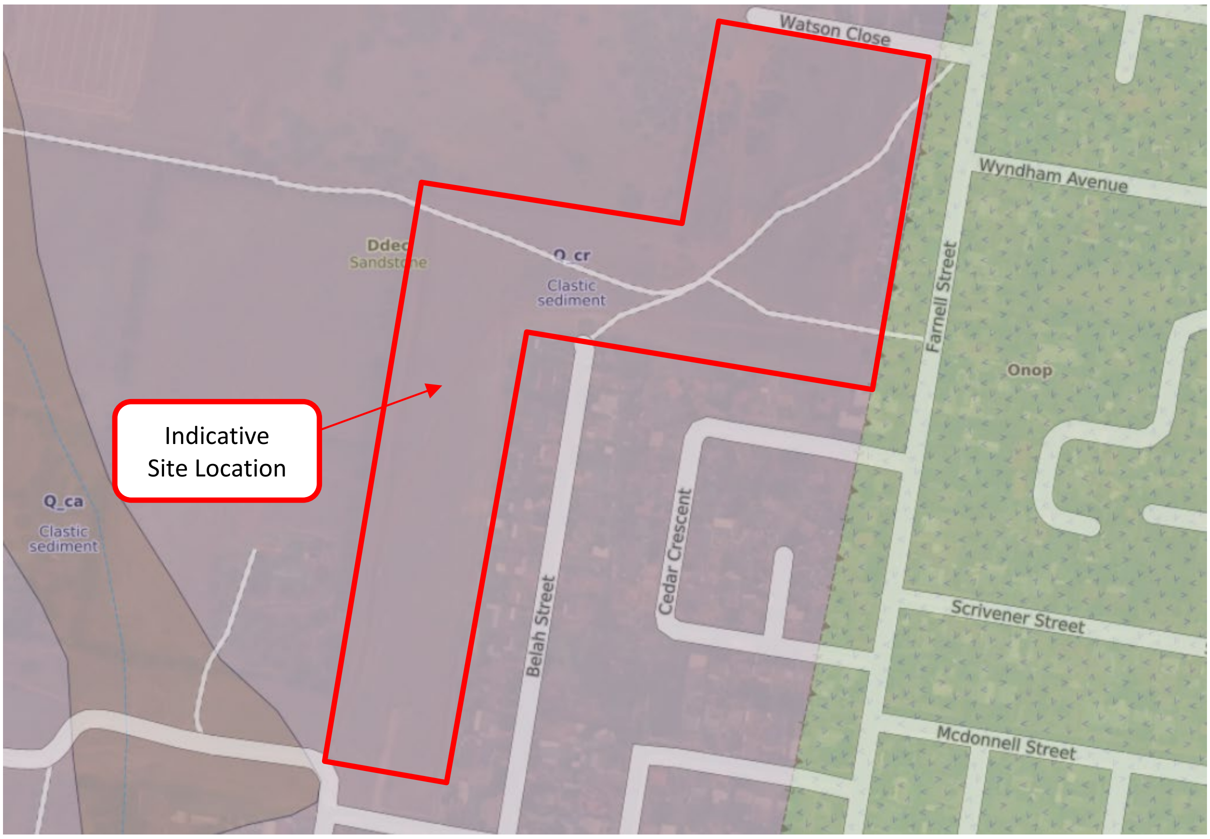


Figure 2 - Geological Map Excerpt (Q_cr - Colluvial and Residual Deposits)

3.2 Soil Landscape

Based on the information provided by the NSW Office of Environment and Heritage, Soil Landscapes of Central and Eastern NSW, on site soil landscape has been identified as Bald Hill. The Bald Hill soil landscape covers Narrow elongate crests, ridges and gently inclined side slopes at Forbes and south and west of Forbes on predominately sandstones. The limitations for this soil landscape are water erosion hazard, rock outcrop; shallow, strongly acid, highly permeable soils with low fertility, low available water holding capacity and localised high organic matter.

3.3 Mine Subsidence

Reference to the Mine Subsidence District Data Source, the Site is not located within a Mine Subsidence District.

3.4 Acid Sulphate Soils (ASS)

The NSW Government data available on NSW Planning Portal indicates the site is located in an area with no known acid sulphate soils. An extract of the acid sulphate soil map is shown in Figure 3.

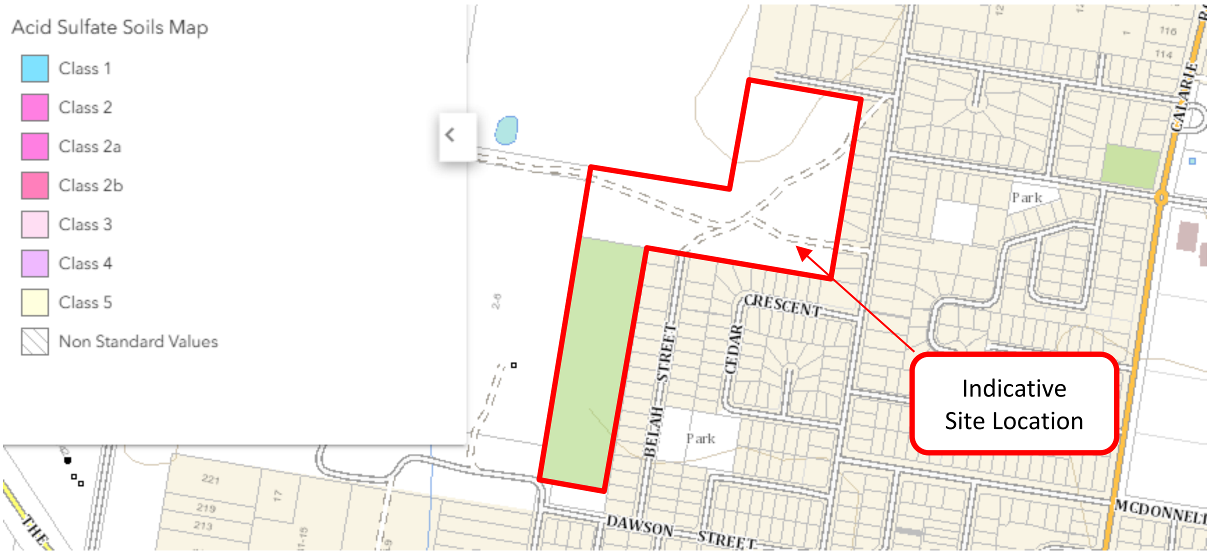


Figure 3 - ASS Map Excerpt

4 Geotechnical Investigation

4.1 Investigation Methodology

The site investigation was conducted from 8 April 2025 to 9 April 2025 under full time supervision of an experienced EP Risk Geotechnical Professional in accordance with AS1726-2017 Geotechnical Site Investigations. The investigations involved the following:

- Preparation of a Safe Work Method Statement (SWMS) for all the fieldwork and procuring the site service plans from Before You Dig Australia.
- Excavation of fourteen (14) test pits at locations of interest within the footprint of the proposed development.
- Logging of soil/rocks encountered and collection of representative soil and rock samples to be tested by a NATA-accredited laboratory.
- Upon completion the test pits were filled with spoil and light compaction by excavator bucket, mounded and tracked over.

The test pits were excavated using a 6T excavator. The locations of the test pits are shown in **Appendix C - Geotechnical Investigation Locations**.

4.2 Subsurface Profile

A project geological classification has been developed based on the results of the investigation and a summary of the units and their distribution are presented in **Table 1** and **Table 2**. The borehole logs and accompanying explanatory notes are presented in **Appendix C – Test Pit Logs**.

Table 1. Observed Geological Units

Unit #	Origin	Material	Description
Unit 1a	Topsoil/Fill	Sandy Silt /Gravelly CLAY	Low to medium plasticity, red-brown, fine to medium grained sand, fine to medium grained, sub-rounded gravel
Unit 1b		GRAVEL	Fine to medium grained, sub-angular, grey
Unit 2	Residual Soil	Silty CLAY	Medium to high plasticity, mottled grey, mottled pale brown, red-brown, with fine to coarse grained sand, fine to medium grained, sub-rounded gravel, with clasts
Unit 3	XW* Material	SILTSTONE	Silty CLAY, low to medium plasticity, pale grey, pale brown, pale maroon, with fine to medium grained sand

*XW-extremely weathered.

Table 2. Distribution of Subsurface Geological Units Across the Investigated Area

Test ID	Depth Below Ground Level (m BGL)			
	Topsoil/Fill		Residual Soil	XW Material
	Unit 1a	Unit 1b	Unit 2	Unit 3
TP01	0.0-0.05	NE	0.05-3.0*	NE
TP02	0.0-0.2	NE	0.2-1.1	1.1-1.8*
TP03	0.0-0.2	NE	0.2-3.0*	NE
TP04	0.0-0.1	NE	0.1-3.0*	NE
TP05	0.0-0.1	NE	0.1-1.4	1.4-2.5*
TP06	0.0-0.1	NE	0.1-1.0	1.0-3.0*
TP07	0.0-0.1	NE	0.1-2.0	2.0-3.0*
TP08	0.0-0.05	NE	0.05-3.0*	NE
TP09	0.0-0.1	NE	0.1-3.0*	NE
TP10	0.0-0.15	NE	0.15-2.0*	NE
TP11	NE	0.0-0.1	0.1-2.5*	NE
TP12	0.0-0.2	NE	0.2-1.5*	NE
PP01	0.0-0.05	NE	0.05-3.0*	NE
PP02	0.0-0.1	NE	0.1-1.4	1.4-2.5*

*)-limit of the investigation
NE-not encountered

4.3 Groundwater

Groundwater was not encountered during the investigation. It should be noted that the groundwater conditions will vary with seasonal changes and weather conditions along with related site conditions.

4.4 Laboratory Results

Geotechnical laboratory testing was conducted on selected bulk and undisturbed samples collected during the site investigation. All testing was performed by Coffey Testing and ALS (Newcastle) – NATA accredited laboratory in accordance with the relevant Australian Standards and technical procedures. The detailed results of laboratory testing are presented in **Appendix E – Laboratory Test Results** and are summarised in the following sections.

4.4.1 California Bearing Ratio (CBR)

CBR testing was conducted on three (3) soil samples to inform the design CBR for the proposed road within the proposed development. The results are summarised in **Table 3**.

Table 3. California Bearing Ratio Test Results

Test ID	Depth (m BGL)	Sample Description	W[1](%)	SOMC[2] (%)	SMDD[3] (t/m³)	Swell (%)	CBR (%)
TP03	0.3-1.0	Silty CLAY	10.9	15.5	1.79	1.5	**4.5**[4]
TP05	1.4-1.8	Silty CLAY	12.6	14.5	1.79	5.0	**5.0**[5]
TP12	0.2-1.0	Silty CLAY	13.4	20.5	1.59	3.0	**2.5**[4]

[1] Field Moisture Content
[2] Standard Optimum Moisture Content
[3] Standard Maximum Dry Density
[4] CBR at 2.5mm (%)
[5] CBR at 5mm (%)

4.4.2 Particle Size Distribution (PSD)

PSD test results undertaken on samples of soil are presented in **Table 4** confirming the material description from the test pit logs.

Table 4. Particle Size Distribution Test Results

Test ID	Depth (m BGL)	% passing 2.36 mm sieve	% passing 75 µm sieve	Sample Description
TP03	1.4-2.2	95	80	Silty CLAY with sand
TP05	0.5-1.0	89	64	Silty CLAY with sand
TP06	0.5-1.0	72	52	Silty CLAY with gravel and sand
TP06	1.0-1.5	96	84	Silty CLAY
TP07	2.0-2.5	81	64	Silty Clay with gravel and sand

4.4.3 Atterberg Limits

A summary of Atterberg Limits and Linear Shrinkage Test results are presented in **Table 5** and are plotted graphically in Figure 4

Table 5. Atterberg Limits Test Results

Test ID	Depth (m BGL)	Soil	Classification	Atterberg Limits			Linear Shrinkage (%)
				LL (%)	PL (%)	PI (%)	
TP03	1.4-2.2	Silty CLAY with sand	CH	58	19	39	13.5
TP05	0.5-1.0	Silty CLAY with sand	CH	59	16	43	17.0
TP06	0.5-1.0	Silty CLAY with gravel and sand	CH	62	19	43	16.5
TP06	1.0-1.5	Silty CLAY	CH	52	24	28	8.0
TP07	2.0-2.5	Silty CLAY with gravel and sand	CI	47	24	23	6.0

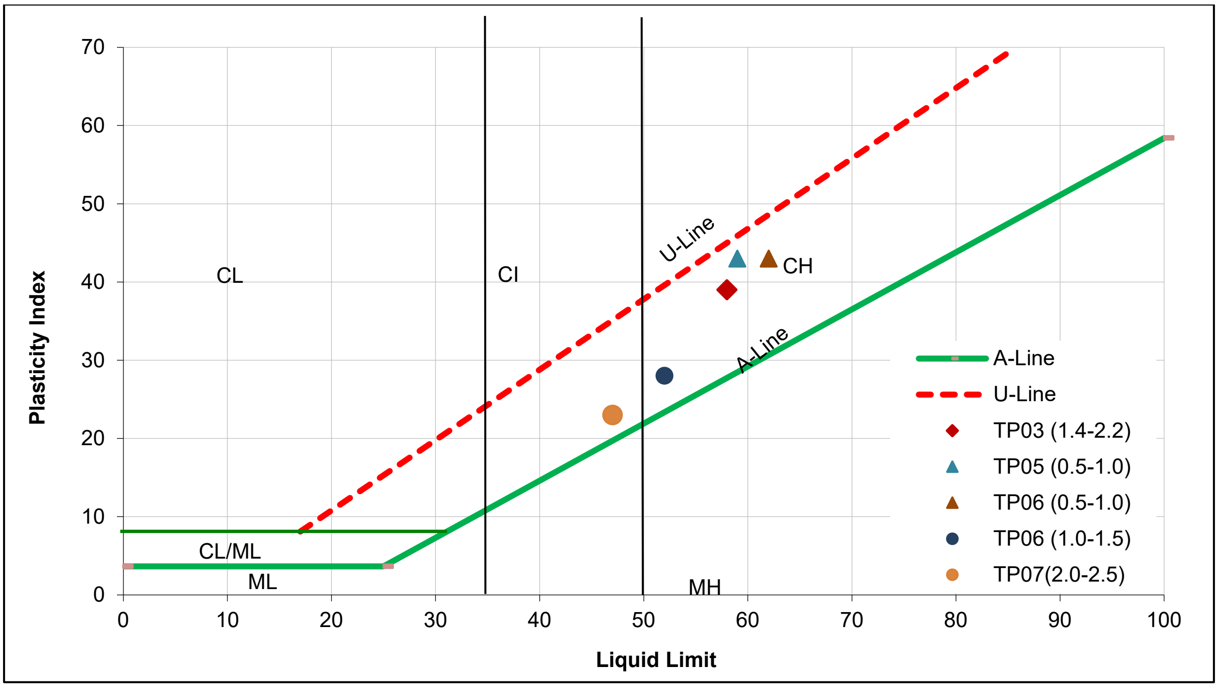


Figure 4 - Atterberg Limit Plot

4.4.4 Shrink Swell

Undisturbed soil samples were collected during the site investigation and the results are presented in **Table 6**.

Table 6. Shrink Swell Index Test Results

Test ID	Soil Type	Depth (m BGL)	Shrinkage		Swell			Shrink – Swell Index (Iss%)
			Shrinkage Field Moisture Content (%)	Dried Shrinkage (%)	Field Moisture Content (%)	Inundated Moisture Content (%)	Swell Strain (%)	
TP03	Silty CLAY	1.4-1.9	18.8	2.0	19.2	24.5	4.6	2.4
TP05	Silty CLAY	1.4-2.0	15.1	0.3	15.1	21.9	0.5	0.3
TP08	Silty CLAY	1.2-1.6	20.9	4.6	21.8	24.2	2.4	3.2
TP09	Silty CLAY	1.4-1.8	18.4	2.3	17.5	24.8	3.7	2.3

4.4.5 Aggressivity

The Australian Standard AS2159-2009 provides criteria for assessment of the level of exposure classification for steel and concrete to enable the designers to incorporate protective measures for each element into the design. The assessment criteria are based upon the pH, concentrations of Sulphate and Chloride in soil, the soil permeability, and the groundwater level.

Soil aggressivity testing was undertaken on two (2) sample recovered from the test pits. An assessment of the exposure classification for the soil sample tested based on the above criteria is presented in **Table 7**.

Table 7. Aggressivity Test Results

Test ID	Soil type	Sulphates (SO_4) in soil (mg/kg - ppm)	pH	Chlorides in groundwater (mg/kg-ppm)	Resistivity ohm.cm	Exposure classification	
						Aggressive to steel	Aggressive to concrete
TP06	Silty CLAY	430	7.5	1770	813	Mild	Non-aggressive
TP07	Silty CLAY	200	5.0	1200	1100	Mild	Mild

5 Preliminary Pavement Design

5.1 Design Traffic Loadings

Preliminary design traffic loadings have been selected, and pavement thickness design calculations have been undertaken by EP Risk in accordance with Forbes Shire Council – Development Control Plan. The design traffic data has been determined based on the following assumptions presented in **Table 8**.

Table 8. Recommended Road Type and Design ESA's

Road Type	Roads Identification	Design ESA's
Local Access	TBC	2 x 10^5
Collector	TBC	6 x 10^5

Where traffic data varies from the above assumptions, a review of pavement design may be required.

5.2 Design Parameters

Pavement thickness has been undertaken in accordance with Austroads AGPT02-17 Guide to Pavement Technology, Part 2. Pavement Structural Design based on the following parameters:

- Design subgrade CBR of 2.5% for residual/colluvial soil materials with CBR swell ≥2.5%.
- Design subgrade CBR of 4.5% for stiff residual clay.

The design subgrade has been determined in accordance with Section 5 of Austroads 2017 based on laboratory testing results and field interpretation. Reference to Table 5.2 Guide to classification of expansive soils (Austroads2017-Part 2 Pavement Structural Design) indicate that the soils tested for CBR are moderately to very highly expansive. Where filling is undertaken within the road alignments, all fill materials should generally be a minimum of CBR 2.5% based on a 4-day soak when compacted to 100% standard relative density ad SOMC.

5.3 Pavement Design – Flexible Unbound Pavement

The option of pavement construction utilising flexible unbound pavement are presented in **Table 9**.

Table 9. Recommended Flexible Pavement Composition – CBR 2.5% and 4.5%

Road Type	Local Access	Collector	Local Access	Collector
Wearing Course (mm)	30 AC10*	45AC14*	30 AC14*	45 AC14*
Basecourse (mm)	150	150	150	150
Subbase (mm)	290 (150)	345 (200)	170	200
Select (mm)**	(300)	(300)		
Total Thickness (mm)	470 (640)	540 (695)	350	395
Subgrade CBR	2.5%		4.5%	
Design ESA	2 x 10^5	6 x 10^5	2 x 10^5	6 x 10^5

AC14/AC10 with 10mm primer seal placed under the asphaltic concrete wearing surface.

**Where reactive clay has a CBR is less than 3% and CBR swell ≥2.5%, the pavement option using a select subgrade should be adopted (shown in brackets) or lime/cement stabilisation undertaken.

A minimum of fourteen days duration shall apply prior to application of subsequent asphalt layer(s). That period may be extended or shortened subject to approval by Council.

As alternative to the asphalt concrete; the roads can be covered by a two-coat bituminous flush seal wearing course, subject to council approval. In this case, the thickness of subbase/select needs to be increased by the thickness of asphalt layer. A minimum of fourteen days duration shall apply prior to application of subsequent asphalt layer(s). That period may be extended or shortened subject to approval by Council.

The determination of a subgrade suitable to adopt a CBR 4.5% design should be undertaken by a geotechnical consultant or suitably qualified council engineer. If the soaked CBR of the subgrade is <3%, the subgrade could be chemically stabilised to a minimum depth of 300mm. Lime stabilisation could be considered to improve the CBR <3% for low strength subgrade material and typically, stabilisation with 2-3% lime or cement would allow the adoption of the pavement thickness not shown in brackets for CBR 2.5% in **Table 9**. The subgrade CBR should be confirmed at the time of construction. Alternatively, a low-strength subgrade with a CBR <3% and swell ≥2.5% encountered at the design subgrade level (DSL) can be constructed using the select design shown in brackets utilising a select layer.

Where weathered bedrock or stiff residual clay is encountered at the design subgrade level (DSL), the pavement thickness design as indicated in **Table 10** should be adopted. Where consistent weathered material is encountered at the DSL, adoption of the CBR 4.5% design is considered appropriate following ripping and re-compaction to a depth of 300mm below DSL.

5.4 Subgrade Preparation

For construction of a new pavement, subgrade preparation should be in accordance with the following procedures:

- Remove topsoil/uncontrolled fill to the design subgrade level (DSL).
- Excavation of residual soil/weathered material to DSL.
- Ripping the insitu subgrade 300mm below DSL and recompact to a minimum 100% SMDD. Moisture content should be within 60% to 90% of SOMC for weathered bedrock and 80% to 100% for reactive clay subgrade material.
- Static proof-rolling of the exposed subgrade using a heavy (minimum 10 tonne) roller under the direction of an experienced geotechnical consultant.
- Loose or yielding areas should be excavated and replaced with compacted select fill or suitable subgrade replacement comprising of material of similar consistency to the subgrade.
- Confirmation of design subgrade parameters by a geotechnical consultant.

Where filling or subgrade replacement is required, the materials employed should be free of organics or other deleterious material. The material should also have a maximum particle size of 100mm or one third of the layer thickness, with a minimum soaked CBR of minimum 2.5%. Low expansive/reactive material should be used as subgrade and general fill where possible in the top 1m to design levels. Following satisfactory preparation of the subgrade, the pavement should be placed in accordance with the recommendations of this report and Forbes Shire Council. In case of discrepancies, clarification should be obtained from the council.

5.5 Materials

5.5.1 Specifications and Compaction Requirements

Pavement materials and compaction requirements for new pavement construction should conform to Forbes Shire Council Specifications and Guidelines and those outlined in **Table 10**.

Table 10. Material Specification and Compaction Requirements

Pavement Course	Material Specification	Compaction Requirements
Base Course High quality crushed rock (Class 1 for collector roads and Class 2 for local roads)	Material complying with TfNSW QA Specifications 3051 Category B and D CBR ≥80%, with 2% < PI < 6%	Min 98% Modified (AS 1289 5.2.1) or Min 102% Standard (AS 1289 5.1.1)
Subbase Subbase quality crushed rock	Material complying with TfNSW QA Specifications 3051 Category B and D and CBR ≥30% with PI < 10%	Min 100% Standard (AS1289.5.1.1)
Select Granular material	CBR ≥30%	Min 98% Modified (AS 1289 5.2.1) or Min 102% Standard (AS 1289 5.1.1)
Subgrade or replacement	Minimum CBR as appropriate for the design option of 2.5% or 4.5%	Min 95% Modified (AS 1289 5.2.1) or Min 100% Standard (AS 1289 5.1.1)

All granular pavement material quality should be in general accordance with TfNSW QA Specification 3051 for Traffic Category D "Light" for local roads and Traffic Category B "Heavy for collector roads. Where recycled base or subbase are proposed conformance with the Council specifications are required.

Minimum testing on all potential imported pavement materials should be in accordance with TfNSW 3051 Ed 7. Pre-treatment of material prior to testing would be advisable for materials subject to breakdown.

5.5.2 Wearing Course

Wearing courses should be in accordance with Austroads AGPT04B-07 Guide to Pavement Technology Part 4B: Asphalt.

The design and construction of wearing courses should be in in consultation with the preferred supplier considering traffic volume and type. All pavement surfaces should be primer sealed prior to the application of the asphaltic concrete ('AC') wearing course. A minimum delay of 14 days is required after the primer seal before placement of the AC wearing course. The delay period on application of the wearing course following primer seal may be altered following discussion with the supplier.

5.5.3 Inspections

The subgrade will require inspection by an experienced geotechnical consultant after boxing out or filling to design subgrade level. The purpose of inspections is to confirm design parameters, assess the suitability of the subgrade to support the pavement, and delineate areas which may require subgrade replacement or remedial treatment prior to construction.

The design CBR should be confirmed by 4-day soak CBR testing at the time of construction by sampling at design subgrade level.

All works and materials used in construction should be constructed in accordance with Council Specifications and as specified in this report. Where discrepancies may occur, clarification should be sought from Council.

5.6 Drainage

The moisture regime associated with a pavement has a major influence on the performance considering the stiffness/strength of the pavement materials is dependent on the moisture content of the material used. Accordingly, to protect the pavement materials from wetting up and softening, particular care would be required to provide a waterproof seal for the pavement materials, together with adequate surface and sub-surface drainage of the pavement and adjacent areas.

It is recommended that subsoil drainage be installed at, or below subgrade level along both sides of the road where cohesive soils are encountered. Exclusion of the subsoil drainage may be considered where free draining granular soils are encountered. CBR swell results from the preliminary investigation indicate moderate to very highly expansive soils. Where expansive soils are encountered, design measures and subsurface drainage measures to control subgrade swell should be adopted as indicated in Austroads Guide to Pavement Technology and the relevant Transport for New South Wales Supplement(s). Preferred measures shall also be discussed with Council’s Representative prior to adoption in any pavement construction. Designs utilising a minimum 150mm select layer are provided in Preliminary Pavement Design section.

The pavement thickness designs presented above assume drained pavement conditions. The selection, construction and maintenance of appropriate drainage mechanisms will be required for adequate performance.

6 Preliminary Site Classification

Australian Standard AS 2870-2011 establishes performance requirements and specific designs for common foundation conditions as well as providing guidance on the design of footing systems using engineering principles. Site classes as defined on Table 2.1 and 2.3 of AS 2870 are presented in **Table 11**.

Table 11. General Definition of Site Classes

Site Class	Foundation	Characteristic Surface Movement
A	Most sand and rock sites with little or no ground movement from moisture changes	-
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes	0 – 20 mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	20 – 40 mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes	40 – 60 mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes	60 – 75 mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes	> 75 mm
A to P	Filled sites (refer to clause 2.4.6 of AS 2870)	-
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.	

Reactive sites are sites consisting of clay soils that swell on wetting and shrink on drying, resulting in ground movements that can damage lightly loaded structures. The amount of ground movement is related to the physical properties of the clay and environmental factors such as climate, vegetation, and watering. A higher probability of damage can occur on reactive sites where abnormal moisture conditions occur, as defined in AS 2870, due to factors such as:

- Presence of trees on the building site or adjacent site, removal of trees prior to or after construction, and the growth of trees too close to a footing. The proximity of mature trees and their effect on foundations should be considered when determining building areas within each allotment (refer to AS 2870).
- Failure to provide adequate site drainage or lack of maintenance of site drainage, failure to repair plumbing leaks and excessive or irregular watering of gardens.
- Unusual moisture conditions caused by removal of structures, ground covers (such as pavements), drains, dams, swimming pools, tanks etc.

Regarding the performance of footings systems, AS 2870 states “footing systems designed and constructed in accordance with this Standard on a normal site (see Clause 1.3.2) that is:

a) not subject to abnormal moisture conditions; and

b) maintained, such that the original site classification remains valid and abnormal moisture conditions do not develop, are expected to usually experience no damage, a low incidence of damage category 1 and an occasional incidence of damage category 2.”

Damage categories are defined in Appendix C of AS 2870, which is reproduced in CSIRO Information Sheet BTF 18, Foundation Maintenance and Footing Performance: A Homeowner’s Guide attached as **Appendix F – Foundation Maintenance and Footing Performance**.

The laboratory Shrink Swell test results summarised in Table 6 indicate that the tested natural clay soils are of low to highly reactive, with I_{ss} values in the range of 0.3% to 3.2%.

The classification of sites with controlled fill of depths greater than 0.4m (deep fill) comprising of material other than sand would be Class P. An alternative classification may however be given to sites with controlled fill where consideration is made to the potential for movement of the fill and underlying soil based on the moisture conditions at the time of construction and the long-term equilibrium moisture conditions.

Based on the subsurface profiles encountered during the Site inspection and in accordance with the AS 2870-2011; the Site in its existing condition and in the absence of abnormal moisture conditions would likely be classified as detailed in **Table 12**.

Table 12. Anticipated Site Classifications

Farnell St, Forbes NSW	Site Classification
In Existing Condition prior to regrade	**Class H1-D** to **Class H2-D**, highly reactive
Following site regrade activities	**Class H1-D**, highly reactive to **Class E-D**, extremely reactive

A characteristic surface movement (y_s) of 50mm to 66mm has been calculated for the site dependent on the soil profile existing state prior to regrade, using a depth of suction (Hs) change of 3m. Following regrade activities, characteristics surface movement (Ys) is estimated to be in the order of 55mm to 103mm using worst case scenarios as the depth of the cracked zone is considered zero as per AS2870-2011 Clause 2.3.2. Actual site classifications will be dependent on regrade activities including depth to rock and filling depth along with the materials used as fill.

The above site classifications and footing recommendations are for the site conditions present at the time of fieldwork and consequently the site classification may need to be reviewed with consideration of any site works that may be undertaken after the investigation and this report.

Site works may include:

- Changes to the existing soil profile by cutting and filling.
- Landscaping, including trees removed or planted in the general building area; and
- Drainage and watering systems.

Designs and design methods presented in AS 2870-2011 are based on the performance requirement that significant damage can be avoided if site conditions are properly maintained. Performance requirements and foundation maintenance are outlined in Appendix B of AS 2870. The above site classification assumes that the performance requirements as set out in Appendix B of AS 2870 are acceptable and that site foundation maintenance is undertaken to avoid extremes of wetting and drying.

Details on appropriate site and foundation maintenance practices are presented in Appendix B of AS 2870-2011 and in CSIRO Information Sheet BTF 18, Foundation Maintenance and Footing Performance: A Homeowner's Guide. Adherence to the detailing requirement outlined in Section 5 of AS 2870-2011 is essential, Section 5.6. Additional requirements for Classes M, H1, H2 and E sites, including architectural restrictions, plumbing and drainage requirements.

7 General Construction Considerations

7.1 Excavations

Excavations or trenches in the Silty/Sandy CLAY and extremely weathered material could be expected to stand close to vertical in the short-term. Where personnel are to enter excavations, options for short-term excavations stability include benching or battering back of the excavations to 1H:1V or the support of excavations within the residual soil and extremely weathered rock profile with appropriate shoring. It is recommended that long-term excavations are either battered at 2H:1V or flatter and protected against erosion or be supported by engineer designed and suitably constructed retaining walls. Excavations may be battered steeper than 2H:1V in rock materials, subject to specific geotechnical Investigation.

The excavation recommendations provided above should be considered with reference to the Safe Work Australia Code of Practice ‘Excavation Work’, dated January 2020.

7.2 Retaining Walls

All retaining structures should be designed by an engineer. Design of retaining walls should:

- Input in design the surcharge loadings from slopes and structures above the wall.
- Consider loading from any proposed compaction of fill behind the wall.
- Provide adequate surface and subsurface drainage behind all retaining walls, including a free draining granular backfill to prevent the build-up of hydrostatic pressures behind the wall.
- Utilise materials that are not susceptible to deterioration.
- Ensure walls are founded in materials appropriate for the loading conditions.

Footings for proposed retaining walls should be founded below any fill within stiff or better consistency clay or weathered rock.

7.3 Filling and Material Management

7.3.1 Filling

Fill should be placed and compacted in accordance with AS 3798-2007. It is expected that construction of a suitable fill platform to support structural loads, such as pavements, ground slabs, footing and stiffened raft slabs, would include the following:

- Stripping of topsoil.
- Sieving oversize material (boulders).
- Site materials will likely require treatment or moisture re-conditioning prior to placement and compaction.
- Proof rolling of the exposed subgrade to detect any weak or deforming areas of subgrade that should be excavated and replaced with controlled fill.
- Placement of fill in horizontal layers with compaction of each layer to a minimum dry density ratio of 95% Standard Relative Density (SRD) as per Australian Standard AS 1289 Clause 5.1. at moisture contents of 85- 115% of SOMC and 98% SRD for fill ≥1m depth. Fill within 0.5m of design subgrade in road alignments is to be compacted to 100% standard relative density and at a 80-100% of SOMC to reduce

potential volume change in expansive clays. Over compaction and moisture contents significantly dry of SOMC should be avoided to reduce swell potential

- All fill materials should be supported by properly designed and constructed retaining walls or else battered at a slope of 2H:1V or flatter and protected against erosion by vegetation or similar and the provision of adequate drainage.

7.3.2 Material Management

Materials excavated on site are considered suitable for re-use as engineering fill, noting that highly reactive clay soils have been encountered which will potentially create Class E, extremely reactive site classifications where used as engineered fill particularly within 1.5m of finished surface level. It is noted that site materials generally range from moderately to highly reactive. Care should be taken in the utilisation of site materials to avoid increasing the site classifications. This however may be impractical, although soils of lower reactivity where encountered could be suitable to reduce the reactivity when used in the upper 1.5m of fill.

Materials should be managed during regrade where practical to allow use of required design CBR and lower reactivity materials in the top 1m of filling and subgrade preparation to provide better outcome for pavement construction and site classification.

7.4 Geotechnical Design Parameters

The geotechnical design parameters for the proposed development have been assessed based on results of the site and laboratory tests of the ground investigation. These are provided for the different geological units in **Table 14**.

Table 13. Geotechnical Design Parameters – Soil

Geotechnical Units	Bulk Unit Weight (kN/m3)	Undrained Cohesion Cu (kPa)	Drained Cohesion c' (kPa)	Drained friction angle ϕ' (°)	Poisson's Ratio (-)	Elastic Modulus E' (MPa)	Earth Pressure coefficient ka	Earth pressure coefficient kp
Residual Soil Silty CLAY (very stiff)	20	100	7	26	0.3	15	0.39	2.56
XW* Material Silty CLAY (hard)	21	200	15	28	0.3	30	0.36	2.77

*XW- extremely weathered

7.5 Footings

All foundations should be designed and constructed in accordance with 2870-2011, Residential Slabs and Footings with reference to site classifications as presented in Section 6.

All footings should be founded below any topsoil, slopewash, deleterious soils or uncontrolled fill. All footings for the same structure should be founded on strata of similar stiffness and reactivity to minimise the risk of differential movement and should be confirmed by specific investigation for proposed structures.

Potential for differential movement should be considered due to variation in depth to rock and filling across the Site and articulation incorporated into the design.

7.5.1 High Level Footings

High-level footing alternatives could be expected to comprise slabs on ground with edge beams or pad footings for the support of concentrated loads. Such footings designed in accordance with engineering principles and founded in stiff or better soils (below topsoil, uncontrolled fill or other deleterious material) may be proportioned on an ultimate bearing capacity of 250 kPa. Footings founded in very stiff or better cohesive soils could be designed for an ultimate bearing capacity of 500kPa.

Where controlled lot filling has been carried out, high-level footing types should be founded below any topsoil onto the engineered fill that is placed and compacted in accordance with AS3798-2007 for an ultimate bearing capacity of 250kPa.

Footings designed in accordance with engineering principles and founded uniformity on competent weathered material may be proportioned on an ultimate bearing capacity of 2,500 kPa. The founding conditions should be assessed by a geotechnical consultant or experienced engineer to confirm suitable conditions.

7.5.2 Piered Footings

Piered footings are considered as an alternative to deep edge beams or high-level footings and provide an alternate founding solution. It is suggested that bored pier footings, founded in very stiff or better natural clay could be proportioned on an ultimate end bearing pressure of 500 kPa or if founded in competent weathered rock, could be proportioned on an ultimate end bearing pressure of 2,500 kPa.

All footings should be founded below any topsoil, deleterious soils or uncontrolled fill. All footings for the same structure should be founded on strata of similar stiffness and reactivity to minimise the risk of differential movements.

Inspection of high level or pier footings excavations should be undertaken to confirm the founding conditions, and the base should be cleared of fall-in prior to the formation of the footings.

NB: It should be noted that the ultimate values occur at large settlement (>5% of minimum footing dimensions). A factor of safety of 2.5-3 is consider adequate for the ultimate values shown above.

8 Basin Construction

Sediment control basin(s) is planned to be constructed within the proposed development. The materials existent within the development have been tested and the results are outlined in this section.

Testing of the subsurface soils at the proposed basins construction indicates that the soils are suitable for the use in construction of the proposed basins. A zoned embankment may be preferred to allow the use of a lesser quality materials on downstream embankment construction.

8.1 Laboratory Testing

One Emerson Class test was undertaken to determine whether the basin soil require stabilisation. Results of the testing are detailed in the laboratory reports attached in **Appendix D - Laboratory Test Results** and summarised in **Table 14**.

Table 14. Emerson Class Test Result

Test pit	Depth (m BGL)	Sample Description	Emerson Class
TP07	0.5-1.0	Silty CLAY with sand	4

The Emerson Class results indicate that the material tested is non-dispersive. Based on the type of cohesive soils (Silty CLAY) and their consistency (very stiff) it is estimated that the permeability of site material ranges between 10^{-7} m/s to 10^{-9}m/s.

Permanent and temporary sediment and water detention basin should be designed and constructed in accordance with Councils Engineering Guidelines with reference to **Table 15.**

Table 15. Drainage Basin Materials and Compaction Requirements

Zone	Material Specifications	Compaction Requirements
1- Clay Core / Clay Liner & Embankment Material	Liquid limit >50% 10% < Plasticity Index (PI) < 50%, Permeability <10^{-9}m/s Emerson Class >4 Maximum Particle Size <50mm Percentage Clay Content >25	98% standard relative density AS1289 5.7.1 at a moisture content of -1 to +3% of standard optimum moisture
2 - Outer Embankment Material (lower standard)	10%< PI <50%, Permeability < 10^{-7}m/s Emerson Class >2 Maximum Particle Size <75mm Percentage Clay Content >20 %	95% standard relative density AS1289 5.7.1 at a moisture content of -2 to +2% of standard optimum moisture
Topsoil	Suitable for sustaining planned vegetation plantings	Not applicable
Cut-Off Trench / Keyway	Minimum Stiff (CL-CH) Clay or better with material as specified for Zone 1	Minimum 2.4m wide and keyed into a minimum depth of 0.5 m into impervious material (compaction as per Zone 1)
Batter Slopes	1 Vertical: 6 Horizontal (Impoundment) 1 Vertical: 3 Horizontal (External)	
Spillway	Constructed in accordance with Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia (Geoscience Australia), 2019.	

8.2 Basin Construction Guidelines

Basins will need to be constructed in general accordance with Council Engineering Guidelines and the following recommendations. Embankments should be battered at a slope of 1V:3H or flatter for downstream batters or for batters above the permanent water level and 1V:6H for impoundment areas below the permanent water level or as otherwise agreed with Council or handrails installed to assist egress.

Earthworks and testing shall be undertaken in accordance with AS 3798-2007 *Guidelines on Earthworks for Commercial and Residential Developments*. Table 16 above provides material requirements guidelines and compaction specifications for the construction of a zoned or non-zoned basin embankment. A zoned embankment can be considered where material of specified quality is limited. In this case attention will be required to the location of the core and how it interfaces with existing soil profile.

8.2.1 Foundation Preparation for Embankments

Foundation preparation for foundations for new embankments could generally be expected to comprise the following:

- Removal of topsoil and fill and excavation of the cut-off trench into stiff or better impervious material to a minimum depth of 0.5m.
- Inspection by an experienced geotechnical consultant shall be conducted to confirm the suitability of the foundation.
- Proof rolling of the exposed foundation area under the embankment with a heavy (minimum 10 tonne static) roller. Soft or weak areas detected during the proof rolling should be excavated and replaced with compacted fill / subgrade replacement comprising low permeability clay.
- Compaction of the various zones to achieve a minimum dry density ratio as detailed in **Table 16.**
- Protection of the prepared foundation to prevent excessive wetting or drying prior to placement of embankment fill material; and
- Formation of the embankment in accordance with the above recommendations and specifications contained herein.

It is recommended that trafficking of the material exposed at foundation level be minimised during construction to prevent the permanent deformation of the subgrade.

Any abrupt changes between founding conditions, e.g., transition from rock to soil should be eliminated during foundation preparation. This could be expected to involve foundation preparation practices such as selective grading or mixing of material to provide a transition between material types and moisture / density control of subgrade compaction. This is particularly relevant where gravelly sand bands/pebbly sandstone are observed as they will provide potential pathways for groundwater to enter the embankment.

8.2.2 Impoundment Area

The finished surface of the impoundment area should be treated as indicated below following excavation:

- Ripping of impoundment area excluding constructed embankments to a depth of 300mm and re-compaction as per Zone 1
- Where rock is exposed (not anticipated) at the surface; subject to geotechnical inspection it will either require ripping and re-compaction or over excavation and lining with a minimum of 300mm of Zone 1 material and

- Protection of subgrade to prevent excessive drying and desiccation cracking of the subgrade prior to filling of the basin.

8.2.3 Cut Off Trench/Keyway

Basins lose water through evaporation and seepage. Little can be done for evaporation losses, but with good construction methods seepage losses can be reduced.

One critical aspect is the construction of the cut-off trench. A cut-off trench or keyway as it is otherwise referred should be a minimum of 2.4 m width or 1.5 times the height of the Basin at the bottom of the trench. This keyway will minimise seepage under the embankment and increase the stability of the Basin embankment. It should be taken down to a minimum of 500 mm into stiff or better impervious clay or rock and backfilled with the appropriate quality clay that is thoroughly compacted to the specification requirements.

8.2.4 Vegetation

Topsoil should be spread over the exposed surfaces of the embankment to a depth of at least 150 mm and sown with pasture grass to establish a good cover as soon as possible. Never allow any vegetation larger than pasture grass to become established on or near the embankment. Tree roots, especially eucalyptus tree roots can cause the core to crack resulting in the failure of the Basin. As a rule of thumb, trees and shrubs should be kept to a minimum distance of 1.5 times the height of the tree away from the embankment of the Basins. This especially applies to eucalypts.

8.2.5 Basin Construction Reference

All works and materials used in construction of the basins should be designed and constructed in accordance with Council's specific requirements detailed in their Engineering Design and Construction Guidelines or as specified within this report. Where discrepancies occur clarification should be sought from Council on their requirements.

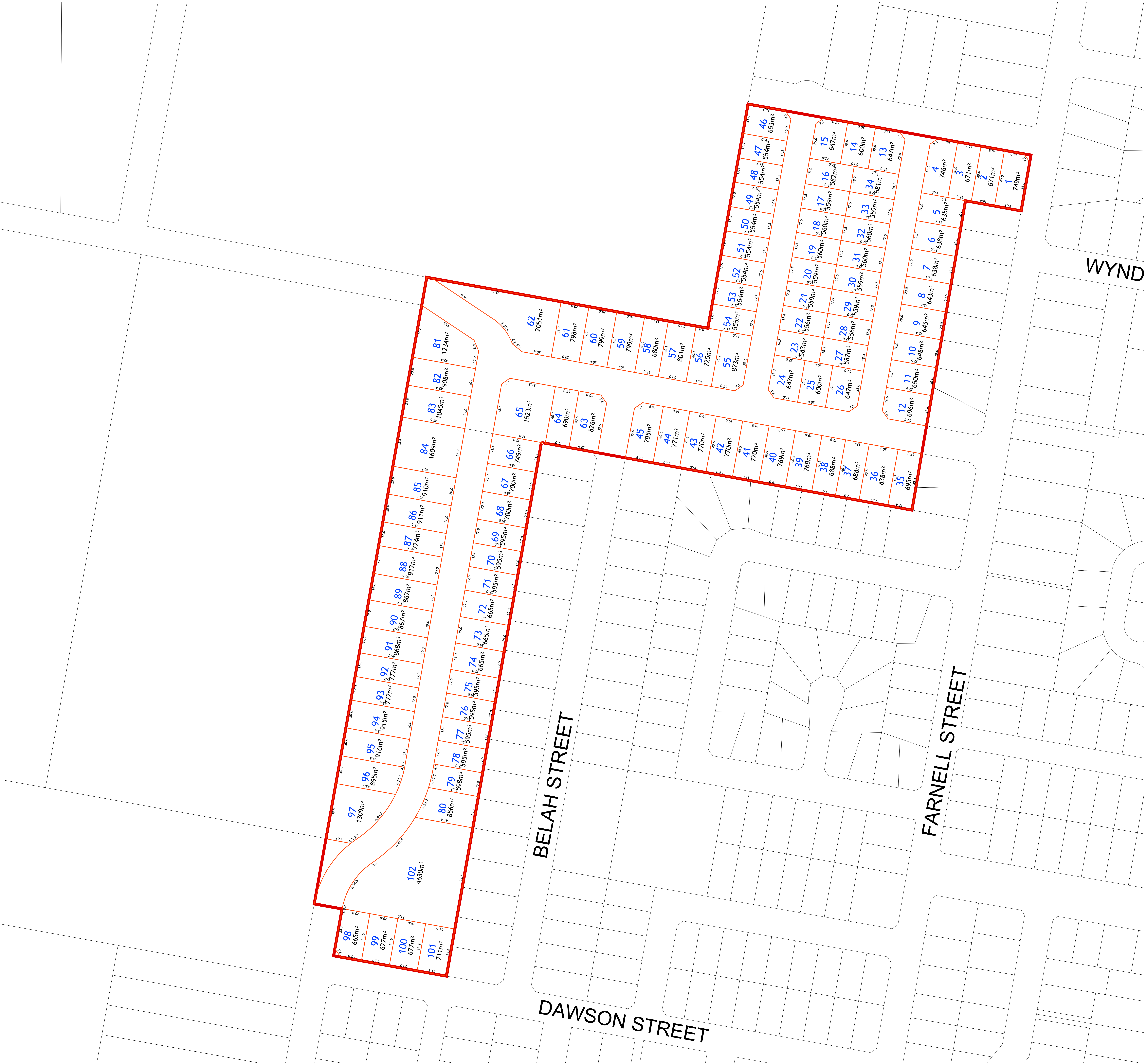
Earthworks and testing should generally be undertaken in accordance with AS3798-2007 "Guidelines on Earthworks for Commercial and Residential Developments".

9 References

- Austroads AGPT04B-07, Guide to Pavement Technology Part 4B: Asphalt, Austroads Ltd, May 2007
- Austroads AGPT02-17, "Guide to Pavement Technology Part 2: Pavement Structural Design," Austroads Ltd, 2017.
- eSPADE, Online website of NSW Office of Environment and heritage (www.environment.nsw.gov.au)
- Look, Burt – Handbook of Geotechnical Investigation and Design Tables, Taylor & Francis 2007.
- NearMap, MapBrowser | Nearmap
- Minview, (MinView | Regional NSW | Mining, Exploration and Geoscience)
- NSW Department of Planning and Environment, Resources and Geoscience (www.resourcesandgeoscience.nsw.gov.au)
- Safe Work Australia, Excavation Work Code of Practice, January 2020
- Standards Australia, AS1726-2017, "Geotechnical site investigations".
- Standards Australia, AS2159-2009, "Piling – Design & Installation".
- Standards Australia AS2870-2011, "Residential Slabs and Footings".
- Standards Australia AS3798-2007, "Guidelines on Earthworks for Commercial and Residential Structures".
- Standards Australia, HB 160 – Soils Testing, 2006
- TfNSW QA Specification 3051 (Ed 7 Rev 1), "Granular Base and Subbase Materials for Surfaced Road Pavements," Roads and Maritime Services, June 2020.

Appendix A

FARNELL STREET FORBES – RESIDENTIAL DEVELOPMENT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BELAH STREET
DAWSON STREET
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6 638m²
7 638m²
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9 645m²
10 648m²
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88 912m²
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91 868m²
92 777m²
93 777m²
94 915m²
95 916m²
96 895m²
97 1309m²
98 665m²
99 677m²
100 677m²
101 711m²
102 4630m²

Appendix B

PHOTOLOG

 	**Plate 1** **Description:** Site observation, looking towards the east from the northeast boundary of the site **Date: 08/04/2025**
 	**Plate 2** **Description:** Site observation, looking towards the southeast from the northeast boundary of the site **Date: 08/04/2025**

	**Plate 3** **Description:** Site observation, looking towards the west from the northeast boundary of the site **Date: 08/04/2025**
	**Plate 4** **Description:** Site observation, looking towards the northwest from the northeast boundary of the site **Date: 08/04/2025**

	**Plate 5** **Description:** Site observation, looking towards the southwest from the northeast boundary of the site **Date: 08/04/2025**
	**Plate 6** **Description:** Site observation, looking towards the east from the northwest part of the site **Date: 08/04/2025**

	**Plate 7** **Description:** Site observation, looking towards the south from the northwest part of the site **Date: 08/04/2025**
	**Plate 8** **Description:** Site observation, looking towards the west from north of TP06 **Date: 08/04/2025**

	**Plate 9** **Description:** Site observation, looking towards the east from south of TP06 **Date: 08/04/2025**
	**Plate 10** **Description:** Site observation, looking towards the south from south of TP06 **Date: 08/04/2025**

9 Apr 2025 at 10:07:49 am
E 593098 N 6307662
196° S

Plate 11

Description: Site observation, looking towards the south from the southwest boundary of the site

Date: 09/04/2025

9 Apr 2025 at 10:57:54 am
E 593125 N 6307657
355° N

Plate 12

Description: Site observation, looking towards the north from the south boundary of the site

Date: 09/04/2025

	**Plate 13** **Description:** Site observation, looking towards the west from the south boundary of the site **Date: 09/04/2025**
	**Plate 14** **Description:** Site observation, looking towards the southwest from the southwest boundary of the site **Date: 09/04/2025**

Appendix C

GEOTECHNICAL INVESTIGATION LOCATIONS

Geotechnical Investigation
Farnell St, Forbes NSW, Australia

Appendix C - Geotechnical Investigation Locations

EP RISK

www.eprisk.com.au

Job No: EP3269
Date: 06-05-2025
Version: v1

0 50 m 100 m

Approximate Scale Only

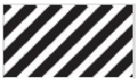
Coordinate System: WGS 84
Drawn By: JA Checked By: OP
Scale of regional map not shown
Source: © Department of Finance, Services & Innovation 2018

Appendix D

TEST PIT LOGS

Soil Logging Symbols

CLAYS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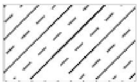
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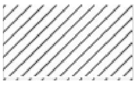
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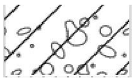
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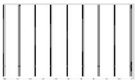
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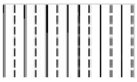
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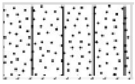
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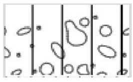
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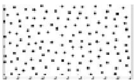
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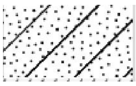
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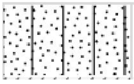
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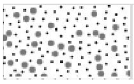
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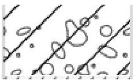
GRAVELS


GRAVEL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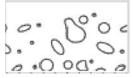
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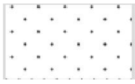
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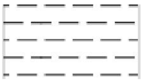
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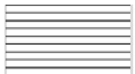
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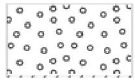
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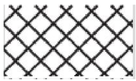
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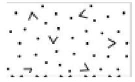
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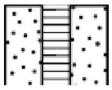
ASPHALT

GROUNDWATER WELL SYMBOLS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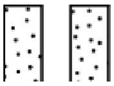
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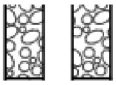
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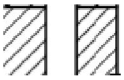
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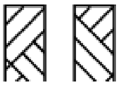
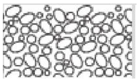
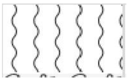

CASING – grout seal


BACKFILL

OTHER


TOPSOIL – sandy SILT


TOPSOIL – highly organic

Rock Description Explanation Sheet (1 of 2)

Weathering Condition (Degree of Weathering):

The degree of weathering is a continuum from fresh rock to soil. Boundaries between weathering grades may be abrupt or gradational.

Rock Material Weathering Classification

Weathering Grade	Symbol	Definition
Residual Soil	RS	Soil-like material developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume, but the material has not been significantly transported.
Extremely Weathered Rock	XW	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded in water, but substance fabric and rock structure still recognisable.
Highly Weathered Rock	HW	Strong discolouration is evident throughout the rock mass, often with significant change in the constituent minerals. The intact rock strength is generally much weaker than that of the fresh rock.
Moderately Weathered Rock	MW	Modest discolouration is evident throughout the rock fabric, often with some change in the constituent minerals. The intact rock strength is usually noticeably weaker than that of the fresh rock.
Slightly Weathered Rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh Rock	FR	Rock shows no sign of decomposition or staining.

Notes:

1. Minor variations within broader weathering grade zones will be noted on the engineering borehole logs.
2. Extremely weathered rock is described in terms of soil engineering properties.
3. Weathering may be pervasive throughout the rock mass or may penetrate inwards from discontinuities to some extent.
4. The 'Distinctly Weathered (DW)' class as defined in AS1726-2017 is divided to incorporate HW and MW in the above table. The symbol DW should not be used.

Strength Condition (Intact Rock Strength):

Strength of Rock Material

(Based on Point Load Strength Index, corrected to 50mm diameter – $I_{s(50)}$. Field guide used if no tests available. Refer to AS 4133.4.1-2007.

Term	Symbol	Point Load Index (MPa) $I_{s(50)}$		Field Guide to Strength
Very Low	VL	>0.03	≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 3cm thick can be broken by finger pressure.
Low	L	>0.1	≤0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long by 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
Medium	M	>0.3	≤1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.
High	H	>1	≤3	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.
Very High	VH	>3	≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
Extremely High	EH	>10		Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

Notes:

1. These terms refer to the strength of the rock material and not to the strength of the rock mass which may be considerably weaker due to the effect of rock defects.
2. Anisotropy of rock material samples may affect the field assessment of strength.
3. Extremely Low Strength ('EL') is now not considered a description of rock strength in line with the updated AS1726-2017 as by definition EL rock should be described in terms of soil properties.

Rock Description Explanation Sheet (2 of 2)

Discontinuity Description: Refer to AS1726-2017, Table A10.

Anisotropic Fabric	
BED	Bedding
FOL	Foliation
LIN	Mineral lineation
Defect Type	
LP	Lamination Parting
Pt	Bedding Parting
FP	Cleavage / Foliation Parting
Jt	Joint
SZ	Sheared Zone
CZ	Crushed Zone
BZ	Broken Zone
HFZ	Highly Fractured Zone
AZ	Alteration Zone
VN	Vein

Roughness (e.g. Planar, Smooth is abbreviated Pln / Sm)		**Class**
Stepped (Stp)	Rough or irregular (R or Irr)	I
	Smooth (Sm)	II
	Slickensided (Sl)	III
Undulating (Un)	Rough (R)	IV
	Smooth (Sm)	V
	Slickensided (Sl)	VI
Planar (Pln)	Rough (R)	VII
	Smooth (Sm)	VIII
	Slickensided (Sl)	IX

Aperture		**Infilling**		
Closed	CD	No visible coating or infill	Clean	Cn
Open	OP	Surfaces discoloured by mineral/s	Stain	St
Filled	FL	Visible mineral or soil infill <1mm	Veneer	Vr
Tight	TI	Visible mineral or soil infill >1mm	Coating	Ct

Other	
Clay	Clay
Fe	Iron
Co	Coal
Carb	Carbonaceous
Sinf	Soil Infill Zone
Qz	Quartz
Ca	Calcite
Chl	Chlorite
Py	Pyrite
Int	Intersecting
Inc	Incipient
DI	Drilling Induced
H	Horizontal
V	Vertical

Note: Describe ‘Zones’ and ‘Coatings’ in terms of composition and thickness (mm).

Discontinuity Spacing: On the geotechnical borehole log, a graphical representation of defect spacing vs depth is shown. This representation takes into account all the natural rock defects occurring within a given depth interval, excluding breaks induced by the drilling / handling of core. Refer to AS1726-2017, BS5930-1999.

Defect Spacing			**Bedding Thickness (Sedimentary Rock Stratification)**	
Spacing/Width (mm)	Descriptor	Symbol	Descriptor	Spacing/Width (mm)
			Thinly Laminated	< 6
<20	Extremely Close	EC	Thickly Laminated	6 – 20
20 – 60	Very Close	VC	Very Thinly Bedded	20 – 60
60 – 200	Close	C	Thinly Bedded	60 – 200
200 – 600	Medium	M	Medium Bedded	200 – 600
600 – 2000	Wide	W	Thickly Bedded	600 – 2000
2000 – 6000	Very Wide	VW	Very Thickly Bedded	> 2000
>6000	Extremely Wide	EW		

Defect Spacing in 3D	
Term	**Description**
Blocky	Equidimensional
Tabular	Thickness much less than length or width
Columnar	Height much greater than cross section

Defect Persistence (areal extent)
Trace length of defect given in metres

Symbols: The list below provides an explanation of terms and symbols used on the geotechnical borehole, test pit and penetrometer logs.

Test Results			
PI	Plasticity Index	c'	Effective Cohesion
LL	Liquid Limit	c_u	Undrained Cohesion
LI	Liquidity Index	c'_R	Residual Cohesion
DD	Dry Density	ϕ'	Effective Angle of Internal Friction
WD	Wet Density	ϕ_u	Undrained Angle of Internal Friction
LS	Linear Shrinkage	ϕ'_R	Residual Angle of Internal Friction
MC	Moisture Content	c_v	Coefficient of Consolidation
OC	Organic Content	m_v	Coefficient of Volume Compressibility
WPI	Weighted Plasticity Index	$c_{\alpha\varepsilon}$	Coefficient of Secondary Compression
WLS	Weighted Linear Shrinkage	e	Voids Ratio
DoS	Degree of Saturation	ϕ'_{cv}	Constant Volume Friction Angle
APD	Apparent Particle Density	q_t / q_c	Piezocone Tip Resistance (corrected / uncorrected)
s_u	Undrained Shear Strength	q_d	PANDA Cone Resistance
q_u	Unconfined Compressive Strength	$I_{s(50)}$	Point Load Strength Index
TCR	Total Core Recovery	*RQD*	Rock Quality Designation

Test Symbols	
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetration Test
CPTu	Cone Penetrometer (Piezocone) Test
PANDA	Variable Energy DCP
PP	Pocket Penetrometer Test
U50	Undisturbed Sample 50 mm (nominal diameter)
U100	Undisturbed Sample 100mm (nominal diameter)
UCS	Uniaxial Compressive Strength
Pm	Pressuremeter
FSV	Field Shear Vane
DST	Direct Shear Test
PR	Penetration Rate
PLI	Point Load Index Test (axial)
D	Point Load Test (diametral)
L	Point Load Test (irregular lump)

▽ Groundwater level	▶ Water Inflow	◁ Water Outflow

Test Pit No: TP01

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6308192.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593504.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	FILL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL		6		FILL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts		VSt and H	7		RESIDUAL SOIL
									8		
									13		
									14		
									10		
									9		
									9		
									8		
			1						9		
									8		
									7		
									9		
									10		
						1.40m: Colour change to red			9		
									10		
									10		
								H	11		
									11		
			2						12		
									13		
									11		
						2.20m: Colour change to pale brown			15		
									13		
									14		
									13		
									12		
									15		
									13		
			3						14		
						Test Pit TP01 Terminated at 3.00 m					Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP01

Test Pit No: TP02

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6308141.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593443.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered			▩	ML	FILL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts	<PL		6 6		FILL
			1	▨	CL-CI	Silty CLAY: low to medium plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts		VSt to H	7 8 9 10 9 9 10 9 11		RESIDUAL SOIL
				▨	CL-CI	Extremely weathered SILTSTONE recovered as Silty CLAY, low to medium plasticity, grey, red-brown, pale brown, with fine to medium grained sand	<<PL		15 16		EXTREMELY WEATHERED ROCK DCP:-HB
			2 3			Test Pit TP02 Terminated at 1.80 m					Refusal on bedrock

Remarks:

EP3269.003

Geotechnical Investigation

TP02

Test Pit No: TP03

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6308077.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593479.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL	VSt and H	7		TOPSOIL
									7		
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts			9		RESIDUAL SOIL
									12	B	
									14		
									11		
									9		
									9		
									9		
									9		
			1						8		
									8		
									10		
									10		
						1.40m: Colour changed to mottled grey, red			10	U50 B	
								H	11		
									12		
									12		
									13		
									13		
			2						14		
									14		
									15		
									13		
									13		
									12		
									13		
									14		
							~PL		12		
									12		
			3			Test Pit TP03 Terminated at 3.00 m					Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP03

Test Pit No: TP04

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6307990.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593474.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	FILL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL		6		FILL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts		VSt and H	5		RESIDUAL SOIL
									10		
									13		
									14		
									12		
									10		
									9		
									10		
									10		
			1						8		
									9		
									8		
									8		
									9		
									8		
						1.60m: Colour change to red			7		
									9		
									10		
								H	11		
			2						12		
									11		
						2.20m: Colour change to grey, mottled pale brown	~PL		13		
									13		
									13		
									12		
									12		
									11		
									12		
									14		
			3			Test Pit TP04 Terminated at 3.00 m					Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP04

Test Pit No: TP05

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6308026.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593417.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered			▩	ML	FILL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL		7		FILL
				▨	CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained sand and trace of fine to medium grained, sub-rounded gravel and clasts		VSt and H	8		RESIDUAL SOIL
									15		
									13		
									15		
									9	B	
									9		
									8		
									6		
									6		
			1						8		
									7		
									8		
									8		
				▨	CL-CI	Extremely weathered SILTSTONE recovered as Silty CLAY, low to medium plasticity, pale grey, with fine to medium grained sand			7	B	EXTREMELY WEATHERED ROCK
									9		
									10		
								H	15		
									11		
									12		
			2						13		
									16		
									12		
									17		
									26		
						Test Pit TP05 Terminated at 2.50 m					DCP:-HB Refusal on bedrock
			3								

Remarks:

EP3269.003

Geotechnical Investigation

TP05/PP05

Test Pit No: TP06

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	9.4.25	Northing	6308044.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	9.4.25	Easting	593315.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL	VSt and H	11		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts			8		RESIDUAL SOIL
									8		
									12		
									14		
									16	B	
											DCP:-HB
			1		CI-CH	Extremely weathered SANDSTONE recovered as Silty CLAY, medium to high plasticity, pale brown, with fine to medium grained sand				B	EXTREMELY WEATHERED ROCK
			2								
			3			Test Pit TP06 Terminated at 3.00 m				D	Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP06/PP04

Test Pit No: TP07

Engineering Log - Test Pit

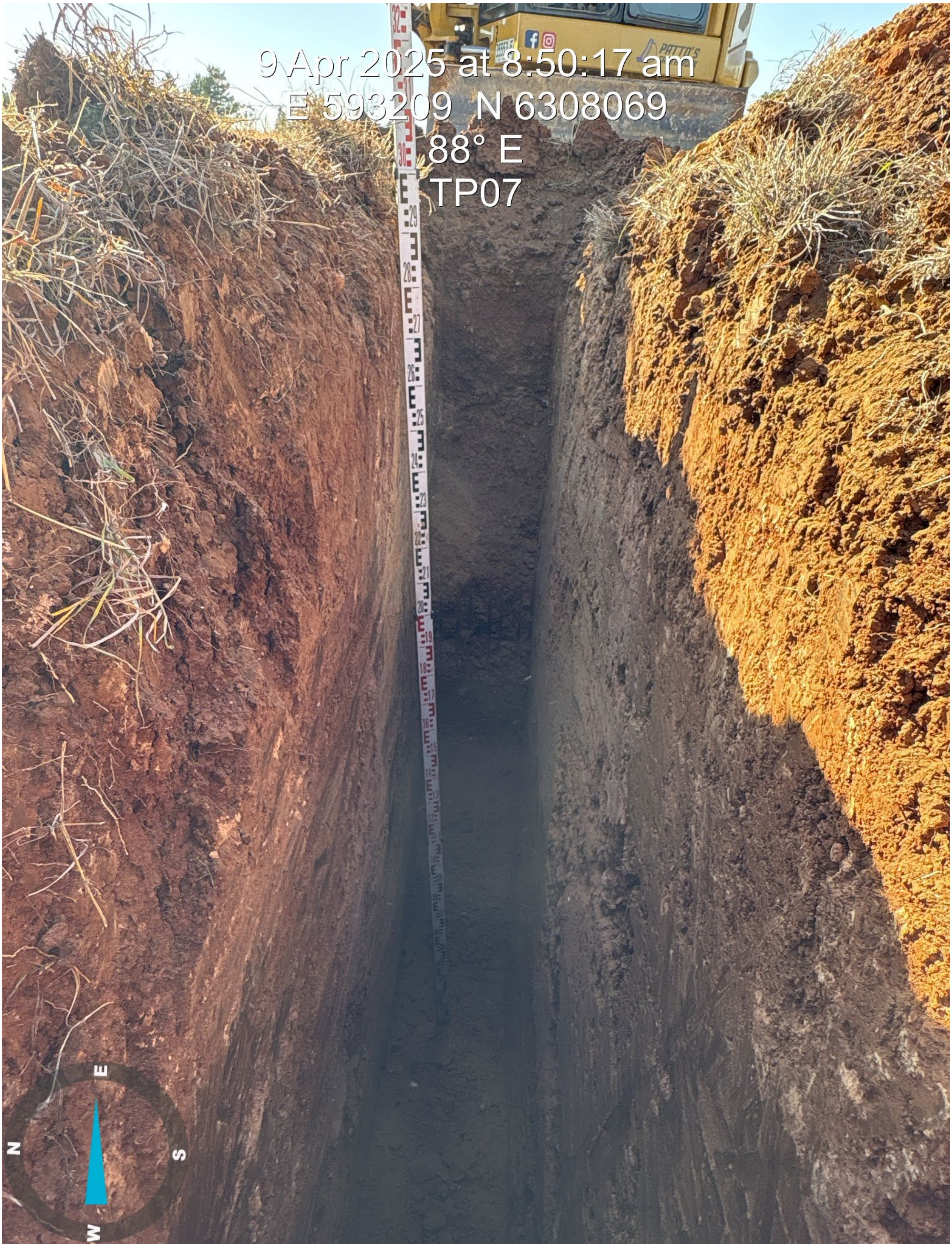
SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	9.4.25	Northing	6308063.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	9.4.25	Easting	593212.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand	<PL	VSt and H	12		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with medium to coarse grained sand and fine to medium grained, sub-rounded gravel and clasts			12		RESIDUAL SOIL
									10		
									10		
									12		
									10	B	
									8		
									8		
									10		
									5		
			1						6		
									6		
									6		
									7		
									7		
									8		
									7		
									7		
									4		
									6		
			2		CL-CI	Extremely weathered SILTSTONE recovered as Silty CLAY, low to medium plasticity, pale brown, with fine to medium grained sand, medium to coarse grained, sub-rounded gravel			6	B	EXTREMELY WEATHERED ROCK
									10		
									10		
									9		
									10		
									12	D	
											DCP:-HB
						2.80m: Colour change to pale maroon					
			3			Test Pit TP07 Terminated at 3.00 m					Target depth

Remarks:



EP3269.003
Geotechnical Investigation

TP07/PP03

Test Pit No: TP08

Engineering Log - Test Pit

SHEET 1 OF 1

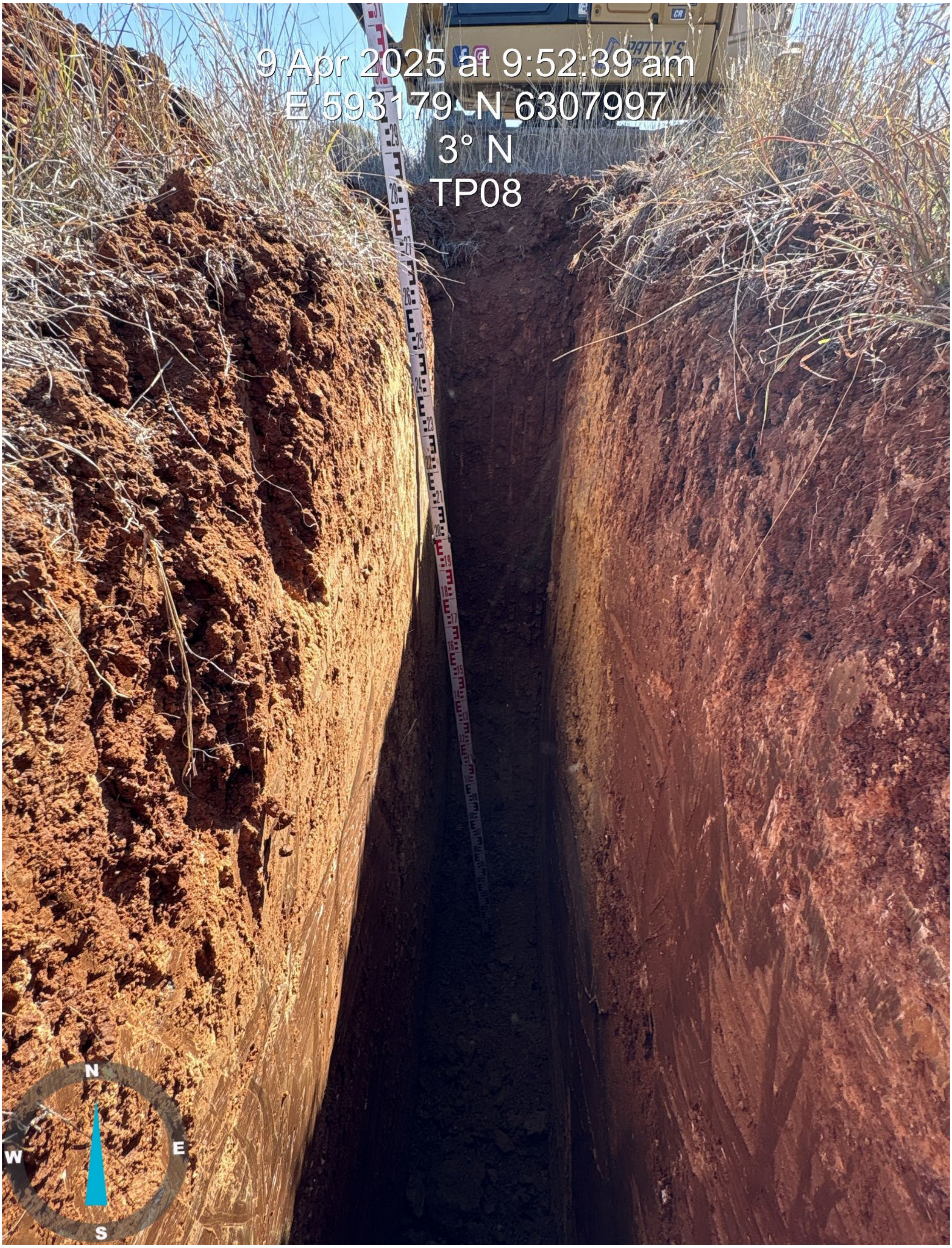
Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	9.4.25	Northing	6308000.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	9.4.25	Easting	593181.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts	<PL	VSt and H	10		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts			9		RESIDUAL SOIL
									10		
									11		
									11		
									10		
									8		
									9		
									9		
									7		
			1						7		
									7		
							~PL		6	U50	
									7		
									6		
									7		
									6		
						1.70m: Colour change to pale brown			6		
									6		
									8		
			2						6		
			3			Test Pit TP08 Terminated at 3.00 m					Target depth

Remarks:

EP LIB 05.GLB Log CW NON-CORED BOREHOLE LOG EP3269 ADWJ FORBES FARNELL ST (GEO SAMPLES ONLY).GPJ <<DrawingFile>> 14/05/2025 09:48 10.03.00.09 Developed by Datgel



EP RISK

EP3269.003

Geotechnical Investigation

TP08/PP02

Test Pit No: TP09

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6307927.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593197.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts		VSt and H	7		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts	<PL		10		RESIDUAL SOIL
									11		
									16		
									18		
											DCP:-HB
			1								
						1.40m: Colour change to pale brown	~PL			U50	
			2								
			3			Test Pit TP09 Terminated at 3.00 m					Target depth

Remarks:

EP3269.003
Geotechnical Investigation

TP09

Test Pit No: TP10

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6307853.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593138.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts	<PL	VSt and H	9 9		TOPSOIL
			1		CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts			10 10 11 11 12 12 10 12 11 12 12 12 13 12 10 9 9 8		RESIDUAL SOIL
			2 3			Test Pit TP10 Terminated at 2.00 m			7 7 8		Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP10

Test Pit No: TP11

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	8.4.25	Northing	6307770.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	8.4.25	Easting	593168.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered			▩	GP	FILL: GRAVEL: fine to medium grained, sub-angular, grey	D		9		FILL
			1 2	▨	CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts 2.20m: Colour change to pale brown	<PL ~PL	VSt and H	10 9 9 10 11 9 10 11 11 12 11 10 9 10 9 9 10 8 7 7 7 8 7 7		RESIDUAL SOIL
			3			Test Pit TP11 Terminated at 2.50 m					Target depth

Remarks:

EP3269.003

Geotechnical Investigation

TP11

Test Pit No: TP12

Engineering Log - Test Pit

SHEET 1 OF 1

Client ADW Johnson Pty Ltd
Project Farnell Street, Forbes NSW
Location Farnell Street, Forbes NSW

Project No. EP3269
Logged By MC
Checked By OP

Started Excavation 9.4.25
Completed Excavation 9.4.25
Northing 6307718.00
Easting 593119.00
Slope 90°
Bearing ---
Equipment 6t Excavator
Ground Level

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered			▩	CL-CI	FILL: Gravelly CLAY: low to medium plasticity, red-brown, fine to medium grained, sub-rounded gravel	<PL		7 6		FILL
			1	▨	CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts		VSt to H	7 10 11 12 11 13 14 16 15 14 14 15	B	RESIDUAL SOIL DCP:-HB
			2 3			Test Pit TP12 Terminated at 1.50 m					Refusal on bedrock

Remarks:

EP RISK

EP3269.003

Geotechnical Investigation

TP12

Test Pit No: PP01

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	9.4.25	Northing	6308007.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	9.4.25	Easting	593141.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
E	Not Encountered				ML	TOPSOIL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts	<PL		9		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained, sub-rounded gravel, medium to coarse grained sand and clasts		VSt to H	8 11 11		RESIDUAL SOIL
			1					VSt	10 10 9 9 8 9 7 7		
							~PL		8 9 6 7 7		
						1.70m: Colour change to pale brown			7 6 7		
			2						8 7		DCP:-HB
			3			Test Pit PP01 Terminated at 3.00 m					Target depth

Remarks:

Test Pit No: PP02

Engineering Log - Test Pit

SHEET 1 OF 1

Client	ADW Johnson Pty Ltd	Project No.	EP3269
Project	Farnell Street, Forbes NSW	Logged By	MC
Location	Farnell Street, Forbes NSW	Checked By	OP

Started Excavation	9.4.25	Northing	6308026.00	Slope	90°	Equipment	6t Excavator
Completed Excavation	9.4.25	Easting	593447.00	Bearing	---	Ground Level	

EXCAVATION				MATERIAL DESCRIPTION					TESTING, SAMPLING & OTHER INFORMATION		
Method	Water	RL (m)	Depth (m)	Graphic Log	Classification	Description of Soil (soil type: plasticity/grainsize, colour and other components)	Moisture Condition	Consistency	Tests DCP Results (blows/ 100mm)	Samples	Additional Comments (material origin, pocket penetrometer values, investigation observations)
	Not Encountered				ML	FILL: Sandy SILT: low plasticity, red-brown, fine to medium grained sand, with clasts	<PL		7		FILL
					CI-CH	Silty CLAY: medium to high plasticity, red-brown, with fine to medium grained sand and trace of fine to medium grained, sub-rounded gravel and clasts		VSt and H	8		RESIDUAL SOIL
									14		
									12		
									13		
									9		
									10		
									9		
									8		
									7		
			1						8		
									6		
									8		
									7		
					CL-CI	Extremely weathered SANDSTONE recovered as Sandy CLAY, low to medium plasticity, pale grey, fine to medium grained sand			9		EXTREMELY WEATHERED ROCK
								H	11		
									12		
									13		
									11		
									11		
			2						13		
									12		
									15		
									16		
									20		
						Test Pit PP02 Terminated at 2.50 m					DCP:-HB Refusal on bedrock
			3								

Remarks:

Appendix E

LABORATORY TEST RESULTS

Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745A
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 06/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP03 (0.30 - 1.00m)**

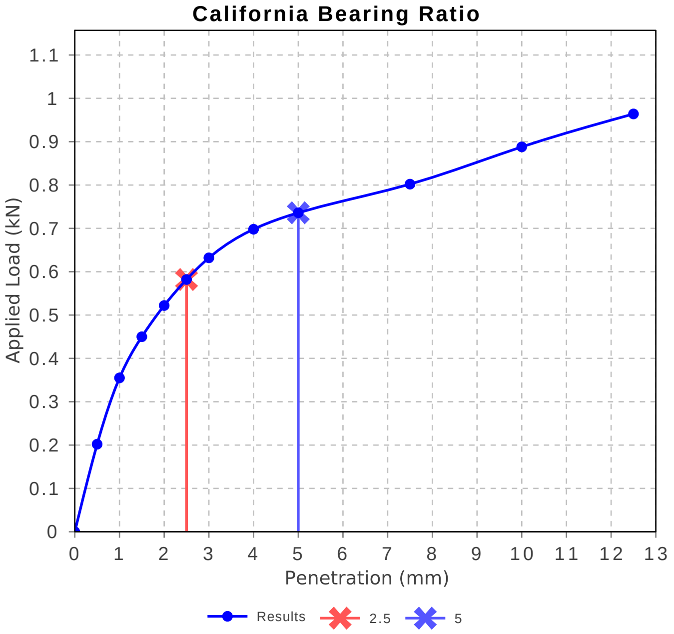
coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

Accredited for compliance with ISO/IEC 17025 - Testing

R. Kirby-Faust

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**4.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual/Tactile		
Maximum Dry Density (t/m^3)	1.79		
Optimum Moisture Content (%)	15.5		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.76		
Field Moisture Content (%)	10.9		
Moisture Content at Placement (%)	15.2		
Moisture Content Top 30mm (%)	22.4		
Moisture Content Rest of Sample (%)	19.2		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours (h)	29.3		
Swell (%)	1.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	3.8		



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745C
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 08/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP03 (1.40 - 2.20m)**

Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

Accredited for compliance with ISO/IEC 17025 - Testing

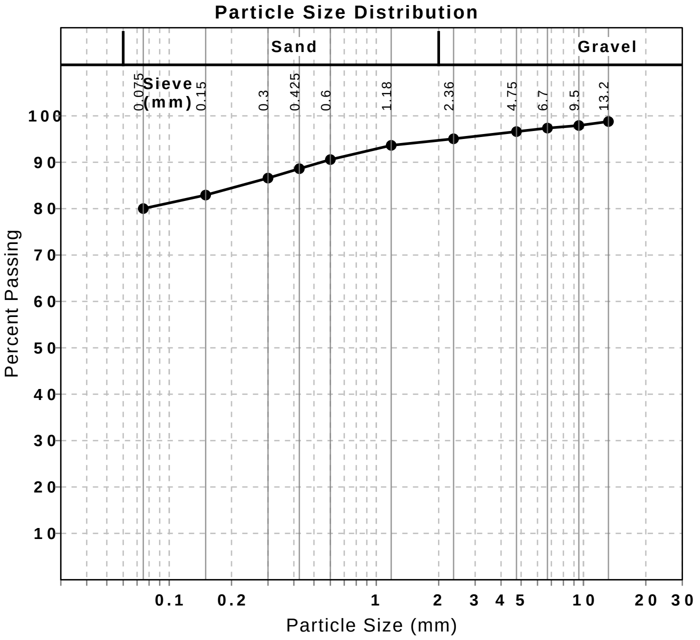
Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	58		
Plastic Limit (%)	19		
Plasticity Index (%)	**39**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1		
Linear Shrinkage (%)	**13.5**		
Cracking Crumbling Curling	Curling		

Particle Size Distribution (AS1289 3.6.1)

Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**99**			1		
9.5 mm	**98**			1		
6.7 mm	**97**			1		
4.75 mm	**97**			1		
2.36 mm	**95**			2		
1.18 mm	**94**			1		
0.6 mm	**91**			3		
0.425 mm	**89**			2		
0.3 mm	**87**			2		
0.15 mm	**83**			4		
0.075 mm	**80**			3		



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745D
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 08/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP05 (0.50 - 1.00m)**

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

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R. Kirby-Faust

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

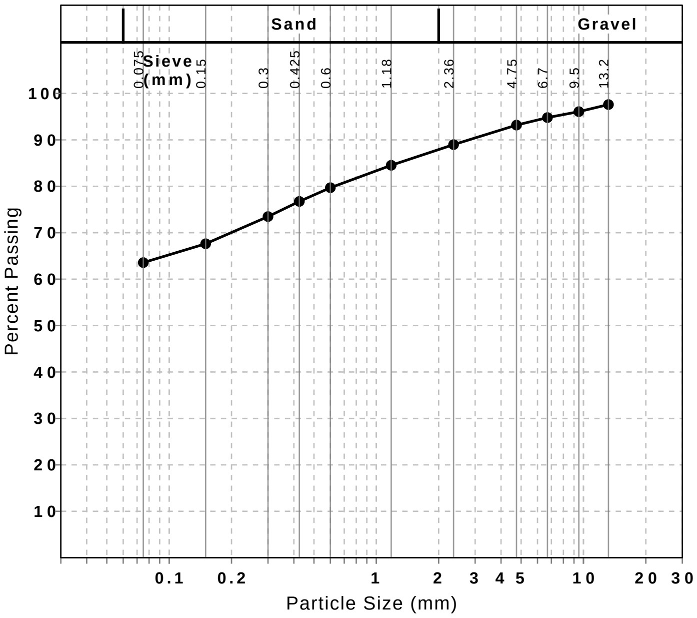
Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	59		
Plastic Limit (%)	16		
Plasticity Index (%)	**43**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1		
Linear Shrinkage (%)	**17.0**		
Cracking Crumbling Curling	Curling		

Particle Size Distribution (AS1289 3.6.1)

Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
13.2 mm	**98**			2		
9.5 mm	**96**			2		
6.7 mm	**95**			1		
4.75 mm	**93**			2		
2.36 mm	**89**			4		
1.18 mm	**85**			4		
0.6 mm	**80**			5		
0.425 mm	**77**			3		
0.3 mm	**73**			3		
0.15 mm	**68**			6		
0.075 mm	**64**			4		

Particle Size Distribution



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745E
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 06/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP05 (1.40 - 1.80m)**

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Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

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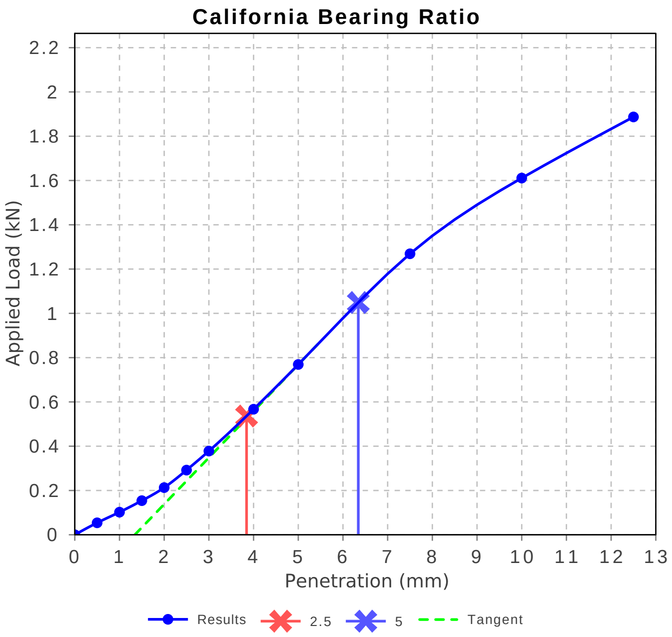
R. Kirby-Faust

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual/Tactile		
Maximum Dry Density (t/m^3)	1.79		
Optimum Moisture Content (%)	14.5		
Laboratory Density Ratio (%)	99.0		
Laboratory Moisture Ratio (%)	101.0		
Dry Density after Soaking (t/m^3)	1.70		
Field Moisture Content (%)	12.6		
Moisture Content at Placement (%)	14.4		
Moisture Content Top 30mm (%)	20.8		
Moisture Content Rest of Sample (%)	19.2		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours (h)	29.5		
Swell (%)	5.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745G
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 08/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP06 (0.50 - 1.00m)**

Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

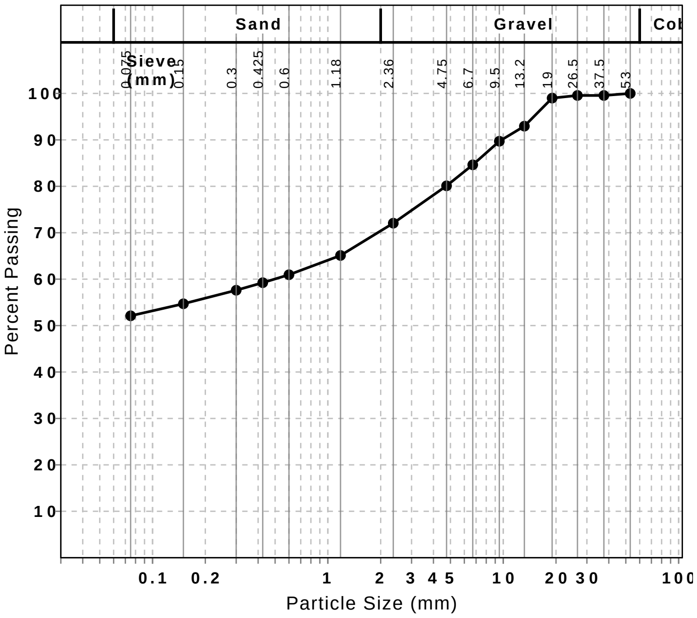
Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	62		
Plastic Limit (%)	19		
Plasticity Index (%)	**43**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1		
Linear Shrinkage (%)	**16.5**		
Cracking Crumbling Curling	Curling		

Particle Size Distribution (AS1289 3.6.1)

Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
53 mm	**100**			0		
37.5 mm	**100**			0		
26.5 mm	**100**			0		
19 mm	**99**			1		
13.2 mm	**93**			6		
9.5 mm	**90**			3		
6.7 mm	**85**			5		
4.75 mm	**80**			5		
2.36 mm	**72**			8		
1.18 mm	**65**			7		
0.6 mm	**61**			4		
0.425 mm	**59**			2		
0.3 mm	**58**			2		
0.15 mm	**55**			3		
0.075 mm	**52**			3		

Particle Size Distribution



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745H
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 09/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP06 (1.00 - 1.50m)**

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

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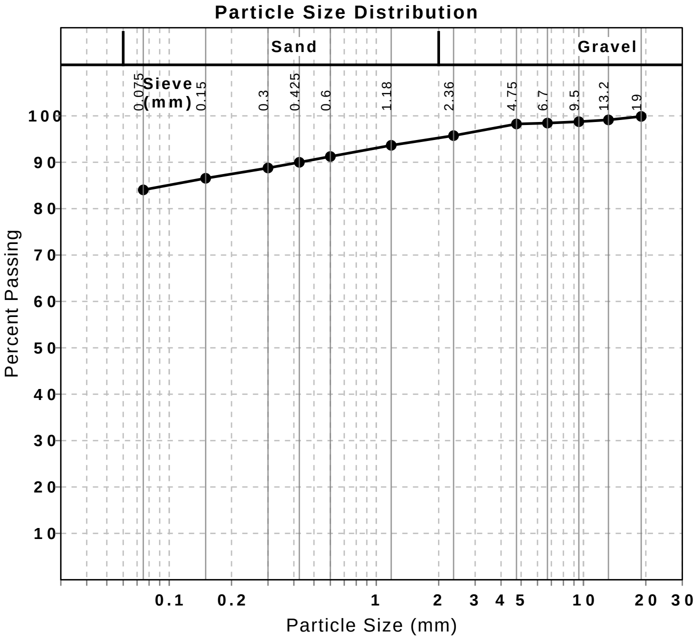
Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	52		
Plastic Limit (%)	24		
Plasticity Index (%)	**28**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1		
Linear Shrinkage (%)	**8.0**		
Cracking Crumbling Curling	None		

Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
19 mm	**100**			0		
13.2 mm	**99**			1		
9.5 mm	**99**			0		
6.7 mm	**98**			0		
4.75 mm	**98**			0		
2.36 mm	**96**			3		
1.18 mm	**94**			2		
0.6 mm	**91**			2		
0.425 mm	**90**			1		
0.3 mm	**89**			1		
0.15 mm	**87**			2		
0.075 mm	**84**			2		



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745I
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 09/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP07 (0.50 - 1.00m)**

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

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Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description	Sandy CLAY - Red		
Nature of Water	Distilled		
Temperature of Water (^{o}C)	22		
* Mineral Present	Carbonate		

Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745J
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 09/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP07 (2.00 - 2.50m)**

coffey
TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

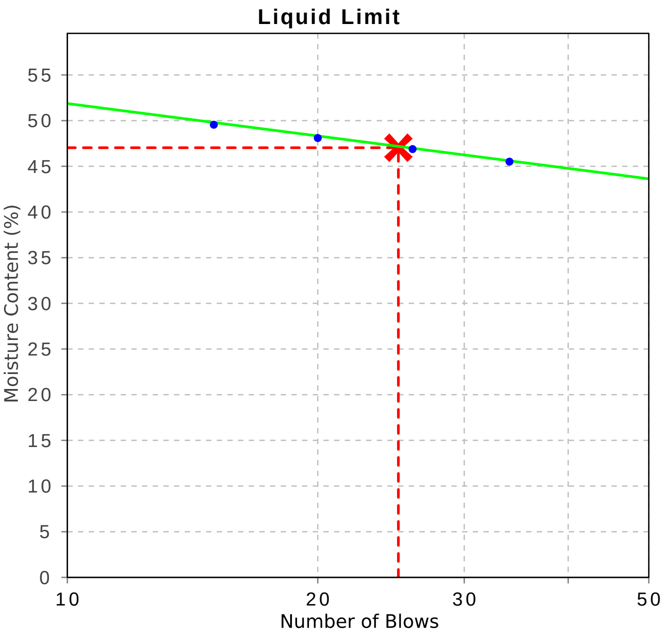
Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	47		
Plastic Limit (%)	24		
Plasticity Index (%)	**23**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1		
Linear Shrinkage (%)	**6.0**		
Cracking Crumbling Curling	None		

Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
37.5 mm	**99**			1		
26.5 mm	**99**			0		
19 mm	**97**			1		
13.2 mm	**96**			1		
9.5 mm	**91**			4		
6.7 mm	**89**			3		
4.75 mm	**86**			3		
2.36 mm	**81**			5		
1.18 mm	**77**			4		
0.6 mm	**74**			3		
0.425 mm	**73**			2		
0.3 mm	**71**			1		
0.15 mm	**68**			3		
0.075 mm	**64**			4		



Material Test Report

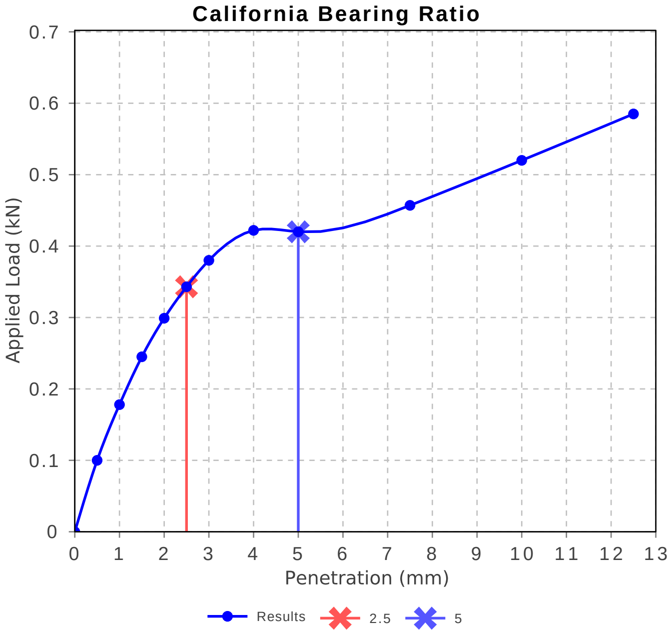
Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Sample Number: NEWC4745M
Date Sampled: 08/04/2025
Dates Tested: 30/04/2025 - 06/05/2025
Sampling Method: Sampled by Client
The results apply to the sample as received
Preparation Method: In accordance with the test method
Site Selection: Selected by Client
Sample Location: **TP12 (0.20 - 1.00m)**

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual/Tactile		
Maximum Dry Density (t/m^3)	1.59		
Optimum Moisture Content (%)	20.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.54		
Field Moisture Content (%)	13.4		
Moisture Content at Placement (%)	20.3		
Moisture Content Top 30mm (%)	32.3		
Moisture Content Rest of Sample (%)	24.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours (h)	24.5		
Swell (%)	3.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		



Material Test Report

Report Number: **NEWC25312-1**
Issue Number: 1
Date Issued: 12/05/2025
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project Number: NEWC25312
Project Name: Farnell Street, Forbes NSW
Project Location: Farnell Street, Forbes NSW
Client Reference: EP3269
Work Request: 4745
Dates Tested: 30/04/2025 - 01/05/2025
Location: Test Pit - Material Evaluation

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: (02) 4016 2300
Email: Newcastle Laboratory

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Shrink Swell Index AS 1289 7.1.1 & 2.1.1

Sample Number	NEWC4745B	NEWC4745F	NEWC4745K	NEWC4745L	
Date Sampled	08/04/2025	08/04/2025	08/04/2025	08/04/2025	
Date Tested	01/05/2025	01/05/2025	01/05/2025	01/05/2025	
Material Source	**	**	**	**	
Sample Location	TP03 (1.40 - 1.90m)	TP05 (1.40 - 2.00)	TP08 (1.20 - 1.60m)	TP09 (1.40 - 1.80m)	
Inert Material Estimate (%)	0	0	0	0	
Pocket Penetrometer before (kPa)	600+	330	350	580	
Pocket Penetrometer after (kPa)	160	230	200	180	
Shrinkage Moisture Content (%)	18.8	15.1	20.9	18.4	
Shrinkage (%)	**2.0**	**0.3**	**4.6**	**2.3**	
Swell Moisture Content Before (%)	19.2	15.1	21.8	17.5	
Swell Moisture Content After (%)	24.5	21.9	24.2	24.8	
Swell (%)	**4.6**	**0.5**	**2.4**	**3.7**	
Shrink Swell Index Iss (%)	**2.4**	**0.3**	**3.2**	**2.3**	
Visual Description	silty CLAY (mottle)	silty CLAY (grey/white)	silty CLAY (brown)	sandy CLAY (brown)	
Cracking	SC	UC	SC	UC	
Crumbling	No	No	No	No	
Remarks	**	**	**	**	

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
Cracking Terminology: UC Uncracked, SC Slightly Cracked, MC Moderately Cracked, HC Highly Cracked, FR Fragmented.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

CERTIFICATE OF ANALYSIS

Work Order	: **ES2510654**	Page	: 1 of 2
Client	: **EP RISK MANAGEMENT**	Laboratory	: Environmental Division Sydney
Contact	: OVI PRUTEANU	Contact	: Jason Dighton
Address	: 3/19 BOLTON STREET NEWCASTLE NSW 2300	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: EP3269	Date Samples Received	: 16-Apr-2025 13:10
Order number	: EP3269 Aggresivity	Date Analysis Commenced	: 23-Apr-2025
C-O-C number	: ----	Issue Date	: 24-Apr-2025 17:32
Sampler	: MC		
Site	: ----		
Quote number	: ES23EPRISK0002 - ES PRIMARY WORK ONLY		
No. of samples received	: 2		
No. of samples analysed	: 2		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- ED045G: The presence of Thiocyanate, Thiosulfate and Sulfite can positively contribute to the chloride result, thereby may bias results higher than expected. Results should be scrutinised accordingly.

Analytical Results

Sub-Matrix: **SOIL** (Matrix: **SOIL**)			*Sample ID*	**TP07_3.0**	**TP06_3.0**	**----**	**----**	**----**
			Sampling date / time	10-Apr-2025 00:00	10-Apr-2025 00:00	----	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES2510654-001**	**ES2510654-002**	--------	--------	--------
				Result	Result	----	----	----
EA002: pH 1:5 (Soils)								
pH Value	----	0.1	pH Unit	**5.0**	**7.5**	**----**	**----**	**----**
EA010: Conductivity (1:5)								
Electrical Conductivity @ 25°C	----	1	µS/cm	**910**	**1230**	**----**	**----**	**----**
EA055: Moisture Content (Dried @ 105-110°C)								
Moisture Content	----	1.0	%	**10.6**	**19.6**	**----**	**----**	**----**
EA080: Resistivity								
Resistivity at 25°C	----	1	ohm cm	**1100**	**813**	**----**	**----**	**----**
ED040S : Soluble Sulfate by ICPAES								
Sulfate as SO4 2-	14808-79-8	10	mg/kg	**200**	**430**	**----**	**----**	**----**
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	10	mg/kg	**1200**	**1770**	**----**	**----**	**----**

Appendix F

FOUNDATION MAINTENANCE AND FOOTING PERFORMANCE

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

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).

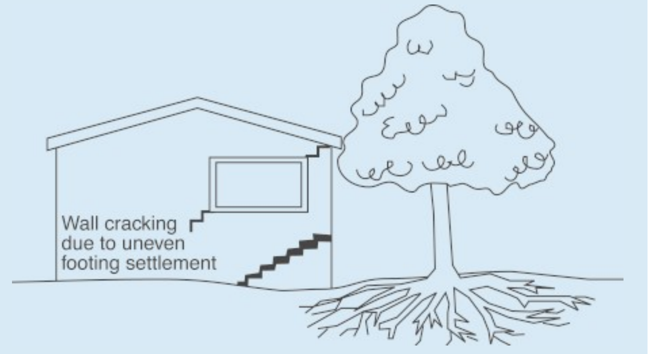
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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.

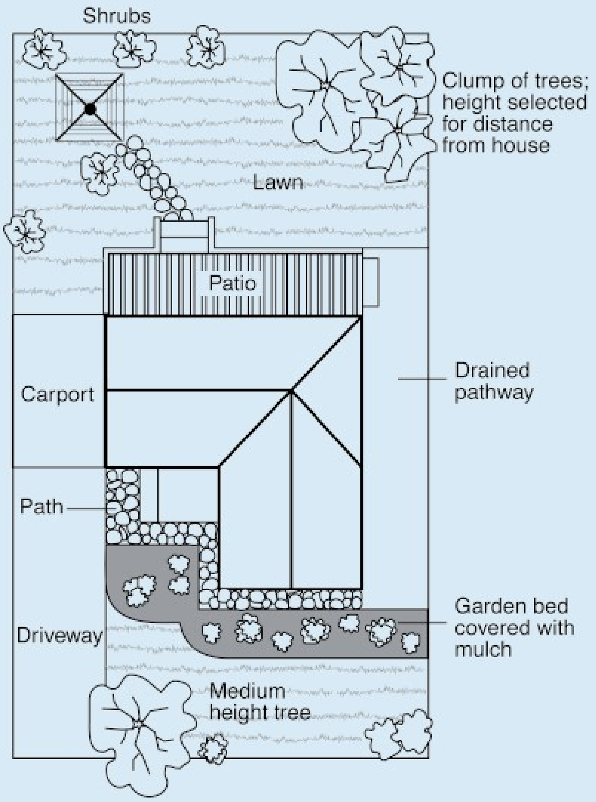
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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Email: publishing.sales@csiro.au