Geotechnical Investigation

Anambah Road, Anambah NSW

Prepared for: Thirdi Group c/-Mid North Coast Projects

EP3867.001   11 December 2024

Geotechnical Investigation

Anambah Road, Anambah NSW

Thirdi Group c/-Mid North Coast Projects
53 Hume St,
Crows Nest NSW 2065

11 December 2024

Our Ref: EP3867.001

LIMITATIONS

This Geotechnical Investigation was conducted on the behalf of Thirdi Group c/-Mid North Coast Projects for the purpose/s stated in **Section 1**.

EP Risk has prepared this document in good faith, but is unable to provide certification outside of areas over which EP Risk had some control or were reasonably able to check. The report also relies upon information provided by third parties. EP Risk has undertaken all practical steps to confirm the reliability of the information provided by third parties and do not accept any liability for false or misleading information provided by these parties.

It is not possible in a Geotechnical Investigation to present all data, which could be of interest to all readers of this report. Readers are referred to any referenced investigation reports for further data.

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QUALITY CONTROL

Version	Author	Date	Reviewer	Date	Quality Review	Date
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1 Introduction

EP Risk Management Pty Ltd (EP Risk) was engaged by Thirdi Group C/- Mid North Coast Projects (Thirdi) to undertake a Geotechnical Investigation at 559 Anambah Road, Gosforth NSW (Lot177 DP874171 and Lot 55 DP874170) for the proposed Development Application (DA) for Anambah Manufactured Housing Estate.

The masterplan creates additional subdivisions within the Anambah Residential Community for roads, pedestrian networks, utilities and services, drainage infrastructure, community garden, outdoor recreational spaces and a clubhouse.

The proposed layout of the development is included in **Appendix A – Anambah Residential Community**.

The engagement was undertaken in line with the conditions of engagement and the investigation scope as outlined in our proposal EP18281 dated 14 August 2024.

1.1 Objectives and Scope

It is understood that the geotechnical investigation is required for the Development Application (DA) and is aimed to identify any significant geotechnical constraints. It is noted that the current investigation extends on the western side of the previous investigation undertaken by EP Risk for Thirdi Anambah Pty Ltd in June 2024 (EP3627.002).

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.
- Advance twelve (12) test pits to a maximum depth of 2.7m below ground level (BGL) or prior bedrock refusal within the proposed development extension to inform the pavement design, preliminary site classification and service excavations.
- Dynamic Cone Penetrometer testing was conducted adjacent to the test pit to assess the consistency of the strata.
- Collection of representative undisturbed, disturbed and bulk samples for 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 report including the investigation findings, pavement design, preliminary site classification, excavatability assessment and laboratory test results.

2 Site Location and Description

The Site is located at 559 Anambah Road, Gosforth NSW 2320, legally described as Lot 177 in DP874171 and Lot 55 in DP874170 and surrounded by undeveloped land.

The elevation of the Site ranges from approximately Reduced Level (R.L) 80m Australian Height Datum (AHD) in the southwestern corner of the site to approximately R.L 40m AHD along the ephemeral creeks that cross the site in a predominantly northwest to southeast direction. Rock outcrops were observed on the elevated part of the Site in the north-western area.

Site drainage is assumed to follow surface contours in a predominately south and south-east direction and towards the north along natural drainage lines to lower elevated areas of the Site. Part of the Site drains towards the north to lower elevations. Water storage dams associated with the grazing were also observed on site, constructed in natural drainage lines. The Site vegetation comprised of short pasture grass used for grazing and scattered trees. Several erosion scarps were observed along the drainage lines. Photos collected during site investigation are shown in **Appendix B – Photolog**.

An excerpt from SixMaps showing the indicative location of the Site is presented in Figure 1.

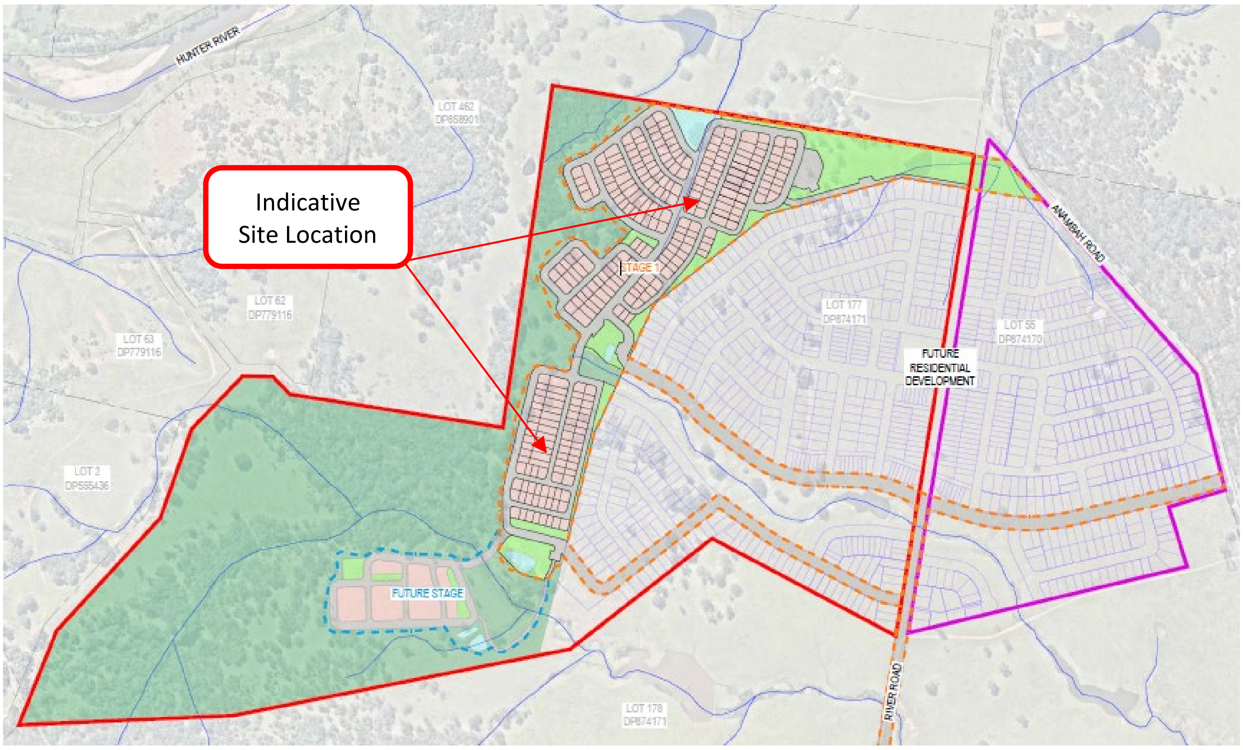


Figure 1 – Indicative Site Location

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:

- Carboniferous Aged (330.9-303.7Ma) - Seaham Formation (Curs) of Ungrouped Rouchel Block Units known to contain tillite, varved siltstone, tuff, red and green zeolitic mudstone with dropstones interbedded in thick-bedded lithic sandstone and conglomerate.
- Permian Aged (298.9-251.9Ma) - Lochinvar Formation (Pdal) of Dalwood Group containing basalt, siltstone, sandstone.

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

Figure 2 – Geological Map Excerpt

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 Rothbury. The Rothbury soil landscape covers undulating to rolling hills with elevations ranging from 60 – 140 m. Average slopes are 6 – 10% with some to 12%. Slope lengths are 800 – 1,000 m with local relief of 60 – 80 m. Drainage lines are common throughout the area and occur at intervals of 200 – 1,000 m. As limitations or this type of soil are erosion hazard, localised waterlogging, and poor drainage.

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 within Class 5 acid sulphate soil classification. Acid sulphate soils are not typically found in Class 5 areas. Areas classified as Class 5 are located within 500 metres on adjacent class 1,2,3 or 4 land. An extract of the acid sulphate soil map is shown in Figure 3.

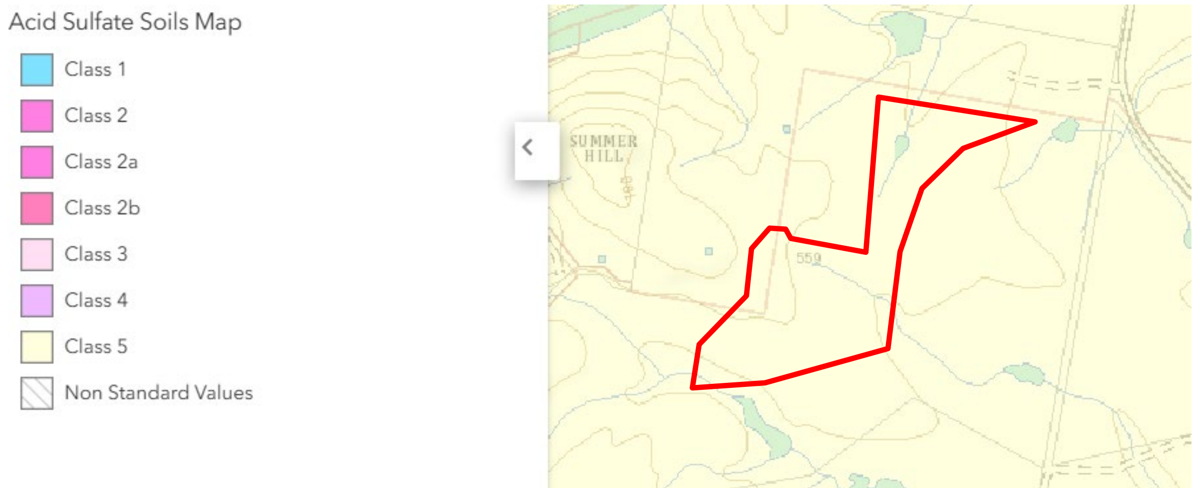


Figure 3 – Acid Sulphate Soil Map Excerpt

4 Geotechnical Investigation

4.1 Investigation Methodology

The site investigation was conducted on 12 September 2024 under full time supervision of an experienced EP Risk Geotechnical Professional in accordance with AS1726-2017 Geotechnical Site Investigations. The investigation 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.
- Excavating twelve (12) 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.
- Reinstatement test pits with spoil. Upon completion the soil placed in test pits was compacted by the excavator bucket and by excavator run over.

The test pits were excavated using a Kobelco 15T excavator fitted with a 400mm bucket. A ripper attachment was also used to advance the test pits in medium to high strength bedrock. 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 D – Test Pit Logs.**

Table 1. Observed Geotechnical Units

Unit #	Origin	Material	Description
Unit 1a	Topsoil	Silty/Sandy CLAY	Low to high plasticity, grey, brown, dark brown, fine to medium grained sand
Unit 1b		Clayey SAND	Fine grained, grey
Unit 2a	Slopewash	Silty CLAY	Low to medium plasticity, pale grey
Unit 2b		Clayey SAND/SAND	Fine to medium grained, grey
Unit 3	Residual Soil	Silty/Sandy CLAY	Medium to high plasticity, brown, pale brown, grey, orange, fine to coarse grained sand
Unit 4a	XW* Material	MUDSTONE	Silty/Sandy CLAY and Clayey SAND/GRAVEL, medium to high plasticity, brown, orange, red, grey, fine to coarse grained sand, fine to coarse, sub-angular and angular gravel
Unit 4b		SANDSTONE	Silty/Sandy CLAY/Clayey SAND, medium to high plasticity, brown, orange, red, grey, fine to coarse grained sand

XW-extremely weathered.

Table 2. Distribution of Subsurface Geological units Across the Investigated Locations

TP - ID	Depth Below Ground Level (m BGL)						
	Topsoil		Slopewash		Residual Soil	XW Material	
	Unit 1a	Unit 1b	Unit 2a	Unit 2b	Unit 3	Unit 4a	Unit 4b
TP01-P	0.0-0.2	NE	NE	NE	0.2-0.6	0.6-1.9*	NE
TP02-L	0.0-0.19	NE	NE	NE	0.19-0.57	0.57-2.7*	NE
TP03-P	0.0-0.18	NE	NE	0.18-0.4	0.4-0.9	0.9-2.0*	NE
TP04-L	NE	0.0-0.17	0.17-0.49	NE	0.49-0.6	0.6-2.7*	NE
TP05-P	NE	0.0-0.18	NE	0.18-0.4	0.4-0.88	NE	0.88-2.7*
TP06-P	NE	0.0-0.14	0.14-0.5	NE	0.5-1.38	NE	1.38-2.7*
TP07-L	NE	0.0-0.2	NE	0.2-0.42	0.42-0.7	NE	0.7-2.7*
TP08-P	NE	0.0-0.17	NE	0.17-0.31	0.31-0.83	NE	0.83-2.7*
TP09-P	NE	0.0-0.14	NE	NE	NE	0.14-2.7*	NE
TP10-L	0.0-0.17	NE	NE	0.17-0.4	0.4-1.25	NE	1.25-2.3*
TP11-P	0.0-0.18	NE	NE	NE	0.18-0.8	0.8-2.5*	NE
TP12-L	NE	0.0-0.1	NE	NE	NE	NE	0.1-1.5*

*)-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 Test Results

Geotechnical laboratory testing was conducted on selected bulk, disturbed and undisturbed samples collected during the site investigation. All testing was performed by Coffey Testing (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 Atterberg Limits

A summary of Atterberg Limits and Linear Shrinkage Test results are presented in Table 3 and are plotted graphically in Figure 4.

Table 3. Atterberg Limits Test Results

Test Pit ID	Depth (m BGL)	Soil	Classification	Atterberg Limits			Linear Shrinkage (%)
				LL (%)	PL (%)	PI (%)	
TP02 - L	0.2-0.5	Silty CLAY	CI-CH	85	22	63	17.5
TP10 - P	0.8-1.5	Silty Sandy CLAY	CI-CH	29	12	17	6.5

LL – Liquid Limit
PL – Plastic Limit
PI – Plasticity Index

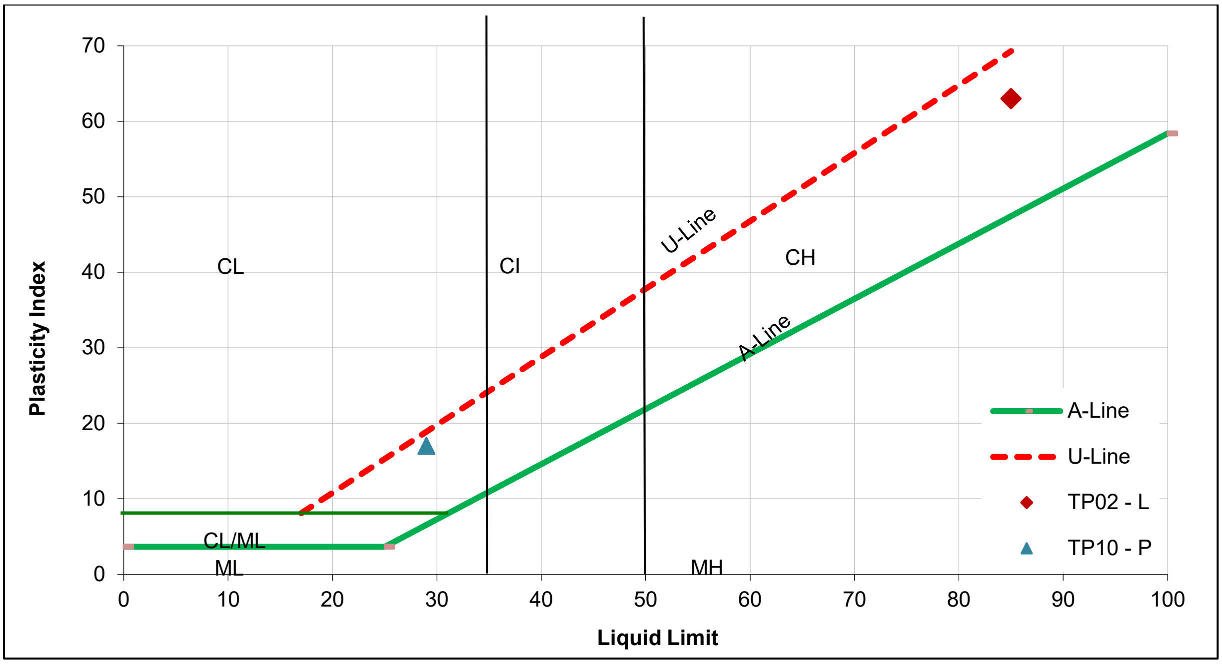


Figure 4 – Atterberg Limit Plot

4.4.2 Particle Size Distribution

Particle Size Distribution (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 Pit ID	Depth (m BGL)	% passing 2.36 mm sieve	% passing 75 µm sieve	Sample Description
TP02 - L	0.2-0.5	99	90	Silty CLAY
TP10 - P	0.5-1.5	90	39	Silty Sandy CLAY

4.4.3 California Bearing Ratio (CBR)

CBR tests were conducted on two soil samples to inform the design CBR for the proposed road within the proposed development. The results are summarised in Table 5.

Table 5. California Bearing Ratio Test Results

Test ID	Depth (m BGL)	Sample Description	W[1](%)	SOMC[2] (%)	SMDD[3] (t/m^3)	Swell (%)	CBR (%)
TP01 - P	0.5-1.0	XW* Mudstone (Sandy CLAY)	16.6	21.0	1.66	0.0	10[5]
TP05 - P	0.9-1.5	XW* Sandstone (Sandy CLAY)	10.3	16.5	1.74	0.0	14[5]

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

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 Pit 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 (%)	
TP07 – L	SAND/Silty CLAY	0.25-0.75	26.7	7.2	19.6	23.5	1.0	**4.3**
TP10 – L	Clayey SAND/Silty CLAY	0.25-0.75	21.3	2.7	20.1	24.7	0.0	**1.5**

4.4.5 Point Load Testing

It is noted the rock samples collected from test pits are competent bedrock fragments as the lower strength bedrock was broken down into soil during excavation. All the rock samples were collected dry and were tested dry which could potentially contribute to a higher strength rock interpretation. Point load testing has been conducted on selected rock samples collected from test pits and the test results are shown in Table 7.

Table 7. Point Load Test Results

TP ID	Rock	Depth (m BGL)	Moisture condition	Is (MPa)	Is (50) MPa	Rock strength
TP04 - L	Mudstone	2.2-2.7	Dry	0.34	0.46	Medium Strength
TP04 - L	Mudstone	2.2-2.7	Dry	0.18	0.22	Low Strength
TP04 - L	Mudstone	2.2-2.7	Dry	0.12	0.15	Low Strength
TP04 - L	Mudstone	2.2-2.7	Dry	0.12	0.15	Low Strength
TP04 - L	Mudstone	2.2-2.7	Dry	0.19	0.24	Low Strength

4.4.6 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 three (3) sample recovered from test pits. An assessment of the exposure classification for the soil sample tested based on the above criteria is presented in Table 8.

Table 8. Aggressivity Test Results

Test Pit 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
TP02-L	Silty CLAY	<10	8.1	<10	58000	Non-Aggressive	Non-Aggressive
TP04-L	Silty CLAY	260	6.0	52	24000	Non-Aggressive	Non-Aggressive
TP07-L	Clayey SAND	69	7.1	240	4100	Mild	Mild

5 Pavement Design

5.1 Design Traffic Loadings

Design traffic loadings have been selected and pavement thickness design calculations have been undertaken by EP Risk in accordance with *Maitland City Council – Manual of Engineering Standards - Pavement Design*.

The design traffic data has been determined based on the following assumptions presented in Table 9.

Table 9. Recommended Road Type and Design ESA's

Road Type	Roads Identification	Design ESA's
Local - Secondary	TBC	2×10^5
Local - Primary	TBC	5×10^5
Collector - Secondary	TBC	1×10^6
Collector - Primary	TBC	1.5×10^6
Distributor– Secondary (Bus Route)	TBC	2×10^6

Where traffic data varies from the above assumptions a review of pavement design will be required particularly considering connectivity with adjacent developments.

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 3% for cohesive residual soils.
- Design subgrade CBR of 6% for extremely weathered Mudstone/Sandstone, Silty/Sandy CLAY.
- Design subgrade CBR of 10% for slightly weathered Mudstone/Sandy GRAVEL/CLAY and residual soil.
- Design Traffic as per Table 9.

The design subgrade has been determined in accordance with Section 5 of Austroads 2017 based on laboratory testing results and field interpretation.

The CBR Swell results when compared to Table 5.2 in Austroads Guide to pavement Technology Part 2: Pavement Structural Design indicate that soils have generally a low expansive nature.

Where filling is undertaken within the road alignments, all fill materials should generally be a minimum of CBR 3% based on a 4-day soak when compacted to 100% standard relative density and SOMC except where the final pavement design is based on a subgrade design CBR of 10%.

5.3 Pavement Design – Flexible Unbound Pavement

Pavement thickness design was conducted based on the *Maitland City Council – Manual of Engineering Standards - Pavement Design*. In accordance with the council directive, an overall pavement thickness of 300mm minimum, with 100mm minimum base thickness and 125mm minimum sub-base thickness is required. Due to the profile of standard SA kerb and roll kerb and gutter. Basecourse is normally specified as a minimum of 150mm for construction practicality.

The option of pavement construction utilising flexible unbound pavement materials for Silty CLAY, XW Mudstone (Sandy CLAY/GRAVEL) are presented in Table 10, Table 11 and Table 12.

Table 10. Recommended Flexible Pavement Composition – CBR 3%

Road Type	Distributor - Bus Route	Collector Primary	Collector Secondary	Local - Primary	Local Secondary
Wearing Course (mm)	45 AC14 HD*	45 AC14 HD*	45 AC14 HD*	30 AC10*	30 AC10*
Basecourse (mm)	150	150	150	160**	160**
Subbase (mm)	125	345 (125)	325 (125)	290 (125)	250 (125)
Select (mm)***	300	(300)	(300)	(300)	(300)
Total Thickness (mm)	620	540	520	480 (615)	425 (615)
Subgrade CBR	min 3%	min 3%	min 3%	min 3%	min 3%
Design ESA	2.0×10^6	1.5×10^6	1.0×10^6	5.0×10^5	2.0×10^5

AC14/AC10 with 10mm primer seal placed under the asphaltic concrete wearing surface
** Basecourse layer will be 160mm to suit standard kerb & gutter (modified SA) or roll kerb
*** Minimum CBR 30% required for the CBR 3% option. Where CBR swell is ≥2.5% select should be increased to 300mm with subbase thickness reduced accordingly as per bracketed values.

Table 11. Recommended Flexible Pavement Composition – CBR 6%

Road Type	Distributor - Bus Route	Collector Primary	Collector Secondary	Local - Primary	Local Secondary
Wearing Course (mm)	45 AC14 HD*	45 AC14 HD*	45 AC14 HD*	30 AC10*	30 AC10*
Basecourse (mm)	150	150	150	160**	160**
Subbase (mm)	230	220	200	140	140
Total Thickness (mm)	425	415	395	330	330
Subgrade CBR	min 6%	min 6%	min 6%	min 6%	min 6%
Design ESA	2.0×10^6	1.5×10^6	1.0×10^6	5.0×10^5	2.0×10^5

AC14/AC10 with 10mm primer seal placed under the asphaltic concrete wearing surface
** Basecourse layer will be 160mm to suit standard kerb & gutter (modified SA) or roll kerb.

Table 12. Recommended Flexible Pavement Composition – CBR 10%

Road Type	Distributor - Bus Route	Collector Primary	Collector Secondary	Local - Primary	Local Secondary
Wearing Course (mm)	45 AC14 HD*	45 AC14 HD*	45 AC14 HD*	30 AC10*	30 AC10*
Basecourse (mm)	150	150	150	160**	160**
Subbase (mm)	150	150	150	125	125
Total Thickness (mm)	345	345	345	315	315
Subgrade CBR	min 10%	min 10%	min 10%	min 10%	min 10%
Design ESA	2.0×10^6	1.5×10^6	1.0×10^6	5.0×10^5	2.0×10^5

AC14/AC10 with 10mm primer seal placed under the asphaltic concrete wearing surface
** Basecourse layer will be 160mm to suit standard kerb & gutter (modified SA) or roll kerb.

A minimum of fourteen days duration shall apply prior to application of asphalt layer. That period may be extended or shortened subject to approval by Council. It is noted Maitland City Council requires minimum 40mm AC (14) "Heavy Duty" for Classified Roads a 45mm AC14 wearing course has been specified to comply with 3-time nominal size of aggregate and provide improved durability.

For areas where the clay subgrade has a CBR <3 (not expected) or swell ≥2.5%, the pavement design incorporates a 300mm select layer with minimum CBR of 30% or other measures detailed in Austroads Guidelines for managing soils with a swell potential. Select with CBR of 30% is specified for the design Subgrade of 3%. The design CBR needs to be confirmed on road alignment following the regrade activities on site. Where subgrade is at elevated moisture content at the time of construction a select layer will be likely be required and should be provisioned for particularly in lower lying areas in the southern section of the site.

5.4 Subgrade Preparation

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

- Remove topsoil to the design subgrade level.
- Ripping the encountered weathered Mudstone/Sandstone to 300-350mm below DSL and recompact to a minimum 100% of SMDD. Moisture contents should be within 70% to 90% of SOMC for weathered bedrock and closer to SOMC where highly expansive subgrade materials are encountered or used as fill.
- 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 3%. 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 constructed in accordance with the recommendations or this report and *Maitland City Council – Manual of Engineering Standards (MCC-MoES)*. In case of discrepancy clarification should be obtained from Council.

5.5 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 along both side of all roads within the development in accordance with Council requirements, at subgrade level. CBR swell results from the preliminary investigation are indicating low expansive soils. If expansive soils are encountered, design measures and subsurface drainage measures to control subgrade swell should be adopted as indicated in Austroads Pavement 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 300mm select layer are provided in Table 10.

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.

5.6 Materials

5.6.1 Specifications and Compaction Requirements

Pavement materials and compaction requirements for new pavement construction should conform to Council requirements outlined in MCC-MoES and the following requirements outlined in Table 13.

Table 13. Material Specification and Compaction Requirements

Pavement Course	Material Specification	Compaction Requirements
Base Course DGB20 (Class 1 &2) & NGB20** MoES (Cl 9.1.2)	Material complying with Council MoES Table 242.3 for the appropriate traffic category	Min 98% Modified (AS 1289 5.2.1)
Subbase Subbase quality crushed rock (DGS20, DGS40, GMS40, NGS20, NGS40) MoES (Cl 9.1.2)	Material complying with Council MoES	Min 95% Modified (AS 1289 5.2.1)
Select Granular material	Minimum CBR 30% when part of the design, (min 15% for Design CBR of ≤3%) and PI ≤15% conforming to Council MoES	Min 100% Standard (AS 1289 5.1.1)
Subgrade or replacement	Minimum CBR as appropriate for the design option.	Min 100% Standard (AS 1289 5.1.1)

*) - Class 1 material should be used on sub-arterial category roads

**) NGB and NGS material cannot be used on collector category road or higher due to higher design traffic. Material should comply with Council MoES Appendix D – Pavement Material Properties for the appropriate traffic category

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.

5.6.2 Wearing Course

Wearing courses should be in accordance with the Council's specifications with reference to TfNSW QA Specifications R116 for Dense Graded Asphalt. It is noted that a minimum of 40mm AC14 (Heavy Duty) wearing course is utilised for classified roads in accordance with Council Specifications. 45mm of AC14 heavy duty has been specified to meet the minimum 3 time the nominal size of aggregate. Recent trials have also shown that 48mm of AC14 is the optimal thickness for durability.

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.

5.6.3 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 10-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.

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 14.

Table 14. 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 soil returned an I_{ss} value of 4.3% in TP07-L and an Iss value of 1.5% for TP10-L.

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 15.

Table 15. Anticipated Site Classifications

Gosforth - Anambah Road	Site Classification
In Existing Condition prior to regrade	**Class M** – Moderately Reactive to **Class H2** – Highly Reactive
Following regrade activities	**Class H1** Highly Reactive to **Class E –** Extremely Reactive

A characteristic surface movement (y_s) of 23mm to 69mm has been calculated for the site dependent on the soil profile in its existing state prior to regrade, using a depth of design suction (Hs) change of 2.3m. Following regrade characteristic surface movement (ys) in the order of 42mm to over 75mm have been calculated 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 utilised as fill. It is noted that the classification of Class M in existing condition was due to the presence of relatively shallow rock in the twelve (12) test pits conducted. Where the residual soil depth is 2.3m or greater Class H2 is possible and potentially Class E where reactive material is present and following regrade.

It is noted that previous investigation has identified highly to extremely reactive material on site. Careful earthworks management will be required to achieve optimal site classification outcomes with the material present on site and reduce the potential for classification as Class E. Particularly where significant regrade is undertaken.

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 Excavatability Assessment

Practical machine refusal for the 15-tonne excavator was encountered on a combination of mudstone and sandstone in five (5) test pits out of the twelve (12) excavated test pits. Refusal depths ranged from 1.5m BGL to 2.5m BGL. The strength of bedrock encountered in test pits assessed by point load testing ranges from low to medium strength. To assess the excavatability of the bedrock, the strength range is plotted on the graph in Figure 5 for excavatability as per the suggested method by Pettifer and Fookes. The area of the chart covered indicates that hard ripping by a D8 will be typically the excavation method for the type of rock encountered within the Site area.

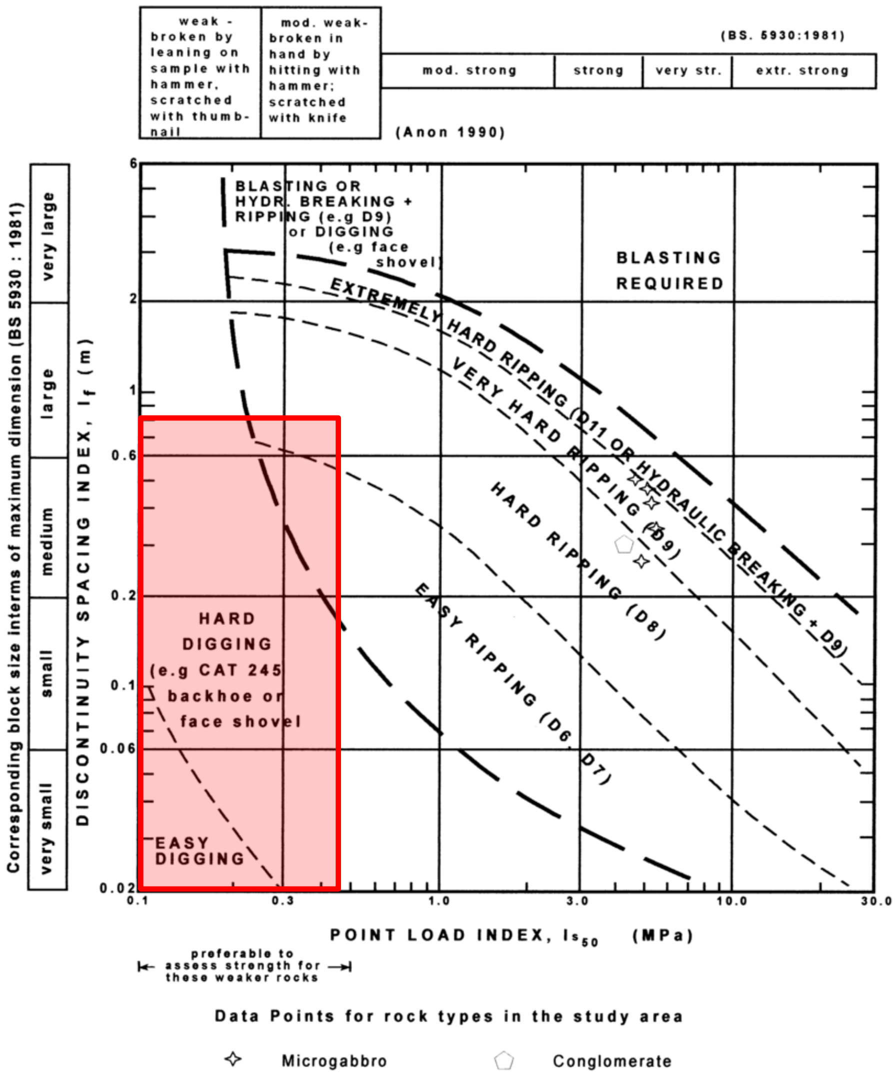


Figure 5 – Excavatability Assessment (Pettifer and Fookes).

Excavations to depths of 1.5m-2.0 m BGL in weathered bedrock are expected to be readily achievable using larger (>25T) conventional earthmoving equipment. Excavations below 2.2 m deep (especially in confined space like trenches) in slightly weathered/fresh bedrock may require excavators fitted with tiger teeth buckets or single ripper attachment.

Excavatability conditions have not been assessed beyond the depths to which the test pits were excavated; however, the following general comments regarding rock mass excavatability conditions can be made:

- Rock strength as well as rock mass defect (joint) spacing could be expected to control rock mass excavatability. Rock strength is likely to be variable and layers of weaker rock can underlie stronger bedrock.
- Excavatability could be expected to be dependent on the plant used, the experience of the operator and the degree of confinement within the excavation.

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.

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 Structures

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

- Count surcharge loading 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 topsoil or slopewash within stiff or better consistency clay or weathered rock.

7.3 Filling and Material Management

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.
- Removal of any unsuitable soil (soft and loose slopewash soils).
- Wet material where encountered (along the drainage lines across the site and in the southern part of the site) will likely require treatment or moisture re-conditioning (drying and blending with dryer fill material) 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 at a 70-100% of SOMC. Due to

the reactivity of materials on site. They should be placed as close to SOMC as possible without over compaction to reduce the potential for moisture related volume change.

- 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.

7.3.1 Material Management

Materials excavated on Site apart from topsoil and slopewash are considered suitable for re-use as engineering fill. Some materials such as slopewash will likely require treatment such as blending and moisture re-conditioning to produce suitable structural fill, subject to further assessment and weather conditions prior to and during construction. Material should be managed during regrade to allow use of required design CBR and lower reactivity material in the top 1m of filling and subgrade preparation to provide better outcome for pavement construction and site classification. Higher CBR material used in the upper 0.3-0.5m of subgrade will influence the design CBR which can be adopted.

7.4 Geotechnical Design Parameters

The geotechnical 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: soils in Table 16 and for bedrock in Table 17. The design parameters for bedrock have been assumed based on the observations during site investigation.

The low consistency topsoil layer has been considered unsuitable for shallow foundations and no design parameters have been calculated for these units.

Table 16. 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/ SLOPEWASH Silty/Sandy CLAY (stiff or better)	19	50-75	3-5	26	0.3	10	0.39	2.56
RESIDUAL SOIL/ SLOPEWASH Clayey SAND (medium dense or better)	18	-	-	32	0.3	12	0.31	3.25

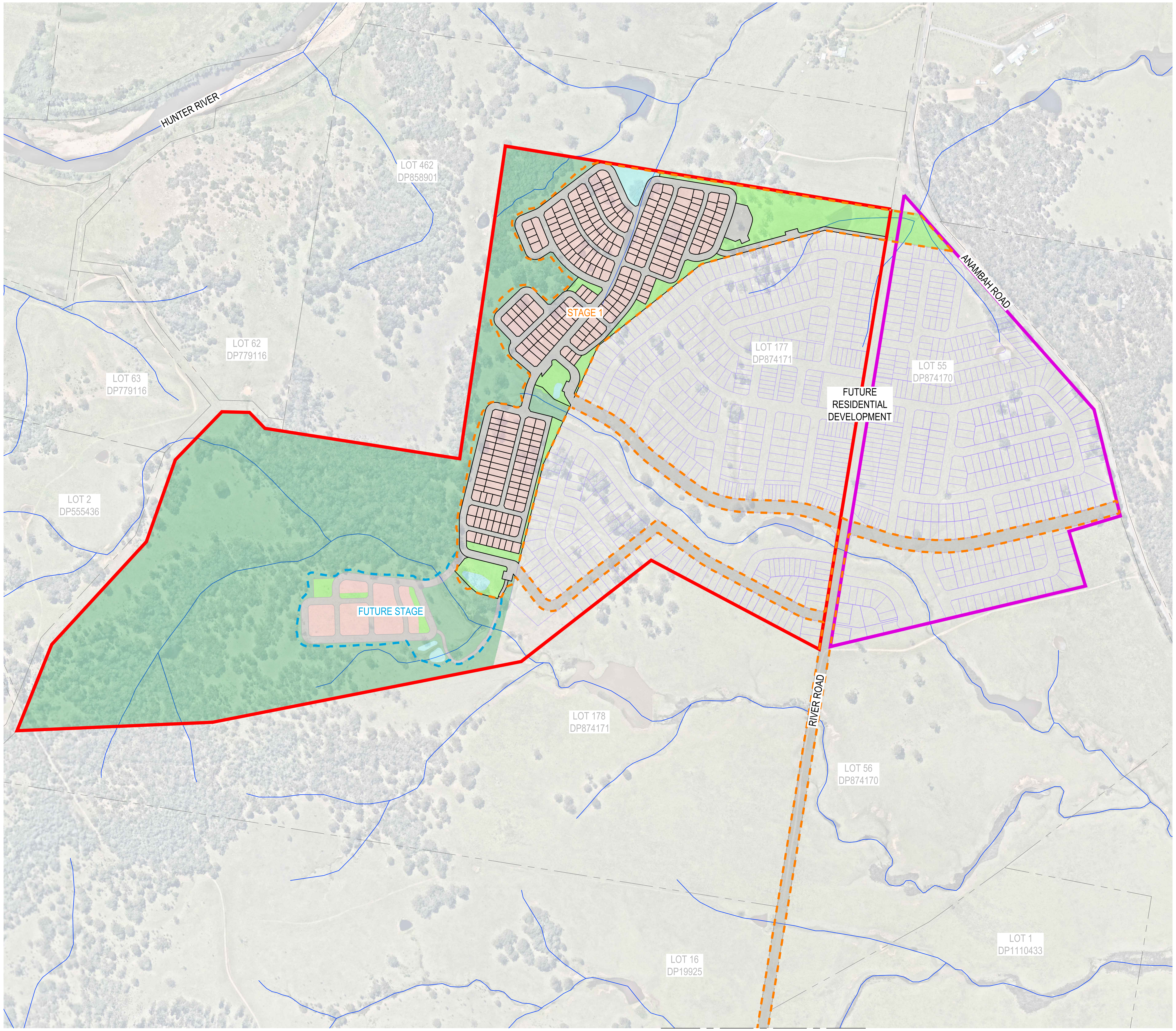
Table 17 - Geotechnical Design Parameters-Rock					
Geotechnical Unit (strength)	**Bulk Unit Weight (kN/m3)**	**Allowable Bearing Pressure (MPa)***	**Ultimate shaft adhesion (kPa)****	**Poisson's Ratio (-)**	**Elastic Modulus E' (MPa)**
MUDSTONE very low strength (Class V)	20	0.7	50	0.3	50
MUDSTONE low strength (Class IV)	21	1	150	0.2	100
MUDSTONE medium strength (Class III)	22	2	350	0.2	200
SANDSTONE very low strength (Class V)	20	0.8	150	0.35	50
SANDSTONE low strength (Class IV)	21	2	250	0.3	100
*) Bearing pressure to limit the settlement to <1% of minimum footing size **) clean socket of roughness category R2 or better					

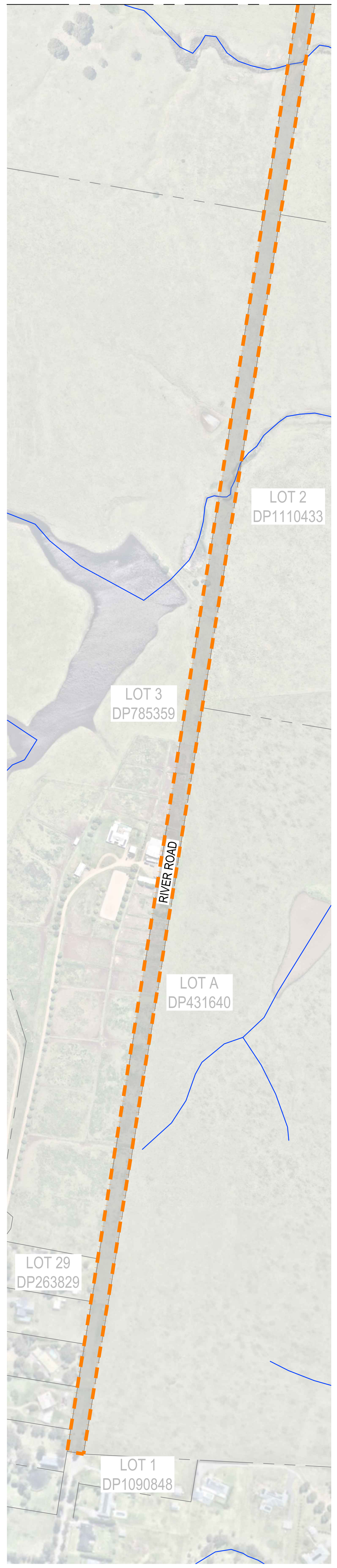
8 References

- Austroads AGPT05-19, "Guide to Pavement Technology Part 5: Pavement Evaluation and Treatment Design," Austroads Ltd, October 2019
- Austroads AGPT02-17, "Guide to Pavement Technology Part 2: Pavement Structural Design," Austroads Ltd, 2017.
- Australian Standard AS2870-2011 "Residential slabs and footing"
- Australian Standard AS3798-2007 "Guideline on earthworks for commercial and residential developments".
- Australian Standard AS2159-2009, "Piling - Design & Installation," Standards Australia, 2009
- eSPADE, Online website of NSW Office of Environment and heritage (eSPADE v2.2 (nsw.gov.au))
- Maitland City Council – Manual of Engineering Standards April 2023.
- Minview, (MinView | Regional NSW | Mining, Exploration and Geoscience)
- NSW Planning Portal, (NSW Planning Portal Spatial Viewer)
- Pells, P.J.N., Mostyn, G., Bertuzzi, R. and Wong, P.K., Classification of Sandstone and Shale in the Sydney Region: A Forty Year Review – Australian Geomechanics Volume 54, No.2 June 2019.
- TfNSW QA Specification 3051 (Ed 7 Rev 0), "Granular Base and Subbase Materials for Surfaced Road Pavements," Roads and Maritime Services, April 2011
- TfNSW QA Specification 3051 (Ed 7 Rev 0), "Granular Base and Subbase Materials for Surfaced Road Pavements," Roads and Maritime Services, August 2018.

Appendix A

ANAMBAH RESIDENTIAL COMMUNITY





INSET A
SCALE 1:4000

LEGEND

LOT 117 DP 874171
LOT 55 DP 874170

PROPOSED
- LOT BOUNDARY
- MANUFACTURED HOME ESTATE
- ROAD RESERVE
- DRAINAGE RESERVE
- OPEN SPACE / COMMUNITY FACILITIES
- RETAINED BUSHLAND

STAGING
- STAGE 1 - SUBJECT DETAILED DA
- FUTURE STAGE - CONCEPT DA

EXISTING
- LOT BOUNDARY
- WATER COURSE

FUTURE DEVELOPMENT
- LOT BOUNDARY

REV	DATE	DESCRIPTION	AMD BY	APP BY
1	06.12.24	ISSUE FOR APPROVAL	MAJP	TJH

0 40 80 120 160 200m
SCALE 1:4000 AT ORIGINAL SIZE

Third.i COMMUNITIES

MAKER ENG SURVEY DESIGN DELIVER

DRAWN: M.PHILLIPS
DESIGNED: M.PHILLIPS
DRAFT CHECK: -
DESIGN CHECK: -
APPROVED: T.HOWE

559 ANAMBAH ROAD GOSFORTH
CONCEPT & STAGE 1 DEVELOPMENT APPLICATION
SKETCHES
NOTIFICATION PLAN

NOT FOR CONSTRUCTION

DRAWING NUMBER	SHEET No.	ORIG. SIZE	REVISION
MKR00884-00-SK020		A1	1

Matthew Phillips, 6/12/2024 4:14 PM

C:\12d\data\12DSYNERGY\MKR00884 Thirdi_Anambah_280\02 Design\Drawings\00 SK\MKR00884-00-SK020.dwg

Appendix B
PHOTOLOG

	**Plate 1** **Description: Looking north from BH01 location** **Date: 12/09/2024**
	**Plate 2** **Description: Looking southeast from the BH01 Location** **Date:12/09/2024**

	**Plate 3** **Description: Water dam east of site boundary** **Date: 12/09/2024**
	**Plate 4** **Description: Rock outcrops in the elevated areas of the site** **Date: 12/09/2024**

	**Plate 5** **Description: Ephemeral creek running across the site** **Date: 12/09/2024**
	**Plate 6** **Description: Soil scarps along the ephemeral creek** **Date: 12/09/2024**

Appendix C

GEOTECHNICAL INVESTIGATION LOCATIONS

EP RISK

www.eprisk.com.au

Geotechnical Site Investigation

559 Anambah Road, Gosforth NSW, Australia

Job No: EP3864
Date: 23-09-2024
Version: v1

N

0 50 m 100 m

Approximate Scale Only

Appendix C - Geotechnical Investigation Locations

Coordinate System: WGS 84

Drawn By: HE Checked By: NM

Scale of regional map not shown

Source: © Department of Finance, Services & Innovation 2018

ISO 9001 ISO 45001 ISO 14001

Appendix D

TEST PIT LOGS

EP RISK

Soil Logging Symbols

CLAYS

- CLAY
- silty CLAY
- sandy CLAY
- gravelly CLAY

SILTS

- SILT
- clayey SILT
- sandy SILT
- gravelly SILT

SANDS

- SAND
- clayey SAND
- silty SAND
- gravelly SAND

GRAVELS

- GRAVEL
- clayey GRAVEL
- silty GRAVEL
- sandy GRAVEL

SEDIMENTARY ROCK

- SANDSTONE
- SILTSTONE
- SHALE
- CONGLOMERATE

FILL

- FILL
- CONCRETE
- ASPHALT

GROUNDWATER WELL SYMBOLS

- WELL SCREEN
- CASING – filter pack
- CASING – backfill
- CASING – bentonite seal
- 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-P

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384257.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357136.00	Bearing	---	Ground Level	55 AHD

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	55	0.0		CL-CI	TOPSOIL: Silty CLAY: low to medium plasticity, dark brown	<PL	St	3, 4		TOPSOIL
E			0.2		CI-CH	Silty CLAY: medium to high plasticity, brown	~PL	St	3, 3, 15		RESIDUAL SOIL
E											DCP:-Refusal
E / R		54	0.6–1.9		SC	Extremely weathered Mudstone recovered as Sandy CLAY, low to medium plasticity, red, fine to coarse grained sand	<<PL	VSt to H		B	EXTREMELY WEATHERED ROCK
		53	1.90			Test Pit TP01-P Terminated at 1.90 m					Refusal on bedrock

Remarks:

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP01-P

Engineering Log - Test Pit

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384217.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357269.00	Bearing	---	Ground Level	45 AHD

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	45	0		CL	TOPSOIL: Silty CLAY: low plasticity, dark brown	<PL	F	2, 2		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, brown	~PL	F	2, 2, 1, 2	B	RESIDUAL SOIL
		44	1		CL-CI	Extremely weathered Mudstone recovered as Sandy CLAY, low to medium plasticity, red, grey, orange, medium to coarse grained sand	<<PL	F; VSt; VSt to H	2, 5, 8, 8, 8, 14, 9, 10, 10, 11		EXTREMELY WEATHERED ROCK
		43	2								
		42	3			Test Pit TP02-L Terminated at 2.70 m					Target depth

Remarks:

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP02-L

Engineering Log - Test Pit

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384384.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357473.00	Bearing	---	Ground Level	48 AHD

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	48	0		CL-CI	TOPSOIL: Sandy CLAY: low to medium plasticity, grey, fine to medium grained sand	<PL	F	1, 1		TOPSOIL
					SC	Clayey SAND: fine to medium grained, grey	D to M	VL to L	0, 1		SLOPE WASH
					CI-CH	Sandy CLAY: medium to high plasticity, grey, brown, fine to coarse grained sand	~PL	F to St	1, 2, 2, 3, 3	B	RESIDUAL SOIL
		47	1			Extremely weathered Mudstone recovered as Sandy CLAY, medium to high plasticity, grey, brown, red, with fine to corase grained sand	<PL	H	12, 13, 15		EXTREMELY WEATHERED ROCK
		46	2			Test Pit TP03-P Terminated at 2.00 m					Refusal on bedrock
		45	3								

Remarks:

EP RISK	EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
	TP03-P	

Test Pit No: TP04-L

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384459.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357429.00	Bearing	---	Ground Level	53 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	L	1, 1		TOPSOIL
					CL-CI	Silty CLAY: low to medium plasticity, pale grey	<PL	VS to S	1, 0, 3		SLOPE WASH
					CI-CH	Silty CLAY: medium to high plasticity, grey, orange	~PL	St	4	B	RESIDUAL SOIL
		52	1		SC	Extremely weathered Sandstone and Mudstone recovered as Clayey SAND, fine to coarse grained, grey, orange	D	D to VD	8, 9, 15, 19		EXTREMELY WEATHERED ROCK
R		51	2							B	
		50	3			Test Pit TP04-L Terminated at 2.70 m					Target depth

Remarks:

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP04-L

Test Pit No: TP05-P

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384621.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357471.00	Bearing	---	Ground Level	58 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	L and MD	2, 2		TOPSOIL
					SW	SAND: fine to medium grained, pale grey			3, 1		SLOPE WASH
					CI-CH	Silty CLAY: medium to high plasticity, brown	~PL	VS to F; St to VSt	0, 1, 2, 3, 6		RESIDUAL SOIL
		57	1		CI-CH	Extremely weathered Sandstone recovered as sandy CLAY, medium to high plasticity, brown-orange, fine to coarse grained sand	<PL	St to VSt; VSt to H	9, 9, 10, 10, 15	B	EXTREMELY WEATHERED ROCK
		56	2								
		55	3			Test Pit TP05-P Terminated at 2.70 m					Target depth

Remarks:

EP LIB 05.GLB Log CW NON-CORED BOREHOLE LOG EP3867 THIRDI ANAMBAH ANAMBAH RD GEOTECH.GPJ <<DrawingFile>> 28/10/2024 12:53 10.03.00.09 Developed by Datgel

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
TP05-P	

Engineering Log - Test Pit

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384711.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357593.00	Bearing	---	Ground Level	48 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	D	4, 5		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, grey	~PL	F to St	4, 2, 2		SLOPE WASH
					CI-CH	Silty CLAY: medium to high plasticity, grey, orange	<PL	H	4, 11, 14		RESIDUAL SOIL
		47	1		CL-CI	Sandy CLAY: low to medium plasticity, orange, medium to coarse grained sand	<PL		14, 12, 18	B	
R		46	2		SC	Extremely weathered Sandstone recovered as Sandy CLAY, low to medium plasticity, grey and orange, medium to coarse grained sand	<<PL				EXTREMELY WEATHERED ROCK
		45	3			Test Pit TP06-P Terminated at 2.70 m					Target depth

Remarks:

EP RISK	EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
	TP06-P	

Test Pit No: TP07-L

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384765.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357531.00	Bearing	---	Ground Level	58 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	MD and D	2, 3		TOPSOIL
					SP	SAND: fine to medium grained, pale grey			6, 3	U50	SLOPE WASH
					CI-CH	Silty CLAY: medium to high plasticity, grey, orange	<PL	F	2, 2, 2		RESIDUAL SOIL
		57	1		SC	Extremely weathered Sandstone recovered as Clayey SAND, fine to medium grained, orange	D	VD	11	B	EXTREMELY WEATHERED ROCK DCP:-8/50mm HB
		56	2		SP	Extremely weathered Sandstone recovered as Clayey SAND, medium to coarse grained, orange, with (400 to 500mm) boulders of Sandstone.					
						Test Pit TP07-L Terminated at 2.70 m					Target depth
		55	3								

Remarks:

EP LIB 05.GLB Log CW NON-CORED BOREHOLE LOG EP3867 THIRDI ANAMBAH ANAMBAH RD GEOTECH.GPJ <<DrawingFile>> 28/10/2024 12:53 10.03.00.09 Developed by Datgel

EP RISK	EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
	TP07-L	

Test Pit No: TP08-P

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384805.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357454.00	Bearing	---	Ground Level	66 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	L and MD	3, 2		TOPSOIL
					SW	SAND: fine to medium grained, pale grey			0		SLOPE WASH
					CI-CH	Silty CLAY: medium to high plasticity, grey, brown	~PL	F to St	1, 1, 1, 3	B	RESIDUAL SOIL DCP:-12/HB
		65	1		CI-CH	Extremely weathered Sandstone recovered as Sandy CLAY, medium to high plasticity, pale grey, brown, fine to coarse grained sand	<<PL	H			EXTREMELY WEATHERED ROCK
		64	2								
						Test Pit TP08-P Terminated at 2.70 m					Target depth
		63	3								

Remarks:

EP RISK	EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
	TP08-P	

Engineering Log - Test Pit

Test Pit No: TP09-P

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384870.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357703.00	Bearing	---	Ground Level	49 AHD

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				SC	TOPSOIL: Clayey SAND: fine grained, grey	D	D	6, 7		TOPSOIL
		48	1		GP	Extremely weathered Mudstone recovered as Clayey Sandy GRAVEL, fine to coarse grained, sub-angular, pale grey and Sandy CLAY, medium to high plasticity, brown, grey, with fine grained sand	D <<PL	D and VD VSt to H	10, 15, 9, 9	B	EXTREMELY WEATHERED ROCK DCP:-15/HB
		47	2								
		46	3			Test Pit TP09-P Terminated at 2.70 m					Target depth

Remarks:

EP LIB 05.GLB Log CW NON-CORED BOREHOLE LOG EP3867 THIRDI ANAMBAH ANAMBAH RD GEOTECH.GPJ <<DrawingFile>> 28/10/2024 12:53 10.03.00.09 Developed by Datgel

EP RISK	EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW Geotechnical Investigation	
	TP09-P	

Test Pit No: TP10-L

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384982.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357548.00	Bearing	---	Ground Level	54 AHD

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	TOPSOIL: Sandy CLAY: low plasticity, grey, brown, fine grained sand	~PL	F	1, 1		TOPSOIL
					SC	Clayey SAND: fine grained, pale brown	D	L	1, 1	U50	SLOPE WASH
		53	1		CL	Silty CLAY: low plasticity	~PL	F to St	2, 1, 2, 3, 4, 5, 8, 11, 15	B	RESIDUAL SOIL
		52	2		CI-CH	Extremely weathered Sandstone recovered as Sandy CLAY, low to medium plasticity, brown, orange, fine to coarse grained sand	<<PL	VSt to H	18		EXTREMELY WEATHERED ROCK
		51	3			Test Pit TP10-L Terminated at 2.30 m					Refusal on bedrock

Remarks:

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP10-L

Engineering Log - Test Pit

Test Pit No: TP11-P

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6385028.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357669.00	Bearing	---	Ground Level	44 AHD

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	TOPSOIL: Sandy CLAY: low to medium plasticity, brown, fine grained sand	~PL	St and VSt	7 3		TOPSOIL
					CI-CH	Silty CLAY: medium to high plasticity, pale brown	<PL	F St to VSt	1 1 1 3 3 6	B	RESIDUAL SOIL
		43	1		CL-CI	Extremely weathered Sandstone/Mudstone recovered as Silty CLAY, medium to high plasticity, grey, brown, with fine to coarse grained sand	<<PL	H	14 11 14		EXTREMELY WEATHERED ROCK
		42	2								
						Test Pit TP11-P Terminated at 2.50 m					Refusal on bedrock
		41	3								

Remarks:

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP11-P

Test Pit No: TP12-L

Engineering Log - Test Pit

SHEET 1 OF 1

Client	Thirdi Group Pty Ltd	Project No.	EP3867
Project	Thirdi Anambah Anambah Rd Geotech	Logged By	JA
Location	Anambah Rd, Anambah 2320	Checked By	OP

Started Excavation	12.9.24	Northing	6384986.00	Slope	90°	Equipment	15t Excavator
Completed Excavation	12.9.24	Easting	357808.00	Bearing	---	Ground Level	49 AHD

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				SP	TOPSOIL: SAND: fine to medium grained, brown	D	D to VD	10		TOPSOIL
					SP	Extremely weathered Sandstone, recovered as Clayey SAND. fine to coarse grained, brown, with boulders up to 800mm			4, 10, 7, 8, 6, 6		EXTREMELY WEATHERED ROCK DCP:-18/HB
		48	1								
						Test Pit TP12-L Terminated at 1.50 m					Refusal on bedrock
		47	2								
		46	3								

Remarks:

EP LIB 05.GLB Log CW NON-CORED BOREHOLE LOG EP3867 THIRDI ANAMBAH ANAMBAH RD GEOTECH.GPJ <<DrawingFile>> 28/10/2024 12:53 10.03.00.09 Developed by Datgel

EP RISK

EP3867 - Thirdi Anambah- Anambah Road, Gosforth NSW
Geotechnical Investigation

TP12-L

Appendix E

LABORATORY TEST RESULTS

Material Test Report

Report Number:	**NEWC24161-1**
Issue Number:	3 - *This version supersedes all previous issues*
Reissue Reason:	
Date Issued:	29/10/2024
Client:	EP Risk Management PO Box 57, Lochinvar NSW 2321
Project Number:	NEWC24161
Project Name:	EP3867 Thirdi Gosforth Anambah Road
Project Location:	Gosforth, NSW
Client Reference:	EP3867
Work Request:	2435
Sample Number:	NEWC2435A
Date Sampled:	12/09/2024
Dates Tested:	16/09/2024 - 24/09/2024
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:	**TP01 - P (0.50 - 1.00m)**

coffey TESTING

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16 Callistemon Close Warabrook NSW 2304
Phone: 0424 521 225
Email: Kerrina.Christiansen@coffeytesting.com

ilac-MRA NATA

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	5 mm		
CBR %	**10**		
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)	1.66		
Optimum Moisture Content (%)	21.0		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	100.5		
Dry Density after Soaking (t/m^3)	1.67		
Field Moisture Content (%)	16.6		
Moisture Content at Placement (%)	21.1		
Moisture Content Top 30mm (%)	22.5		
Moisture Content Rest of Sample (%)	23.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours (h)	75.6		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0.0		

Dry Density - Moisture Relationship (AS 1289 5.1.1 & 2.1.1)		Min	Max
Mould Type	1 LITRE MOULD A		
Compaction	Standard		
Maximum Dry Density (t/m^3)	1.66		
Optimum Moisture Content (%)	21.0		
Oversize Sieve (mm)	19.0		
Oversize Material Wet (%)	0		
Method used to Determine Plasticity	Visual/Tactile		
Curing Hours (h)			

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	16.6

Material Test Report

Report Number:	**NEWC24161-1**
Issue Number:	3 - *This version supersedes all previous issues*
Reissue Reason:	
Date Issued:	29/10/2024
Client:	EP Risk Management PO Box 57, Lochinvar NSW 2321
Project Number:	NEWC24161
Project Name:	EP3867 Thirdi Gosforth Anambah Road
Project Location:	Gosforth, NSW
Client Reference:	EP3867
Work Request:	2435
Sample Number:	NEWC2435B
Date Sampled:	12/09/2024
Dates Tested:	16/09/2024 - 19/09/2024
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:	**TP02 - L (0.20 - 0.50m)**

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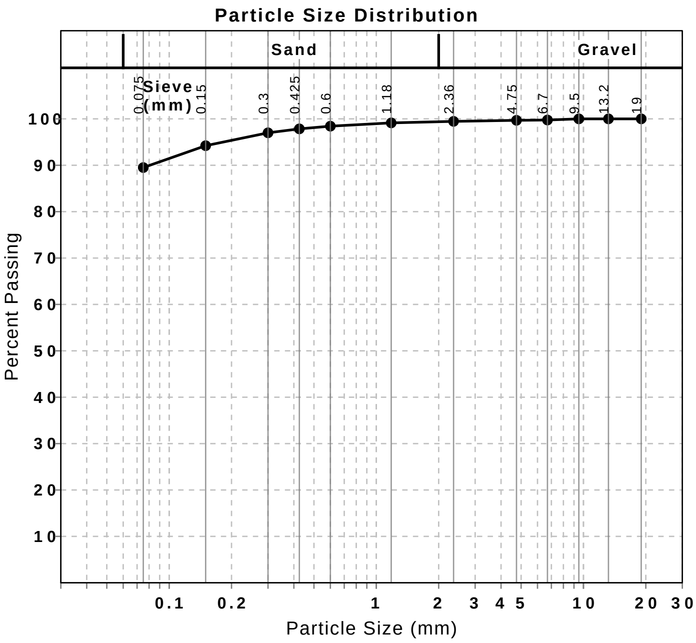
Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	85		
Plastic Limit (%)	22		
Plasticity Index (%)	**63**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1 / AS 1289.3.1.2 / AS 1289.3.9.1 / AS 1289.3.9.2		
Linear Shrinkage (%)	**17.5**		
Cracking Crumbling Curling	Curling		

Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
19 mm	**100**			0		
13.2 mm	**100**			0		
9.5 mm	**100**			0		
6.7 mm	**100**			0		
4.75 mm	**100**			0		
2.36 mm	**99**			0		
1.18 mm	**99**			0		
0.6 mm	**98**			1		
0.425 mm	**98**			1		
0.3 mm	**97**			1		
0.15 mm	**94**			3		
0.075 mm	**90**			5		



Material Test Report

Report Number:	**NEWC24161-1**
Issue Number:	3 - *This version supersedes all previous issues*
Reissue Reason:	
Date Issued:	29/10/2024
Client:	EP Risk Management PO Box 57, Lochinvar NSW 2321
Project Number:	NEWC24161
Project Name:	EP3867 Thirdi Gosforth Anambah Road
Project Location:	Gosforth, NSW
Client Reference:	EP3867
Work Request:	2435
Sample Number:	NEWC2435F
Date Sampled:	12/09/2024
Dates Tested:	16/09/2024 - 24/09/2024
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 - P (0.90 - 1.50m)**

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California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**14**		
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)	1.74		
Optimum Moisture Content (%)	16.5		
Laboratory Density Ratio (%)	101.0		
Laboratory Moisture Ratio (%)	101.0		
Dry Density after Soaking (t/m^3)	1.76		
Field Moisture Content (%)	10.3		
Moisture Content at Placement (%)	16.5		
Moisture Content Top 30mm (%)	16.2		
Moisture Content Rest of Sample (%)	16.7		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours (h)	52.8		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	1.2		

Dry Density - Moisture Relationship (AS 1289 5.1.1 & 2.1.1)		Min	Max
Mould Type	1 LITRE MOULD A		
Compaction	Standard		
Maximum Dry Density (t/m^3)	1.74		
Optimum Moisture Content (%)	16.5		
Oversize Sieve (mm)	19.0		
Oversize Material Wet (%)	1		
Method used to Determine Plasticity	Visual/Tactile		
Curing Hours (h)			

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	10.3

Material Test Report

Report Number:	**NEWC24161-1**
Issue Number:	3 - *This version supersedes all previous issues*
Reissue Reason:	
Date Issued:	29/10/2024
Client:	EP Risk Management PO Box 57, Lochinvar NSW 2321
Project Number:	NEWC24161
Project Name:	EP3867 Thirdi Gosforth Anambah Road
Project Location:	Gosforth, NSW
Client Reference:	EP3867
Work Request:	2435
Sample Number:	NEWC2435L
Date Sampled:	12/09/2024
Dates Tested:	16/09/2024 - 23/09/2024
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:	**TP10 - P (0.80 - 1.50m)**

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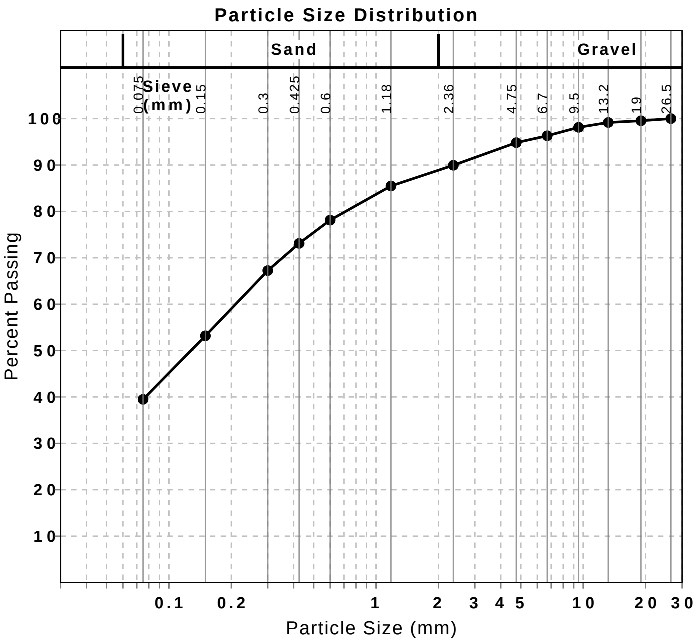
Approved Signatory: Raphael Kirby-Faust
Geotechnician
Laboratory Accreditation Number: 431

Atterberg Limit (AS1289 3.1.1 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Air Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	29		
Plastic Limit (%)	12		
Plasticity Index (%)	**17**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.1 / AS 1289.3.1.2 / AS 1289.3.9.1 / AS 1289.3.9.2		
Linear Shrinkage (%)	**6.5**		
Cracking Crumbling Curling	Curling		

Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
26.5 mm	**100**			0		
19 mm	**100**			0		
13.2 mm	**99**			0		
9.5 mm	**98**			1		
6.7 mm	**96**			2		
4.75 mm	**95**			1		
2.36 mm	**90**			5		
1.18 mm	**85**			4		
0.6 mm	**78**			7		
0.425 mm	**73**			5		
0.3 mm	**67**			6		
0.15 mm	**53**			14		
0.075 mm	**39**			14		



Material Test Report

Report Number: **NEWC24161-1**
Issue Number: 3 - *This version supersedes all previous issues*
Reissue Reason:
Date Issued: 29/10/2024
Client: EP Risk Management
PO Box 57, Lochinvar NSW 2321
Project: NEWC24161 - EP3867 Thirdi Gosforth Anambah Road
Project Location: Gosforth, NSW
Client Reference: EP3867
Work Request: 2435
Dates Tested: 16/09/2024 - 19/09/2024
Location: EP3867 Thirdi Gosforth , Anambah Road

coffey TESTING
Newcastle Laboratory
16 Callistemon Close Warabrook NSW 2304
Phone: 0424 521 225
Email: Kerrina.Christiansen@coffeytesting.com

Accredited for compliance with ISO/IEC 17025 - Testing

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

Determination of Point Load (AS 4133.4.1)

Sample #	Specimen	Depth	Location	Test Type	I_s (Mpa)	$I_{s(50)}$ (Mpa)	$I_{s(50)}$ Min	$I_{s(50)}$ Max	Rock Type	Moisture Condition
NEWC2435E	1	**	TP04 - L (2.20 - 2.70m)	Irregular	0.34	0.46	**	**	**	Natural
NEWC2435E	2	**	TP04 - L (2.20 - 2.70m)	Irregular	0.18	0.22	**	**	**	Natural
NEWC2435E	3	**	TP04 - L (2.20 - 2.70m)	Irregular	0.12	0.15	**	**	**	Natural
NEWC2435E	4	**	TP04 - L (2.20 - 2.70m)	Irregular	0.12	0.15	**	**	**	Natural
NEWC2435E	5	**	TP04 - L (2.20 - 2.70m)	Irregular	0.19	0.24	**	**	**	Natural

Material Test Report

Report Number: **NEWC24161-1**
Issue Number: 3 - *This version supersedes all previous issues*
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PO Box 57, Lochinvar NSW 2321
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Project Name: EP3867 Thirdi Gosforth Anambah Road
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Client Reference: EP3867
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Dates Tested: 16/09/2024 - 16/09/2024
Location: EP3867 Thirdi Gosforth , Anambah Road

coffey TESTING

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Geotechnician
Laboratory Accreditation Number: 431

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	NEWC2435I	NEWC2435M			
Date Sampled	12/09/2024	12/09/2024			
Date Tested	16/09/2024	16/09/2024			
Material Source	**	**			
Sample Location	TP07 - L - U50 (0.25 - 0.75m)	TP10 - L - U50 (0.25 - 0.50m)			
Inert Material Estimate (%)	0	0			
Pocket Penetrometer before (kPa)	150	150			
Pocket Penetrometer after (kPa)	80	120			
Shrinkage Moisture Content (%)	26.7	21.3			
Shrinkage (%)	**7.2**	**2.7**			
Swell Moisture Content Before (%)	19.6	20.1			
Swell Moisture Content After (%)	23.5	24.7			
Swell (%)	**1.0**	**0.0**			
Shrink Swell Index Iss (%)	**4.3**	**1.5**			
Visual Description	**	Sandy CLAY with some silt (brown)			
Cracking	SC	MC			
Crumbling	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

Environment Testing

NATA Accredited
Accreditation Number 1261
Site Number 18217

Accredited for compliance with ISO/IEC 17025 – Testing
NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Coffey Testing P/L Newcastle
16 Callistemon Close
Warabrook
NSW 2304

Attention: **Jackson Antilla**

Report **1141806-S**
Project name EP3867 THIRDI GOSFORTH
Project ID NEWC24161
Received Date Sep 23, 2024

Client Sample ID			**NEWC2435B**	**NEWC2435D**	**NEWC2435H**
Sample Matrix			**Soil**	**Soil**	**Soil**
Eurofins Sample No.			**N24-Se0056732**	**N24-Se0056733**	**N24-Se0056734**
Date Sampled			**Sep 12, 2024**	**Sep 12, 2024**	**Sep 12, 2024**
Test/Reference	LOR	Unit			
Chloride	10	mg/kg	< 10	52	240
Conductivity (1:5 aqueous extract at 25 °C as rec.)	10	uS/cm	17	41	250
pH (1:5 Aqueous extract at 25 °C as rec.)	0.1	pH Units	8.1	6.0	7.1
Resistivity*	0.5	ohm.m	580	240	41
Sulphate (as SO4)	10	mg/kg	< 10	260	69
Sample Properties					
% Moisture	1	%	22	16	8.9

Environment Testing

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Chloride	Sydney	Sep 25, 2024	28 Days
- Method: LTM-INO-4270 Anions by Ion Chromatography			
Conductivity (1:5 aqueous extract at 25 °C as rec.)	Sydney	Sep 25, 2024	7 Days
- Method: LTM-INO-4030 Conductivity			
pH (1:5 Aqueous extract at 25 °C as rec.)	Sydney	Sep 25, 2024	7 Days
- Method: LTM-GEN-7090 pH by ISE			
Sulphate (as SO4)	Sydney	Sep 25, 2024	28 Days
- Method: In-house method LTM-INO-4270 Sulphate by Ion Chromatograph			
% Moisture	Sydney	Sep 23, 2024	14 Days
- Method: LTM-GEN-7080 Moisture			

Company Name: Coffey Testing P/L N'castle
Address: 16 Callistemon Close
Warabrook
NSW 2304

Project Name: EP3867 THIRDI GOSFORTH
Project ID: NEWC24161

Order No.:
Report #: 1141806
Phone: 02 4016 2300
Fax:

Received: Sep 23, 2024 11:30 AM
Due: Sep 30, 2024
Priority: 5 Day
Contact Name: Jackson Antilla

Eurofins Analytical Services Manager : Andrew Black

Sample Detail						Aggressivity Soil Set	Moisture Set
Sydney Laboratory - NATA # 1261 Site # 18217						X	X
External Laboratory							
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**		
1	NEWC2435B	Sep 12, 2024		Soil	N24-Se0056732	X	X
2	NEWC2435D	Sep 12, 2024		Soil	N24-Se0056733	X	X
3	NEWC2435H	Sep 12, 2024		Soil	N24-Se0056734	X	X
Test Counts						3	3

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follow guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013. They are included in this QC report where applicable. Additional QC data may be available on request.
2. Unless otherwise stated, all soil/sediment/solid results are reported on a dry weight basis.
3. Unless otherwise stated, all biota/food results are reported on a wet weight basis on the edible portion.
4. For CEC results where the sample's origin is unknown or environmentally contaminated, the results should be used advisedly.
5. Actual LORs are matrix dependent. Quoted LORs may be raised where sample extracts are diluted due to interferences.
6. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds where annotated.
7. SVOC analysis on waters is performed on homogenised, unfiltered samples unless noted otherwise.
8. Samples were analysed on an 'as received' basis.
9. Information identified in this report with **blue** colour indicates data provided by customers that may have an impact on the results.
10. This report replaces any interim results previously issued.

Holding Times

Please refer to the 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours before sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and despite any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the sampling date; therefore, compliance with these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether, the holding time is seven days; however, for all other VOCs, such as BTEX or C6-10 TRH, the holding time is 14 days.

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre	**ppm:** parts per million
µg/L: micrograms per litre	**ppb:** parts per billion	**%:** Percentage
org/100 mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units	**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres
CFU: Colony Forming Unit	**Colour:** Pt-Co Units (CU)	

Terms

APHA	American Public Health Association
CEC	Cation Exchange Capacity
COC	Chain of Custody
CP	Client Parent - QC was performed on samples pertaining to this report
CRM	Certified Reference Material (ISO17034) - reported as percent recovery.
Dry	Where moisture has been determined on a solid sample, the result is expressed on a dry weight basis.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
LOR	Limit of Reporting.
LCS	Laboratory Control Sample - reported as percent recovery.
Method Blank	In the case of solid samples, these are performed on laboratory-certified clean sands and in the case of water samples, these are performed on de-ionised water.
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC represents the sequence or batch that client samples were analysed within.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
SRA	Sample Receipt Advice
Surr - Surrogate	The addition of a similar compound to the analyte target is reported as percentage recovery. See below for acceptance criteria.
TBTO	Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment; however, free tributyltin was measured, and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits.
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalency Quotient or Total Equivalence
QSM	US Department of Defense Quality Systems Manual Version 6.0
US EPA	United States Environmental Protection Agency
WA DWER	Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC - Acceptance Criteria

The acceptance criteria should only be used as a guide and may be different when site-specific Sampling Analysis and Quality Plan (SAQP) have been implemented.

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is ≤30%; however, the following acceptance guidelines are equally applicable:

Results <10 times the LOR:	No Limit
Results between 10-20 times the LOR:	RPD must lie between 0-50%
Results >20 times the LOR:	RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range, not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS. SVOCs recoveries 20 – 150%, VOC recoveries 50 – 150%

PFAS field samples containing surrogate recoveries above the QC limit designated in QSM 6.0, where no positive PFAS results have been reported or reviewed, and no data was affected.

QC Data General Comments

1. Where a result is reported as less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown are not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time.Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery, the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results, a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data; thus, it is possible to have two sets of data.

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Environment Testing

Quality Control Results

Test			Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank									
Chloride			mg/kg	< 10			10	Pass	
Sulphate (as SO4)			mg/kg	< 10			10	Pass	
Method Blank									
Conductivity (1:5 aqueous extract at 25 °C as rec.)			uS/cm	< 10			10	Pass	
LCS - % Recovery									
Chloride			%	112			70-130	Pass	
Conductivity (1:5 aqueous extract at 25 °C as rec.)			%	95			70-130	Pass	
Resistivity*			%	95			70-130	Pass	
Sulphate (as SO4)			%	100			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Spike - % Recovery									
				Result 1					
Chloride	N24-Se0056732	CP	%	94			70-130	Pass	
Sulphate (as SO4)	N24-Se0056732	CP	%	91			70-130	Pass	
Test	**Lab Sample ID**	**QA Source**	**Units**	**Result 1**			**Acceptance Limits**	**Pass Limits**	**Qualifying Code**
Duplicate									
				Result 1	Result 2	RPD			
Chloride	S24-Se0059121	NCP	mg/kg	420	420	1.0	30%	Pass	
Conductivity (1:5 aqueous extract at 25 °C as rec.)	N24-Se0056732	CP	uS/cm	17	15	15	30%	Pass	
pH (1:5 Aqueous extract at 25 °C as rec.)	N24-Se0056732	CP	pH Units	8.1	8.1	<1	30%	Pass	
Resistivity*	N24-Se0056732	CP	ohm.m	580	670	15	30%	Pass	
Sulphate (as SO4)	S24-Se0059121	NCP	mg/kg	88	88	1.0	30%	Pass	
Duplicate									
Sample Properties				Result 1	Result 2	RPD			
% Moisture	S24-Se0052872	NCP	%	16	13	20	30%	Pass	

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Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	No
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Authorised by:

Andrew Black	Analytical Services Manager
Dilani Samarakoon	Senior Analyst-Inorganic
Roopesh Rangarajan	Senior Analyst-Sample Properties
Ryan Phillips	Senior Analyst-Inorganic

Glenn Jackson
Managing Director

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

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Appendix F

FOUNDATION MAINTAINENCE AND FOOTING PERFORMANCE

Foundation Maintenance and Footing Performance: A Homeowner's Guide

BTF 18 replaces Information Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

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

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

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

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

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

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

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

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

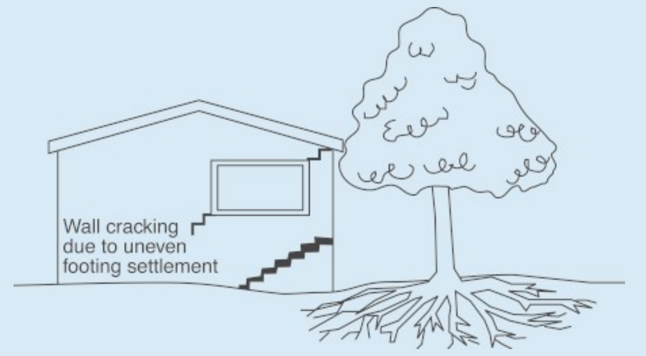
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

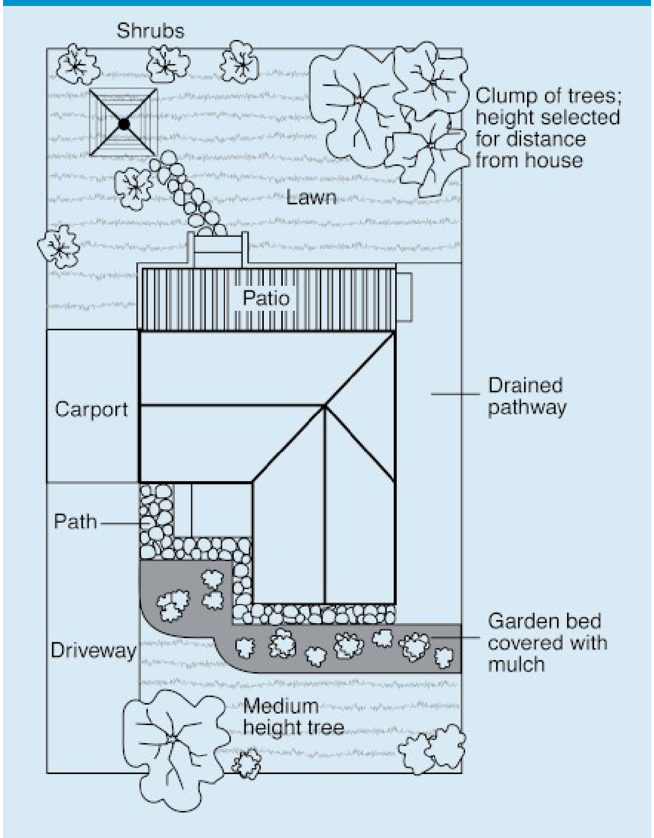
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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