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Report on
Geotechnical Investigation

Pondicherry Residential Rezoning
Pondicherry, Oran Park, NSW

Prepared for
Department of Planning and Environment
And Camden Council

Project 76778.28
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The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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Executive Summary

Douglas Partners Pty Ltd carried out a Geotechnical Investigation for the proposed rezoning of the Pondicherry site at Oran Park. The area is to be developed by Greenfields Development Company 2 Pty Ltd. The objective of the investigation is to evaluate the suitability of the site for rezoning with regard to the geotechnical constraints on the site.

The site is located within the local government area of Camden Council and comprises an irregular shaped area of approximately 238 ha and is bound by vacant rural land to the north, South Creek and rural land to the east, Oran Park Precinct to the south and The Northern Road to the west and beyond by further rural residential and agricultural land. The site currently forms part of an active grazing and crop farming property which includes two large farm dams in the eastern / south eastern portion of the site and several smaller dams throughout the site. The southernmost large dam provides a stormwater detention function for part of the existing Oran Park Precinct located to the south of the site. A major transmission line and associated easement runs east-west through the southern portion of the land. While most of the site has been cleared for use as grazing land, there are discontinuous zones of open to densely wooded areas along the creek lines and gullies in the south-western corner of the site.

The western and central portions of the site form the dendritic drainage systems (by way of ridgeline spurs) of the South Creek associated tributaries in the southern portion of the site (with gullies generally flowing east to south-east) and Lowes Creek in the northern portion of the site (with gullies generally flowing northerly) which has entrenched the bedrock forming side slopes mostly to approximately 3 – 5°, but locally steeper towards the crests of ridgelines to approximately 5 – 10°. The gullies have been dammed in most locations for watering of stock. The highest elevation within this portion is RL 116 (in the south-west corner of the site). These areas have been cleared for grazing with scattered open wooded areas.

The remainder of the site comprises alluvium infilled valley floors of the northerly and north-easterly flowing tributaries associated with South Creek and gentler sloping hillsides feeding the creek. Surface levels range from approximately RL 86 to the north-west adjacent the tributaries to RL 76 central eastern edge of the site. While most of the unit has been cleared for use as grazing land, there are discontinuous zones of open to densely wooded areas along the creek lines and gullies in the south-western corner of the site.

Soil landscapes over the site broadly reflect the underlying geology and topography, with the Blacktown and South Creek Soil Landscapes of Hazelton and Tille (1990) being dominant. Thick residual and erosional soil profiles of the Blacktown Soil Landscapes can be prone to slope instability due to slumping and soil creep, particularly on steep south-facing slopes underlain by shale. The majority of naturally occurring slopes in the site have a gradient of less than 15% and, as such, the risk of hill slope instability is considered very low for the site.

Soils of the Blacktown and South Creek Soil Landscapes are of typically moderate erodibility, with calculated potential soil loss for the first 12 months after urban development of up to 135 t/ha for soils on moderate slopes.

The Atterberg limits results indicate that the natural clays are variously of low to high plasticity. The shrink-swell index test results indicate that the natural clays are of low to high shrink-swell potential. The soils tested would be expected to be moderately to highly susceptible to shrinkage and swelling

movements with changes in soil moisture content. Dispersion potential, as indicated by the Emerson crumb test, was determined to be Emerson class numbers 1, 2, 4 and 8 (highly to non-erodible). California bearing ratio testing (CBR) indicates that the site clays are likely to range in design values of 2 – 4%.

On the basis of a preliminary assessment of soil erosion hazards and slope stability, it is considered that urban or rural-residential development is generally feasible over the entire site, provided that appropriate soil and water management measures are adopted.

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Table of Contents

Report on Geotechnical Investigation
Pondicherry Residential Rezoning
Pondicherry, Oran Park, NSW

1. Introduction

This report presents the results of a geotechnical investigation undertaken by Douglas Partners Pty Ltd (DP) as part of an overall Land Capability Assessment at Pondicherry, Oran Park, NSW. The investigation was commissioned in an email, dated 27 February 2017, from Mr Paul Hume of Greenfields Development Company 2 Pty Ltd (GDC2) on behalf of Department of Planning & Environment and Camden Council and was undertaken in accordance with DP's proposal MAC170014.P.001.Rev1, dated 6 February 2017. The site has previously been identified by the former Growth Centres Commission for potential rezoning and urban development under the State Environmental Planning Policy (Sydney Regional Growth Centres) 2006. The site is currently zoned RU1 (primary production) and is proposed to be rezoned for various purposes, including (and primarily) residential type land use.

DP understands that the geotechnical investigation is required to inform the precinct planning stages of the proposed rezoning of the site. In particular, the investigation will assist in the preparation of the Indicative Layout Plan and the Precinct Planning Report that will be submitted to DPE for rezoning purposes. It is understood that the proposed development is likely to comprise approximately 2,500 residential dwellings and a rail corridor through the site. As the rail corridor construction will not be part of the current proposal we have not provided comment on it.

The investigation comprised a review of published information and field mapping by a senior geotechnical engineer and senior scientist followed by test pit excavation, laboratory testing of selected samples, engineering analysis and reporting. Details of the work undertaken and the results obtained are given in the report, together with comments relating to development potential, conceptual planning, design and construction practice.

A site concept plan was supplied by the client for use in the assessment and selected details have been incorporated into Drawings A1 – A5 (refer Appendix A of this report).

2. Scope of Works

The brief required the identification of geotechnical constraints to urban development, particularly with respect to slope instability and erosion and preparation of a preliminary soil and water management plan (SWMP) to provide guidelines on procedures and development criteria that will apply during subdivision construction. It is noted however that the SWMP is preliminary only and will require further review and refinement once the development footprint is determined.

DP has carried out salinity (Project 76778.29) and contamination (Project 76778.30) investigations in conjunction with the geotechnical investigation. The salinity and contamination investigations are reported separately and a Land Capability Study Report (Project 76778.27) provides an overview of all investigations and results.

Based on the above scope of work, the geotechnical investigation comprised:

- A review of published soils and geological information.
- A scoping study of the site, comprising site inspections to identify potential zones for geotechnical sample collection.
- Site walkover assessments by a senior geotechnical engineer and/or senior scientist identifying areas of potential site instability, erosion risks and other geotechnical constraints.
- A services search via the dial-before-you-dig service.
- Location of the test pits and other site features by a dGPS receiver.
- Excavation and logging of 11 test pits (Test Pits 1 – 11).
- Collection of regular disturbed samples to assist in strata identification and for laboratory testing.
- Laboratory testing (in-house) of selected samples for a range of geotechnical properties, including moisture content, Atterberg limits, shrink-swell index, Emerson Class Number and California bearing ratio (CBR).
- Storage of remaining soil samples pending the need for additional testing and evaluation.
- Preparation of constraints maps, indicating areas of site instability, erosion hazards and areas suitable for urban development.
- Preparation of this report, outlining the scope of work with details of the results obtained, assessment of constraints, recommendations regarding management and mitigation issues and comments with respect to design and construction practice.

This document represents the details of the findings of the study and is accompanied by technical notes and results within Appendices A to D.

3. Site Description

3.1 Site Identification

The site is located within the local government area of Camden Council and comprises an irregular shaped area of approximately 238 ha. The site is currently registered as nine separate lots as listed below and shown on Drawing 1, Appendix A.

- Part Lot E, Deposited Plan (D.P) 438723;
- Lot A, D.P. 420694;
- Lot F, D.P. 420694;
- Lot B, D.P. 420694;
- Lot 1, D.P. 623190;
- Part Lot 2, D.P. 1066809;

- Lot 71, D.P. 752024;
- Part Lot C, D.P. 391340; and
- Part Lot 9070, D.P. 11225752.

The site location and boundaries are shown on Drawing 1.

3.2 Site Description

The site is bound by vacant rural land to the north, South Creek and rural land to the east, Oran Park Precinct to the south and The Northern Road to the west and beyond by further rural residential and agricultural land. The site currently forms part of an active grazing and crop farming property which includes two large farm dams in the eastern / south eastern portion of the site and several smaller dams throughout the site. The southernmost large dam provides a stormwater detention function for part of the existing Oran Park Precinct located to the south of the site. A major transmission line and associated easement runs east-west through the southern portion of the land. While most of the site has been cleared for use as grazing land, there are discontinuous zones of open to densely wooded areas along the creek lines and gullies in the south-western corner of the site.

The site can be divided into the following topographic features:

1. Two separate surface drainage systems comprising creeks, gullies and dams are located at the site separated by a gently undulating ridgeline running approximately north east to south west through the site. The eastern / south eastern part of the site drains toward South Creek, while the northern / north western part of the site drains towards the north, into Howes Creek.
2. Gullies located at the site have entrenched the bedrock forming side slopes mostly to approximately 3 – 5°, but locally steeper towards the crests of ridgelines to approximately 5 – 10°. The gullies have been dammed in most locations for watering of stock. The highest elevation at the site is 116 m AHD (Australian Height Datum) and is located in the south-west corner of the site.
3. The low lying portions of the site comprise alluvium infilled valley floors associated with South Creek and gentler sloping hillsides feeding the creek. Surface levels range from approximately 86 m AHD to the north-west to 76 m AHD toward the central eastern edge of the site.

4. Regional Geology and Soil Landscapes

4.1 Geology

The site can be broadly divided into two broad geological units comprising sedimentary rocks and alluvial deposits (refer Figures 1 below, for additional detail).

The rolling hills, ridgelines and lower slopes in the northern, western and central portions of the site are underlain by Bringelly Shale (mapping unit Rwb) of the Triassic age Wianamatta Group (Penrith 1:100 000 Geological Series Sheet 9030; Ref 1). The Bringelly Shale in the vicinity of the site includes an unnamed, fine to medium grained quartz-lithic sandstone member, typically comprises shale, carbonaceous claystone, laminite and some minor coaly bands which weather to form clays of high plasticity.

The lower lying eastern portion of the site is generally underlain by Quaternary alluvial deposits (mapping unit Qal) of the Nepean River which are mainly derived from weathering of Permian and Triassic bedrock and typically comprise grey-brown, medium grained quartz sand with layers of silt and humic clay.

Figure 1: Geological Landscapes (Yellow – Quaternary Alluvium and Blue – Bringelly Shale)

4.2 Soil Landscapes

Soil landscapes over the site broadly reflect the underlying geology and topography. With reference to the Soil Landscapes of the Penrith 1:100 000 Sheet (Ref. 2) the site is broadly divided into two distinct soil landscapes, the Blacktown residual soils present over most of the central and western part of the site and the South Creek alluvial soils present in the western portion of the site. The two soil landscapes are further described below (refer Figure 2 below for additional detail):

- **The Blacktown Soil Landscape** (mapping unit bt) is a residual soil group associated with the gently undulating slopes and broad rounded crests and ridges on the Wianamatta Group in the eastern part of the site. The unit comprises up to four soil horizons that range from shallow red-brown hard-setting sandy clay soils on crests and upper slopes to deep brown to yellow sand and clay soils overlying grey plastic mottled clay on mid to lower slopes. These soils are typically of low fertility, are moderately reactive and have a generally low wet bearing strength.
- **South Creek Soil Landscape** (mapping unit sc) is an alluvial soil group associated with floodplains, valley flats and drainage depressions of the channels on the Cumberland Plain. Usually flat with incised channels, mainly cleared, and is mapped along South Creek and associated minor creek extending south and south-west through southernmost dam. Mapping indicates soils associated with this landscape comprise very deep layered sediments over bedrock or relict soils. Red and yellow podsolic soils occur.

Figure 2: Soil Landscapes (Dark Green – Blacktown Soils and Light Green – South Creek Soils)

4.3 Groundwater

A detailed groundwater study was not undertaken in the site area as part of this study. However, there are two distinct groundwater settings in the area:

1) Groundwater within Wianamatta Group shale; and
2) Groundwater within potentially unconsolidated Quaternary deposits of the South Creek flood plain.

Groundwater flow in unconsolidated Quaternary deposits is likely to be by porous flow in sandy horizons (however, groundwater was only noted in Pit 9 – refer Drawing 1). Shales of the Wianamatta Group on the other hand have a very low intrinsic permeability, and groundwater flow is likely to be dominated by fracture flow.

5. Field Work Methods

5.1 Horizontal and Vertical Control

All field measurements and mapping for this project have been carried out using the Geodetic Datum of Australia 1994 (GDA94) and the Map Grid of Australia 1994 (MGA94), Zone 56. Digital mapping has been carried out in a Geographic Information System (GIS) environment using Mapinfo software.

The test pit locations were nominated and located on site by DP. The locations of the test pits are shown on Drawing 1 (Appendix B). The surface levels relative to Australian Height Datum (AHD) and coordinates (to MGA94 Zone 56) given on the test pit logs (Appendix B) were determined with the use of a differential GPS for which an accuracy of ± 2 cm is typical.

5.2 Site Mapping

An inspection of Pondicherry was undertaken 10 March 2017 and 13 March 2017 by a senior geotechnical engineer and/or senior scientist to identify geotechnical constraints (such as areas of instability and erosion). Mapping reference points (MRP 1 – 85) shown on Drawing 4 were located to reference surface features shown on a high resolution georeferenced aerial map.

5.3 Test Pitting

The excavation of 11 test pits (Pits 1 – 11) was undertaken to depths of 2.3 – 3.0 m using a backhoe fitted with a 450 mm wide bucket. The field work was undertaken by a geotechnical engineer who collected disturbed samples, 'undisturbed' samples (in 50 mm diameter thin-walled tubes) and bulk samples to assist in strata identification and for laboratory testing. After backfilling each test pit, the surface was reinstated to its previous level. Dynamic cone penetrometer (DCP) tests were carried out to depths up to 1.2 m adjacent to the pits to assess the penetration resistance of the near-surface soils. The DCP results are given on the test pit logs.

6. Field Work Results

6.1 Field Mapping

The geotechnical and geological observations at various Map Reference Points (MRP) within the Pondicherry site are included in Appendix B, are further detailed on Drawing 4 and summarised below:

Stability

- The landform is predominantly gently sloping undulating terrain of gradual topographical relief. Crests and gullies are mostly broad, although incised gullies to depths of 1 m were noted along some drainage lines (Mapping Reference Point (MRP) 49 shown in Figures 4 and MRP 72, 76);

Figure 4 – Incised gully at MRP 49

- In general the site is considered to be stable with slopes typically less than 10 degrees;
- No areas of hillslope instability were observed during the site walkover (as was expected of such gentle relief);
- Steepened creek banks have the potential for minor instability and localised bank collapse.

Erosion

- Sheet erosion is also locally developed where there has been disruption of the vegetation by previous development (e.g. gullies, or recent clearing) and likely large scale flows following inclement weather. An example of this type of erosion (at MRP 41, 45, 47, 49 and 76), which exposes the underlying clays, is shown in Figure 5 and is located on the southern edges of the northern large dam.

Figure 5 – Sheet erosion at MRP 41

Soil and Rock Profiles

- Soil exposures in the incised drainage lines, MRP 49, 72 and 76, (Blacktown and South Creek soil group) indicated a relatively deep topsoil profile of between 0.2 m to 0.3 m).
- Where observed topsoil was significantly organic and root affected only in the top 150 mm. Below the topsoil, the profile remained quite silty but was not significantly organic.
- Rock profiles observed in the quarry/silage area indicated a typically fine grained shale (MRP 56), refer Figure 3);

Figure 3 – Shale outcropping at MRP 56

Stockpiles and Uncontrolled Fill

- The largest uncontrolled fill areas observed on site comprised the dam embankment walls with the two larger examples totalling 1,400 m long and up to approximately 8 m high (MRP 5, 9, 24, 25, 31, 35, 37, 39, 41, 60 and 68);

- Many of the drainage depression lines were piped and backfilled to form crossings, whilst some structures and the mulching yard were built up using fill up to depths of approximately 2 m (MRP 1, 3, 4, 26, 29, 43, 48, 57, 73, 74, 75, 78, 81 and 85). A previous dam was filled at MRP 86 to depths unknown;
- The quarry/silage excavations in the centre of the site have been formed partially by excavation and filling (MRP56).
- A small fill mound associated with a cattle loading ramp was noted in the central part of the site (MRP 18);
- There are localised piles of soil and ripped rock within the site, the larger examples being at MRP 45, 46, 53, 54, 69, 70 and 83 and 84. Whilst a mulch stockpile was noted at MRP 83;
- General filling was noted along all access roads/tracks and dam walls.

Waterlogging and Salinity

- The bases of the unnamed tributaries (and dendritic gullies) are generally infilled with recent alluvium which is characterised by water logging and discontinuous channel erosion. Many areas of waterlogging were noted (including but not limited to MRP 7, 10, 14 – 16, 19 – 22, 28, 30, 34, 58, 59, 63 – 66, 71, 72, 77, 79 and 80).

6.2 Subsurface Investigation

Details of the subsurface conditions encountered in the pits are given in the test pit logs included in Appendix C. The logs should be read in conjunction with the accompanying notes defining classification methods and descriptive terms.

As identified in Section 5.2, the site comprises two distinct soil landscapes with the test pits encountering variable subsurface conditions that were generally consistent with the soil mapping. The general succession of strata is broadly summarised as follows:

- TOPSOIL – silty clay and/or clayey silt encountered in all pits to depths in the range 0.2 – 0.3 m;
- ALLUVIAL – firm to hard silty clay and/or sandy silty clay encountered in Pits 6, 9 and 10 to depths in the range 2.3 – 3.0m, and to termination depth of 3.0 m in Pit 9;
- RESIDUAL – firm to hard silty clay and/or sandy silty clay encountered in Pits 1 – 5, 7, 8 and 11 to depths in the range 0.9 – 2.3 m;
- BEDROCK – variably extremely low up to low to medium strength shale first encountered in most pits, except Pit 9, at depths in the range 0.9 – 2.3 m. Pits 1 – 7 and 11 were terminated upon refusal of the excavator bucket at depths in the range 2.3 – 2.9 m.

No free groundwater was observed in most of the pits during excavation for the short time that they were left open with exception of Pit 9. Pit 9 encountered groundwater at a depth 2.9 m.

It must be noted, however, that the pits were immediately backfilled following excavation which precluded longer term monitoring of any groundwater levels that might be present. It must also be noted, groundwater levels are affected by factors such as soil permeability and weather conditions (which will vary with time).

7. Laboratory Testing

Selected samples from the test pits were tested in the laboratory for measurement of field moisture content, Atterberg limits, shrink-swell index and Emerson Class Number. The detailed test report sheets are given in Appendix C, with the results summarised in Table A1 (following pages).

Table A1: Results of Laboratory Testing

Pit No.	Depth (m)	FMC (%)	LL (%)	PL (%)	PI (%)	LS (%)	I_{ss} (%/ΔpF)	ECN (%)	Material
1	0.5	21.2	61	20	41	16.5	-	-	Silty Clay
1	1.0	-	-	-	-	-	-	1	Silty Clay
1	1.4 – 1.8	18.3	-	-	-	-	2.6	-	Extremely Weathered Shale
1	2.5	-	39	16	23	10.5	-	-	Extremely Weathered Shale
2	0.5	-	47	16	31	13.5	-	2	Silty Clay
2	1.0 – 1.4	16.6	-	-	-		0.7	1	Sandy Silty Clay
2	2.0	-	32	15	17	19.5	-	-	Sandy Silty Clay
3	0.5	20.7	46	17	29	12.0	-	1	Silty Clay
3	1.3 – 1.7	10.7	-	-	-	-	-	-	Silty Clay
3	2.0	14.8	50	19	31	10.0	-	-	Silty Clay
4	0.5	24.4	65	21	44	15.0	-	8	Silty Clay
4	1.5 – 1.9	17.2	40	15	25	13.0	2.6	-	Interbedded Extremely/Highly Weathered Shale
4	2.0	-	40	15	25	13.0	-	-	Interbedded Extremely/Highly Weathered Shale
5	0.2 – 0.6	12.3	41	19	22	11.5	-	-	Silty Clay
5	0.5	12.3	58	19	39	14.0	-	1	Silty Clay
6	0.5	-	63	25	38	15.5	-	4	Sandy Silty Clay

Table A1: Results of Laboratory Testing (Continued)

Pit No.	Depth (m)	FMC (%)	LL (%)	PL (%)	PI (%)	LS (%)	I_{ss} (%/∆pF)	ECN (%)	Material
6	1.0 – 1.4	14.6	-	-	-	-	1.5	3	Sandy Silty Clay
6	1.5	-	-	-	-	-	-	1	Sandy Silty Clay
7	0.5	21.0	60	20	40	13.5	-	3	Silty Clay
7	1.0	-	-	-	-	-	-	1	Silty Clay
7	1.0 – 1.4	17.2	50	19	31	13.0	-	-	Interbedded Extremely/Highly Weathered Shale
7	2.5	10.5	48	18	30	9.5			Interbedded Extremely/Highly Weathered Shale
8	0.5	24.8	73	21	52	20.0	-	4	Silty Clay
8	1.0 – 1.4	18.3	-	-	-	-	2.8	-	Silty Clay
8	2.5	-	53	20	33	14.5	-	-	Extremely Weathered Shale
9	0.5	29.5	78	25	53	19.5	-	4	Silty Clay
9	1.0 – 1.4	24.8	-	-	-	-	3.9	-	Silty Clay
9	2.0	-	-	-	-	-	-	4	Silty Clay
9	3.0	-	43	14	29	13.0	-	-	Sandy Silty Clay
10	0.5	-	50	16	34	13.5	-	2	Silty Clay
10	0.9 – 1.3	19.0	-	-	-	-	1.7	-	Silty Clay
10	3.0	-	46	19	27	12.0	-	-	Extremely Weathered Shale
11	1.0	-	-	-	-	-	-	1	Silty Clay

Where
FMC = Field moisture content
LL = Liquid limit
LS = Linear shrinkage
ECN = Emerson Class Number
PL = Plastic limit
PI = Plasticity Index
I_{ss} = Shrink-swell index

The Atterberg limits results indicate that the natural clays are variously of low to high plasticity. The shrink-swell index test results indicate that the natural clays are of low to high shrink-swell potential. The soils tested would be expected to be moderately to highly susceptible to shrinkage and swelling movements with changes in soil moisture content.

The results of the Emerson crumb tests (Emerson Class Numbers ranging from 1 to 8) indicate that the soils tested are highly to non-dispersive.

The CBR tests were carried out on samples compacted nominally to a dry density ratio of 100% relative to standard compaction at approximately standard optimum moisture content. The samples were then soaked for four days under surcharge loadings of 4.5 kg. The results are summarised in Table A2.

Table A2: Summary of CBR Test Results

Pit No	Depth (m)	W_F (%)	OMC (%)	MDD (t/m^3)	Swell (%)	CBR (%)	Material
1	2.0	16.9	17.0	1.81	4.5	2.5	Extremely Weathered Shale
3	2.0	13.0	15.0	1.83	4.0	2.0	Extremely Weathered Shale
4	0.5	24.7	23.5	1.60	2.0	3.5	Silty Clay
5	0.5	22.1	20.0	1.68	3.0	2.5	Silty Clay
6	2.5	12.0	14.0	1.88	3.0	2.0	Highly Weathered Shale
7	2.5	11.0	13.5	1.89	4.0	2.5	Interbedded Extremely/Highly Weathered Shale
8	1.5	17.8	18.5	1.74	2.5	2.5	Silty Clay
9	0.5	28.6	25.0	1.53	1.0	3.5	Silty Clay
10	1.0	23.5	19.5	1.69	3.5	2.0	Silty Clay
11	1.0	16.0	15.5	1.93	0.5	2.5	Silty Clay

Where W_F = Field moisture content; OMC = Optimum moisture content
MDD = Maximum dry density; CBR = California bearing ratio

The results of the field moisture content tests (at the time of the sampling) listed in Table A2 indicate the proposed subgrade soils ranged between approximately 0.1% dry to 3.6% wet of standard optimum moisture content (SOMC).

8. Comments

8.1 General

The following comments are based on a review of available information, the results of field mapping, test pitting, laboratory testing and our involvement in similar projects in the South Western Sydney area. Comments are provided on development constraints related to geotechnical and geological factors to assist in the conceptual planning of the proposed development. Further investigations will therefore be required to be undertaken at the appropriate times as the planning, design and construction of the development proceeds and accordingly, this report and the comments given within must be considered as being preliminary in nature.

8.2 Slope Instability

Thick residual soil profiles of the Blacktown Soil Landscape can be prone to slope instability due to slumping and soil creep, particularly on steep south-facing slopes underlain by shale. The high clay content of these soils results in poor drainage, and therefore reduced cohesion during periods of high rainfall or where natural drainage has been disturbed by development. Instability due to slumping is typically associated with thick soils and slopes in excess of 20% gradient (or greater than 11º) as described by Fell (Ref 3). However, no distinct slope instability (slump flow landslides or soil creep) affecting the soil and bedrock profile has been identified within the moderately steep hillslope sections and no areas exceed 20%.

8.3 Erosion Potential

Water erosion hazard forms a landscape limitation for the site. The site inspections identified gullies entrenching of recent alluvial deposits within stream courses and the residual soil and bedrock profiles. Localised areas of sheet and rill erosion were also noted in areas of previous surface disturbance and where over-grazing has occurred. In general, however, existing farm dams across gullies and vegetated areas between gully sections appear to act as effective catch points for eroded soils.

Soils of the Blacktown Soil Landscapes are typically of moderate erodibility (erodibility factor [K] values of 0.02 – 0.04, the value being determined by a combination of laboratory tests as well as soil structure and permeability). The more sodic or saline soils of the Blacktown Soil Landscape can have high erodibility and the erosion hazard for this landscape is estimated as moderate to very high (Ref 2). The soil erosion hazard for the alluvial South Creek Soil Landscape is estimated as moderate to high for non-concentrated flow, and very high for concentrated flow.

It is considered that the erosion hazard within the site would be within usually accepted bounds which may be managed by good engineering and land management practices (refer Sections 8.4 and 8.5).

8.4 General Development Considerations

8.4.1 Site Classification

The plasticity and shrink-swell index test results indicate that the tested materials are expected to exhibit foundation soil reactivity (shrink-swell) movements equivalent to a range of Class M to Class H2 sites using approximate in-house correlation between plasticity and reactivity.

Classification of individual allotments within the site should comply with the requirements of AS 2870 – 2011 *"Residential Slabs and Footings"* (Ref 4). Based on previous experience in similar geological settings, the subsurface profiles would most likely be equivalent to Class M (moderately reactive) or Class H1/H2 (highly reactive), with the possibility of some Class S where cut is taken to rock. The final classifications will dependent on soil reactivity, soil strength and whether or not rock is present within the depth of the design suction change.

Class P conditions may be present in the floodplain/drainage depressions should weak soils be encountered during project-specific subsurface investigation. Re-classification of such areas to M or H1/H2 may be possible subject to the extent of earthworks undertaken during construction.

8.4.2 Site Preparation and Earthworks

Site preparation for the construction of residential structures should include the removal of topsoils and other deleterious materials from the proposed building areas.

In areas that require filling, the stripped surfaces should be test rolled in the presence of a geotechnical engineer. Any areas exhibiting significant deflections under proof rolling should be appropriately treated by over-excavation and replacement with low plasticity filling placed in near horizontal layers no thicker than 250 mm compacted thickness. In accordance with Camden Council requirements, each layer should be compacted to a minimum dry density ratio of 98% relative to standard compaction with placement moisture contents maintained within 3% of standard optimum. The upper 0.5 m in areas of pavement construction should achieve a minimum dry density ratio of 100% relative to standard compaction.

All batters should be constructed no steeper than 3H:1V (horizontal:vertical) and appropriately vegetated to reduce the effects of erosion.

To validate site classifications, sufficient field inspections and in-situ testing of future earthworks should be undertaken in order to satisfy the requirements of a Level 1 inspection and testing service as defined in AS 3798 – 2007 *Guidelines on Earthworks for Commercial and Residential Developments* (Ref 5).

Earthworks required for pavement construction will need to be based on batters formed no steeper than 3H:1V in the residual clays. All batters should be suitably protected against erosion, with toe and spoon drains constructed as a means of controlling surface flows on the batters.

If embankments are proposed for use as water quality control ponds, then the results of testing completed to date indicates that the site soils would be suitable for re-use as embankment materials. Subject to the detailed design, detention basins (ie: short term storage only) could be dimensioned with maximum batter slopes of 4:1 (H:V), with allowance made for accommodating the results of erosion (such as topsoiling and turfing) if soils with an ECN of less than 4 are proposed for use. Subject to design permeability requirements, the use of lines on both the embankments and within parts of the reservoir area may also be necessary.

Site observations have indicated the presence of silty topsoils and silty clays which could be adversely affected by inclement weather. The site soils are typically stiff to very stiff consistency when dry, they can rapidly lose strength during rainfall and saturation (as indicated by firm clays in the attached logs), and result in difficult trafficability conditions. As a result, surface drainage which directs runoff away from work areas should be installed prior to construction, possibly in conjunction with the designation of construction equipment haul routes to minimise trafficking of stripped areas.

Conventional sediment and erosion control measures should be implemented during the construction phase, with exposed surfaces to be topsoiled and vegetated as soon as practicable following the completion of earthworks.

8.4.3 Desilting of Dam Reservoirs

If the existing farm dams are to be drained and filled to design level. The following general procedure is recommended:

- Pump out ponded water and discharge across land a minimum distance of 50 m from any existing waterways;
- Strip all vegetation and other deleterious material (such as saturated silt and clay) to expose the underlying stiff clay/weathered rock;
- Suitably bench the exposed surface to facilitate near-horizontal filling placement;
- Test rolling of the surface to receive filling with six passes of a 10 tonne dead weight roller operating in static mode, with final pass undertaken in the presence of a geotechnical engineer in order to identify areas requiring remedial work;
- Filling should be placed in near horizontal layers no thicker than 250 mm compacted thickness. In accordance with Camden Council requirements, each layer should be compacted to a minimum dry density ratio of 98% relative to standard compaction with placement moisture contents maintained within 3% of standard optimum;

- Saturated *'organic'* soils (as determined by the geotechnical engineer) from the pond base can be spread out and dried. Once dried the material can be blended with stockpiled topsoil and spread across the finished surface of lots;
- Any saturated *'non-organic'* soils (as determined by the geotechnical engineer) can be spread out and dried. Once moisture conditioned, the materials can be reused as engineered filling (refer Section 8.4.3) subject to inspection and approval.

Prior to discharging, an assessment of the pond water should be undertaken to confirm the adequacy of the above disposal method. The assessment should include (as a minimum) turbidity testing to the satisfaction of Camden Council.

8.4.4 Pavements

8.4.4.1 General

In order to assist in the conceptual design process, preliminary pavement thickness designs for arterial, boulevards, collectors and local access roads are provided in Table A3 (following page). Each category has been determined in accordance with Camden Council's requirements and has been assigned the road categories according to the following:

- Category B (major collector) – ESA = 2×10^6
- Category C (collector) – ESA = 1×10^6
- Category E (local access road / minor collector) – ESA = 5×10^5
- Category F (minor access road) – ESA = 1×10^5
- Category G (shareway) – ESA = 2×10^4

The preliminary pavement thickness designs given in Table A3 are based on the requirements of Camden Council, AUSTROADS – 2012 (Ref 6), the design parameters detailed above and a range of likely CBR values. Additional Investigations will need to be undertaken at the appropriate time to provide a final pavement thickness design.

Table A3: Preliminary Pavement Thicknesses

Design ESA	Total Pavement Thickness (mm) for Design CBR (%)				
	2%	3%	4%	5%	7%
5×10^6	790	650	560	500	420
2×10^6	720	600	520	460	390
1×10^6	670	560	480	430	360
5×10^5	620	520	450	400	340
1×10^5	510	420	370	330	280
2×10^4	460	380	330	300	250

It is anticipated that some pavements will likely encounter a rock subgrade of low strength, or stronger. As a result, a design CBR value of 7% will most likely be feasible for those conditions but will need to be confirmed once geometric design and subdivision layout is finalised.

It is expected that most of the clay subgrades will generally encounter clays of CBR 2 – 4%. Pavement thickness design, however, will be optimised when a detailed subgrade investigation is undertaken.

All pavement subgrades should be moisture conditioned to within 2% of SOMC during subgrade preparation to reduce the risk of cracking due to adverse shrink and swell movements within the pavement post-construction.

It must be noted that given the low CBR results obtained during testing and the large areas affected by possible waterlogging, passing of proof rolls may be difficult resulting in removal and replacement or select/bridging layers to improve subgrades.

8.4.5 Mine Subsidence

A review of the Mine Subsidence Board district mapping indicates the site is located outside existing mine subsidence districts and is not underlain by any registered mines.

8.5 Soil and Water Management Plan

Soil and water management is an integral part of the development process and should adopt a preventative rather than a reactive approach to the site limitations, such that the work can proceed without undue pollution of receiving streams.

Once consent is given, a detailed soil and water management plan (SWMP) developed in accordance with the methods of the NSW Department of Housing (Ref 7) will be required and will be incorporated into the engineering design of the development methods for:

- Minimising water pollution due to erosion of soils or the development of saline conditions.
- Reducing or managing salinity to provide acceptable conditions for building and revegetation works.
- Minimisation of soil erosion during and after construction.
- Maximising the re-use of materials on site.
- Ensuring that buildings and infrastructure are within acceptable risk of instability (for both property and life).

The following provides a conceptual SWMP with the objectives of controlling site works:

General Instructions: These conditions include methods to ensure compliance with the SWMP, specially:

- the SWMP will be read with the engineering plans and site specific instructions issued in relation to the development;

- contractors will ensure that all soil and water management works are undertaken as instructed in the specification and constructed in accordance with AS 3798 - 2007 (Ref 5);
- All subcontractors will be informed by the Superintendent of their responsibilities in minimising the potential for soil erosion and pollution of downslope areas.

Land Disturbance: These conditions provide methods to minimise soil erosion, the exposure of potentially or known saline subsoils and direction of overland drainage into areas of potential slope instability, specifically:

- The erosion hazard will be kept as low as possible by limiting of construction area size at any one time and clearly defining the area by barrier fencing upslope and sediment fencing downslope (to be installed before the commencement of construction activities);
- Access areas will be clearly defined and limited in size while being considerate of the needs of efficient work areas. All site workers will clearly recognise these boundaries;
- The prohibition of entry into areas outside physical works except for essential management works;
- Restriction of work in creek lines during periods of rainfall, with programming of works in these areas to be within periods of anticipated lower rainfall;
- The programming of development roadworks and major excavations to minimise the time of soil exposure and to coincide with periods of anticipated lower rainfall;
- Placement of topsoils and subsoils in separate stockpiles (where required) with appropriate sediment fencing and dimensions selected to minimise the surface area of soils exposed to rainfall and hence erosion and leaching of saline materials;
- The creation of larger lots on steeper slope sections to permit the more sensitive development of the individual site;
- Orientation of access roads and services to minimise the requirements of excavation and possible retaining structures;
- Where excavation of filling of batters is required, the construction of these at as low as practical gradient with a maximum 3:1 (H:V) in the clay soil profiles;
- The placement of excavated soils in filled areas in the sequence of excavation (i.e. to place potentially saline or sodic subsoils below a capping of non-saline material);
- During windy conditions, large, unprotected areas will be kept moist by sprinkling with water to keep dust under control. In the event that water is not available in sufficient quantities, soil binders and/or retardants will be used or the surface will be left in a cloddy state that resists removal by wind;
- The inclusion of techniques, such as spray coating or a secured protective turf overly on cut and fill batters to minimise erosion;
- The maximisation and/or replacement of native tree cover and deep-rooted plants, particularly in areas of known or potential slope instability;
- Where vegetation cover is not adequate to control erosion, the improvement of soil resistance to erosion by the addition of lime and gypsum (the proportion to be determined by site specific testing);

- Maintenance including watering of lands established with grass cover until an effective cover has been established. Where there has been inadequate vegetation establishment, further application of seed should be carried out. During establishment, trafficking of the treated areas should be minimised;
- The design of stormwater drainage, including lined catch drains at the crest of cut slopes, stormwater pipes and dissipators as required to minimise concentrated runoff and to provide controlled discharge of the collected runoff;
- The sampling and analysis of groundwater samples from monitoring bores installed prior to construction in order to assess impacts on groundwater quality.

Pollution Control: These conditions provide measures to protect downstream areas for water-borne pollution, specifically:

- The installation of sediment fences to contain the coarser sediment fraction as near as possible to their source;
- Ensuring that stockpiles are not located within hazard areas, including areas of likely high velocity flow, such as waterways, paved areas and driveways;
- The installation of sediment basins downslope of areas to be disturbed, with the design based upon a design storm event;
- The inclusion of one or more pegs in the floor of the sediment basins to indicate the level at which design capacity occurs and when collected sediment will be removed;
- Disposal of trapped materials from sediment basins to locations where further erosion and consequent pollution to downslope lands and waterways will not occur;
- Sampling and laboratory analysis of collected waters to ensure compliance with benchmark parameters prior to discharge;
- The treatment of collected waters by gypsum and settling of flocculated particles before any discharge occurs (unless the design storm event is exceeded);
- The removal of sediment basins (where not required as part of the on-going site management) only after the lands they are protecting are stabilised.

Site Inspection and Maintenance: These conditions provide for self and external auditing of the performance of construction and pollution protection measures, together with appropriate maintenance of erosion and sedimentation structures, specifically:

- A self-auditing program against an established checklist to be completed by the site manager at least weekly, immediately before site closure and immediately following rainfall events in excess of 5 mm in any one 24 hour period. The audit should include the recording of the condition of temporary sediment and water control devices, any maintenance requirements for these structures, volumes and disposal sites of material removed from sediment retention systems. A copy of the audit should be provided to the project superintendent;
- Provision for periodic inspection of records and site conditions by an external, suitably qualified person, for oversight of soil and water management works. The person will be responsible for ensuring that the SWMP is being implemented correctly, repairs are being undertaken as required and modifications to the SWMP are made if and when necessary. A short written report will be provided at appropriate intervals and will confirm that the works have been carried out according to the approved plans.

9. Summary of Geotechnical Land Capability

Assessment of the urban capability of the study area has been carried out on the basis of geotechnical considerations, specifically risk of slope instability, soil erodibility and foundation conditions.

General development considerations will require the classification of residential lots to comply with the requirements of AS 2870 – 2011 (Ref 4). The requirements of AS 1170 – 2002 *Structural Code* (Ref 8) are particularly noted in relation to earthquake loading requirements for commercial or industrial development.

The distribution of the geotechnical constraints is summarised in Drawing A5.

As no landslide or creep activity has yet been identified within steeper hillsides (refer Drawing A5) of the site, any minor slope instability will be addressed by good engineering practices

Other than erosion-triggered slumping of a material (probably a few cubic metres at any event) from the low height banks of the gullies within the alluvium infilled valley floors, there does not appear to be a significant risk of stream bank instability. It is considered that stream bank instability impose only minor constraints on development readily managed by good engineering practice.

It is considered that the erosion hazard within the areas proposed for development would be within usually accepted limits which could be managed by good engineering and land management practices (refer Sections 8.4 and 8.5).

The engineering and management practices applicable to erosion control will also be required to address localised waterlogging limitations of soils along the courses of South Creek and associated tributaries, its associated gullies and localised areas about existing farm dams. These hazards are considered to impose minor geotechnical constraints to development (i.e. limited to significant placement of new engineered filling and drainage) to development of residential development or extensive building complexes.

Uncontrolled filling (or suspected uncontrolled filling) was identified in several locations across the site. It is considered that the presence of uncontrolled filling will impose a minor geotechnical constraint to development and will generally involve the removal of uncontrolled filling (and if in situ materials are considered geotechnically suitable) replacement under controlled conditions.

10. Further Investigation

The geotechnical investigation undertaken has indicated that the site will be suitable for residential development, with comments given on geotechnical limitations, development guidelines, likely site classification, stability considerations and indicative pavement thicknesses. Conceptual comments on design and construction aspects are also given in the report. Detailed geotechnical investigation and assessment will be required as the design of the development proceeds and as such, this report must be considered as being preliminary in nature. Specific geotechnical investigation would include (but not necessarily be limited to):

- Detailed geotechnical investigations on a stage-by-stage basis for determination of pavement thickness designs and lot classifications.
- Routine inspections and earthworks monitoring during construction.

11. References

1. Geological Survey of New South Wales, 1991. Geology of 1:100 000 Penrith Geological Series Sheet 9030 (Edition 1).
2. Bannerman, S. M and Hazelton, P A. Soil Landscapes of the Penrith 1:100 000 Sheet. Soil Conservation Service of NSW, Sydney.
3. Australian Standard AS 2870 – 2011 Residential Slabs and Footings.
4. Practice Note Guidelines for Landslide Risk Management, Australian Geomechanics Society Landslide Taskforce (2007).
5. Australian Standard AS 3798 – 2007 Guidelines on Earthworks for Commercial and Residential Developments.
6. Austroads 2012. Pavement Design – A Guide to the Structural Design of Road Pavements.
7. NSW Department of Housing, 1998. Managing Urban Stormwater, Soils and Construction.
8. Australian Standard AS 1170 – 2002 *Structural Code.*

12. Limitations

Douglas Partners (DP) has prepared this report for this project at Pondicherry, Oran Park in accordance with DP's proposal dated MAC170014.P.001.Rev1 dated 6 February 2017 and acceptance received from Greenfields Development Company No. 2 Pty Ltd dated 27 February 2017. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of the Department of Planning & Environment, Camden Council and GDC2 for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to

DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A1

About This Report

Introduction

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

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

Copyright

This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

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

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

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

About this Report

Site Anomalies

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

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

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

Sampling

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

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

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

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

Large Diameter Augers

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

Continuous Spiral Flight Augers

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

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

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

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

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

The test results are reported in the following form.

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

  4,6,7
  N=13

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

  15, 30/40 mm

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

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

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Symbols & Abbreviations

Douglas Partners

Introduction

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

Drilling or Excavation Methods

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

Water

▷	Water seep
▽	Water level

Sampling and Testing

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

Description of Defects in Rock

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

Defect Type

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

Orientation

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

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

Coating or Infilling Term

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

Coating Descriptor

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

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

 Asphalt

 Road base

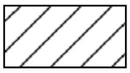
 Concrete

 Filling

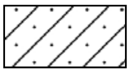
Soils

 Topsoil

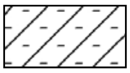
 Peat

 Clay

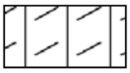
 Silty clay

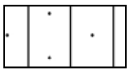
 Sandy clay

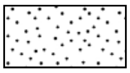
 Gravelly clay

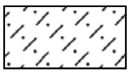
 Shaly clay

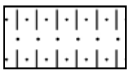
 Silt

 Clayey silt

 Sandy silt

 Sand

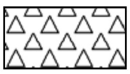
 Clayey sand

 Silty sand

 Gravel

 Sandy gravel

 Cobbles, boulders

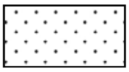
 Talus

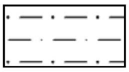
Sedimentary Rocks

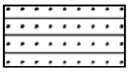
 Boulder conglomerate

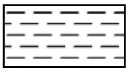
 Conglomerate

 Conglomeratic sandstone

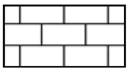
 Sandstone

 Siltstone

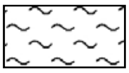
 Laminite

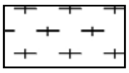
 Mudstone, claystone, shale

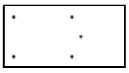
 Coal

 Limestone

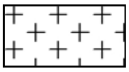
Metamorphic Rocks

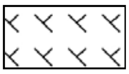
 Slate, phyllite, schist

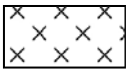
 Gneiss

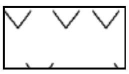
 Quartzite

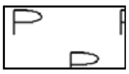
Igneous Rocks

 Granite

 Dolerite, basalt, andesite

 Dacite, epidote

 Tuff, breccia

 Porphyry

Description and Classification Methods

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

Soil Types

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

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

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

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

The proportions of secondary constituents of soils are described as:

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

Definitions of grading terms used are:

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

Cohesive Soils

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

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

Cohesionless Soils

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

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

Soil Descriptions

Soil Origin

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

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

Transported soils may be further subdivided into:

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

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

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

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

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

Degree of Fracturing

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

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

Rock Descriptions

Rock Quality Designation

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

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

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

Stratification Spacing

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

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

Appendix B1

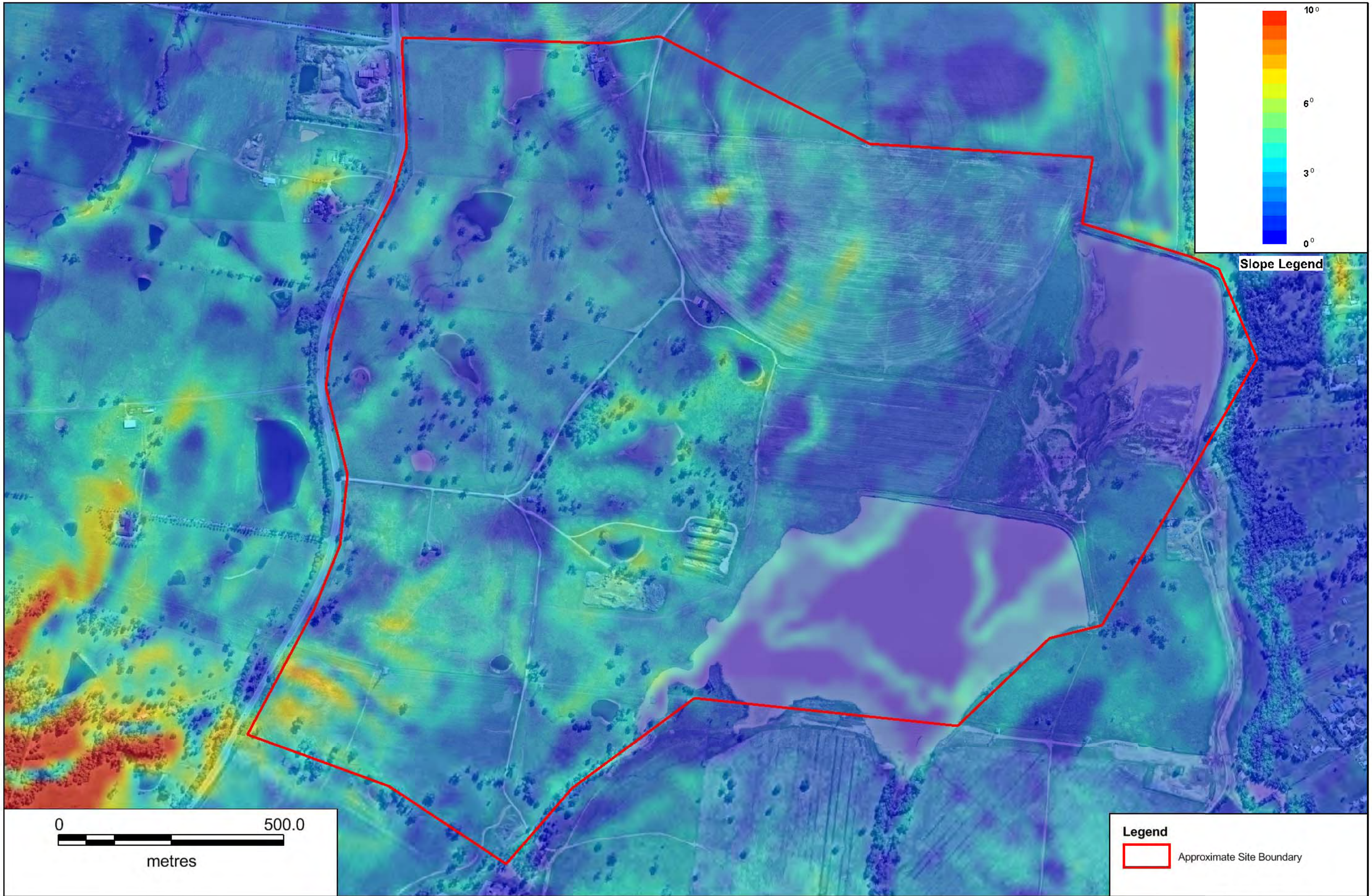
Drawings
Appendix Table B1 –
Summary of Observations at Mapping Reference Points

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Greenfields Development Company No. 2 Pty Ltd		TITLE: **Test Pit Locations** **Geotechnical Land Capability Study** **Pondicherry, Oran Park, NSW**	PROJECT No: 76778.28
	OFFICE: Macarthur	DRAWN BY: IKA		DRAWING No: A1
	SCALE: As shown	DATE: 9.08.2017	MGA N	REVISION: 0

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Greenfields Development Company No. 2 Pty Ltd		TITLE: **Topography**	PROJECT No: 76778.28
OFFICE: Macarthur	DRAWN BY: IKA	**Geotechnical Land Capability Study**	DRAWING No: A2
SCALE: As shown	DATE: 9.08.2017	**Pondicherry, Oran Park, NSW**	REVISION: 0

N
MGA



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Greenfields Development Company No. 2 Pty Ltd		TITLE: Ground Surfaces Slopes Geotechnical Land Capability Study Pondicherry, Oran Park, NSW
	OFFICE: Macarthur	DRAWN BY: IKA	
	SCALE: As shown	DATE: 9.08.2017	

PROJECT No:	76778.28
DRAWING No:	A3
REVISION:	0

MGA N

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Greenfields Development Company No. 2 Pty Ltd		TITLE:	Topography
OFFICE: Macarthur	DRAWN BY: IKA		Geotechnical Land Capability Study
SCALE: As shown	DATE: 9.08.2017		Pondicherry, Oran Park, NSW

PROJECT No:	76778.28
DRAWING No:	A4
REVISION:	0

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Greenfields Development Company No. 2 Pty Ltd		TITLE: **Geotechnical Constraints**
OFFICE: Macarthur	DRAWN BY: IKA	**Geotechnical Land Capability Study**
SCALE: As shown	DATE: 9.08.2017	**Pondicherry, Oran Park, NSW**

N
MGA

PROJECT No:	76778.28
DRAWING No:	A5
REVISION:	0

Appendix Table B1 - Mapping Reference Points

MRP	Observations
1	Concrete pipe with surrounding fill
2	Suspected stock water bore
3	Occupied residence constructed with brick concrete and slate tiles. Garden includes landscaping and tennis court.
4	Two reinforced concrete pipes each approximately 500 mm diameter located under road and draining into dam.
5	Dam wall up to approximately 3 - 4 m height comprising gravelly silty clay with piped culvert spillway through western abutment
6	Algae growth
7	Water logged area along drainage line
8	Cattle feeding area
9	Dam wall filling comprising gravelly silty clay with shale. Dam wall up to approximately 1 m height and formed at approximately 2(H):1(V)
10	Water logged area along drainage line
11	Occupied residence with some possible ACM in construction materials
12	Mobile phone transmission tower
13	Suspected stock water bore
14	Water logged area along drainage line
15	Water logged area along drainage line
16	Water logged area along drainage line
17	Fuel powered motor driving water distribution to crop area
18	Cattle feeding area
19	Water logged area along drainage line
20	Water logged area along drainage line
21	Water logged area along drainage line
22	Water logged area along drainage line
23	Cattle feeding area
24	Dam wall filling comprising light brown / red gravelly silty clay.
25	Dam wall filling light red / grey gravelly silty clay. Dam wall up to approximately 2 m height and formed at between 2(H):1(V) and 3(H):1(V)
26	Occupied residence with possible ACM in eaves and walls. House on fill bed up to approximately 1 m height
27	Corrugated steel sheds
28	Water logged field
29	Concrete pipe approximately 500 mm diameter with surrounding sandstone fill
30	Water logged area in field
31	Dam wall up to approximately 3 - 4 m height comprising gravelly silty clay
32	Grass covered mound possibly constructed with uncontrolled fill
33	Grass covered mound possibly constructed with uncontrolled fill
34	Water logged area along drainage line
35	Dam wall filling comprising clays with ironstone gravels. Dam wall is up to approximately 5 m height and formed at between 2(H):1(V) and 3(H):1(H)
36	Notched stillway
37	Dam wall up to approximately 5 m height and formed at 2(H):1(V) comprising gravelly silty clay
38	Dam wall height increases to approximately 6 m height
39	Dam wall up to approximately 4.5 m height and formed at 3(H):1(V) comprising gravelly silty clay

Appendix Table B1 - Mapping Reference Points

MRP	Observations
40	Efflorescence observed on ground surface
41	Dam wall up to approximately 7 - 8 m height and formed at 2(H):1(V) comprising gravelly silty clay
42	Steel pump out point from dam
43	Concrete pipe approximately 500 mm diameter with approx. 1 m surrounding sandstone fill
44	Man made gully
45	Stockpile
46	Stockpiles
47	Gully
48	Steel pipe approximately 0.5 m in diaemeter surrounded with approximately 1 m sandstone crushed rock
49	Eroded gully approximately 1 m
50	Slight terracing of surface approximately up to 1 m
51	Area suspected to have historically been part of the current dam to the north
52	Possible man made channel
53	Stockpiles
54	Stockpiles
55	Water logged field
56	Active fill storage area exhibiting a sweet / foul suspected urea odour. Walls comprise partial uncontrolled filling. Other cells to the south not in use at the time.
57	Mulching area on a fill platform.
58	Water logged field
59	Water logged field
60	Dam wall up to approximately 5 m height and formed at 2(H):1(V) comprising gravelly silty clay
61	Suspected stock water bore
62	Occupied residence constructed with possible ACM
63	Water logged
64	Water logged
65	Water logged
66	Water logged
67	Stockpile
68	Dam wall up to approximately 2.5 m height and comprising gravelly silty clay
69	Stockpile
70	Stockpile
71	Water logged
72	Water logged area surrounding erosion gully
73	Uncontrolled fill in embankment
74	Uncontrolled fill in embankment
75	1:1 grading steep embankment comprising uncontrolled fill
76	Erosion gully up to 1 m depth
77	Water logged area
78	Concrete pipe approximately 750 mm diameter
79	Water logged
80	Water logged
81	750 mm diameter concrete pipe under road

Appendix Table B1 - Mapping Reference Points

MRP	Observations
82	Mulch stockpile
83	Stockpile containing light red brown gravelly silty clays
84	Stockpiles of quarried sandstone
85	Black coated steel pipe culvert
86	Backfilled prior farm dam

Appendix C1

Test Pit Logs
Laboratory Test Results

Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189

Douglas Partners
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NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Tim White
NATA Accredited Laboratory Number: 828

Shrink Swell Index AS 1289 7.1.1 & 2.1.1					
Sample Number	17-189A	17-189B	17-189D	17-189F	17-189AA
Sampling Method	Sampled by Engineering Department	Sampled by Engineering Department	Sampled by Engineering Department	Sampled by Engineering Department	Sampled by Engineering Department
Date Sampled	10/06/2017	10/06/2017	10/06/2017	10/06/2017	10/06/2017
Date Tested	04/08/2017	04/08/2017	04/08/2017	04/08/2017	14/08/2017
Material Source	**	**	**	**	**
Sample Location	TP 1 (1.4-1.8 m)	TP 2 (1.0-1.4 m)	TP 4 (1.5-1.9 m)	TP 6 (1.0-1.4 m)	TP 8 (1.0-1.4 m)
Inert Material Estimate (%)	0	0	0	0	1
Pocket Penetrometer before (kPa)	440	600	590	570	210
Pocket Penetrometer after (kPa)	290	410	350	220	160
Shrinkage Moisture Content (%)	18.3	16.6	17.2	14.6	18.3
Shrinkage (%)	**3.8**	**1.3**	**3.8**	**2.0**	**4.2**
Swell Moisture Content Before (%)	17.7	16.8	12.1	15.0	20.7
Swell Moisture Content After (%)	21.3	17.7	21.1	20.5	24.0
Swell (%)	**1.7**	**0.1**	**1.6**	**1.6**	**1.6**
Shrink Swell Index Iss (%)	**2.6**	**0.7**	**2.6**	**1.5**	**2.8**
Visual Description	Shale - grey shale	Sandy silty clay - grey mottled light br	Shale - grey sandy shale	Sandy Silty Clay - grey mottled red & li	Silty Clay - Red mottled brown
Cracking	Slightly Cracked	Highly Cracked	Slightly Cracked	Moderately Cracked	Slightly Cracked
Crumbling	No	No	No	No	No
Remarks	**	**	**	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

Material Test Report

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Work Request: 189

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NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Tim White
NATA Accredited Laboratory Number: 828

Shrink Swell Index AS 1289 7.1.1 & 2.1.1		
Sample Number	17-189AB	17-189AC
Sampling Method	Sampled by Engineering Department	Sampled by Engineering Department
Date Sampled	10/06/2017	10/06/2017
Date Tested	14/08/2017	14/08/2017
Material Source	**	**
Sample Location	TP 9 (1.0-1.4 m)	TP 10 (0.9 - 1.3m)
Inert Material Estimate (%)	0	2
Pocket Penetrometer before (kPa)	150	220
Pocket Penetrometer after (kPa)	110	210
Shrinkage Moisture Content (%)	24.8	19.0
Shrinkage (%)	**7.1**	**2.9**
Swell Moisture Content Before (%)	26.5	23.9
Swell Moisture Content After (%)	28.7	26.0
Swell (%)	**0.0**	**0.3**
Shrink Swell Index Iss (%)	**3.9**	**1.7**
Visual Description	SILTY CLAY - grey mottled light brown silty clay	SILTY CLAY - grey mottled red , light brown & dark grey silty clay
Cracking	Uncracked	Moderately Cracked
Crumbling	No	No
Remarks	**	**

Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.
NATA Accreditation does not cover the performance of pocket penetrometer readings.

Material Test Report

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Work Request: 189

Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content	Material
17-189C	TP 3 (1.3-1.7 m)	10.7 %	Shale - red, grey shale
17-189E	TP 5 (0.2-0.6 m)	12.3 %	Silty Clay - red mottled grey silty clay with iron induration
17-189G	TP 6 (2.50 m)	13.3 %	SHALE - Grey, sandy shale.
17-189J	TP 7 (2.5 m)	10.5 %	SHALE - grey shale
17-189P	TP 3 (0.5 m)	20.7 %	SILTY CLAY - red mottled grey silty clay
17-189Q	TP 4 (0.5 m)	24.4 %	SILTY CLAY - red silty clay
17-189R	TP 5 (0.5 m)	12.3 %	SILTY CLAY - red mottled grey silty clay
17-189S	TP 7 (0.5 m)	21.0 %	SILTY CLAY - red mottled grey and dark grey silty clay
17-189T	TP 8 (0.5 m)	24.8 %	SILTY CLAY - red mottled brown silty clay
17-189U	TP 9 (0.5 m)	29.5 %	SILTY CLAY - light brown mottled grey and red silty clay
17-189Z	TP 7 (1.0 - 1.4 m)	17.2 %	SHALE - grey shale
17-189AD	TP 1 (0.5 m)	21.2 %	SILTY CLAY - grey mottled red silty clay
17-189AI	TP 3 (2.0 m)	14.8 %	**

Material Test Report

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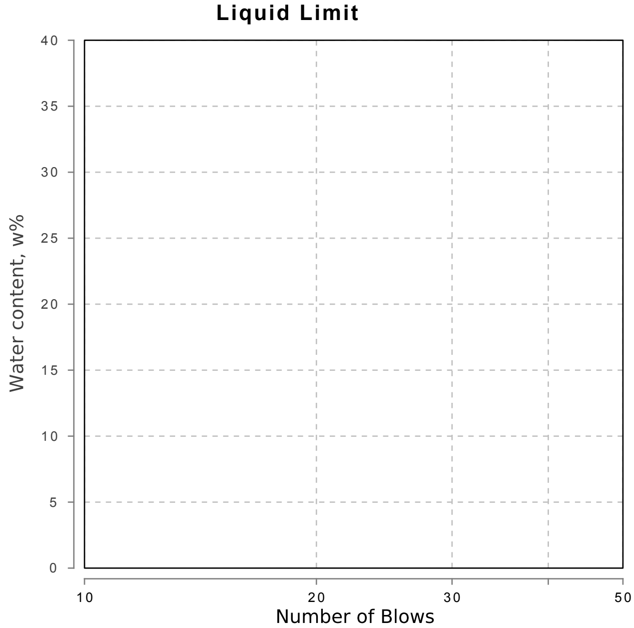
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189AD
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 1 (0.5 m)**
Material: SILTY CLAY - grey mottled red silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	61		
Plastic Limit (%)	20		
Plasticity Index (%)	**41**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	16.5		
Cracking Crumbling Curling	Curling		



Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189N
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 1 (1.0 m)**

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		

Material Test Report

Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189AG
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 1 (2.5 m)**

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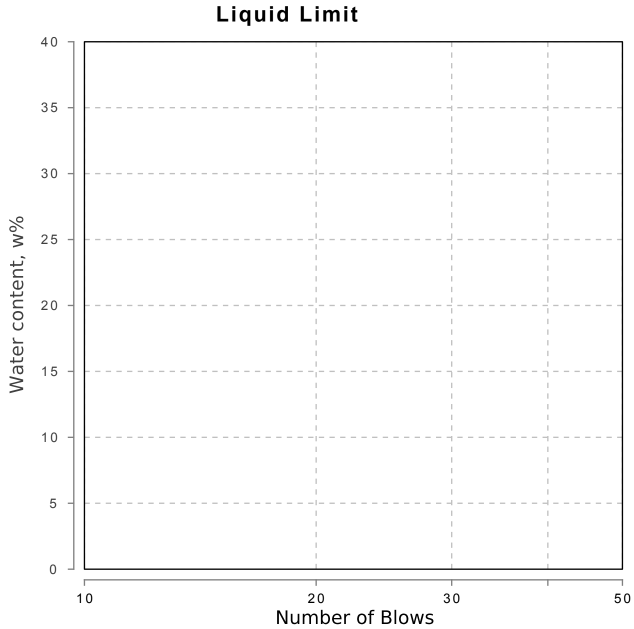
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	39		
Plastic Limit (%)	16		
Plasticity Index (%)	**23**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	10.5		
Cracking Crumbling Curling	None		



Material Test Report

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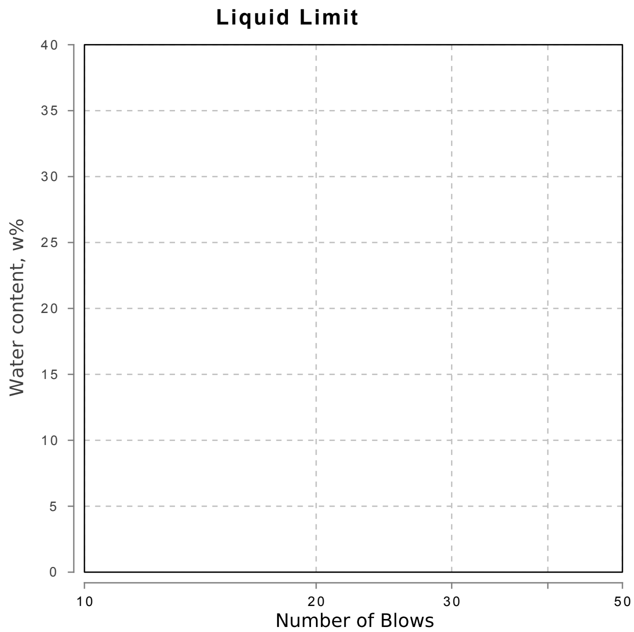
Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189O
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 2 (0.5 m)**
Material: SILTY CLAY - light brown mottled grey and red silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	47		
Plastic Limit (%)	16		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		



Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189B
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 2 (1.0-1.4 m)**

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		

Material Test Report

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Report Number: **76778.29-1**
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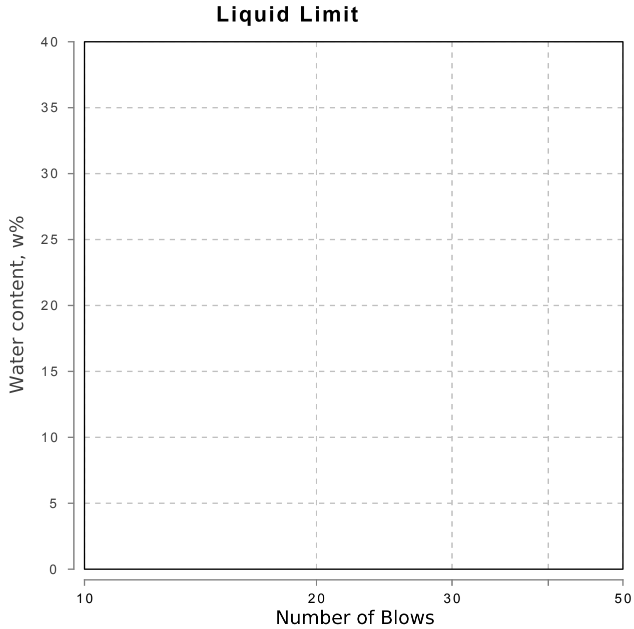
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189AH
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 2 (2.0 m)**

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	32		
Plastic Limit (%)	15		
Plasticity Index (%)	**17**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	9.5		
Cracking Crumbling Curling	Curling		



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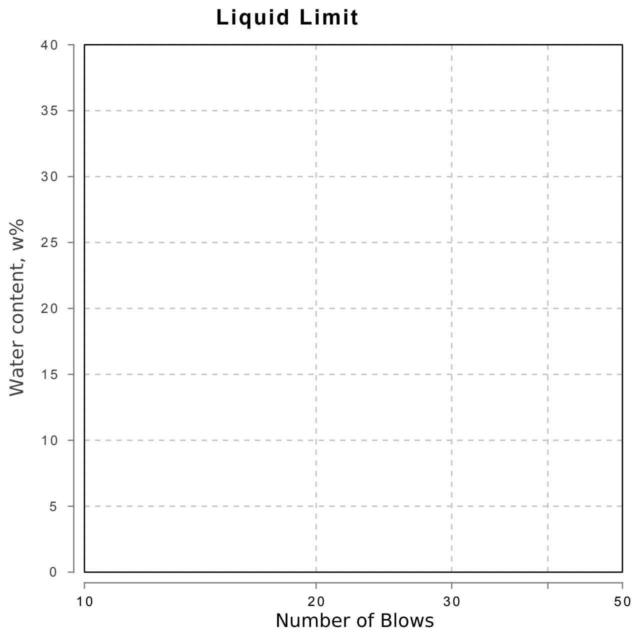
Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189P
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 3 (0.5 m)**
Material:	SILTY CLAY - red mottled grey silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	46		
Plastic Limit (%)	17		
Plasticity Index (%)	**29**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		



Material Test Report

Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189AI
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 3 (2.0 m)**

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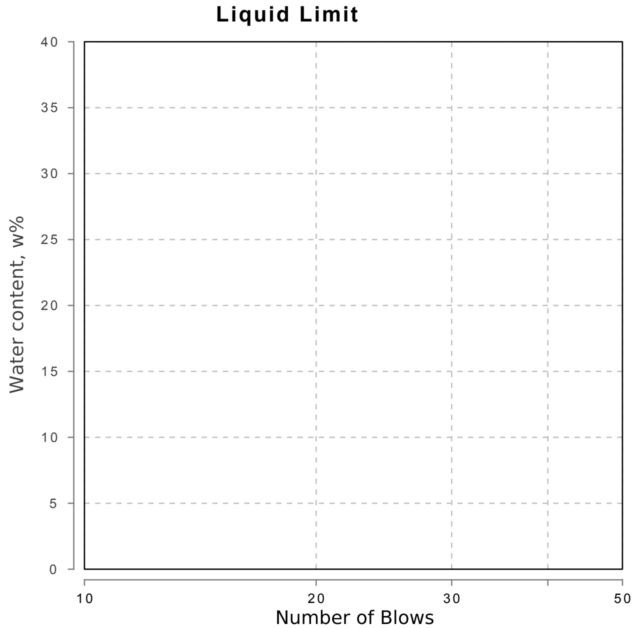
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	50		
Plastic Limit (%)	19		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	10.0		
Cracking Crumbling Curling	Curling		



Material Test Report

Report Number:	**76778.29-1**
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Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189Q
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 4 (0.5 m)**
Material:	SILTY CLAY - red silty clay

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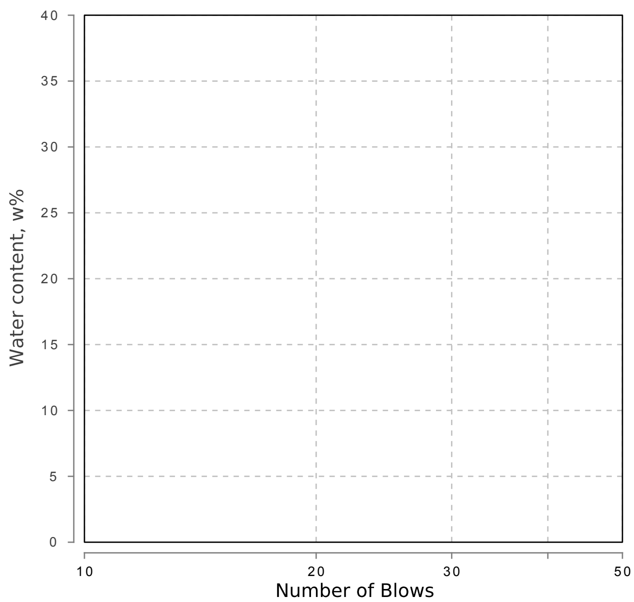
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	65		
Plastic Limit (%)	21		
Plasticity Index (%)	**44**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	15.0		
Cracking Crumbling Curling	None		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**8**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		

Liquid Limit



Material Test Report

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Report Number: **76778.29-1**
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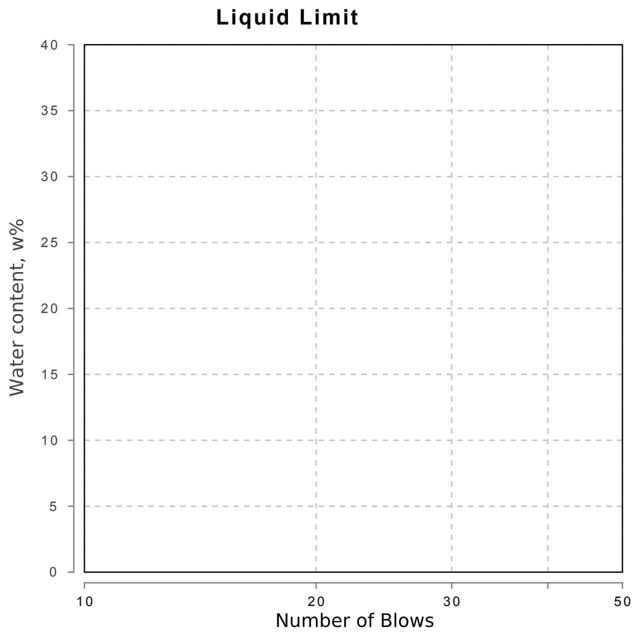
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189L
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 4 (2.0 m)**
Material: SHALE - grey sandy shale

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	40		
Plastic Limit (%)	15		
Plasticity Index (%)	**25**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.0		
Cracking Crumbling Curling	Curling		



Material Test Report

Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189R
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 5 (0.5 m)**
Material:	SILTY CLAY - red mottled grey silty clay

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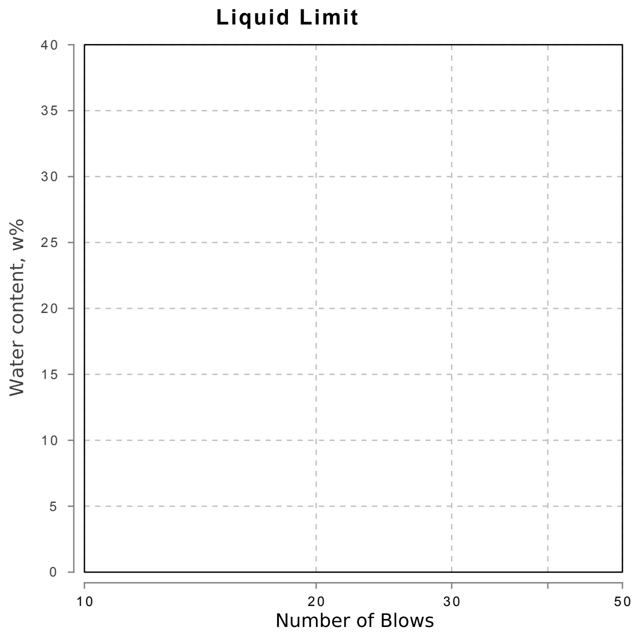
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	58		
Plastic Limit (%)	19		
Plasticity Index (%)	**39**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		



Material Test Report

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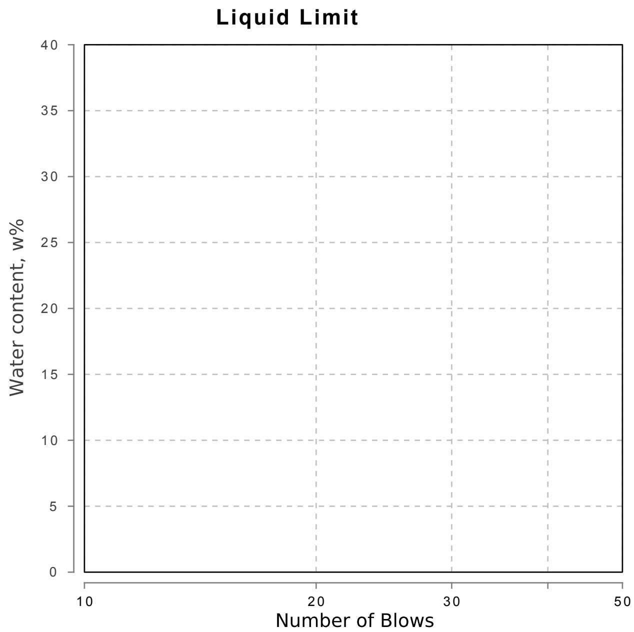
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189E
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 5 (0.2-0.6 m)**
Material: Silty Clay - red mottled grey silty clay with iron induration

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	41		
Plastic Limit (%)	19		
Plasticity Index (%)	**22**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.5		
Cracking Crumbling Curling	Curling		



Material Test Report

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Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189AE
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 5 (2.5 m)**
Material:	SHALE - grey shale

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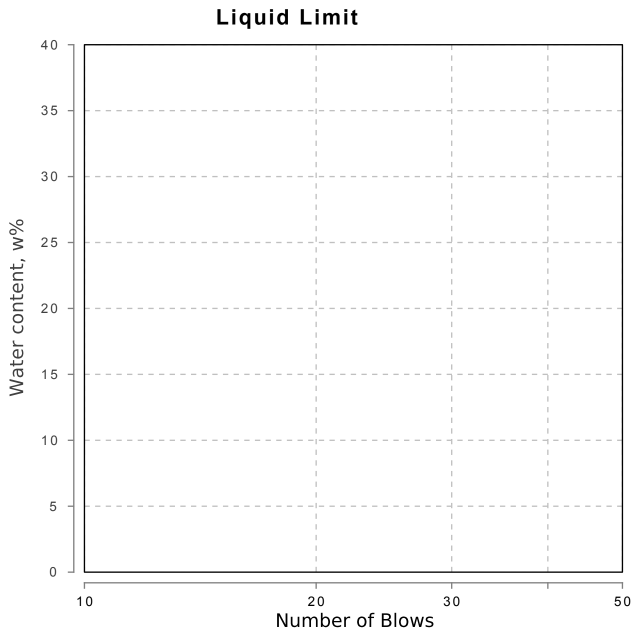
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	44		
Plastic Limit (%)	17		
Plasticity Index (%)	**27**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	11.0		
Cracking Crumbling Curling	Curling		



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Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189I
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 6 (0.5 m)**
Material:	SANDY SILTY CLAY - stiff, red mottled grey and light brown sandy , silty clay

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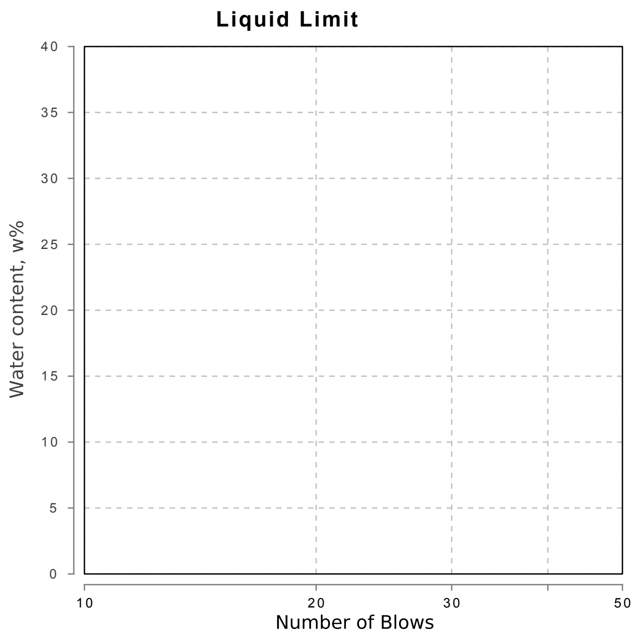
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	63		
Plastic Limit (%)	25		
Plasticity Index (%)	**38**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	15.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		



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Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189F
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 6 (1.0-1.4 m)**

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^oC)	20		

Material Test Report

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5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189H
Date Sampled: 16/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 6 (1.5 m)**

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^oC)	20		

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Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189G
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 6 (2.50 m)**
Material: SHALE - Grey, sandy shale.

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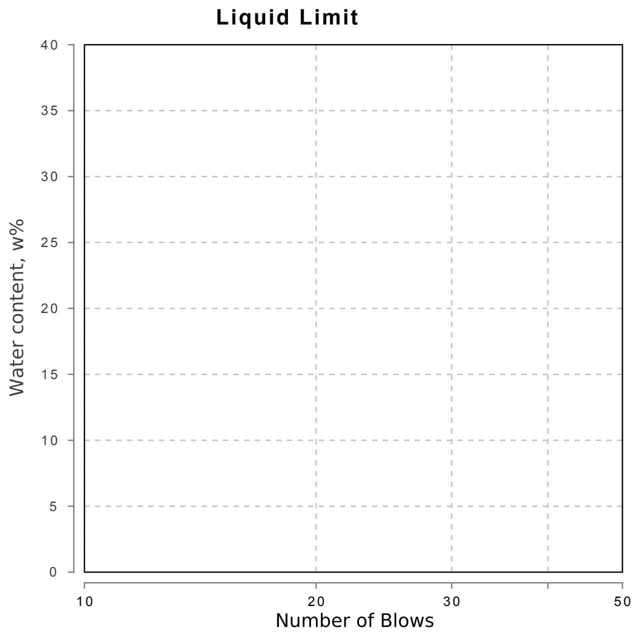
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	50		
Plastic Limit (%)	16		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	10.0		
Cracking Crumbling Curling	Curling		



Material Test Report

Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189S
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 7 (0.5 m)**
Material:	SILTY CLAY - red mottled grey and dark grey silty clay

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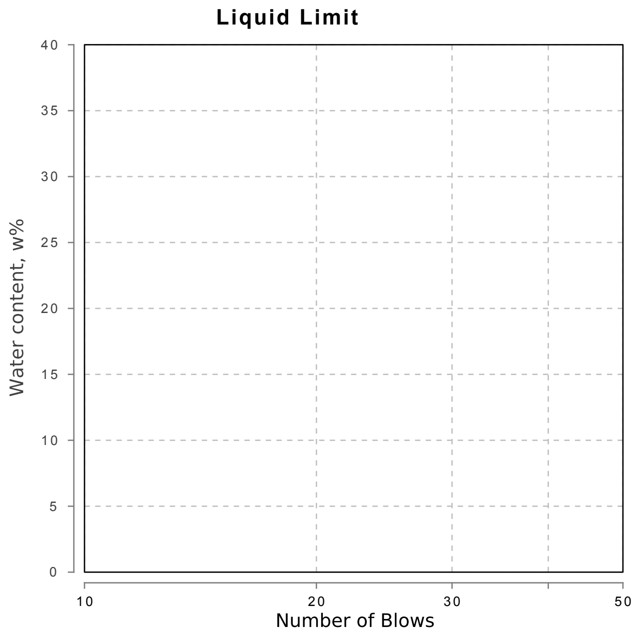
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	60		
Plastic Limit (%)	20		
Plasticity Index (%)	**40**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**3**		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		



Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189W
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 7 (1.0 m)**
Material: SILTY CLAY - red mottled grey silty clay with some ironstone gravel

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled Water		
Temperature of Water (^oC)	20		

Material Test Report

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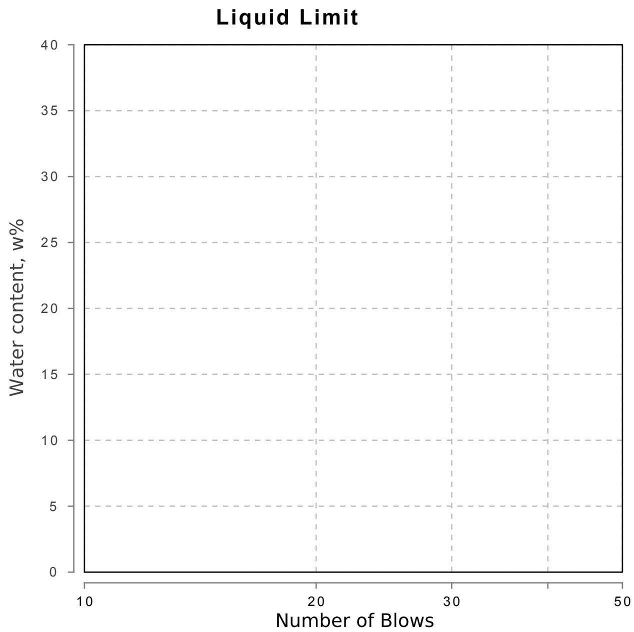
Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189Z
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 7 (1.0 - 1.4 m)**
Material:	SHALE - grey shale

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	50		
Plastic Limit (%)	19		
Plasticity Index (%)	**31**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.0		
Cracking Crumbling Curling	Curling		



Material Test Report

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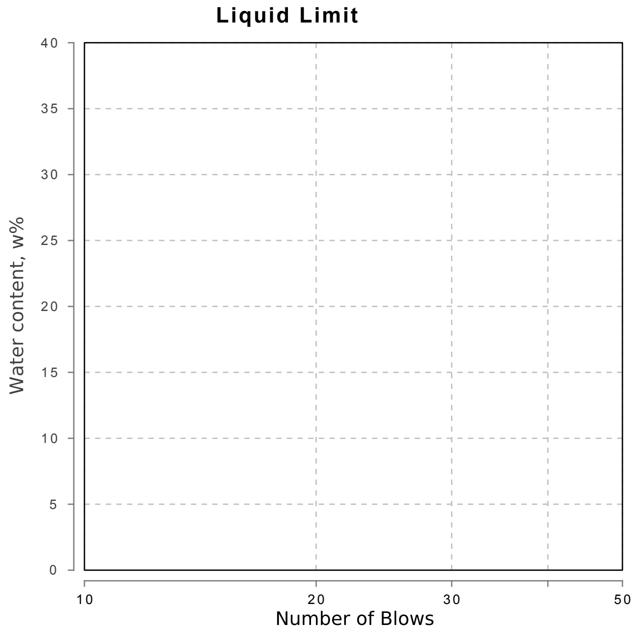
Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189J
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 7 (2.5 m)**
Material: SHALE - grey shale

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	48		
Plastic Limit (%)	18		
Plasticity Index (%)	**30**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	9.5		
Cracking Crumbling Curling	Curling		



Material Test Report

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Report Number: **76778.29-1**
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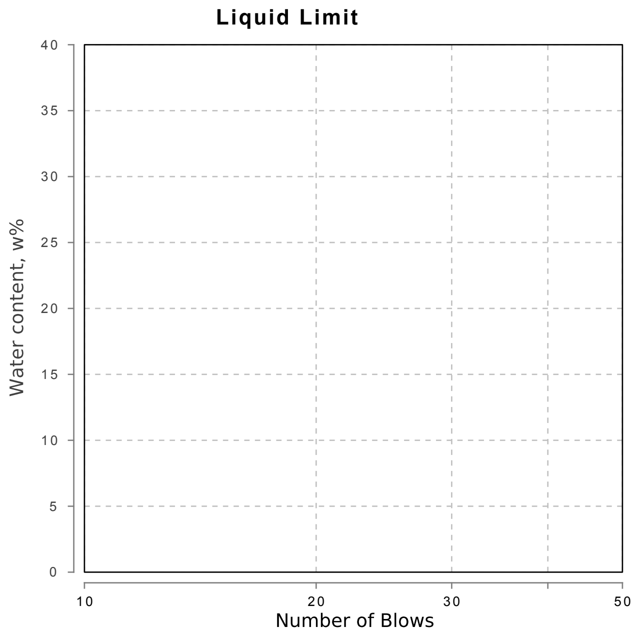
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189T
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 8 (0.5 m)**
Material: SILTY CLAY - red mottled brown silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	73		
Plastic Limit (%)	21		
Plasticity Index (%)	**52**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	20.0		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		



Material Test Report

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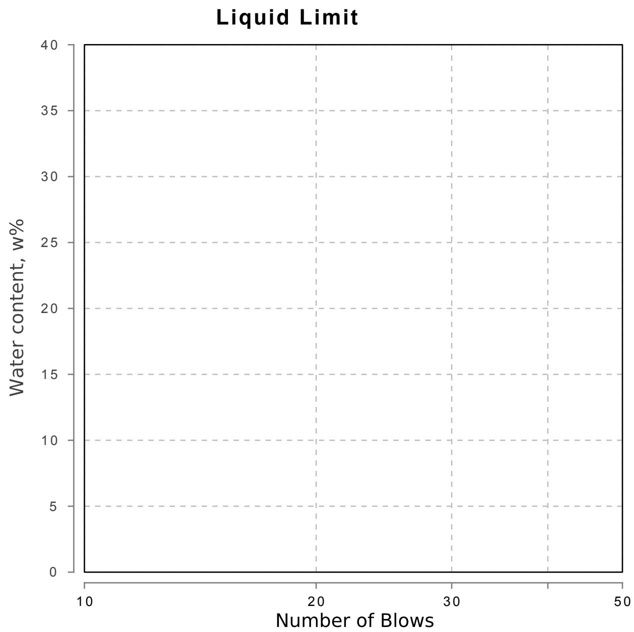
Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189AF
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 8 (2.5 m)**
Material: SHALE - grey shale

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	53		
Plastic Limit (%)	20		
Plasticity Index (%)	**33**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	14.5		
Cracking Crumbling Curling	None		



Material Test Report

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Report Number: **76778.29-1**
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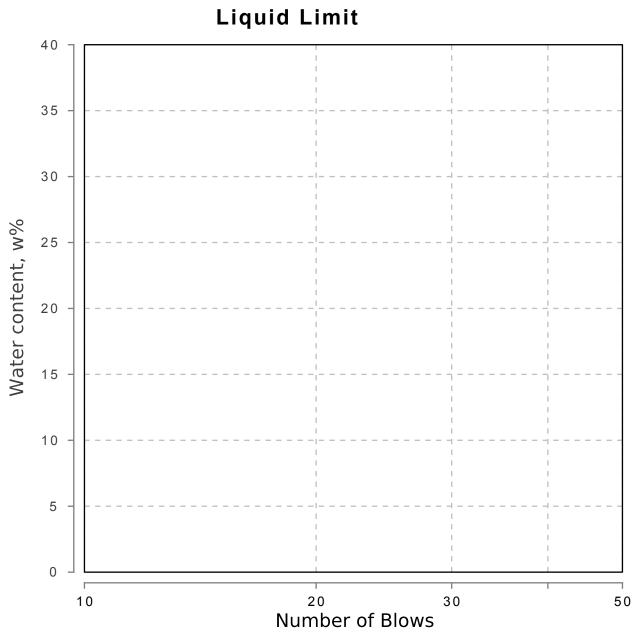
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189U
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 9 (0.5 m)**
Material: SILTY CLAY - light brown mottled grey and red silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	78		
Plastic Limit (%)	25		
Plasticity Index (%)	**53**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	19.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description			
Nature of Water	Distilled water		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		



Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189X
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 9 (2.0 m)**
Material: SILTY CLAY - light brown mottled grey and red silty clay

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**4 ***		
Soil Description			
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		
* Mineral Present	Carbonate		

Material Test Report

Report Number: **76778.29-1**
Issue Number: 2 - *This version supercedes all previous issues*
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189M
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 9 (3.0 m)**
Material: SANDY SILTY CLAY - grey mottled light brown

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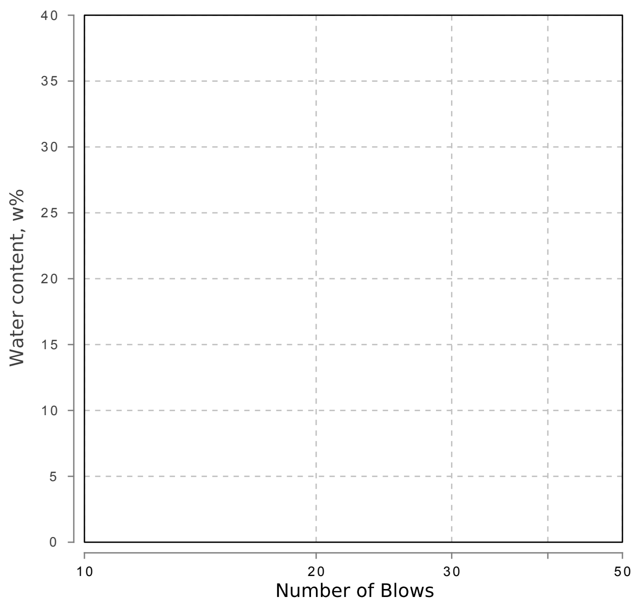
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	43		
Plastic Limit (%)	14		
Plasticity Index (%)	**29**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.0		
Cracking Crumbling Curling	Curling		

Liquid Limit



Material Test Report

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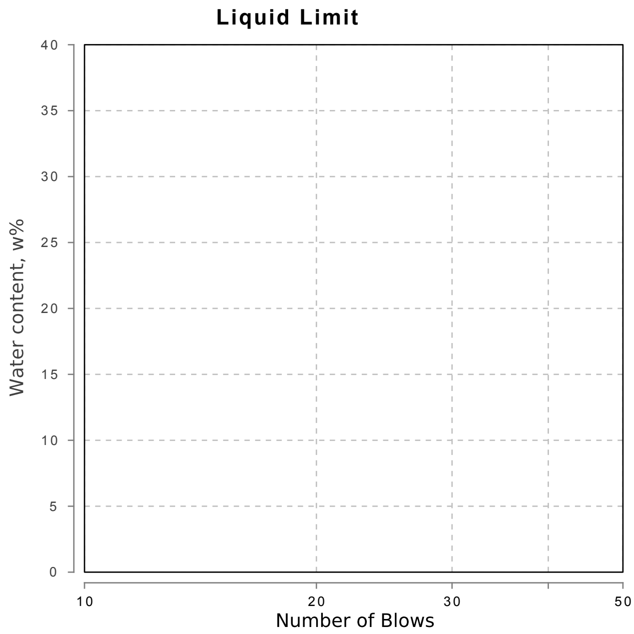
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189V
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 10 (0.5 m)**
Material: SILTY CLAY - light brown mottled grey and red silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	50		
Plastic Limit (%)	16		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	Curling		

Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**2**		
Soil Description			
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		



Material Test Report

Report Number:	**76778.29-1**
Issue Number:	2 - *This version supercedes all previous issues*
Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	189
Sample Number:	17-189K
Date Sampled:	10/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**TP 10 (3.0 m)**
Material:	SHALE - grey shale

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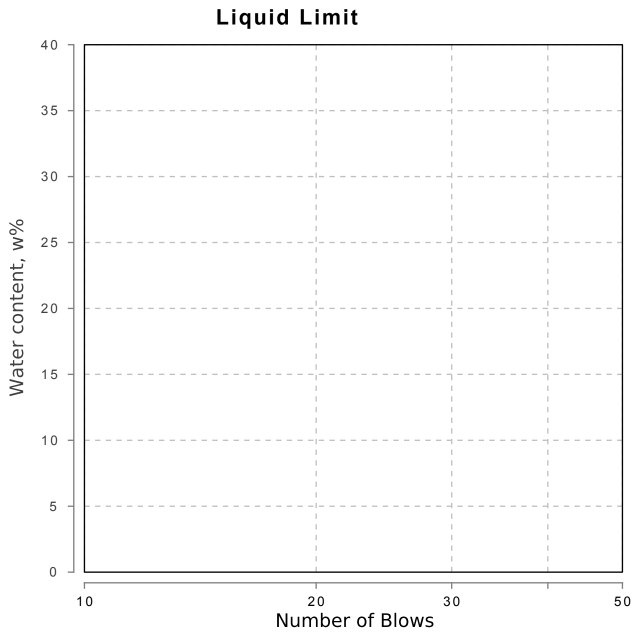
Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Air Dried		
Liquid Limit (%)	46		
Plastic Limit (%)	19		
Plasticity Index (%)	**27**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.0		
Cracking Crumbling Curling	Curling		



Material Test Report

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Report Number: **76778.29-1**
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Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 189
Sample Number: 17-189Y
Date Sampled: 10/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **TP 11 (1.0 m)**
Material: SILTY CLAY - red mottled grey silty clay with trace ironstone gravel

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Emerson Class Number of a Soil (AS 1289 3.8.1)		Min	Max
Emerson Class	**1**		
Soil Description			
Nature of Water	Distilled Water		
Temperature of Water (^{o}C)	20		

Material Test Report

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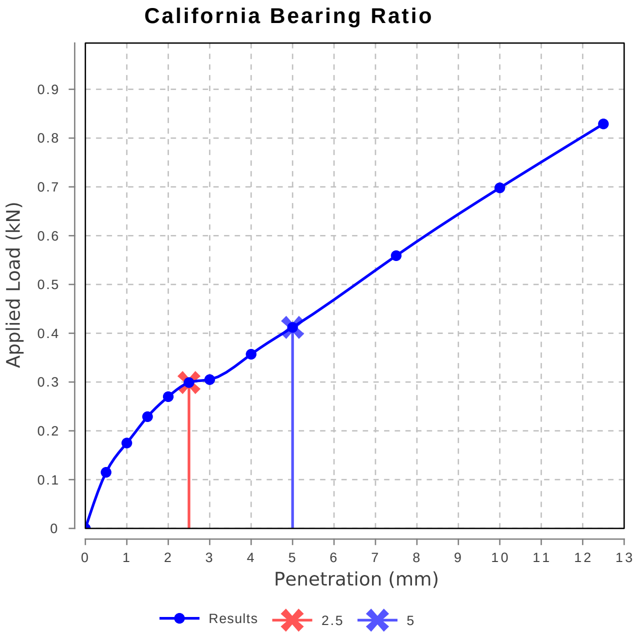
NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Dan Byrnes
NATA Accredited Laboratory Number: 828

Report Number: **76778.29-1**
Issue Number: 1
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354A
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **1 (2.0m)**
Material: SHALE - grey shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.81		
Optimum Moisture Content (%)	17.0		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.72		
Field Moisture Content (%)	16.9		
Moisture Content at Placement (%)	17.0		
Moisture Content Top 30mm (%)	24.1		
Moisture Content Rest of Sample (%)	18.7		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	4.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

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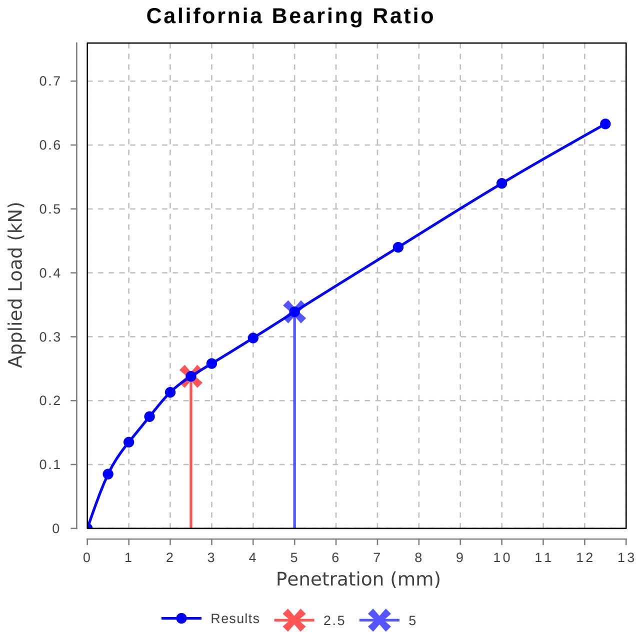
Report Number: **76778.29-1**
Issue Number: 1
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354B
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **3 (2.0m)**
Material: SHALE - grey shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**2.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.83		
Optimum Moisture Content (%)	15.0		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.75		
Field Moisture Content (%)	13.0		
Moisture Content at Placement (%)	15.1		
Moisture Content Top 30mm (%)	22.7		
Moisture Content Rest of Sample (%)	17.8		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	4.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

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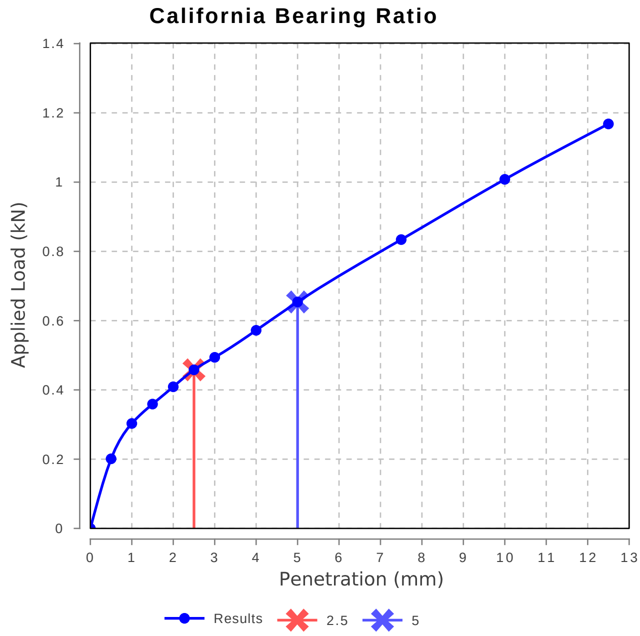
Report Number: **76778.29-1**
Issue Number: 1
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354C
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **4 (0.5m)**
Material: SILTY CLAY - red silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**3.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.60		
Optimum Moisture Content (%)	23.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	101.0		
Dry Density after Soaking (t/m^3)	1.56		
Field Moisture Content (%)	24.7		
Moisture Content at Placement (%)	23.5		
Moisture Content Top 30mm (%)	27.0		
Moisture Content Rest of Sample (%)	23.9		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	2.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

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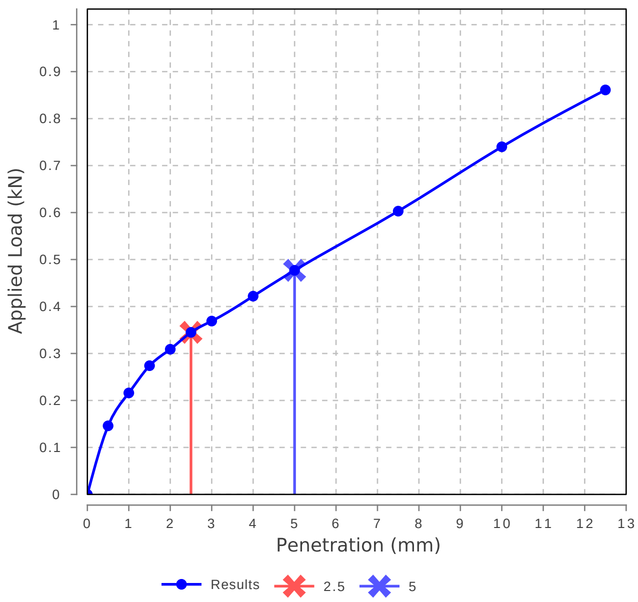
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	354
Sample Number:	17-354D
Date Sampled:	10/08/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**5 (0.5m)**
Material:	SILTY CLAY - red mottled grey silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.68		
Optimum Moisture Content (%)	20.0		
Laboratory Density Ratio (%)	99.5		
Laboratory Moisture Ratio (%)	101.5		
Dry Density after Soaking (t/m^3)	1.63		
Field Moisture Content (%)	22.1		
Moisture Content at Placement (%)	20.3		
Moisture Content Top 30mm (%)	25.4		
Moisture Content Rest of Sample (%)	22.3		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	3.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		

California Bearing Ratio



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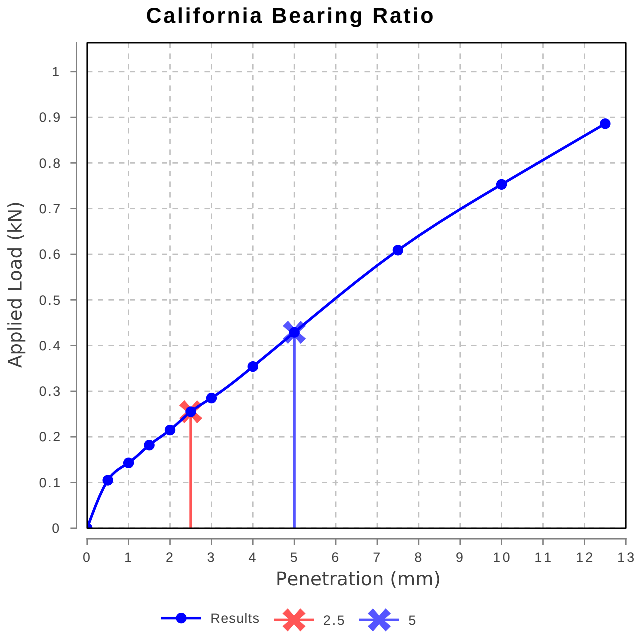
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354E
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **6 (2.5m)**
Material: SHALE - grey sandy shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.88		
Optimum Moisture Content (%)	14.0		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	98.0		
Dry Density after Soaking (t/m^3)	1.83		
Field Moisture Content (%)	12.0		
Moisture Content at Placement (%)	13.9		
Moisture Content Top 30mm (%)	21.5		
Moisture Content Rest of Sample (%)	17.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	3.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	5		



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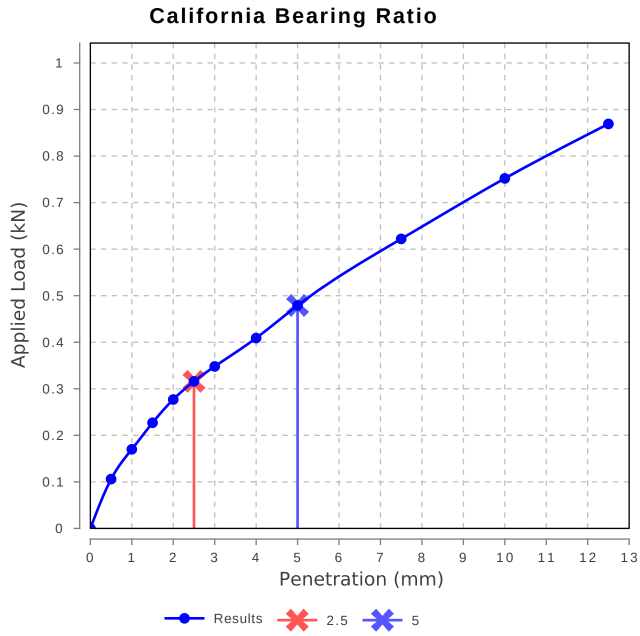
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354F
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **7 (2.5m)**
Material: SHALE - grey shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.89		
Optimum Moisture Content (%)	13.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.82		
Field Moisture Content (%)	11.0		
Moisture Content at Placement (%)	13.6		
Moisture Content Top 30mm (%)	19.6		
Moisture Content Rest of Sample (%)	16.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	4.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	6		



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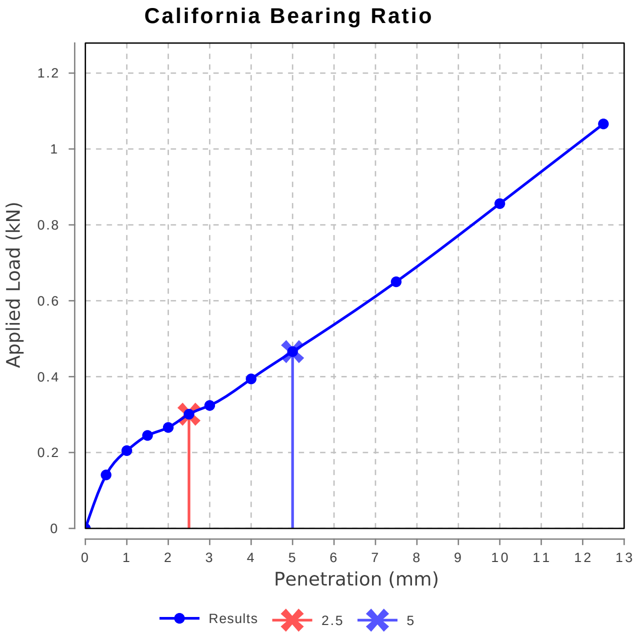
Date Issued: 22/08/2017
Client: Greenfields Development Company 2 Pty Ltd
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354G
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **8 (1.5m)**
Material: SILTY CLAY - grey mottled red and light brown silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.74		
Optimum Moisture Content (%)	18.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	98.5		
Dry Density after Soaking (t/m^3)	1.70		
Field Moisture Content (%)	17.8		
Moisture Content at Placement (%)	18.2		
Moisture Content Top 30mm (%)	23.3		
Moisture Content Rest of Sample (%)	20.5		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	2.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



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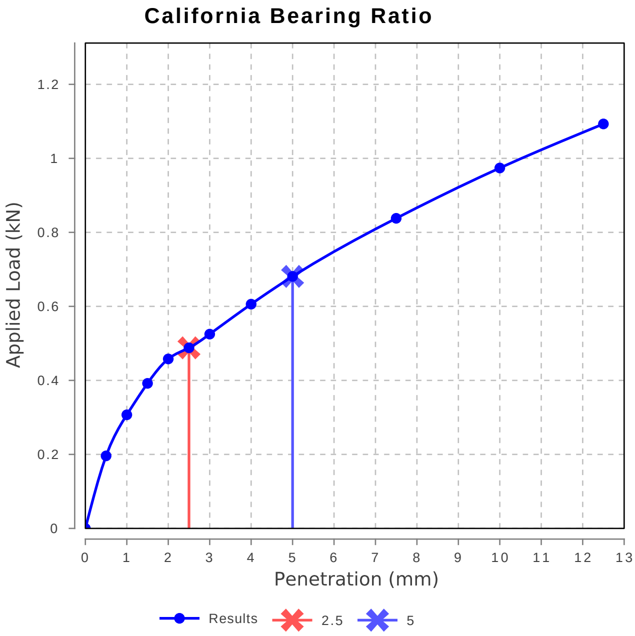
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354H
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **9 (0.5m)**
Material: SILTY CLAY - light brown mottled grey and red silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**3.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.53		
Optimum Moisture Content (%)	25.0		
Laboratory Density Ratio (%)	100.5		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.52		
Field Moisture Content (%)	28.6		
Moisture Content at Placement (%)	25.1		
Moisture Content Top 30mm (%)	28.5		
Moisture Content Rest of Sample (%)	26.0		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	1.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



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Date Issued:	22/08/2017
Client:	Greenfields Development Company 2 Pty Ltd 5 Peter Brock Drive, Oran Park NSW 2570
Contact:	Paul Hume
Project Number:	76778.29
Project Name:	Proposed Residential Subdivision
Project Location:	Pondicherry, Oran Park
Work Request:	354
Sample Number:	17-3541
Date Sampled:	10/08/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**10 (1.0m)**
Material:	SILTY CLAY - grey mottled red, light brown and dark grey silty clay

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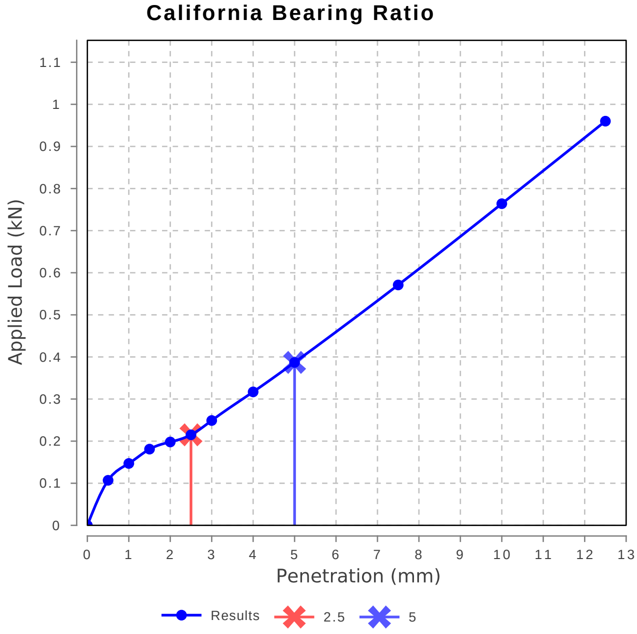
California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**2.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.69		
Optimum Moisture Content (%)	19.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	99.0		
Dry Density after Soaking (t/m^3)	1.64		
Field Moisture Content (%)	23.5		
Moisture Content at Placement (%)	19.4		
Moisture Content Top 30mm (%)	24.0		
Moisture Content Rest of Sample (%)	20.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	3.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



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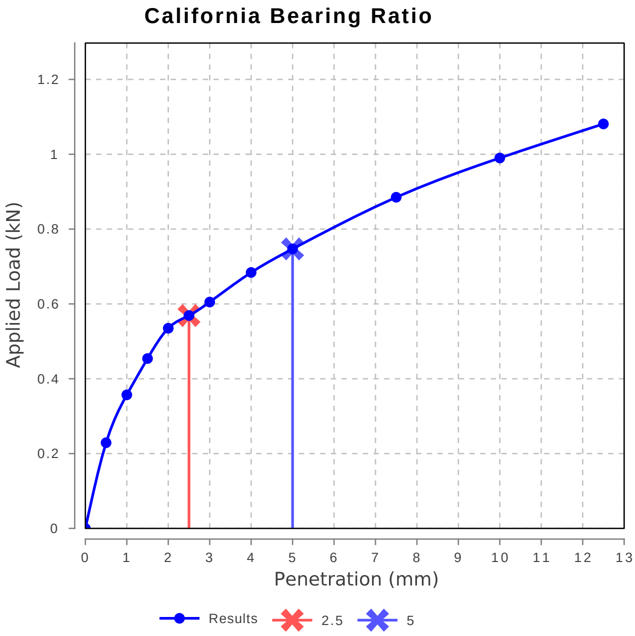
5 Peter Brock Drive, Oran Park NSW 2570
Contact: Paul Hume
Project Number: 76778.29
Project Name: Proposed Residential Subdivision
Project Location: Pondicherry, Oran Park
Work Request: 354
Sample Number: 17-354J
Date Sampled: 10/08/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **11 (1.0m)**
Material: SILTY CLAY - red mottled grey silty clay

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**4.5**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.93		
Optimum Moisture Content (%)	15.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	102.0		
Dry Density after Soaking (t/m^3)	1.91		
Field Moisture Content (%)	16.0		
Moisture Content at Placement (%)	15.6		
Moisture Content Top 30mm (%)	17.7		
Moisture Content Rest of Sample (%)	16.1		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Appendix D1

CSIRO Publication

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.

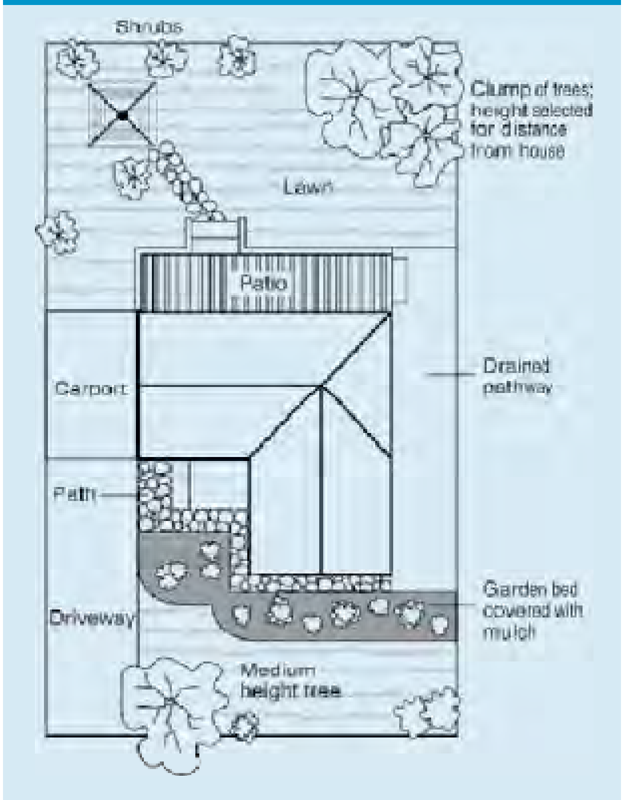
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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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