Geotechnical Site Classification
Stage 1 Potters Lane, Raymond Terrace

Ref: P990 – R – 001 – Rev.0
Written by: Matthew Lay (Senior Geotechnical Engineer)
Reviewed by: Nathan Roberts (Geotechnical Engineering Manager)
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Client: EP Risk Management Pty Ltd

<table>
<thead>
<tr>
<th>Job Number</th>
<th>Report Type</th>
<th>Report Number</th>
<th>Revision Number</th>
<th>Author</th>
<th>Reviewer</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>P990</td>
<td>R-</td>
<td>001</td>
<td>0</td>
<td>Matthew Lay</td>
<td>Nathan Roberts</td>
<td>28/02/2017</td>
</tr>
</tbody>
</table>
28/02/2017

Dear Sir,

RE: Subdivision Lot Classification,
Stage 1 Potters Lane, Raymond Terrace
Geotechnical Site Classification Report

As requested by EP Risk Management Pty Ltd, Valley Civilab Pty Ltd have performed a geotechnical site investigation for the purpose of a Site Classification to AS 2870-2011 with Foundation Parameter Recommendations. The following report (Ref: P990 – R – 001 – Rev.0) outlines the geotechnical conditions found at Lot 101 to Lot 129 Potters Lane, Raymond Terrace, including site classification, suitable foundation recommendations and bearing capacities.

If you have further questions or queries regarding the attached report, please contact the signatory below.

For and on behalf of
Valley Civilab Pty Ltd

Nathan Roberts
Geotechnical Engineering Manager
Bachelor of Engineering (Civil)
1. **Introduction**

At the request of EP Risk Management Pty Ltd, Valley Civilab Pty Ltd (VC) have carried out a limited geotechnical investigation for the purpose of a site classification for lots 101 to 129 Stage 1 Potters Lane, Raymond Terrace subdivision.

The development consists of the subdivision of 29 residential lots.

The purpose of the investigation was to provide recommendations on the following:

- Surface and Sub-surface conditions;
- Laboratory testing results;
- Site preparation;
- Excavation conditions;
- Suitability of site soils for fill and founding conditions;
- Site Classification to AS 2870-2011;
- Alternative footing types and foundation design parameters.

2. **Site Description**

The site was located at Stage 1 Potters Lane development at 44 Rees James Road, Raymond Terrace NSW. The site was bordered by James Rees Road to the southeast and rural/farmland on all other sides.

At the time of the investigation development included works associated with the subdivision. These included the construction of new asphalt roads with concrete footpaths and some cutting/filling retained with blockwork retaining walls.

At the time of the investigation vegetation had been removed with some large trees and grass surrounding the site.

Topographically the site slopes have been altered. Currently the site slopes vary between 0% and 10% with a general slope down towards the north/northwest.

3. **Preliminary Site Investigation**

3.1 **Geological and Soil Landscape Setting**

Reference to the 1:100,000 (sheet 9231) Newcastle Geological Map indicates that the site is underlain by the Dalwood Group consisting of sandstone, siltstone, mudstone, shale, conglomerate, tuff, basalt and erratics.

Reference to the Newcastle 1:100,000 Soil Landscapes Sheet indicates that the site is underlain by the Bolwarra Heights soil landscape. The Bolwarra Heights soil landscape is characterised by rolling low hills on Permian sediments in the centre-west of sheet in the East Maitland Hills region. Local slopes are generally 5% to 20% on local reliefs of 80m. The landscape is cleared, tall open-forest. Soils for the landscape consist of moderately deep, well-drained yellow podzolic soils, red podzolic soils and brown podzolic soils with some moderately deep, well-drained lithosols on crests and moderately deep imperfectly drained yellow soloths on lower slopes.
3.2 Mine Subsidence
Reference to the Mine Subsidence Board’s Mine Subsidence District Maps indicates that the site lies within an area of no known mine subsidence.

4. Methodology
Fieldwork was undertaken on 16 February 2017 and consisted of:

- a visual assessment of the existing surface of the site and surrounding area;
- the drilling of twenty-two (22) boreholes (BH1-BH22) to depths of up to 3.0m;
- the driving of twenty-two (22) Dynamic Cone Penetrometer probes at BH locations;
- recovery of twenty (20) undisturbed soil sample for laboratory testing.

Laboratory testing consisted of:

- fifteen (15) Shrink Swell Index tests

5. Subsurface Conditions
The subsurface conditions encountered at the site have been summarised into the following units:

UNIT 1 – Topsoil: Sandy SILT, brown/pale brown
UNIT 2A – Fill: Sandy SILT, dark brown
UNIT 2B – Fill: Clayey SILT, brown/dark brown with sand
UNIT 2C – Fill: Sandy Clayey SILT, dark brown
UNIT 2D – Fill: Sandy CLAY, brown/red/white/grey, some boreholes with gravel
UNIT 2E – Fill: Gravelly Sandy SILT, dark brown
UNIT 2F – Fill: Sandy Gravelly CLAY, brown/dark brown/red/orange or brown/dark brown/yellow/white
UNIT 2G – Fill: Clayey Gravelly SAND, light brown
UNIT 3A – Alluvium: Sandy CLAY, dark brown/mottled red/mottled brown, with gravel
UNIT 4A – Residual: Silty CLAY, brown/mottled orange/mottled red
UNIT 4A – Residual: Sandy CLAY, brown/mottled red/mottled orange
UNIT 5A – Bedrock: Weathered Clayey SANDSTONE, light grey/mottled red/mottled orange
UNIT 5A – Bedrock: Weathered SANDSTONE, light grey/white/red/brown

A summary of the soil subsurface unit profiles encountered in each borehole can be seen below in Table 5.1.
Table 5.1 – Summary of soil and subsurface profile

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Depth (m)</th>
<th>UNIT 1</th>
<th>UNIT 2</th>
<th>UNIT 3</th>
<th>UNIT 4</th>
<th>UNIT 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH1</td>
<td>1.5</td>
<td>--</td>
<td>0.0-0.15</td>
<td>--</td>
<td>0.15-0.5</td>
<td>0.5-1.0</td>
</tr>
<tr>
<td>BH2</td>
<td>2.0</td>
<td>--</td>
<td>0.0-0.3</td>
<td>--</td>
<td>0.3-1.0</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>BH3</td>
<td>2.7</td>
<td>--</td>
<td>0.0-0.45</td>
<td>--</td>
<td>0.45-1.4</td>
<td>1.4-2.7</td>
</tr>
<tr>
<td>BH4</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.4</td>
<td>--</td>
<td>1.4-2.2</td>
<td>2.2-3.0</td>
</tr>
<tr>
<td>BH5</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.5</td>
<td>--</td>
<td>1.5-2.0</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>BH6</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.2</td>
<td>--</td>
<td>1.2-2.6</td>
<td>2.6-3.0</td>
</tr>
<tr>
<td>BH7</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.0</td>
<td>--</td>
<td>1.0-1.4</td>
<td>1.4-3.0</td>
</tr>
<tr>
<td>BH8</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.1</td>
<td>--</td>
<td>1.1-1.4</td>
<td>1.4-3.0</td>
</tr>
<tr>
<td>BH9</td>
<td>3.0</td>
<td>--</td>
<td>0.0-1.1</td>
<td>1.1-1.5</td>
<td>1.5-1.7</td>
<td>1.7-3.0</td>
</tr>
<tr>
<td>BH10</td>
<td>2.0</td>
<td>0.0-0.2</td>
<td>--</td>
<td>--</td>
<td>0.2-1.0</td>
<td>1.0-2.0</td>
</tr>
<tr>
<td>BH11</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.4</td>
<td>--</td>
<td>0.4-1.7</td>
<td>1.7-3.0</td>
</tr>
<tr>
<td>BH12</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.5</td>
<td>--</td>
<td>0.5-1.8</td>
<td>1.8-3.0</td>
</tr>
<tr>
<td>BH13</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.5</td>
<td>--</td>
<td>0.5-1.5</td>
<td>1.5-3.0</td>
</tr>
<tr>
<td>BH14</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.4</td>
<td>--</td>
<td>0.4-1.7</td>
<td>1.7-3.0</td>
</tr>
<tr>
<td>BH15</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.3</td>
<td>--</td>
<td>0.3-1.7</td>
<td>1.7-3.0</td>
</tr>
<tr>
<td>BH16</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.3</td>
<td>--</td>
<td>0.3-1.6</td>
<td>1.6-3.0</td>
</tr>
<tr>
<td>BH17</td>
<td>2.5</td>
<td>--</td>
<td>0.0-0.2</td>
<td>--</td>
<td>0.2-2.0</td>
<td>2.0-3.0</td>
</tr>
<tr>
<td>BH18</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.3</td>
<td>--</td>
<td>0.3-1.5</td>
<td>1.5-3.0</td>
</tr>
<tr>
<td>BH19</td>
<td>1.7</td>
<td>--</td>
<td>0.0-0.2</td>
<td>--</td>
<td>0.2-1.4</td>
<td>1.4-1.7</td>
</tr>
<tr>
<td>BH20</td>
<td>3.0</td>
<td>--</td>
<td>0.0-0.2</td>
<td>--</td>
<td>0.2-1.4</td>
<td>1.4-3.0</td>
</tr>
<tr>
<td>BH21</td>
<td>1.5</td>
<td>--</td>
<td>0.0-0.2</td>
<td>--</td>
<td>0.2-1.1</td>
<td>1.1-1.5</td>
</tr>
<tr>
<td>BH22</td>
<td>1.6</td>
<td>--</td>
<td>0.0-0.2</td>
<td>--</td>
<td>0.2-1.0</td>
<td>1.0-1.6</td>
</tr>
</tbody>
</table>

Groundwater and surface water was not encountered at the site.

Refer to Annex A for the borehole location plan and Annex B for the detailed borelog reports.
6. **Laboratory Test Results**
One (1) undisturbed sample was recovered from the boreholes. The sample was transported to Valley Civilab’s NATA accredited soil testing laboratory for analysis.

The laboratory test results are summarised below in **Table 6.1**.

### Table 6.1 – Summary of Shrink Swell Laboratory test results

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Depth (m)</th>
<th>Soil Description</th>
<th>Iss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH1</td>
<td>0.4-0.8</td>
<td>Extremely Weathered Clayey SANDSTONE</td>
<td>2</td>
</tr>
<tr>
<td>BH3</td>
<td>0.5-0.7</td>
<td>Sandy CLAY</td>
<td>1.8</td>
</tr>
<tr>
<td>BH4</td>
<td>0.7-0.9</td>
<td>Fill: Sandy CLAY, with gravel</td>
<td>3.5</td>
</tr>
<tr>
<td>BH5</td>
<td>1.5-1.7</td>
<td>Silty CLAY</td>
<td>3.3</td>
</tr>
<tr>
<td>BH6</td>
<td>0.7-0.9</td>
<td>Fill: Sandy CLAY, with gravel</td>
<td>4.3</td>
</tr>
<tr>
<td>BH7</td>
<td>1.0-1.2</td>
<td>Sandy CLAY</td>
<td>3.2</td>
</tr>
<tr>
<td>BH8</td>
<td>0.6-0.9</td>
<td>Fill: Sandy Gravelly CLAY</td>
<td>4.3</td>
</tr>
<tr>
<td>BH10</td>
<td>0.5-0.7</td>
<td>Sandy CLAY</td>
<td>5.2</td>
</tr>
<tr>
<td>BH11</td>
<td>0.6-0.8</td>
<td>Sandy CLAY</td>
<td>3.2</td>
</tr>
<tr>
<td>BH13</td>
<td>0.9-1.1</td>
<td>Sandy CLAY</td>
<td>4.2</td>
</tr>
<tr>
<td>BH16</td>
<td>1.0-1.2</td>
<td>Sandy CLAY</td>
<td>2.6</td>
</tr>
<tr>
<td>BH17</td>
<td>0.4-0.6</td>
<td>Sandy CLAY</td>
<td>2.7</td>
</tr>
<tr>
<td>BH18</td>
<td>1.2-1.4</td>
<td>Sandy CLAY</td>
<td>1.5</td>
</tr>
<tr>
<td>BH20</td>
<td>0.4-0.6</td>
<td>Silty CLAY</td>
<td>2.7</td>
</tr>
<tr>
<td>BH22</td>
<td>0.6-0.8</td>
<td>Silty CLAY</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Laboratory test results from the soil sample can be found in **Annex C**.

7. **Site Classification**

7.1 **Background Information**
Site classification is based off the characteristic surface movements encountered at the site due to the moisture variations within the soil profile. Characteristic surface movements are estimated in accordance with AS2870-2011 “Residential Slabs & Footings”. Surface movement calculation take into consideration the depth of the soil profile layers, the soil reactivity and the soil suction depth.

The site classification based on characteristic surface movements are summarised below in **Table 7.1**.
Table 7.1 – Summary of AS2870-2011 characteristic surface movement & site classification

<table>
<thead>
<tr>
<th>Characteristic surface movement $(y_s)$ mm</th>
<th>Site Classification AS 2870-2011</th>
<th>Underlying Soil / Geology</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Class A</td>
<td>SAND or ROCK site (non-reactive)</td>
</tr>
<tr>
<td>0 – 20mm</td>
<td>Class S</td>
<td>CLAY (slightly reactive)</td>
</tr>
<tr>
<td>20 – 40mm</td>
<td>Class M</td>
<td>CLAY (moderately reactive)</td>
</tr>
<tr>
<td>40 – 60mm</td>
<td>Class H1</td>
<td>CLAY (highly reactive)</td>
</tr>
<tr>
<td>60 – 75mm</td>
<td>Class H2</td>
<td>CLAY (highly reactive)</td>
</tr>
<tr>
<td>&gt; 75mm</td>
<td>Class E</td>
<td>CLAY (extremely reactive)</td>
</tr>
</tbody>
</table>

Sites subjected to deep-seated moisture change are modified with the addition of “-D”.

As defined by AS2870-2011 other sites should be classified as a Class P (Problem) site. These sites include sites with:

- inadequate bearing capacity
- expected excessive foundation settlement due to loading on the foundation
- significant moisture variations
- mine subsidence risk
- slope stability risk
- erosion issues
- greater than 0.8m of fill for sand sites and greater than 0.4m for other sites (in general)

7.2 Site Classification

The proposed development should be designed in accordance with AS2870-2011 “Residential Slabs and Footings”. Based on the visual inspection, dynamic cone penetrometer tests and soil profile shown above in Section 5, the site classification is summarised below in Table 7.2

Table 7.2 – Site classification & characteristic surface movements

<table>
<thead>
<tr>
<th>Lots</th>
<th>Site Classification</th>
<th>Characteristic Surface Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>101 – 103</td>
<td>Class M</td>
<td>20 – 40mm</td>
</tr>
<tr>
<td>104 – 106</td>
<td>Class H1</td>
<td>40 – 60mm</td>
</tr>
<tr>
<td>107</td>
<td>Class H2</td>
<td>60 – 75mm</td>
</tr>
<tr>
<td>108 – 119</td>
<td>Class H1</td>
<td>40 – 60mm</td>
</tr>
<tr>
<td>120 – 129</td>
<td>Class M</td>
<td>20 – 40mm</td>
</tr>
</tbody>
</table>

Classification of the site has not taken into account the effects of abnormal moisture conditions. If the site undergoes any earthworks operations, the site shall be reclassified in accordance with AS2870-2011.
7.3 Abnormal Moisture Effects
Abnormal moisture conditions in the foundation can be caused by the following:

- Leaking water services
- Prolonged periods of draught or heavy rainfall
- Trenches or other man made water courses
- Poor roof plumbing or obstruction to the roof plumbing system
- Poor rainfall runoff control
- Corroded gutters or downpipes

Abnormal moisture conditions specified above can cause adverse effects to the development’s foundation such as:

- Erosion significantly effecting the lateral and founding support of the structure’s footing system
- Saturation of the founding material which can cause a significant decrease in the strength of the founding material
- Shrinkage creating subsidence of the founding material and causing additional stresses within the building structure
- Swelling which creates an upward force in the footings which causes additional stresses within the building structure

7.4 Effects from Trees
The existence of trees within or adjacent to the building footprint can cause significant soil movement due to the following:

- Roots growing within the foundation and causing an upward force on footings
- Roots drawing in and absorbing the moisture below a footing system causing subsidence due to shrinkage of the soil volume

The site should take into account the tree score effect in accordance with and designed to AS2870-2011. The site was found to have a “Low” tree score effect and has been taken into consideration.

7.5 Footing Recommendations
The site is suitable for the use of both shallow and deep footing systems dependant on the development and structural bearing pressure required. Refer to Section 7.5.1 and 7.5.2 below for bearing pressure parameters.

7.5.1 Shallow Footings
The maximum allowable bearing capacity of 150kPa for shallow level footings founded within soft to firm clay soils below topsoil or other deleterious material is recommended at the site.

If weathered rock is exposed at the base of the excavation of footings it is recommended that the rest of the footing system be piered / taken to bedrock to reduce the risk of differential settlement.

The footing systems must be designed by a structural engineer in accordance with engineering principles and AS 2870 - 2011 “Residential Slabs and Footings” for no less than
the minimum requirements for the site classification and soil reactivity given as per Section 7.2 above.

7.5.2 Deep Footings

The site is suitable for bored piers with an approximate Allowable End Bearing Pressures and Shaft Adhesion estimated below in Table 7.3.

**Table 7.3 – Summary of Allowable end bearing pressures and Shaft adhesion for Bored piles**

<table>
<thead>
<tr>
<th>Soil Strata</th>
<th>Allowable Shaft Adhesion (kPa)</th>
<th>Allowable End Bearing Pressure (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fill, Residual and Alluvial Clays and Sands</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>Weathered Clayey Sandstone and Sandstone</td>
<td>15</td>
<td>400</td>
</tr>
</tbody>
</table>

Notes:
1. AS2159 requires that the contribution of the pile shaft from ground surface to 1.5 piles diameters or 1m (whichever greater) shall be ignored;
2. Assumes minimum embedment depth of 1 x pile diameter into the founding stratum and a total pile depth of at least 5 x pile diameters;
3. The depth of the founding stratum may vary across the building area;
4. Assumes a clean socket with roughness category of R2 or better as defined by Walker and Pells (1998);
5. Allowable bearing capacities are based on a limiting settlement of 1% of the pile diameter and shaft adhesion values include a FOS of 2.5.
6. It should also be considered that for piles designed to resist uplift (tension) loads we recommend a shaft adhesion value of 50% of the tabulated value to be adopted.

The bearing pressures presented above have been correlated from Dynamic Cone Penetration tests and should be considered as estimates only. Bearing pressures of all exposed foundation areas should be confirmed at the time of earthworks and prior to concrete pour by a qualified Geotechnical Engineer.

7.6 Footing Construction

All footings should be excavated, cleaned and inspected by a qualified Geotechnical Engineer. Concrete should be poured with minimal delay. If delays in pouring mass concrete footings is anticipated, a concrete blinding layer should be provided to protect the foundation material.

Should softening of exposed foundation occur, the effected material should be over excavated and backfilled to design footing level by engineered fill or mass concrete.

7.7 Ongoing Footing Maintenance

Foundations including effective site drainage are required to be maintained over the life of the development to ensure footing performance. Refer to Annex D for the following:

8. **Earthworks**

Any earthworks conducted at the site should be controlled in accordance with AS3798-2007 and guided by the sections below.

8.1 **Site Preparation**

It is recommended that the following be undertaken were controlled filling is to be undertaken:

1) Remove all topsoil, root effected zones, material assessed as unsuitable and other deleterious zones (noting the stripped soil is not considered suitable as engineered fill but may be considered for landscaping purposes);

2) Exposed suitable foundation areas should then be ripped 300mm and re-compacted to 100% standard maximum dry density (SMDD) at ±2% of optimum moisture content (OMC);

3) The foundation area should then be proof rolled under the supervision of an experienced geotechnical consultant;

4) any soft spots / heaving areas identified. If identified these areas should be over excavated under the direction of the geotechnical consultant and replaced with engineered fill.

8.2 **Controlled Fill**

Any earthworks conducted at the site should be controlled in accordance with AS3798-2007. Based on the soil profile shown above in **Section 5**, visual observations and in-situ Dynamic Cone Penetrometer testing, the material encountered at the site is deemed not suitable for controlled fill. If the sub-surface conditions encountered at the site during construction differ from those discussed in **Section 5**, VC should be consulted to determine if the material is suitable for controlled fill. Similarly, any won material imported from external sites should consult VC to determine if the fill is suitable for controlled fill.

8.2.1 **Compaction Criteria**

Fill material should be compacted in near-horizontal uniform layers with a maximum compacted thickness of 300mm. It is important to ensure layers are placed in such a way that provides adequate drainage and prevent ponding during construction. The thickness of fill placed during construction should take into account the compaction equipment available.

The moisture of the fill material should be controlled within a specified range of OMC in order to achieve the compaction criteria. In general, soils should be compacted within a moisture range of ±2% of OMC.

For residential developments the following compaction criteria applies:

- Cohesive Soils – 95% Minimum Density Ratio (Standard Compactive Effort)
- Non-cohesive Soils – 70% Minimum Density Index

A suitably qualified geotechnical professional must be consulted to determine that the specified compaction has been achieved.
8.3 **Excavations Conditions**

Excavations within the fill, natural soils and extremely low to very low strength rock that was encountered during the investigations is thought to be achievable with conventional earthmoving equipment such as excavators, backhoes and dozers. Very low to low strength rock may also require ripper tynes attached to excavator arms or dozers for effective excavation. Rock of low strength or greater may possibly require a 12 tonne excavator (or greater) with rock ripper or hydraulic rock hammer, depending on the degree of strength and fracturing in the rock. Excavations in rock would require minimising vibration to neighbouring residences and structures, else other methods may be required (for example pre-drilling the rock, rock sawing using diamond wire saw equipment, grinding or engaging a rock breaking and removal specialist).

Bored piers could be drilled using a 12 tonne excavator or greater with an attached auger. It is recommended that the bottom of bored pier holes should be cleaned out with the excavator fitted with a bucket attachment.


Excavations can seriously affect the stability of adjacent buildings. Careful consideration must be taken in order to prevent the collapse of partial collapse of adjacent structures.

Construction material and equipment should not be placed within the zone of influence of an excavation unless a suitably qualified geotechnical engineer has designed ground support structures to withstand these loads. The zone of influence is dependent on the material encountered at the site and is the area in which possible failures can occur.

Refer to Port Stephens Council’s development guidelines before conducting any excavation works.

8.4 **Batter Slopes**

8.4.1 **Temporary Batter Slopes**

Temporary excavations in natural material or extremely low to very low strength rock may be near vertical provided that:

- The depth does not exceed 1.5m;
- They are open for no more than 24hrs;
- No surcharge loading is applied to the surface within 2.5m of the excavation;
- No one enters the excavation e.g. workers

All other temporary batter slopes during construction should not exceed 1H:1V in soils and 1H:4V in rock and benched, planned and managed in accordance with Safe Work Australia Excavation Work Code of Practice March 2015.
8.4.2 Permanent Batter Slopes

Recommended permanent batter slopes in general are as follows:

- 2H:1V in cohesive soils (e.g. clays) or extremely to very low weathered rock else retained by an engineered retaining wall;
- 3H:1V in non-cohesive soils (e.g. sands) else retained by an engineered retaining wall;
- 1H:1V in low strength rock or greater (permanent rock batters may be steepened to near vertical – subject to inspection by a qualified geotechnical engineer).

8.5 Retaining Walls

In general, design of retaining walls requires determination of the earth pressure coefficient. This depends on the nature of the wall such that:

- Where walls are not propped and some rotation of the wall away from the support soil is permissible, the active earth pressure coefficient (Ka) may be taken as 0.35 for fill and residual soil or 0.3 for extremely low to low strength rock;
- Where the walls can move towards the support soil either during or after construction, passive earth pressures would apply. A Passive Earth Pressure coefficient (Kp) may be taken as 2.5 for fill, residual soil or extremely low to low strength rock;
- Where the walls cannot move towards or away from the support soil then the design should be undertaken using an at rest coefficient (Ko) of 0.5.

For retaining walls surcharge loads from uphill structures should be considered and it is recommended that a minimum surcharge of 5kPa be adopted for this purpose. Retaining walls in excess of 1m high should be designed by a qualified structural engineer, with adequate subsurface and surface drainage provided behind the retaining wall.
9. **Report Limitations**

The geotechnical data and recommendations within the above report are subjected to the specific sampling and testing that was undertaken at the time of the current investigation. It should be noted that underlying site soil conditions can vary significantly across a site and the environment can change overtime. If conditions encountered during construction are different to those contained in this report Valley Civilab should be contacted immediately for site reassessment.

If you have any further questions about this report, please contact the undersigned.

For and on behalf of

Valley Civilab Pty Ltd

Reported by

Matthew Lay
Senior Geotechnical Engineer
Bachelor of Engineering (Civil)

Reviewed by

Nathan Roberts
Geotechnical Engineering Manager
Bachelor of Engineering (Civil)
Annex A
Figure 1 – Plan of Potters Lane, Raymond Terrace NSW showing the approximate location of the borehole.
Annex B
### PAVEMENT CONDITION / REMARK

- Hole Terminated at 2.00 m
- Refusal

### METHOD

#### PENETRATION

- **N** Natural Exposure
- **E** Existing Excavation
- **B** Backhoe Bucket
- **B** Bulldozer Blade
- **R** Ripper

#### PENETRATION

- **W** WATER
  - No Resistance
  - 10 Oct., 73 Water Level on Date shown
  - Water inflow
  - Water outflow

#### SAMPLES & FIELD TESTS

- **U** Undisturbed Sample
- **D** Disturbed Sample
- **B** Bulk Disturbed Sample
- **MC** Moisture Content
- **PP** Pocket Penetrometer (UCS kPa)
- **VS** Vane Shear: P-Peak, R-Remoulded (uncorrected kPa)
- **PBT** Plate Bearing Test

#### CLASSIFICATION SYMBOLS & SOIL DESCRIPTION

- **VS** - Vane Shear: P-Peak, R-Remoulded (uncorrected kPa)
- **PBT** - Plate Bearing Test

#### CONSISTENCY / RELATIVE DENSITY

- **VS** - Very Soft
- **S** - Soft
- **F** - Firm
- **St** - Stiff
- **VS1** - Very Stiff
- **H** - Hard
- **VL** - Very Loose
- **L** - Loose
- **MD** - Medium Dense
- **D** - Dense
- **VD** - Very Dense

---

See Explanatory Notes for details of abbreviations & basis of descriptions.
FILL: Sandy, Clayey SILT, low plasticity, dark brown.

Sandy CLAY, medium plasticity, brown/mottled red,

Weathered SANDSTONE, fine grained, light grey/white.

Becoming with fine to medium rounded gravel at approximately 2.5m.

Hole Terminated at 2.70 m

RESIDUAL SOIL

BEDROCK

WATER inflow

WATER outflow
### Material Description

**Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>FILL: Clayey SLT, low plasticity, brown/dark brown, with fine to medium sand.</td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>FILL: Sandy CLAY, low plasticity, brown/red/white/grey, with fine gravel.</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>Sandy CLAY, high plasticity, brown/mottled red, fine sand.</td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>Silty CLAY, high plasticity, brown/mottled red.</td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>Extremely Weathered Clayey SANDSTONE, fine grained, light grey/orange.</td>
</tr>
<tr>
<td>0.50 - 0.60</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>0.60 - 0.70</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>0.70 - 0.80</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>0.80 - 1.00</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.00 - 1.20</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.20 - 1.30</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.30 - 1.40</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.40 - 1.50</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.50 - 1.60</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.60 - 1.70</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.70 - 1.80</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.80 - 1.90</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>1.90 - 2.00</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.00 - 2.10</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.10 - 2.20</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.20 - 2.30</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.30 - 2.40</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.40 - 2.50</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.50 - 2.60</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.60 - 2.70</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.70 - 2.80</td>
<td>TERMINATED</td>
</tr>
<tr>
<td>2.80 - 2.90</td>
<td>TERMINATED</td>
</tr>
</tbody>
</table>

### Pavement Condition / Remark

Hole Terminated at 3.00 m Terminated

### Method

- N: Natural Exposure
- E: Existing Excavation
- BH: Backhoe Bucket
- B: Bulldozer Blade
- R: Ripper

**Penetration**

- 10 Oct., 73 Water Level on Date shown
- Water inflow
- Water outflow

### Samples & Field Tests

- U: Undisturbed Sample
- D: Disturbed Sample
- B: Bulk Disturbed Sample
- MC: Moisture Content
- PP: Pocket Penetrometer (UCS kPa)
- VS: Vane Shear: P-Peak, R-Remouded (uncorrected kPa)
- PBT: Plate Bearing Test

### Classification Symbols & Soil Description

Based on Unified Classification System

- **Moisture**
  - D: Dry
  - M: Moist
  - W: Wet

- **Consistency/Relative Density**
  - VS: Very Soft
  - S: Soft
  - F: Firm
  - ST: Stiff
  - VST: Very Stiff
  - H: Hard
  - VL: Very Loose
  - L: Loose
  - MD: Medium Dense
  - D: Dense
  - VD: Very Dense
## Non-Core Drill Hole - Geological Log

**Project:** Subdivision Lot Classification  
**Location:** Potters Lane, Raymond Terrace

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Class</th>
<th>Soil Type, Colour, Plasticity or Particle Characteristic and Minor Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>4</td>
<td>FILL: Clayey Silt, low plasticity, brown/dark brown, with fine to medium sand.</td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>6</td>
<td>FILL: Sandy Clay, low plasticity, brown/red/white/grey, with fine gravel.</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>4</td>
<td>FILL: Gravelly, Sandy Silt, low plasticity, dark brown, fine to medium sand.</td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>9</td>
<td>Silty Clay, high plasticity, brown/mottled red.</td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>7</td>
<td>Residual Soil</td>
</tr>
<tr>
<td>0.50 - 0.60</td>
<td>5</td>
<td>Beach Sandstone, fine grained, light brown/white/orange.</td>
</tr>
<tr>
<td>0.60 - 0.70</td>
<td>6</td>
<td>Water inflow</td>
</tr>
<tr>
<td>0.70 - 0.80</td>
<td>11</td>
<td>Water outflow</td>
</tr>
<tr>
<td>0.80 - 0.90</td>
<td>6</td>
<td>2.00 - 2.10</td>
</tr>
<tr>
<td>0.90 - 1.00</td>
<td>6</td>
<td>2.10 - 2.20</td>
</tr>
<tr>
<td>1.00 - 1.10</td>
<td>6</td>
<td>2.20 - 2.30</td>
</tr>
<tr>
<td>1.10 - 1.20</td>
<td>6</td>
<td>2.30 - 2.40</td>
</tr>
<tr>
<td>1.20 - 1.30</td>
<td>8</td>
<td>2.40 - 2.50</td>
</tr>
<tr>
<td>1.30 - 1.40</td>
<td>6</td>
<td>2.50 - 2.60</td>
</tr>
</tbody>
</table>

**Drilling Method:** Natural Exposure

**Penetration:** 4-6

**Samples & Field Tests:**
- U - Undisturbed Sample
- D - Disturbed Sample
- B - Bulk Disturbed Sample
- MC - Moisture Content
- PP - Pocket Penetrometer (UCS kPa)
- VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- PBT - Plate Bearing Test

**Classification Symbols & Soil Description:** Based on Unified Classification System

**Moisture:**
- D - Dry
- M - Moist
- W - Wet

**Consistency:**
- VS - Very Soft
- S - Soft
- F - Firm
- St - stiff
- VSt - Very Stiff
- H - Hard
- VL - Very Loose
- L - Loose
- MD - Medium Dense
- D - Dense
- VD - Very Dense

**Pavement Condition / Remark:** Hole Terminated at 3.00 m Terminated

For more details, see Explanatory Notes for details of abbreviations & basis of descriptions.
### MATERIAL DESCRIPTION

#### Soil Type, Colour, Plasticity or Particle Characteristic

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Classification</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>FILL</td>
<td>Clayey Silt, low plasticity, brown/dark brown, with fine to medium sand.</td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>FILL</td>
<td>Sandy Clay, low plasticity, brown/red/white/grey, with fine gravel.</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>FILL</td>
<td>Sandy Clay, medium plasticity, brown/light brown/mottled orange.</td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>FILL</td>
<td>Sandy Clay, medium to high plasticity, light grey/mottled yellow/mottled yellow brown.</td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>RESIDUAL SOIL / ALLUVIUM</td>
<td>Extremely Weathered Clayey Sandstone, fine to medium grained, light brown/white/orange.</td>
</tr>
<tr>
<td>0.50 - 0.60</td>
<td>RESIDUAL SOIL</td>
<td>Mixed clayey sand and silt.</td>
</tr>
<tr>
<td>0.60 - 0.70</td>
<td>RESIDUAL SOIL</td>
<td>Fine to medium grained sand and silt.</td>
</tr>
</tbody>
</table>

### PENETRATION TESTS

- **LAB SOAKED CBR**
- **DCP AS 1289.6.3.2-1997**

### METHOD

- **N** - Natural Exposure
- **B** - Backhoe Bucket
- **R** - Ripper

### SAMPLES & FIELD TESTS

- **U** - Undisturbed Sample
- **D** - Disturbed Sample
- **MC** - Moisture Content
- **PP** - Pocket Penetrometer (UCS kPa)
- **VANE** - Vane Shear: P-Peak, R-Remoulded (uncorrected kPa)
- **PBT** - Plate Bearing Test

### CONSISTENCY

- **VS** - Very Soft
- **D** - Dry
- **S** - Soft
- **M** - Moist
- **F** - Firm
- **V** - Very Stiff
- **H** - Hard
- **L** - Loose
- **VL** - Very Loose
- **MD** - Medium Dense
- **VD** - Very Dense

### Classifications

- **Clayey Silt**
- **Sandy Clay**
- **Residual Soil**

---

See Explanatory Notes for details of abbreviations & basis of descriptions.
### Material Description

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type, Colour, Plasticity or Particle Characteristic Secondary and Minor Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>Fill: Sandy silt, low plasticity, dark brown, fine sand.</td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>Fill: Sandy, gravelly clay, medium plasticity, brown/dark brown/orange.</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>Sandy clay, high plasticity, brown/light grey/orange.</td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>Extremely weathered clayey sandstone, fine grained, brown/light brown/orange, trace of gravel.</td>
</tr>
</tbody>
</table>

### Pavement Condition / Remark

Hole Terminated at 3.00 m Terminated

### Method

- **Penetration**: DCP AS 1289.6.3.2-1997
- **Samples & Field Tests**: Undisturbed Sample, Disturbed Sample, Moisture Content, Pocket Penetrometer (UCS kPa), Vane Shear: P-Peak, R-Remoulded (uncorrected kPa), Plate Bearing Test
- **Classification Symbols & Soil Description**: Based on Unified Classification System
- **Moisture**: Very Soft - Soft - Firm - Stiff - Very Stiff - Hard
- **Consistency**: Very Loose - Loose - Medium Dense - Dense - Very Dense

### Dates

- **Date Started**: 16/02/2017
- **Date Completed**: 16/02/2017
- **Date Logged**: 16/02/2017

### Additional Information

- **Project**: Subdivision Lot Classification
- **Location**: Potters Lane, Raymond Terrace
- **Contractor**: Valley Civil

See Explanatory Notes for details of abbreviations & basis of descriptions.
**Material Description**

- **0.00 - 0.10 m:** FILL: Sandy Silt, low plasticity, dark brown, fine sand.
- **0.10 - 0.20 m:** FILL: Sandy, Gravelly Clay, medium plasticity, brown/dark brown/yellow/white, fine sand, fine gravel.
- **0.20 - 0.30 m:** Sandy Clay, high plasticity, light brown/light grey/orange.
- **0.30 - 0.40 m:** Weathered Clayey Sandstone, fine to medium grained, light brown/orange/brown.
- **0.40 - 0.50 m:** Residual Soil
- **0.50 - 0.60 m:** Bedrock
- **0.60 - 0.70 m:**
- **0.70 - 0.80 m:**
- **0.80 - 0.90 m:**
- **0.90 - 1.00 m:**
- **1.00 - 1.10 m:**
- **1.10 - 1.20 m:**
- **1.20 - 1.30 m:**
- **1.30 - 1.40 m:**
- **1.40 - 1.50 m:**
- **1.50 - 1.60 m:** Natural Exposure
- **1.60 - 1.70 m:** Existing Excavation
- **1.70 - 1.80 m:** Backhoe Bucket
- **1.80 - 1.90 m:** Bulldozer Blade
- **1.90 - 2.00 m:** Ripper
- **2.00 - 2.10 m:** Buldozer Blade
- **2.10 - 2.20 m:** Ripper
- **2.20 - 2.30 m:** Bulk Disturbed Sample
- **2.30 - 2.40 m:** Moisture Content
- **2.40 - 2.50 m:** Plate Bearing Test

**Method**

- **N:** Natural Exposure
- **E:** Existing Excavation
- **BH:** Backhoe Bucket
- **B:** Bulldozer Blade
- **R:** Ripper

**Samples & Field Tests**

- **U:** Undisturbed Sample
- **D:** Disturbed Sample
- **MC:** Moisture Content
- **PP:** Pocket Penetrometer (UCS kPa)
- **VS:** Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- **PBT:** Plate Bearing Test

**Classification Symbols & Soil Description**

- **MOISTURE:**
  - **D:** Dry
  - **M:** Moist
  - **W:** Wet
- **CONSISTENCY:**
  - **S:** Soft
  - **F:** Firm
  - **St:** Stiff
  - **H:** Hard
  - **VL:** Very Loose
  - **MD:** Medium Dense
  - **D:** Dense
- **RELATIVE DENSITY:**
  - **VS:** Very Soft
  - **S:** Soft
  - **F:** Firm
  - **St:** Stiff
  - **H:** Hard
  - **VL:** Very Loose
  - **MD:** Medium Dense
  - **D:** Dense

See Explanatory Notes for details of abbreviations & basis of descriptions.
### Non-Core Drill Hole - Geological Log

**Project:** Subdivision Lot Classification  
**Location:** Potters Lane, Raymond Terrace

**Date Started:** 16/02/2017  
**Date Completed:** 16/02/2017  
**Date Logged:** 16/02/2017  
**Logged By:** ML  
**Checked By:** ML

**Rig Type:** Drill Rig  
**Mounting:** Trailer Mounted  
**Contractor:**  
**Driller:**

**Hole No.:** BH9  
**File/Job No.:** P990  
**Sheet:** 1 of 1

#### Drilling

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Core</th>
<th>Cuts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0.50 - 0.60</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0.60 - 0.70</td>
<td>11.50</td>
<td></td>
</tr>
<tr>
<td>0.70 - 0.80</td>
<td>Refuse</td>
<td></td>
</tr>
</tbody>
</table>

**Material Description:**
- **FILL:** Sandy Silt, low plasticity, dark brown, fine sand.
- **FILL:** Clayey, gravelly sand, fine to coarse grained, light brown.
- **FILL:** Sandy clay, medium plasticity, brown/dark brown/red, with fine gravel.
- Sandy clay, high plasticity, dark brown/mottled red/mottled brown, fine sand, with fine gravel.
- Sandy CLAY, high plasticity, grey/mottled brown.
- Weathered clayey sandstone, fine grained, light grey/light brown/orange.

**Structure & Other Observations:**
- **HOLE TERMINATED AT 3.00 m**

**Pavement Condition / Remark:** Hole Terminated at 3.00 m Terminated

#### Method

- **Penetration:**  
  - N: Natural Exposure  
  - E: Existing Excavation  
  - BH: Backhoe Bucket  
  - B: Bulldozer Blade  
  - R: Ripper

- **Samples & Field Tests:**
  - U: Undisturbed Sample  
  - D: Disturbed Sample  
  - MC: Moisture Content  
  - PP: Pocket Penetrometer (UCS kPa)  
  - VS: Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)  
  - PBT: Plate Bearing Test

- **Classification Symbols & Soil Description:**
  - Based on Unified Classification System

- **Moisture:**
  - D: Dry  
  - M: Moist  
  - W: Wet

- **Consistency:**
  - VS: Very Soft  
  - S: Soft  
  - F: Firm  
  - St: Stiff  
  - VSt: Very Stiff  
  - H: Hard  
  - VL: Very Loose  
  - L: Loose  
  - MD: Medium Dense  
  - D: Dense  
  - VD: Very Dense

**See Explanatory Notes for details of abbreviations & basis of descriptions.**
## DRILLING

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Bentonite</th>
<th>Blow</th>
<th>Core</th>
<th>Undrilled Log</th>
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</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.40 - 0.50</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50 - 0.60</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.60 - 0.70</td>
<td>1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0.70 - 0.80</td>
<td>750</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.80 - 0.90</td>
<td>Refusal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## MATERIAL

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>Colour</th>
<th>Plasticity</th>
<th>Particle Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20m</td>
<td>Topsoil</td>
<td>Sandy SILT</td>
<td>Low plasticity</td>
<td>Brown/pale brown.</td>
</tr>
<tr>
<td>0.20m</td>
<td>Sandy CLAY</td>
<td>High plasticity</td>
<td>Brown/grey, fine sand.</td>
<td></td>
</tr>
<tr>
<td>1.00m</td>
<td>Weathered SANDSTONE</td>
<td>Fine grained</td>
<td>Light grey/light brown/orange.</td>
<td></td>
</tr>
</tbody>
</table>

## CLASSIFICATION SYMBOLS & SOIL DESCRIPTION

- **U**: Undisturbed Sample
- **D**: Disturbed Sample
- **B**: Bulk Disturbed Sample
- **MC**: Moisture Content
- **PP**: Pocket Penetrometer (UCS kPa)
- **VS**: Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- **PBT**: Plate Bearing Test

## PENETRATION

**N**: Natural Exposure
**E**: Existing Excavation
**BH**: Backhoe Bucket
**B**: Bulldozer Blade
**R**: Ripper

**No Resistance**

**WATER**

10 Oct., 73 Water Level on Date shown

- Water inflow
- Water outflow

## CONSISTENCY

- **D**: Dry
- **M**: Moist
- **W**: Wet

## RELATIVE DENSITY

- **VS**: Very Soft
- **S**: Soft
- **F**: Firm
- **St**: Stiff
- **VSt**: Very Stiff
- **H**: Hard
- **VL**: Very Loose
- **L**: Loose
- **MD**: Medium Dense
- **D**: Dense
- **VD**: Very Dense
**NON-CORE DRILL HOLE - GEOLOGICAL LOG**

**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace

**RIG TYPE:** Drill Rig  
**MOUNTING:** Trailer Mounted  
**CONTRACTOR:**  
**DRILLER:**  
**DATE STARTED:** 16/02/2017  
**DATE COMPLETED:** 16/02/2017  
**DATE LOGGED:** 16/02/2017  
**LOGGED BY:** ML  
**CHECKED BY:** ML

**FILE / JOB NO:** BH11  
**FILE / JOB NO:** P990  
**SHEET:** 1 OF 1

---

**MATERIAL DESCRIPTION**

- **Soil Type, Colour, Plasticity or Particle Characteristic**
- **Secondary and Minor Components**

**MOISTURE & CONSISTENCY RELATIVE DENSITY**

**STRUCTURE & Other Observations**

---

**SAMPLES & FIELD TESTS**

- **Undisturbed Sample**
- **Disturbed Sample**
- **Pocket Penetrometer (UCS kPa)**
- **Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)**
- **Plate Bearing Test**

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**

Based on Unified Classification System

**MOISTURE**

- **Dry**
- **Moist**
- **Wet**

**CONSISTENCY RELATIVE DENSITY**

- **Very Soft**
- **Soft**
- **Firm**
- **Stiff**
- **Very Stiff**
- **Hard**
- **Very Loose**
- **Loose**
- **Medium Dense**
- **Dense**
- **Very Dense**

---

**METHOD**

- **Natural Exposure**
- **Existing Excavation**
- **Backhoe Bucket**
- **Bulldozer Blade**
- **Ripper**

**PENETRATION**

- **No Resistance**

---

**PAVEMENT CONDITION / REMARK**

- Hole Terminated at 3.00 m

---

**Date:** 16/02/2017  
**File:** P990 BH11  1 OF 1

---

See Explanatory Notes for details of abbreviations & basis of descriptions.
### Drilling Log

**Location:** Potters Lane, Raymond Terrace

**Date Started:** 16/02/2017  
**Date Completed:** 16/02/2017  
**Date Logged:** 16/02/2017

**Non-Core Drill Hole - Geological Log**

**Material Description:**
- **Soil Type, Colour, Plasticity or Particle Characteristics**
- **Secondary and Minor Components**

**Consistency / Relative Density**

**Moisture**
- **D** - Dry
- **M** - Moist
- **W** - Wet

**Penetration**
- **Hole Terminated at 3.00 m**

**Samples & Field Tests**
- **UCS kPa**
- **P-Peak, R-Remoulded (uncorrected kPa)**
- **Plate Bearing Test**
- **Pocket Penetrometer (UCS kPa)**
- **Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)**

**Pavement Condition / Remark**
- **Terminated**

**Method**
- **N** - Natural Exposure
- **E** - Existing Excavation
- **BH** - Backhoe Bucket
- **B** - Bulldozer Blade
- **R** - Ripper

**Penetration**
- **No Resistance**

**Surface Elevation**

**Angle from Horizontal:** 90°

**Rig Type:** Drill Rig  
**Mounting:** Trailer Mounted

**Contractor:**

**Driller:**

**Checked By:** ML  
**Logged By:** ML

**File:** P990 BH12  
**Job No:** P990  
**Sheet:** 1 of 1

---

**See Explanatory Notes for details of abbreviations & basis of descriptions.**
**NON-CORE DRILL HOLE - GEOLOGICAL LOG**

**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace

**DRILLING**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Black</th>
<th>Clay</th>
<th>Undisturbed</th>
<th>0.00 - 0.10</th>
<th>5</th>
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<tr>
<td>0.10 - 0.20</td>
<td>6</td>
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<tr>
<td>0.20 - 0.30</td>
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<td>1.50 - 1.60</td>
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<tr>
<td>2.90 - 3.00</td>
<td>3</td>
<td></td>
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</tr>
</tbody>
</table>

**SAMPLES & FIELD TESTS**

- **U** - Undisturbed Sample  
- **D** - Disturbed Sample  
- **MC** - Moisture Content  
- **PP** - Pocket Penetrometer (UCS kPa)  
- **VS** - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)  
- **PBT** - Plate Bearing Test

**METHOD**

- **N** - Natural Exposure  
- **E** - Existing Excavation  
- **BH** - Backhoe Bucket  
- **B** - Bulldozer Blade  
- **R** - Ripper

**CONSISTENCY/RELATIVE DENSITY**

- **VS** - Very Soft  
- **S** - Soft  
- **F** - Firm  
- **St** - Stiff  
- **VSt** - Very Stiff  
- **H** - Hard  
- **VL** - Very Loose  
- **L** - Loose  
- **MD** - Medium Dense  
- **D** - Dense  
- **VD** - Very Dense

**EQUIPMENT**

- **BH13**

**REFERENCES**

- **Degree of Water Inflow**  
- **Degree of Water Outflow**

**PENETRATION**

- **No Resistance**

**PAVEMENT CONDITION / REMARK**

- Hole Terminated at 3.00 m Terminated

See Explanatory Notes for details of abbreviations & basis of descriptions.
**NON-CORE DRILL HOLE - GEOLOGICAL LOG**

**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace  
**RIG TYPE:** Drill Rig  
**MOUNTING:** Trailer Mounted  
**CONTRACTOR:**  
**DRILLER:**  
**DATE STARTED:** 16/02/2017  
**DATE COMPLETED:** 16/02/2017  
**DATE LOGGED:** 16/02/2017  
**LOGGED BY:** ML  
**CHECKED BY:** ML

---

### MATERIAL

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Colour</th>
<th>Plasticity</th>
<th>Particle Characteristic</th>
<th>Secondary and Minor Components</th>
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</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>Sandy Silt, low plasticity, brown/dark brown.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10 - 0.20</td>
<td>Silty Clay, high plasticity, brown/green/mottled red.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3.00 - 3.70</td>
<td>Weathered Clayey Sandstone, fine grained, light brown/light grey/mottled orange/mottled red.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**METHOD**

- **N:** Natural Exposure
- **E:** Existing Excavation
- **BH:** Backhoe Bucket
- **B:** Bulldozer Blade
- **R:** Ripper

**SAMPLING & FIELD TESTS**

- **N:** Undisturbed Sample
- **D:** Disturbed Sample
- **MC:** Moisture Content
- **PP:** Pocket Penetrometer (UCS kPa)
- **VS:** Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- **PBT:** Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**

- **VS:** Very Soft
- **S:** Soft
- **F:** Firm
- **St:** Stiff
- **VSh:** Very Stiff
- **H:** Hard
- **VL:** Very Loose
- **L:** Loose
- **MD:** Medium Dense
- **D:** Dense
- **VD:** Very Dense

**CONSISTENCY/RELATIVE DENSITY**

- **F:** Firm
- **St:** Stiff
- **VSh:** Very Stiff
- **H:** Hard
- **VL:** Very Loose
- **L:** Loose
- **MD:** Medium Dense
- **D:** Dense
- **VD:** Very Dense

---

**PAVEMENT CONDITION / REMARK**

- Hole Terminated at 3.00 m Terminated
**NON-CORE DRILL HOLE - GEOLOGICAL LOG**

**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace  
**HOLE NO.:** BH16  
**FILE / JOB NO.:** P990  
**SHEET:** 1 OF 1

**RIG TYPE:** Drill Rig  
**MOUNTING:** Trailer Mounted  
**CONTRACTOR:**  
**DRILLER:**  
**DATE STARTED:** 16/02/2017  
**DATE COMPLETED:** 16/02/2017  
**DATE LOGGED:** 16/02/2017  
**LOGGED BY:** ML  
**CHECKED BY:** ML

**METHOD:**  
**PENETRATION:**  

**WATER**  
- **10 Oct., 73 Water Level on Date shown**  
- **water inflow**  
- **water outflow**

**SAMPLES & FIELD TESTS**  
- **U** - Undisturbed Sample  
- **D** - Disturbed Sample  
- **B** - Bulk Disturbed Sample  
- **MC** - Moisture Content  
- **PP** - Pocket Penetrometer (UCS kPa)  
- **VS** - Vane Shear: P-Peak, R-Remoulded (uncorrected kPa)  
- **PBT** - Plate Bearing Test

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**  
Based on Unified Classification System

**MOISTURE**  
- **D** - Dry  
- **M** - Moist  
- **W** - Wet

**CONSISTENCY**  
- **VS** - Very Soft  
- **S** - Soft  
- **F** - Firm  
- **St** - Stiff  
- **SIt** - Very Stiff  
- **H** - Hard  
- **VL** - Very Loose  
- **L** - Loose  
- **MD** - Medium Dense  
- **D** - Dense  
- **VD** - Very Dense

**CONSISTENCY & OTHER OBSERVATIONS**

**SAMPLES & FIELD TESTS**

**PAVEMENT CONDITION / REMARK**

**PENETRATION**

**GRAPHIC LOG**

**LOG**

**MOISTURE & CONSISTENCY**

**CONSISTENCY & RELATIVE DENSITY**

**SAMPLING & FIELD TESTS**

**CLASSIFICATION SYMBOLS & SOIL DESCRIPTION**

**BASED ON UNIFIED CLASSIFICATION SYSTEM**

**MATERIAL DESCRIPTION**

**SOIL TYPE, COLOUR, PLASTICITY OR PARTICLE CHARACTERISTIC SECONDARY AND MINOR COMPONENTS**

**FILL:** Sandy Silt, low plasticity, brown/dark brown.  
**RESIDUAL SOIL:** Silty Clay, high plasticity, brown/green/mottled red.  
**BULKY DISTURBED SAMPLE:** Weathered Clayey Sandstone, fine grained, light brown/light grey/mottled orange/mottled red.

**DRILLING**

**DEPTH (m)**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>Colour</th>
<th>Plasticity</th>
<th>Particle Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 - 0.10</td>
<td>FILL</td>
<td>Sandy Silt</td>
<td>low plasticity</td>
<td>brown/dark brown</td>
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<tr>
<td>0.10 - 0.20</td>
<td>RESIDUAL SOIL</td>
<td>Silty Clay</td>
<td>high plasticity</td>
<td>brown/green/mottled red</td>
</tr>
<tr>
<td>0.20 - 0.30</td>
<td>M</td>
<td>Weathered Clayey Sandstone</td>
<td>fine grained</td>
<td>light brown/light grey/mottled orange/mottled red</td>
</tr>
</tbody>
</table>

**HOLE TERMINATED AT 3.00 m**

**SURFACE ELEVATION:**  
**ANGLE FROM HORIZONTAL:** 90°

**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace  
**FILE / JOB NO.:** P990  
**SHEET:** 1 OF 1

**See Explanatory Notes for details of abbreviations & basis of descriptions.**
Soil Type, Colour, Plasticity or Particle Characteristic

Secondary and Minor Components

CLASSIFICATION SYMBOL

Moisture

Consistency

Relative Density

Pavement Condition / Remark

Penetration

Samples & Field Tests

Classification Symbols & Soil Description

Based on Unified Classification System

Sample & Field Tests

Method

N - Natural Exposure
E - Existing Excavation
BH - Backhoe Bucket
B - Bulldozer Blade
R - Ripper

Penetration

U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remouded (uncorrected kPa)
PBT - Plate Bearing Test

Consistency / Relative Density

VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSt - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

M - Moist
W - Wet
### Non-Core Drill Hole - Geological Log

**HOLE NO:** BH18  
**PROJECT:** Subdivision Lot Classification  
**LOCATION:** Potters Lane, Raymond Terrace

**RIG TYPE:** Drill Rig  
**MOUNTING:** Trailer Mounted  
**CONTRACTOR:**  
**DRILLER:**  
**DATE STARTED:** 16/02/2017  
**DATE COMPLETED:** 16/02/2017  
**DATE LOGGED:** 16/02/2017  
**LOGGED BY:** ML  
**CHECKED BY:** ML

#### Drilling

<table>
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<th>Depth (m)</th>
<th>CHIPS</th>
<th>UNDRAILED LOG</th>
<th>SAMPLES &amp; FIELD TESTS</th>
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<tr>
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<td>0.10 - 0.20</td>
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<td>0.20 - 0.30</td>
<td>7</td>
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<td>0.30 - 0.40</td>
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<tr>
<td>0.40 - 0.50</td>
<td>2</td>
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<tr>
<td>0.50 - 0.60</td>
<td>3</td>
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<tr>
<td>0.60 - 0.70</td>
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<tr>
<td>0.70 - 0.80</td>
<td>2</td>
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<td>0.90 - 1.00</td>
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<td>1.20 - 1.30</td>
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<tr>
<td>1.30 - 1.40</td>
<td>12</td>
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<tr>
<td>1.40 - 1.50</td>
<td>Terminated</td>
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</tbody>
</table>

#### Material

**Material Description**

- **Soil Type:** Various soil types, including fill, residual soil, and bedrock.
- **Soil Characteristics:** Sandy silt, low plasticity, dark brown, fine sand; silty clay, high plasticity, brown/mottled red; weathered clayey sandstone, fine grained, light brown/light grey/mottled orange/mottled red.
- **Depth:** Material descriptions are provided at various depths, up to 1.50 meters.

**Molesure & Consistency**

- **Consistency:** Generally, the material shows varying degrees of moisture and consistency.

**Penetration & Other Observations**

- **No Resistance**
- **WATER:** 10 Oct., 73 Water Level on Date shown
- **Structural & Other Observations:** Various observations made during the drilling process.

**Pavement Condition / Remark**

- Hole Terminated at 3.00 m

**Classifications & Soil Description**

- Based on Unified Classification System

**Method**

- **Natural Exposure**
- **Existing Excavation**
- **Backhoe Bucket**
- **Bulldozer Blade**
- **Ripper**

**See Explanatory Notes for details of abbreviations & basis of descriptions.
FILL: Sandy SILT, low plasticity, dark brown, fine sand. Becoming with gravel at approximately 0.1m.
**MATERIAL DESCRIPTION**
Soil Type, Colour, Plasticity or Particle Characteristic
Secondary and Minor Components

- **FILL:** Sandy SILT, low plasticity, dark brown, fine sand.
- **Silty CLAY:** High plasticity, brown/mottled red.
- **Weathered Clayey SANDSTONE:** Fine grained, light grey/mottled red.

**MOISTURE**
Consistency / Relative Density

- **D:** Very Loose
- **L:** Loose
- **VL:** Very Loose
- **S:** Soft
- **F:** Firm
- **St:** Stiff
- **VS:** Very Soft
- **VSt:** Very Stiff
- **H:** Hard
- **VL:** Very Loose
- **MD:** Medium Dense
- **D:** Dense
- **VD:** Very Dense

**CONSISTENCY / RELATIVE DENSITY**

- **VCL 2.02.2 LIB.GLB  Log  IS AU PAVEMENTS 2  P990.GPJ  <<DrawingFile>>  28/02/2017 11:30  10.0.000  Datgel Lab and In Situ Tool - DGD | Lib: VCL 2.02.2 2016-04-08 Prj: VCL 2.02 2016-04-04**

**METHOD**

- **SAMPLES & FIELD TESTS**
  - **U:** Undisturbed Sample
  - **D:** Disturbed Sample
  - **B:** Bulk Disturbed Sample
  - **MC:** Moisture Content
  - **PP:** Pocket penetrometer (UCS kPa)
  - **VS:** Vane Shear: P-Peak, R-Remoulded (uncorrected kPa)
  - **PBT:** Plate Bearing Test

- **CONSISTENCY / RELATIVE DENSITY**
  - **D:** Dry
  - **M:** Moist
  - **W:** Wet

**PENETRATION**

- **WATER**
  - **10 Oct., 73 Water Level on Date shown water inflow**
  - **water outflow**

See Explanatory Notes for details of abbreviations & basis of descriptions.
**Non-Core Drill Hole - Geological Log**

**Project:** Subdivision Lot Classification  
**Location:** Potters Lane, Raymond Terrace

**Rig Type:** Drill Rig  
**Mounting:** Trailer Mounted  
**Contractor:**  
**Driller:**  
**Date Started:** 16/02/2017  
**Date Completed:** 16/02/2017  
**Date Logged:** 16/02/2017  
**Logged By:** ML  
**Checked By:** ML

**Material**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Black</th>
<th>Chipped</th>
<th>Undisturbed Log</th>
</tr>
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<tr>
<td>0.20 - 0.30</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>0.30 - 0.40</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
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**Sample & Field Tests**

- Pocket Penetrometer (UCS kPa)
- Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
- Plate Bearing Test
- Water inflow
- Water outflow

**Method**

- Natural Exposure
- Existing Excavation
- Backhoe Bucket
- Bulldozer Blade
- Ripper

**Pavement Condition / Remark**

- Hole Terminated at 1.50 m
- Refusal

**Penetration**

- DCP AS 1289.6.3.2-1997

**Drilling**

- Water inflow
- Water outflow

**Classification Symbols & Soil Description**

- Based on Unified Classification System

**Moisture**

- D: Dry
- M: Moist
- W: Wet

**Consistency**

- V: Very Soft
- S: Soft
- F: Firm
- St: Stiff
- VH: Very Hard
- VL: Very Loose
- MD: Medium Dense
- D: Dense
- LD: Very Dense

See Explanatory Notes for details of abbreviations & basis of descriptions.
FILL: Sandy Silt, low plasticity, dark brown, fine sand.
Silty Clay, high plasticity, brown/mottled red.
Becoming light grey/mottled red at approximately 0.4m.

Weathered Clayey Sandstone, fine grained, light grey/mottled red.

Hole Terminated at 1.60 m

Vegetation Condition / Remark

METHOD
N - Natural Exposure
E - Existing Excavation
BH - Backhoe Bucket
B - Bulldozer Blade
R - Ripper

PENETRATION
No Resistance

WATER
10 Oct., '73 Water Level on Date Shown
water inflow
water outflow

SAMPLES & FIELD TESTS
U - Undisturbed Sample
D - Disturbed Sample
B - Bulk Disturbed Sample
MC - Moisture Content
PP - Pocket Penetrometer (UCS kPa)
VS - Vane Shear; P-Peak, R-Remoulded (uncorrected kPa)
PBT - Plate Bearing Test

CLASSIFICATION SYMBOLS & SOIL DESCRIPTION
Based on Unified Classification System

MOISTURE
D - Dry
M - Moist
W - Wet

CONSISTENCY
VS - Very Soft
S - Soft
F - Firm
St - Stiff
VSi - Very Stiff
H - Hard
VL - Very Loose
L - Loose
MD - Medium Dense
D - Dense
VD - Very Dense

RIG TYPE: Drill Rig
MOUNTING: Trailer Mounted
PROJECT: Subdivision Lot Classification
LOCATION: Potters Lane, Raymond Terrace
DATE STARTED: 16/02/2017
DATE COMPLETED: 16/02/2017
DATE LOGGED: 16/02/2017
LOGGED BY: ML
CHECKED BY: ML

FILE / JOB NO: P990
SHEET: 1 OF 1

See Explanatory Notes for details of abbreviations & basis of descriptions.
# Shrink Swell Index Report

**Client:** EP Risk Management Pty Ltd  
**Report Number:** P990 - 27/1  
**Address:** 3/19 Bolton Street, Newcastle, NSW, 2300  
**Report Date:** 24/02/2017  
**Project Name:** Geotechnical Investigation - Raymond Terrace  
**Report Date:** 24/02/2017  
**Order Number:**  
**Project Number:** P990  
**Test Method:** AS1289.7.1.1  
**Location:** Potters Lane, Raymond Terrace  
**Test Method:** AS1289.7.1.1  

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<th>PP before (kPa)</th>
<th>PP after (kPa)</th>
<th>Shrinkage Moisture Content (%)</th>
<th>Shrinkage (%)</th>
<th>Swell Moisture Content Before (%)</th>
<th>Swell Moisture Content After (%)</th>
<th>Swell (%)</th>
<th>Unit Weight (t/m³)</th>
<th>Shrink Swell Index Iss (%)</th>
<th>Visual Classification</th>
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<th>Crumbling</th>
<th>Remarks</th>
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<td>S17-698</td>
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**Inert Material Estimate (%):** 15, 10, 10, 15  
**PP before (kPa):** 300, 400, 400, 150  
**PP after (kPa):** 300, 400, 200, 100  
**Shrinkage Moisture Content (%):** 24.1, 19.2, 19.8, 23.6  
**Shrinkage (%):** 3.6, 3.2, 5.1, 7.6  
**Swell Moisture Content Before (%):** 23, 21.6, 21.3, 22.3  
**Swell Moisture Content After (%):** 24.3, 24.4, 29.2, 25.9  
**Swell (%):** 0, 0.1, 2.6, 0.2  
**Unit Weight (t/m³):** - , - , - , -  
**Shrink Swell Index Iss (%):** 2, 1.8, 3.5, 4.3  

**Visual Classification:** refer to attached borelogs, refer to attached borelogs, refer to attached borelogs, refer to attached borelogs  
**Cracking:** Minor, Minor, Minor, Nil  
**Crumbling:** Nil, Nil, Nil, Nil  
**Remarks:**

---

**NATA Accreditation Number:** 14975

**ACCREDITED FOR COMPLIANCE WITH ISO/IEC 17025. THE RESULTS OF THE TESTS, CALIBRATIONS AND/OR MEASUREMENTS INCLUDED IN THIS DOCUMENT ARE TRACEABLE TO AUSTRALIAN/NATIONAL STANDARDS.**

---

**APPROVED SIGNATORY:**

[Signatory Name]

[Title]

NATA Accreditation Number

14975

**Document Code:** RF161-6
### Shrink Swell Index Report

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<td>Sample Location:</td>
<td>Sample Taken@ BH5 -1.5/-1.7</td>
<td>Sample Taken@ BH7 -1.0/-1.2</td>
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<td>200</td>
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<td>200</td>
<td>50</td>
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<td>Shrinkage Moisture Content (%)</td>
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<td>23.8</td>
<td>29.4</td>
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<td>Shrinkage (%)</td>
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<td>Swell Moisture Content After (%)</td>
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APPROVED SIGNATORY

Richard Badior - Senior Geotechnical Officer
NATA Accreditation Number 14975

Document Code RF161-6
# Shrink Swell Index Report

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<th>Inert Material Estimate (%)</th>
<th>PP before (kPa)</th>
<th>PP after (kPa)</th>
<th>Shrinkage Moisture Content (%)</th>
<th>Shrinkage (%)</th>
<th>Swell Moisture Content Before (%)</th>
<th>Swell Moisture Content After (%)</th>
<th>Swell (%)</th>
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<th>Shrink Swell Index Iss (%)</th>
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**Shrink Swell Index Report**

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<th>Sample Number</th>
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- **Inert Material Estimate (%):**
  - 15
  - 15
  - 15
- **PP before (kPa):**
  - 250
  - 400
  - 350
- **PP after (kPa):**
  - 250
  - 400
  - 280
- **Shrinkage Moisture Content (%):**
  - 20.3
  - 27.7
  - 21.7
- **Shrinkage (%):**
  - 4.8
  - 4.1
- **Swell Moisture Content Before (%):**
  - 22.7
  - 27.4
  - 20.6
- **Swell Moisture Content After (%):**
  - 25.1
  - 29.3
  - 24
- **Swell (%):**
  - 0.1
  - 0.2
  - 0.2
- **Unit Weight (t/m³):**
  - -
  - -
  - -
- **Shrink Swell Index Iss (%):**
  - 1.5
  - 2.7
  - 2.3

- **Visual Classification:**
  - refer to attached borelogs
  - refer to attached borelogs
  - refer to attached borelogs

- **Cracking:**
  - Minor
  - Nil
  - Minor

- **Crumbling:**
  - Nil
  - Nil
  - Nil

**Remarks:**

Accredited for compliance with ISO/IEC 17025. The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards.

**APPROVED SIGNATORY**

Richard Badior - Senior Geotechnical Officer
NATA Accreditation Number 14975

Document Code RF161-6
Annex D
Foundation Maintenance and Footing Performance: A Homeowner’s Guide

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 2870-2011, 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

<table>
<thead>
<tr>
<th>Class</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Most sand and rock sites with little or no ground movement from moisture changes</td>
</tr>
<tr>
<td>S</td>
<td>Slightly reactive clay sites, which may experience only slight ground movement from moisture changes</td>
</tr>
<tr>
<td>M</td>
<td>Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes</td>
</tr>
<tr>
<td>H1</td>
<td>Highly reactive clay sites, which may experience high ground movement from moisture changes</td>
</tr>
<tr>
<td>H2</td>
<td>Highly reactive clay sites, which may experience very high ground movement from moisture changes</td>
</tr>
<tr>
<td>E</td>
<td>Extremely reactive sites, which may experience extreme ground movement from moisture changes</td>
</tr>
</tbody>
</table>

Notes
1. Where controlled fill has been used, the site may be classified A to E according to the type of fill used.
2. Filled sites. Class P is used for sites which include soft fills, such as clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soil subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.
3. Where deep-seated moisture changes exist on sites at depths of 3 m or greater, further classification is needed for Classes M to E (M-D, H1-D, H2-D and E-D).
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 will 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. 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.

Uphaul 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 causes a footing to fail 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 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.

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 should

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<tbody>
<tr>
<td>Hairline cracks</td>
<td>&lt;0.1 mm</td>
<td>0</td>
</tr>
<tr>
<td>Fine cracks which do not need repair</td>
<td>&lt;1 mm</td>
<td>1</td>
</tr>
<tr>
<td>Cracks noticeable but easily filled. Doors and windows stick slightly.</td>
<td>&lt;5 mm</td>
<td>2</td>
</tr>
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<td>Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather tightness often impaired.</td>
<td>5–15 mm (or a number of cracks 3 mm or more in one group)</td>
<td>3</td>
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<td>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.</td>
<td>15–25 mm but also depends on number of cracks</td>
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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 2870-2011. AS 2870-2011 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 cause 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.

Table classification of damage with reference to walls

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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 it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

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