Douglas Partners
Geotechnics / Environment / Groundwater

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Report on
Geotechnical Investigation

Proposed Link Road and Residential Units
Closebourne Heritage Estate

Prepared for
Lend Lease Retirement Living

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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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Report on Geotechnical Investigation
Proposed Link Road and Residential Units
Closebourne Heritage Estate

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed link road and residential units at Closebourne Heritage Estate. The investigation was commissioned by Bruce Gould of Lend Lease Retirement Living and was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal NCL180611 dated 9 October 2018.

It is understood that the proposed development includes construction of a link road as well as the construction of several residential units on the former town common oval. Based on recent discussions, it is understood that the proposed unit structures are intended to be supported on piles taken to below all filling.

The aim of the investigation was to assess the subsurface soil and groundwater conditions across the site and comment on the following:

- Subgrade conditions and design subgrade CBR values for the link road;
- Flexible pavement thickness design for the link road;
- Pavement preparation measures;
- Depth of filling within the former oval;
- Site classification for the proposed units;
- Footing design parameters for the proposed units; and
- Site preparation measures.

The investigation included the excavation of thirteen test pits and laboratory testing of selected samples. The details are presented in this report, together with comments and recommendations on the items listed above.

For the purposes of the assessment the client provided DP with the following plans drawn by Lindsay Dynan Consulting Engineers:

- Swept Path Analysis, Drawing DA2004 , Rev A;
- Stage 8, Aged Care Facility, Drawing DA2001, Rev D; and
- Stage 8, Oval Villas, Drawing DA2000, Rev D.

2. Site Description

The site is located within Closebourne Estate at Morpeth, which is situated along Morpeth Road approximately 500 m west of Tank Street, Morpeth. The proposed link road will connect the area around the current aged care facility to the area to the south of Closebourne House and the Town Common Oval (refer Drawing 1).

A number of existing buildings are located within the proposed aged care facility footprint to the north of the site (refer buildings around Closebourne House in Figure 1).

Figure 1: Aerial image of site with the main site features (sourced from NearMaps)

The existing link road alignment is an unsealed pavement. The areas to the south is generally grass covered and falls to the south-east at slopes of less than 5°.

The town common oval is a circular area and is covered with bare earth. Filling has been placed over the area in the last two years. DP has undertaken density testing under a Level 2 testing regime during placement of the recent filling.

3. Desktop Review

Reference to the survey plans provided by the client for the site indicates that the ground surface levels across the site vary from about RL 25 m AHD in the south-eastern area of the site to about RL 31 m AHD in the existing oval.

Reference to the Geological Survey of New South Wales, Statewide geodatabase, 1:250,000 scale or better geology maps indicate that the site is underlain by the Tomago Coal Measures of Late Permian age. The main rock units of the Tomago Coal Measures generally comprise siltstone, sandstone, coal, tuff, claystone, conglomerate and minor clay.

Reference to the NSW acid sulfate soil risk maps indicate no known occurrence of acid sulfate soils at the site.

4. Field Work Methods

The field work was undertaken on 11 October 2018 and comprised the excavation of thirteen tests pits (designated Pits 1001 to 1013), located as follows:

• Pits 1001 to 1003	Area to south of Link Road;
• Pits 1004 to 1006, 1012 and 1013	Link Road; and
• Pits 1007 to 1011	Proposed Units on Town Common Oval.

The pits were excavated to depths ranging from 1.2 m to 3.0 m using a backhoe fitted with a 450 mm wide bucket.

Dynamic penetrometer testing (DPT) was undertaken at each pit location to depths ranging from 0.6 m to 1.2 m.

The subsurface conditions encountered in the pits were logged by an engineering geologist, who also retrieved regular samples for identification and laboratory testing purposes. Pocket penetrometer tests were undertaken at selected depths and locations.

It is recommended that the location and elevation of the pits are picked up by the project surveyor.

Samples were also collected for possible chemical testing. The general sampling procedure for chemical testing comprised:

- Decontamination of all sampling equipment (if used) using a 3% solution of phosphate free detergent (Decon 90) and tap water prior to collecting each sample;
- The use of new disposable gloves for each sampling event;
- Transfer of samples into laboratory-prepared jars and capping immediately;
- Collection of replicate samples for Quality Assurance / Quality Control (QA / QC) purposes;
- Labelling of sample containers with individual and unique identification, including project number, sample location and sample depth; and

- Placement of the sample jars and replicate sample bags into a cooled, insulated and sealed container with ice for transport to the laboratory.

Replicate samples collected in zip-lock bags were screened for the presence of volatile organic compounds (VOCs), using a calibrated MiniRAE Lite photo-ionisation detector (PID) with a 10.6 eV lamp, calibrated to 100 ppm Isobutylene. The PID is capable of detecting over 300 VOCs.

Drawing 1, in Appendix D, shows the approximate test locations.

5. Field Work Results

The subsurface conditions encountered in the test pits are presented in the test pit logs in Appendix B. These should be read in conjunction with the accompanying notes, which explain the descriptive terms and classification methods used in the logs. The following is a summary of these subsurface conditions.

Based on the results of the investigation, the site stratigraphy can be divided into the following general soil and rock units:

UNIT 1A – FILLING (oval)	Grey brown silty clay with trace gravel, dark grey sandy clay or pale brown silty sand. Some anthropogenic materials, such as broken brick, plastic, glass and metal was encountered in some of the pits.
UNIT 1B – FILLING (pavement)	Grey brown sandy gravel or dark grey gravelly clay with occasional coal reject, gravelly sand or clayey gravel.
UNIT 2 – SILTY SAND / SANDY SILT	Loose through to dense, dark grey, grey brown or brown.
UNIT 3 – SILTY CLAY / SANDY CLAY	Typically very stiff to hard, grey mottled red or orange brown mottled grey. Pits 1002 and 1005 encountered stiff to very stiff clay. Occasionally clayey sand was encountered.
UNIT 4 - BEDROCK	Very low strength claystone in Pit 1007, as well as completely weathered rock (silty sand) in Pit 1008.

The depth to the top of each unit is presented in Table 1 below.

Table 1: Summary of Test Locations

Location	Depth to Top of Each Unit (m)					
	Unit 1A (Filling - oval)	Unit 1A (Filling - pavement)	Unit 2 (Silty Sand / Sandy Silt)	Unit 3 (Silty Clay / Sandy Clay)	Unit 4 (Claystone or completely weathered rock)	Depth of Investigation and Reason for Termination (m)
1001	NE	NE	0.0	0.65	NE	1.2 (LOI)
1002	NE	NE	0.0	0.6	NE	1.2 (LOI)
1003	NE	0.0	0.65	1.1	NE	1.3 (LOI)
1004	NE	0.0	0.2	0.8	NE	1.2 (LOI)
1005	NE	0.0	0.28	1.0	NE	1.2 (LOI)
1006	NE	0.0	0.2	0.6	NE	1.2 (LOI)
1007	NE	NE	0.0	0.85	1.35	1.65 (LOI)
1008	0.0	NE	NE	0.3	1.3	2.6 (REF)
1009	0.0	NE	NE	1.4	NE	3.0 (LOI)
1010	0.0	NE	0.9	NE	NE	2.9 (LOI)
1011	0.0	NE	NE	NE	NE	1.6 (LOI)
1012	NE	0.0	0.25	0.75	NE	1.3 (LOI)
1013	0.0	NE	0.8	1.2	NE	1.4 (LOI)
Relevant pits from previous investigations						
129	NE	NE	0.7	2.0	NE	2.0 (LOI)

Notes to Table 1:
REF – Refusal with backhoe
LOI – Limit of Investigation

Pits 126 to 128 were undertaken by DP (Ref 3) within the oval prior to the most recent filling episode. Conditions encountered in the pits included silty sand to depths of up to 0.65 m overlying very stiff sandy clay. An exception was encountered in Pit 128, where silty sand and sandy silt filling with trace brick fragments was encountered to 1.2 m depth, overlying sand with clayey sand below 1.7 m depth. Sandstone bedrock was also encountered in Pit 126 at 1 m depth.

Surface filling was observed at a number of locations across the site. Materials observed within the filling included bricks, asphalt, ash, metal and coal rejects are summarised in Table 2.

Table 2: Potential Contaminant Observations during Field Work

Potential Contaminant Observation	Test Pit / Depth
Bricks	Pit 1010 (0.3 m to 0.55 m) Pit 1011 (0.0 m to 0.5 m), Pit 1012 (0.13 m to 0.25 m) Pit 1013 (0.0 m to 0.23 m)
Ash, Glass, Earthenware	Pit 1013 (0.0 m to 0.23 m)
Plastic	Pit 1011 (0.0 m to 0.5 m) Pit 1012 (0.13 m to 0.25 m) Pit 1013 (0.0 m to 0.23 m)
Metal	Pit 1012 (0.13 m to 0.25 m)
Coal Reject	Pit 1004 (0.1 m to 0.2 m) Pit 1005 (0.15 m to 0.28 m) Pit 1013 (0.0 m to 0.23 m)

The results of PID screening on soil samples are shown on the test pit logs in Appendix B. PID screening generally suggested the absence of gross volatile hydrocarbon impact, with all results less than the PID detection limit of 1 ppm.

There was no visual or olfactory evidence (i.e. staining or odours) to suggest the presence of gross contamination within the soils investigated.

Groundwater was not observed in any the test pits while they remained open. It should be noted that groundwater levels are affected by climatic conditions and soil permeability and will therefore vary with time.

6. Laboratory Testing

DP has undertaken laboratory testing during previous investigations at the site. Table 3 summarises the results of testing from the current investigation, whereas Table 4 provides a summary of testing which is considered relevant from the nearby Stages 5 and 7.

Table 3: Results of Current and Previous CBR / Compaction testing

Pit	Depth (m)	Unit	Description	FMC (%)	SOMC (%)	SMDD (t/m3)	CBR (%)	Swell During soaking phase (%)
Present Investigation								
1004	0.8 – 1.2	3	Silty clay	16.6	18.5	1.72	3.0	5.5

Notes to Table 3:

FMC – Field Moisture content	SMDD – Maximum Dry Density (Standard)
SOMC – Optimum Moisture Content (Standard)	CBR – Californian Bearing Ratio

Table 4: Results of Relevant CBR / Compaction and Shrink Swell testing

Material Type	Geological Unit	Development Stage	No of CBR Tests	Range of CBR Values	No of Shrink-Swell Tests	Range of Iss (% per ΔpF)	Average Iss (%)
Silty sand/Clayey sand	2	5	1	30	-	-	-
		7	2	9 to 12	-	-	-
Sandy Clay, Clay or silty clay	3	5	2	4 to 7	3	1.7 to 1.9	1.8
		7	1	1.5	5	2.1 to 5.5	3.6
		General Overall Site (near development)	3	1.5 to 6	2	2.8 to 4.0	3.4

Notes to Table 4
CBR – Californian Bearing Ratio
Iss – Shrink Swell Index

7. Proposed Development

It is understood that the development of the site will include the following:

- **Link Road** A new link road will be constructed along the existing unsealed pavement alignment. Based on review of the plans provided by the client, it is understood that the surface level of the finished road will near or at grade with existing surface levels within the westernmost approximately half of the link road and up to 1.5 m above existing site levels in the eastern half of the link road (refer Figure 2).

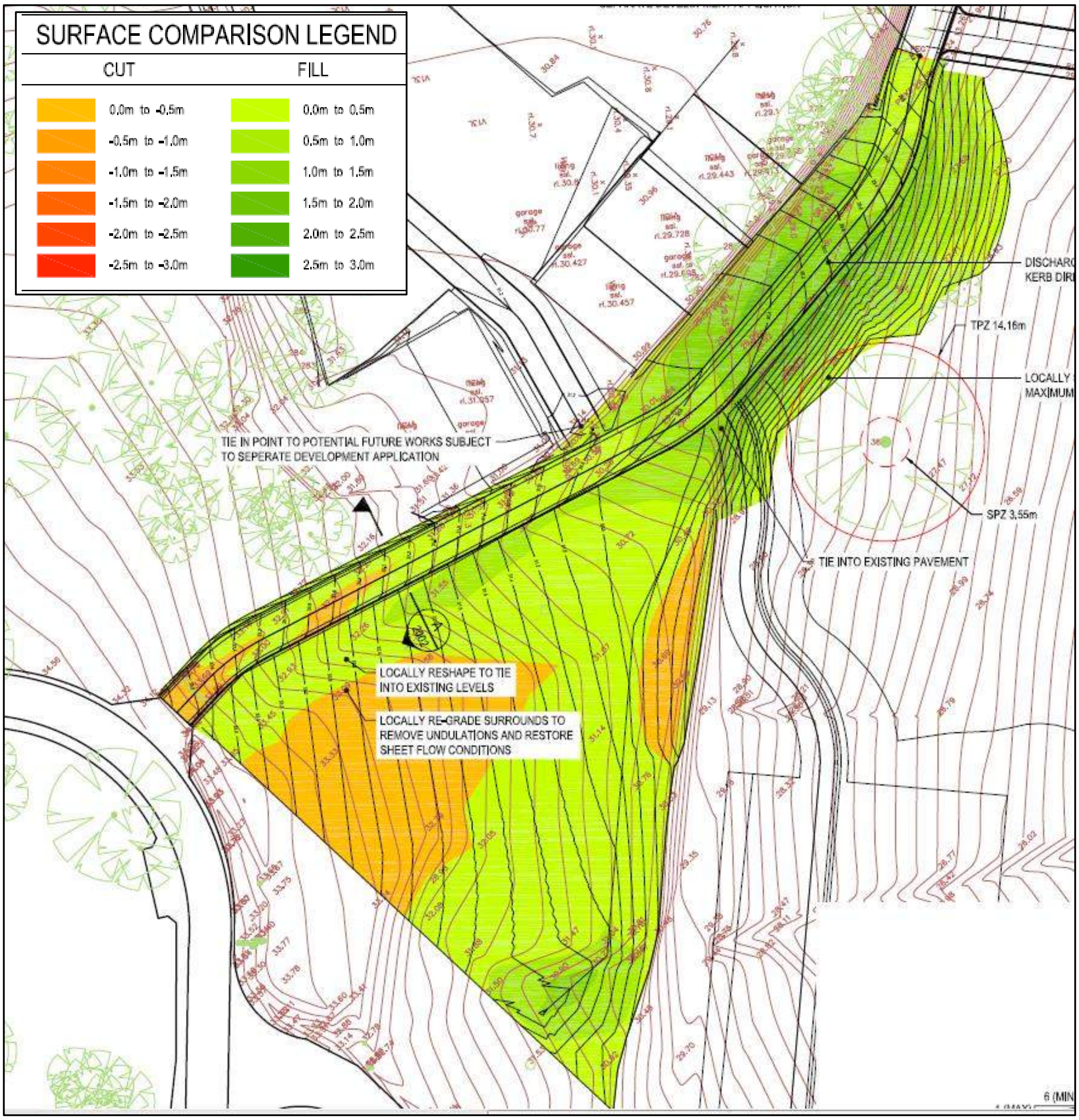

Figure 2: Extract from site regrading plan for link road (drawn by Lindsay Dynan)

- **Residential Units** Single and double storey units will be constructed in areas which are presently covered by the town common oval. The ground floor levels for the structures will be within about 1 m of the existing surface levels.

8. Comments

8.1 Excavation Conditions

Based on the results of the investigation, it is considered that excavation of the filling, topsoil, sands and clays (Units 1 to 3) would be generally achievable using conventional machinery such as a hydraulic excavator.

Contractors should be responsible for selection of excavation equipment based on the proposed excavation depths and equipment capabilities, together with the anticipated conditions.

8.2 Site Classification

Site classification of foundation soil reactivity provides an indication of the propensity of the ground surface to move with seasonal variation in moisture. The site classification is based on procedures presented in AS 2870-2011 (Ref 4), the typical soil profiles revealed in the pits, and the results of laboratory testing.

As outlined in Table 4, the results of shrink-swell testing from across the adjacent stages of the development returned I_{ss} values ranging from 1.7% to 5.5% per ∆pF, with an average 2.9% per ΔpF. Using a 90% confidence interval, a design I_{ss} value of 4% per ΔpF was used in estimation of the characteristic surface movements.

The site in its current condition would be Class P owing to the presence of existing filling which was not placed in accordance with the requirements for Level 1 inspection and testing regime as outlined in AS3798 (Ref 10). The upper sections of filling which have been recently placed at the site were tested under a Level 2 testing regime by DP. The testing generally passed the minimum density requirement and achieved with moisture content ranges within 2% of optimum moisture content for standard compaction. The underlying, pre-existing filling is understood to have been placed progressively over many years (decades) and no record of control of layer thickness, compaction and moisture content have been made available. In this regard, during previous investigation by DP (Ref 2), clay filling was encountered to 1.5 m depth in the eastern side of the town common. Hence this lower filling is deemed uncontrolled filling and is not considered suitable for the support of high level footings.

An indication of the characteristic surface movements can be obtained from the results of previous laboratory testing, and characteristic surface movements, y_s, were estimated to range from approximately 30 mm to 50 mm under normal seasonal moisture fluctuations, primarily depending on the depth of bedrock across the site.

Articulation joints should be provided within masonry walls in accordance with TN61 (Ref 5) in order to reduce the effects of differential movement.

It should be noted that this classification is dependent on proper site maintenance, which should be carried out in accordance with CSIRO Sheet BTF 18 attached in Appendix A and Appendix B of AS 2870-2011 (Ref 4).

8.3 Unit Foundations

Footings should be founded within the natural stiff or stronger silty clays or sandy clay or the underlying bedrock and designed in accordance with AS 2870-2011 (Ref 4). Footings should not be founded in uncontrolled filling. Where uncontrolled filling is present at foundation level, it should be over excavated and replaced with properly placed and compacted engineered filling in accordance with Section 8.5 of this report.

If rock is encountered at footing level in any portion of an individual structure, it is recommended that footings be deepened such that all footings for the structure found on rock to reduce the effects of differential movement.

The recommended maximum allowable bearing pressures for the encountered soil types are presented in Table 5 below:

Table 5: Allowable Bearing Pressure

Founding Strata	Maximum Allowable Bearing Pressure (kPa)
Very stiff to hard clay	200
Very low strength rock or stronger	700

Given that filling was encountered to depths of up to 1.6 m in the pits, it is considered that bored piles will be required to transfer structural loads to the design foundation strata. It is noted that shallow filling was encountered within the pits within the north-western proposed units (i.e. Pits 1007 and 1008 where very stiff or stronger clay was encountered at less than 1 m). Pad footings may be possible within some of the units within this area of the site, although additional investigation would be required to confirm the depth to design foundation strata.

Short bored piles should be designed based on the end bearing pressures presented above in Table 5, above. In the event that the piles are longer than four times the pile diameter, an allowable bearing pressure of 350 kPa and 700 kPa would be applicable for very stiff to hard clay and very low strength rock respectively. For such footing arrangements, it is important that slab panels are not supported on the “uncontrolled” filling but suspended between ground beams / edge beams / strips. This is to avoid potential for cracking due to differential settlement. Consideration should be given to the possible effects of heaving of the placed filling under the suspended slabs.

Groundwater was not encountered during the present investigation. Hence it is anticipated that footing excavations should remain dry during excavation provided surface water is excluded.

Bored piles should be poured immediately after footing excavation to reduce the risk of hole collapse or softening from rain events or groundwater. Care should be taken to ensure the base of the bored pile holes are cleaned and free of all loose debris and water at the time of placing concrete. Accordingly, pier hole inspections are recommended during construction to confirm the above design parameters.

8.4 Pavements

8.4.1 Subgrade Conditions

The anticipated subgrade conditions are expected to comprise silty sand or sandy silt overlying clays (Unit 2 overlying Unit 3) within the western half of the link road and engineered filling within the eastern half of the link road.

Results of laboratory testing on the silty sand (Unit 2) soil indicated four-day soaked CBRs ranging from 9% to 30%, however it is noted that soils with a high silt content can soften appreciably with increases in moisture.

Results of laboratory testing on the clay and sandy clay (Unit 4) indicated a four-day soaked CBR ranging from 1.5% to 7%. The sample of the sandy clay from Pit 1004 returned a soaked CBR of 3.0%. Previous investigations in other areas of the Closebourne site returned soaked CBR values for the silty clay and sandy clay ranging from 1.5% to 6%, with three clay samples returning a soaked CBR of 1.5%.

Therefore, a design CBR of 3% has been adopted for the internal pavements based on the provision of a select subgrade of at least 200 mm in thickness. This requirement has been based on the low soaked CBR values recorded during previous investigation adjacent to the site and presence of silty sand in the majority of the pits, which is anticipated to cause construction difficulties if it becomes wet.

It may be possible to omit the select subgrade layer depending on the condition of the silty sand at the time of construction and depending on the nature of the filling placed to raise the subgrade levels.

8.4.2 Design Traffic

The design traffic loading for the proposed link road has not been provided to DP.

Two pavement thickness designs are presented based on the following design traffic loadings:

- 4×10^3 Equivalent Standard Axles (ESA) has been adopted based on the roads being “minor roads with two way traffic” as defined in Austroads (Ref 6); and
- 4×10^4 ESA, which is based on the roads being consistent with “local access with no buses” as defined in Austroads.

If the traffic loading is to be significantly different from this value, the pavement thickness designs presented in the following sections should be reviewed.

8.4.3 Flexible Pavement Thickness Design

It is understood that the pavements will be privately owned and maintained by Lend Lease and therefore not a Council asset. The pavement thickness design presented below has been based on procedures outlined in Austroads – Guide to Pavement Technology (Ref 6).

The proposed pavement thickness design is outlined in Table 6 below.

Table 6: Pavement Thickness Design – Sealed Flexible Pavement

Layer	Thickness (mm)	
Traffic Loading (ESA)	4 x 10^3 ESA	4 x 10^4 ESA
Design Subgrade CBR	3%	3%
Wearing Course	30 mm AC10*	30 mm AC10*
Basecourse	100	100
Subbase	170	230
Select Subgrade	200$^{(1)}$	200$^{(1)}$
Total	500	560

Notes to Table 6:

A 7 mm or 10 mm prime seal should be placed over the basecourse

(1) Additional select may be required dependent on conditions exposed at the time of excavation

The pavement thicknesses presented above are dependent on the provision and maintenance of adequate surface and subsurface drainage.

The recommended material quality and compaction requirements for sealed flexible pavement are presented in Table 7, below.

Table 7: Material Quality and Compaction Requirements – Sealed Flexible Pavement

Pavement Layer	Material Quality	Compaction Requirements
Basecourse	CBR ≥ 80%, PI ≤ 6%, Grading in accordance with Table 242.3 of Ref 7	Compact to at least 98% dry density ratio Modified (AS 1289.5.2.1, Ref 8)
Subbase	CBR ≥ 30%, PI ≤ 12%. Grading in accordance with Table 242.4 (Ref 7)	Compact to at least 95% dry density ratio Modified (AS 1289.5.2.1, Ref 8)
Select Subgrade	Soaked CBR ≥ 15%	Compact to 100% dry density ratio Standard (AS 1289.5.1.1, Ref 9)
Subgrade	Refer to Section 8.4.1	Compact to at least 100% dry density ratio Standard (AS 1289.5.1.1, Ref 9)

Notes to Table 7

CBR – California bearing ratio (4 day soaked)
PI – Plasticity Index

The select subgrade should be a well-graded material which is suitable for placement over the silty sand, and which requires minimal working / rolling to achieve compaction. Thus coarse material is not expected to be suitable. The maximum particle size of the select should be no greater than one-half the layer thickness.

8.4.4 Pavement Subgrade Preparation

The following general subgrade preparation procedure is suggested;

- Excavate to design subgrade level including the provision of 200 mm of select subgrade or additional embankment filling;
- Remove any additional topsoil, filling deemed unsuitable to remain in place (to be assessed by a geotechnical engineer), weak materials and deleterious materials including organic materials;
- Test roll the surface in order to determine any soft zones and assess moisture condition;
- Assess the need for additional select subgrade material;
- The exposed subgrade should be left exposed for a minimum of time prior to placement of pavement layers to minimise the occurrence of desiccation cracking; and
- Place and compact select subgrade or embankment filling to a minimum dry density ratio of 100% standard (AS 1289.5.1.1) within the range –3% (dry) to -1% (dry) of OMC standard optimum moisture content.

Geotechnical inspections and testing should be undertaken during construction in accordance with AS 3798-2007 (Ref 10).

8.4.5 Pavement Drainage

The pavement thickness design presented in Section 8.4.3 is dependent on the provision of adequate drainage to maintain the subgrade soils as close to the optimum moisture content as possible and to ensure that the pavement layers do not become saturated.

8.5 Earthworks

8.5.1 Material Reuse for Engineered Filling

It is understood that materials won from site excavations will be re-used on the site, particularly to raise the link road in the eastern end.

The material anticipated to be excavated during pavement subgrade preparation predominantly silty sands, sandy clays and bedrock (Units 2, 3 and 4). These soils and rock are considered geotechnically suitable for re-use as engineered fill provided that they are free of deleterious inclusions such as organics and can be produced in suitable particle sizes (generally with a maximum particle size of less than 100 mm and well-graded distribution). It should be noted that some roots and rootlets were encountered in the silty sand materials which would require removal prior to re-use. Similarly, the re-use of soils with a high silt content will require careful control of moisture content.

The filling (Units 1A and 1B) are also considered suitable for re-use on site, however, given the variable nature of the filling and the anthropogenic inclusions, it is suggested that once the coarse material and deleterious material is removed from the filling, it be placed in the lower layers of filling any future hardstand areas.

All proposed fill materials should be screened / sieved or particles broken down by excavation / handling / compaction methods, thus removing / crushing oversized particles greater than 100 mm prior to use as engineered filling.

The clay soils were typically high plasticity and hence consideration should be given to the effect on final soil reactivity and subgrade behaviour should this material be used.

8.5.2 Site Preparation for Placement of Filling

The following general preparation procedure for the placement of filling under the proposed units on the oval is suggested;

- Remove any topsoil, filling deemed unsuitable to remain in place (to be assessed by a geotechnical engineer and dependent on preferred footing types), weak materials and deleterious materials including organic materials;
- Test roll the surface in order to determine any soft zones and assess moisture condition;
- The exposed material should be left exposed for a minimum of time prior to placement of pavement layers to minimise the occurrence of desiccation cracking; and
- Place and compact select subgrade to a minimum dry density ratio of 100% standard (AS 1289.5.1.1) within the range –3% (dry) to -1% (dry) of OMC standard optimum moisture content.

Geotechnical inspections and testing should be undertaken during construction in accordance with AS 3798-2007 (Ref 10).

8.5.3 Fill Batter Slopes

Maximum batter slopes in filling of 2(H):1(V) during construction and long term batters of 3(H):1(V) or flatter are recommended for batter slopes of less than 3 m in height, which are protected against erosion. For batter slopes of greater than 3 m, specific assessment should be undertaken.

9. References

1. Douglas Partners Pty Ltd, “Report on Geotechnical Investigation and Waste Classification Assessment, Proposed Closebourne Estate, Stage 5, Morpeth Road, Morpeth”, Project 81251.05, dated March 2015.
2. Douglas Partners Pty Ltd, “Report on Preliminary Geotechnical and Contamination Assessment, Morpeth House Heritage Estate, Lots 2 and 3, DP 841759, Morpeth Road, Morpeth”, Project 31995, dated February 2006.
3. Douglas Partners Pty Ltd, “Report on Geotechnical and Contamination Assessment, Morpeth House Heritage Estate, Morpeth Road, Morpeth”, Project 31995.02, dated August 2009.
4. Australian Standards AS 2870-2011 "Residential slabs and footings".
5. Cement Concrete & Aggregates Australia, Technical Note 61 “Articulated Walling”, August 2008.

6. Austroads AGPT02-12 “Guide to Pavement Technology, Part 2: Pavement Structural Design”, 2012.

7. Maitland City Council, “Manual of Engineering Standards”.

8. Australian Standard AS 1289.5.2.1-2003, “Methods of testing soils for engineering purposes”, Standards Australia.

9. Australian Standard AS 1289.5.1.1-2003, “Methods of testing soils for engineering purposes”, Standards Australia.

10. Australian Standards AS 3798-2007 "Guidelines on Earthworks for Commercial and Residential Developments", March 2007, Standards Australia.

10. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for the proposed link road and units within the existing oval at the proposed Closebourne Estate with reference to DP’s proposal NCL180611 dated 9 October 2018 and acceptance received from Mr Bruce Gould of Lend Lease Retirement Living. The work was carried out under a consultancy agreement between Lend Lease Retirement Living and DP. This report is provided for the exclusive use of Lend Lease Retirement Living 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. The advice may also be limited by budget constraints imposed by others or by site accessibility.

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 did not include the assessment of 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.

Asbestos has not been detected by observation or by laboratory analysis, either on the surface of the site, or in filling materials at the test locations sampled and analysed. It has however, been detected in the existing buildings at the site. Previous building demolition, may however, result in the possible presence of hazardous building materials (HBM), including asbestos.

Although the sampling plan adopted for this investigation is considered appropriate to achieve the stated project objectives, there are necessarily parts of the site that have not been sampled and analysed. This is either due to undetected variations in ground conditions or to budget constraints or to vegetation preventing visual inspection and reasonable access. It is therefore considered possible that HBM, including asbestos, may be present in unobserved or untested parts of the site, between and beyond sampling locations, and hence no warranty can be given that asbestos is not present.

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Appendix A

About This Report
Sampling Methods
Soil Descriptions
Symbols and Abbreviations
CSIRO Sheet BTF 18

About this Report

Douglas Partners

Introduction

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

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

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Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

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

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

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

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

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Sampling

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

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

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

Test Pits

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

Large Diameter Augers

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

Continuous Spiral Flight Augers

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

Non-core Rotary Drilling

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

Continuous Core Drilling

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

  4,6,7
  N=13
- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

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

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

Soil Descriptions

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Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726-1993, 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.

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

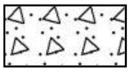
Other

fg	fragmented
bnd	band
qtz	quartz

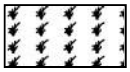
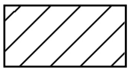
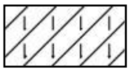
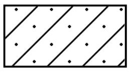
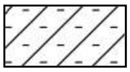
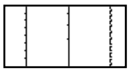
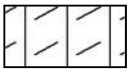
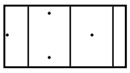
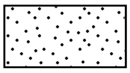
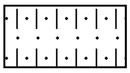
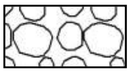
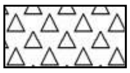
Symbols & Abbreviations

Graphic Symbols for Soil and Rock

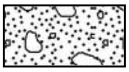
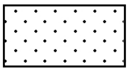
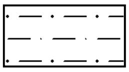
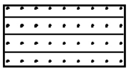
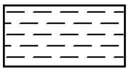
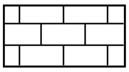
General

■	Asphalt
	Road base
	Concrete
	Filling

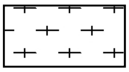
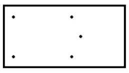
Soils

	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

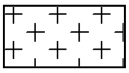
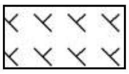
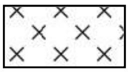
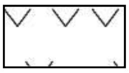
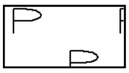
Sedimentary Rocks

	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

Foundation Maintenance and Footing Performance: A Homeowner's Guide

PUBLISHING
BTF 18-2011
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 2870-2011, 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

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

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.

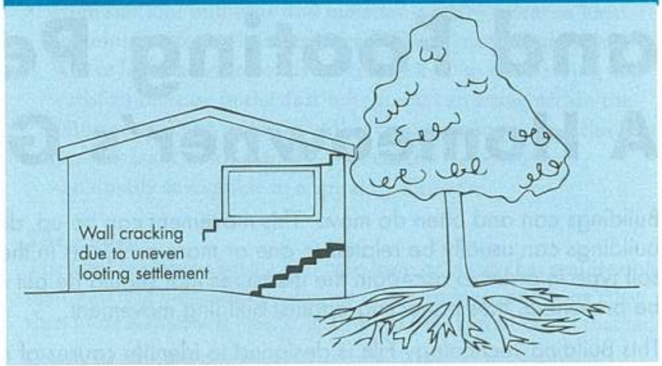
Seasonal swelling/shrinkage in clay
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends 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.

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.

Trees can cause shrinkage and damage



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 causes 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 2870-2011.

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 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

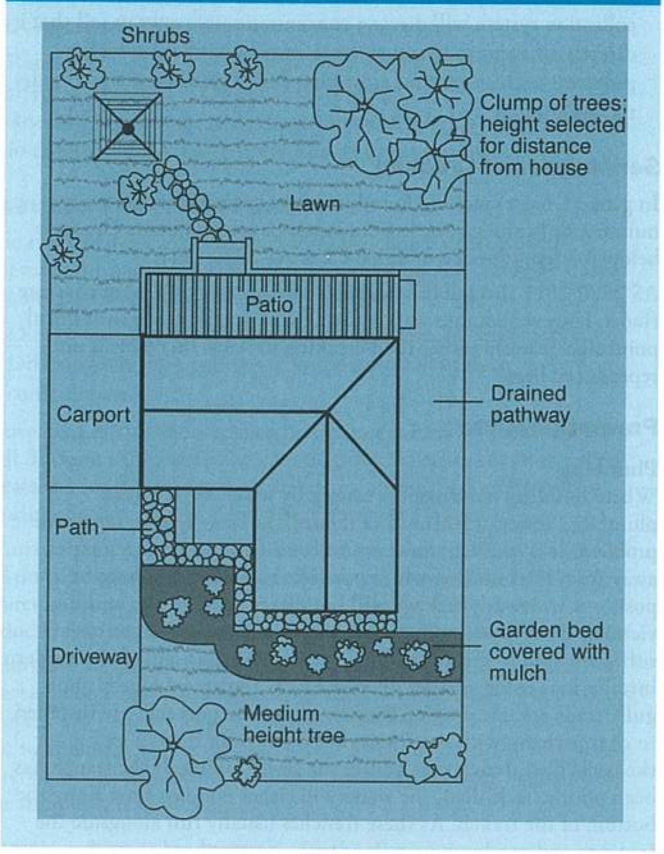
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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 should

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 depends on number of cracks	4

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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Appendix B

Test Pit Logs – Pits 1001 to 1013
Test Pit Logs from Previous Investigations – Pits 3, 10, 126 to 130
Results of Dynamic Penetrometer Tests

TEST PIT LOG

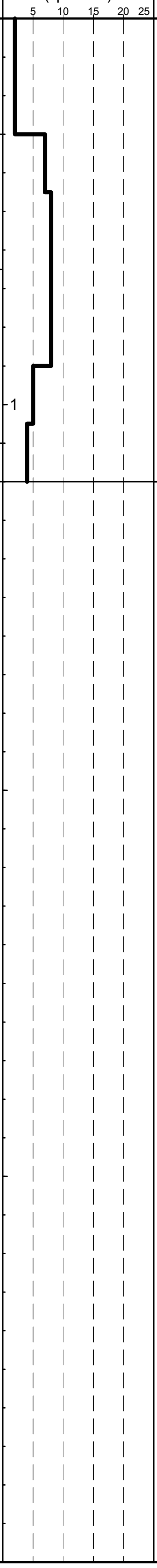
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370712
NORTHING: 6377949
DIP/AZIMUTH: 90°/--

PIT No: 1001
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING: PROGRESS DRILLING & CASING	WATER	GROUND WATER LEVELS	SAMPLING: GEO	ENV	IDs and REMARKS	RL	DEPTH (m)	GRAPHIC LOG	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
		No free groundwater observed					0.0	0.30m	SANDY SILT: dark grey 0-0.3m: rootlets	moist		
								0.65m	SILTY SAND: fine; grey brown; trace clay	moist	VD	
							0.5 1.0	1.10m	SILTY CLAY: pale brown mottled orange; trace fine grained sand; high plasticity; residual	moist, w>PL moist, w>PL	VST	
								1.20m	SILTY CLAY: grey mottled red brown; high plasticity; residual		VST	
							1.5 2.0 2.5 3.0 3.5 4.0		Pit discontinued at 1.20m depth Limit of investigation			

DCP blows/150mm (tip: cone)



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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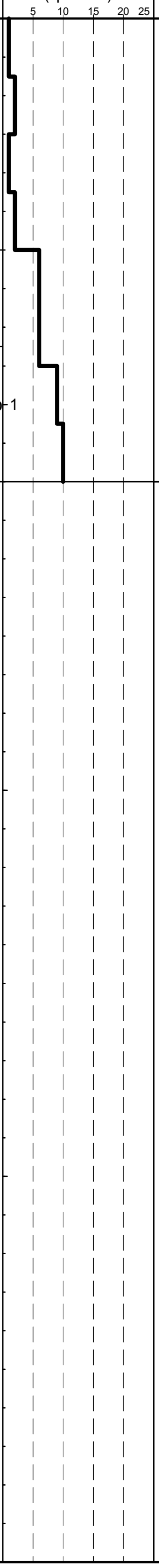
TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370700
NORTHING: 6377928
DIP/AZIMUTH: 90°/--

PIT No: 1002
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING								MATERIAL					
PROGRESS		GROUND WATER LEVELS	SAMPLING			RL	DEPTH (m)	GRAPHIC LOG	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	DCP blows/150mm (tip: cone)	TEST RESULTS & COMMENTS
DRILLING & CASING	WATER		GEO	ENV	IDs and REMARKS								
		No free groundwater observed					0.0 – 0.60m		SANDY SILT: dark grey 0-0.3m: rootlets	moist	MD		
							0.60 – 0.85m		CLAYEY SAND: fine; pale brown	moist	D		
							0.85 – 1.20m		SANDY CLAY: orange brown mottled grey; with silt; medium to high plasticity; residual	moist, w=PL to moist, w>PL	ST to VST		
							1.20m		Pit discontinued at 1.20m depth Limit of investigation				



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

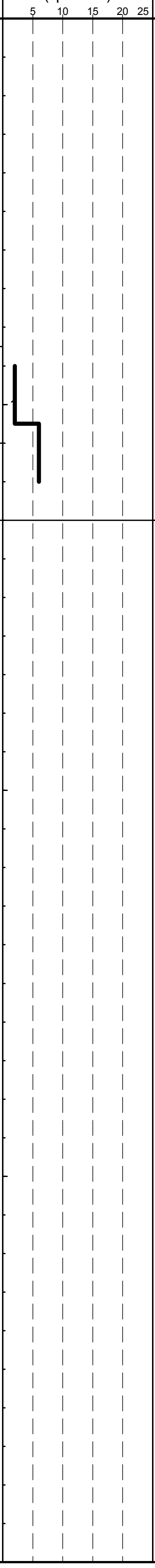
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370697
NORTHING: 6378005
DIP/AZIMUTH: 90°/--

PIT No: 1003
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

Depth (m)	Sampling GEO	Sampling ENV	Ground water levels	Description of strata	Moisture condition	Consistency relative density	Test results & comments
0.0–0.85	B	E E		FILL/SANDY GRAVEL: fine to coarse; sub-angular; grey brown; gravel to 20mm in size	moist	WC	0.10m PID: 1ppm 0.70m PID: 1ppm
0.85–1.10			▽ Free groundwater observed	CLAYEY SAND: fine; pale brown 0.85m: geofabric	moist, w>PL	ST	
1.10–1.30				SILTY CLAY: orange brown mottled grey; trace fine grained sand; residual	moist, w>PL	VST	

Pit discontinued at 1.30m depth
Limit of investigation



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

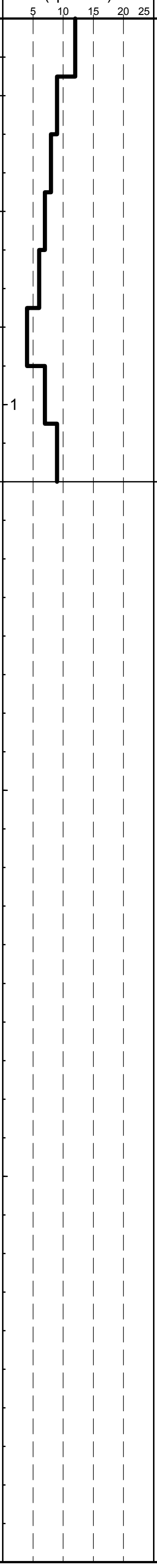
SURFACE LEVEL:
EASTING: 370641
NORTHING: 6377991
DIP/AZIMUTH: 90°/--

PIT No: 1004
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	SAMPLING GEO	SAMPLING ENV	GROUND WATER LEVELS	TEST RESULTS & COMMENTS
0.10m	FILL/SANDY GRAVEL: fine to coarse; sub-rounded; brown; gravel to 20mm in size 0m: grass / rootlets at surface	moist	MC		E	No free groundwater observed	0.05m PID: 1ppm
0.20m	FILL/GRAVELLY CLAY: dark grey; gravel is medium to coarse sized, subangular; with silt; medium plasticity; gravel to 30mm in size; coal reject	moist	WC		E		0.15m PID: 1ppm
0.50m	SANDY SILT: dark brown; sand is fine grained	moist	VD				
0.80m	SILTY SAND: fine; brown; trace clay	moist	VD				
1.20m	SILTY CLAY: orange brown mottled grey; with fine grained sand; medium to high plasticity; residual	moist, w=PL to moist, w>PL	H	B			pp: >600 kPa

Pit discontinued at 1.20m depth
Limit of investigation

DCP blows/150mm (tip: cone)



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS: **GRID DATUM:** MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

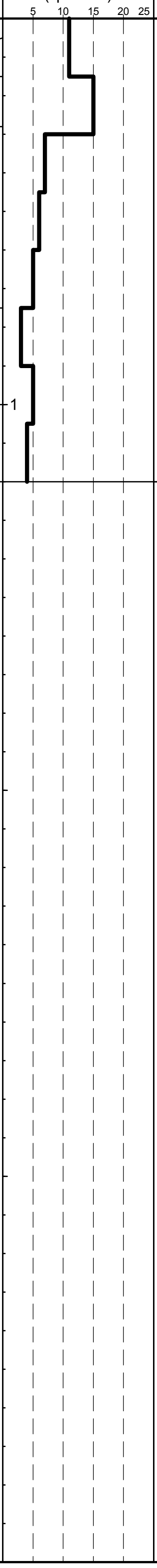
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370679
NORTHING: 6378007
DIP/AZIMUTH: 90°/--

PIT No: 1005
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DEPTH (m)	GROUND WATER LEVELS	SAMPLING GEO	SAMPLING ENV	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
0.05m	No free groundwater observed		E	FILL/GRAVELLY SAND: fine; dark grey; with silt 0-0.05m: rootlets and grass	moist moist	D MC	0.08m PID: 1ppm
0.15m			E	FILL/SANDY GRAVEL: fine to coarse; sub-rounded; brown; gravel to 20mm in size	moist	WC	0.20m PID: 1ppm
0.28m				FILL/CLAYEY GRAVEL: sub-angular; dark grey; gravel to 40mm in size; coal reject			
0.75m		B		SANDY SILT: dark brown; sand is fine grained	moist	VD	
1.00m				SILTY SAND: fine; brown; trace clay	moist	VD	
1.20m				SILTY CLAY: orange brown mottled grey; with fine grained sand	moist, w>PL	ST	

Pit discontinued at 1.20m depth
Limit of investigation



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

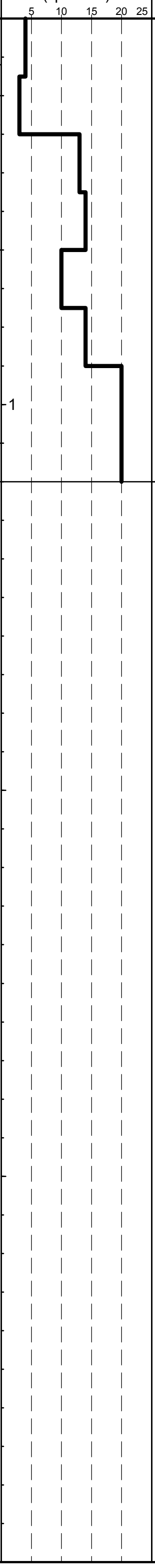
SURFACE LEVEL:
EASTING: 370713
NORTHING: 6378043
DIP/AZIMUTH: 90°/--

PIT No: 1006
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING								MATERIAL				
PROGRESS		GROUND WATER LEVELS	SAMPLING			RL	DEPTH (m)	GRAPHIC LOG	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
DRILLING & CASING	WATER		GEO	ENV	IDs and REMARKS							
		No free groundwater observed		E			0.0	0.12m	FILL/SILTY SAND: fine to medium; dark grey; trace clay 0-0.6m: tree roots and rootlets	moist	MC	0.06m PID: 1ppm
				E				0.20m	FILL/SANDY GRAVEL: sub-angular to angular; orange brown; trace clay; gravel to 20mm in size 0.12-0.2m: weathered rock	moist	MC	0.16m PID: 1ppm
							0.5	0.60m	SILTY SAND: fine to medium; dark grey; trace fine sized gravel	moist	VD	
							1.0	1.10m	CLAYEY SAND: fine to medium; pale grey; residual	moist, w<PL	H	
								1.20m	SANDY CLAY: grey brown mottled orange; sand is fine to medium grained; medium to high plasticity; residual	moist, w<PL	H	

Pit discontinued at 1.20m depth
Limit of investigation

1.5
2.0
2.5
3.0
3.5
4.0



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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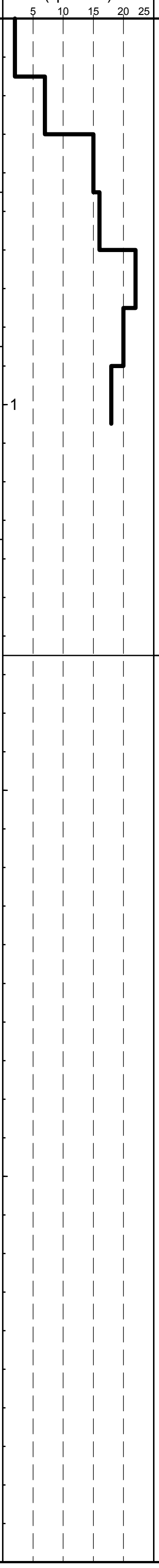
TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370624
NORTHING: 6378107
DIP/AZIMUTH: 90°/--

PIT No: 1007
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING: PROGRESS – DRILLING & CASING	WATER	GROUND WATER LEVELS	SAMPLING: GEO	ENV	IDs and REMARKS	RL	DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
		No free groundwater observed					0.0–0.45m	CLAYEY SAND: fine; dark brown 0-0.85m: roots / rootlets	moist	D	
							0.45–0.85m	SANDY SILT: brown; with clay	moist	D to VD	
							0.85–1.35m	SILTY CLAY: dark grey mottled red brown; high plasticity; residual	moist, w<PL	H	
							1.35–1.65m	CLAYSTONE: pale grey mottled red brown; extremely low strength			
							1.65m	Pit discontinued at 1.65m depth Limit of investigation			



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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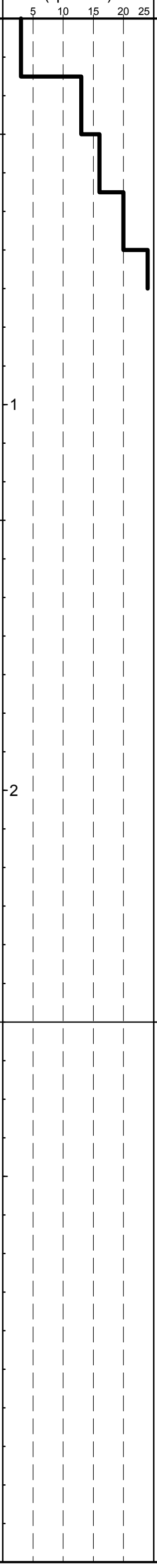
TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370637
NORTHING: 6378059
DIP/AZIMUTH: 90°/--

PIT No: 1008
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING & CASING	WATER	GROUND WATER LEVELS	GEO	ENV	IDs and REMARKS	RL	DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	DCP blows/150mm (tip: cone)	TEST RESULTS & COMMENTS
		No free groundwater observed					0.0 – 0.30m	FILL/SANDY CLAY: grey brown; with silt; medium plasticity; organics / rootlets	moist, w<PL	D to VD		
							0.30m – 1.30m	SILTY CLAY: grey mottled red brown; medium to high plasticity; residual	moist	H		
							1.30m – 2.60m	SILTY SAND: fine; pale grey mottled orange brown; with clay; weakly cemented (weathered rock); residual	moist	H		
							2.60m	Pit discontinued at 2.60m depth practical refusal on weathered rock				



Depth scale (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

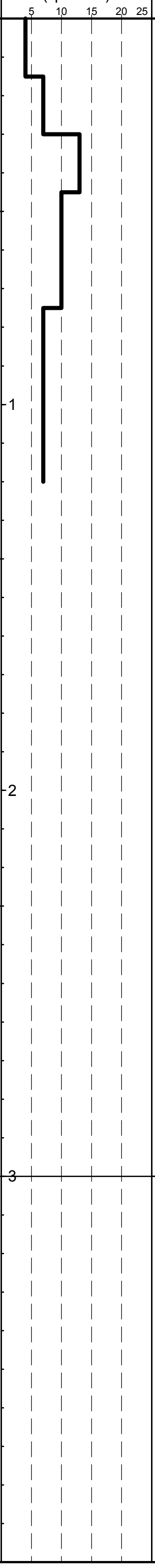
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370666
NORTHING: 6378045
DIP/AZIMUTH: 90°/--

PIT No: 1009
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

GROUND WATER LEVELS	DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
No free groundwater observed	0.0 – 0.50m	FILL/SILTY CLAY: grey brown; with medium to coarse sized subangular gravel; medium to high plasticity; gravel 20mm in size	moist, w>PL	MC	
	0.50m – 1.40m	FILL/SILTY CLAY: dark grey; with fine to medium grained sand; trace fine sized subrounded gravel	moist, w>PL	WC	
	1.40m – 2.30m	SILTY CLAY: orange brown mottled grey; trace fine grained sand; high plasticity; residual	moist, w>PL	VST to H	pp: >600 kPa
	2.30m – 3.00m	SILTY CLAY: grey mottled orange brown; with sand; high plasticity; residual	moist, w=PL	H	pp: >600 kPa
	3.00m	Pit discontinued at 3.00m depth Limit of investigation			

DCP blows/150mm (tip: cone)



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

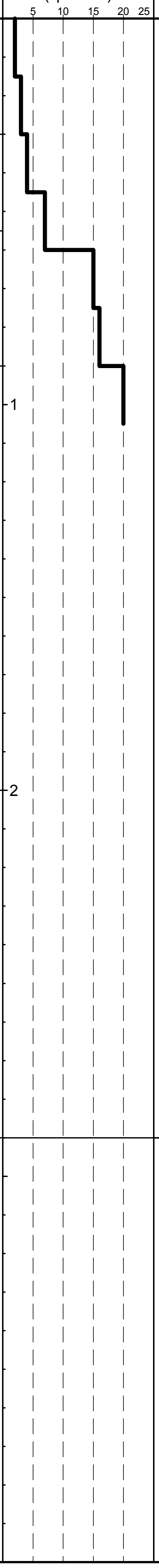
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370696
NORTHING: 6378055
DIP/AZIMUTH: 90°/--

PIT No: 1010
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING — GROUND WATER LEVELS: No free groundwater observed

DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY
0.0–0.30m	FILL/SILTY CLAY: dark grey brown; with fine to medium grained sand; medium to high plasticity 0-2m: rootlets	moist, w>PL	MC
0.30–0.55m	FILL/SANDY CLAY: brown; with fine to medium sized subrounded gravel; brick	moist, w<PL	MC
0.55–0.90m	FILL/SILTY CLAY: orange brown mottled grey; trace fine to medium grained subrounded gravel; medium to high plasticity	moist, w>PL	WC
0.90–2.00m	SILTY SAND: fine; pale grey	moist	VD
2.00–2.90m	SILTY SAND: fine; pale brown; with clay; weakly cemented	moist	VD
2.90m	Pit discontinued at 2.90m depth Limit of investigation		



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

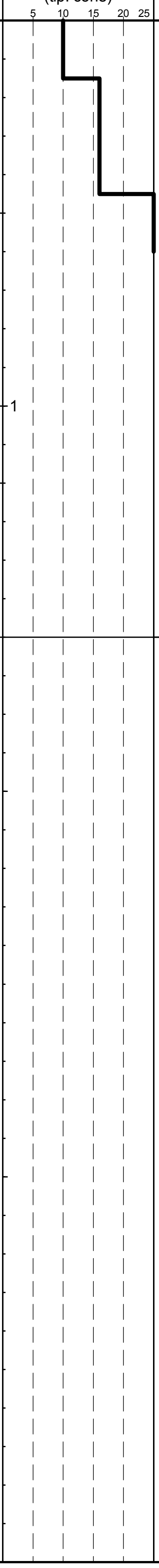
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370656
NORTHING: 6378016
DIP/AZIMUTH: 90°/--

PIT No: 1011
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
0.0 – 0.50m	FILL/SANDY CLAY: dark grey; sand is fine grained; with medium to coarse sized sub-rounded to sub-angular gravel; medium plasticity 0-0.5m: plastic, organics, broken brick	moist, w>PL	MC	
0.50 – 1.00m	FILL/SILTY SAND: fine; pale brown; trace clay 0.5-1m: weakly cemented	moist	H	
1.00 – 1.20m	FILL/SILTY CLAY: orange brown; with fine grained sand; high plasticity	moist, w<PL	H	
1.20 – 1.60m	FILL/SILTY CLAY: grey mottled red brown; high plasticity	moist, w<PL	H	pp: >600 kPa
1.60m	1.6m: VC pipe Pit discontinued at 1.60m depth Limit of investigation			

GROUND WATER LEVELS: No free groundwater observed



REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U$_x$	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

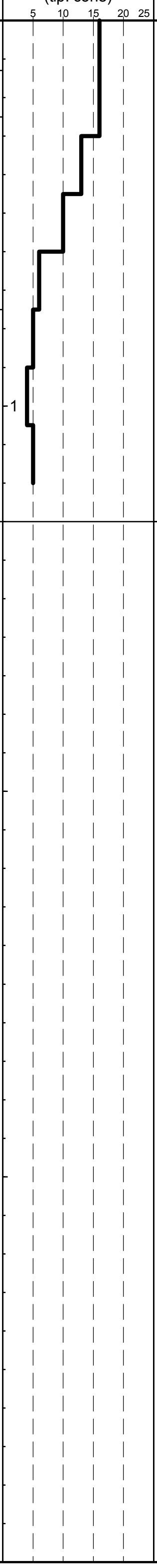
CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370724
NORTHING: 6378073
DIP/AZIMUTH: 90°/--

PIT No: 1012
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

GROUND WATER LEVELS	ENV	DEPTH (m)	DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	TEST RESULTS & COMMENTS
No free groundwater observed	E	0.0 – 0.13m	FILL/GRAVELLY SAND: fine to coarse; grey brown; gravel is medium to coarse sized; trace clay 0-0.75m: tree roots / rootlets	moist	D	0.07m PID: 1ppm
	E	0.13m – 0.25m	FILL/SANDY GRAVEL: fine to coarse; sub-angular; grey; rootlets 0.13-0.25m: glass, metal, brick	moist	VD	0.20m PID: 1ppm
	E	0.25m – 0.75m	SILTY SAND: fine; dark brown; trace clay	moist	VD	0.60m PID: 1ppm
		0.75m – 1.30m	CLAYEY SAND: fine; pale grey yellow brown	moist	D	

Pit discontinued at 1.30m depth
Limit of investigation



DEPTH (m): 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0

REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT LOG

CLIENT: Lend Lease Retirement Living
PROJECT: Proposed Link Road and Units
LOCATION: Morpeth

SURFACE LEVEL:
EASTING: 370720
NORTHING: 6378112
DIP/AZIMUTH: 90°/--

PIT No: 1013
PROJECT NO: 81251.21
DATE: 11/10/2018
SHEET: 1 of 1

DRILLING PROGRESS: DRILLING & CASING	WATER	GROUND WATER LEVELS	SAMPLING: GEO	ENV	IDs and REMARKS	RL	DEPTH (m)	MATERIAL DESCRIPTION OF STRATA	MOISTURE CONDITION	CONSISTENCY RELATIVE DENSITY	DCP blows/150mm (tip: cone)	TEST RESULTS & COMMENTS
		No free groundwater observed		E			0.10m	FILL/SANDY GRAVEL: fine to coarse; sub-rounded to sub-angular; orange brown; trace clay; gravel to 20mm in size 0-0.23m: coal reject cobbles to 100mm in size	moist	MC		0.05m PID: 1ppm
				E			0.23m	SANDY GRAVEL: fine to coarse; sub-angular; dark grey; coal reject	moist	WC		0.18m PID: 1ppm
			B	E			0.80m	SANDY GRAVEL: fine to coarse; sub-angular to angular; grey brown 0.23-0.8m: brick, broken glass, ash, ceramics, plastic; cobbles to 150mm in size	moist	WC		0.60m PID: 1ppm
							1.20m	SILTY SAND: fine; brown; trace clay	moist	VD	1	
				E			1.40m	SILTY CLAY: light grey mottled brown	moist, w>PL	VST to H		

Pit discontinued at 1.40m depth
Limit of investigation

REFER TO EXPLANATORY NOTES FOR DESCRIPTION OF SYMBOLS AND ABBREVIATIONS

RIG: JCB Backhoe 3CXECO **DRILLER:** **LOGGED:** Millard **CHECKED:**

REMARKS:

GRID DATUM: MGA94 Zone 56

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
B	Bulk sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	▷	Water seep	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▼	Water level	SPT	Standard penetration test
E	Envirnmental Sample	PID	Photo ionisation detector (ppm)	V	Shear vane (kPa)

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TEST PIT REPORT

CLIENT: Providence Projects Pty Ltd
PROJECT: Proposed Redevelopment
LOCATION: Lots 2 & 3 Morpeth Road, Morpeth

PROJECT No: 31995
SURFACE LEVEL: --

PIT No: 3
DATE: 07 Jul 04
SHEET 1 **OF** 1

Depth (m)	Description of Strata	Sampling & Testing		
		Type	Depth (m)	Results
	TOPSOIL - Grey silty fine sand			
0.2	SAND - Brown, fine to medium grained sand some silt	D D	0.3 0.5	
0.6	SANDY CLAY - Hard, brown / red-brown sandy clay, M<Wp			
2.5	SANDSTONE - Extremely low strength, grey mottled red-brown sandstone			
2.6	TEST PIT DISCONTINUED AT 2.6m due to virtual refusal on low to medium strength sandstone			

RIG: Case Extendahoe

LOGGED: Wright

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
B	Bulk sample	PID	Photo Ionisation Detector
D	Disturbed sample	U,	Tube sample (x mm dia.)
M	Moisture content (%)	Wp	Plastic limit

CHECKED
Initials:
Date:

Douglas Partners
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TEST PIT REPORT

CLIENT: Providence Projects Pty Ltd
PROJECT: Proposed Redevelopment
LOCATION: Lots 2 & 3 Morpeth Road, Morpeth

PROJECT No: 31995
SURFACE LEVEL: --

PIT No: 10
DATE: 07 Jul 04
SHEET 1 OF 1

Depth (m)	Description of Strata		Sampling & Testing		
			Type	Depth (m)	Results
	FILLING - Silty sand / topsoil	▨			
0.5	FILLING - Intermixed sandy clay and silty sand	▨			
1		▨	D	1.0	
1.5	TEST PIT DISCONTINUED AT 1.5m toe of batter				
2					
3					

RIG: Case Extendahoe

LOGGED: Wright

WATER OBSERVATIONS: No free groundwater observed

REMARKS: Side of batter

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
B	Bulk sample	PID	Photo Ionisation Detector
D	Disturbed sample	U_x	Tube sample (x mm dia.)
M	Moisture content (%)	Wp	Plastic limit

CHECKED
Initials:
Date:

Douglas Partners
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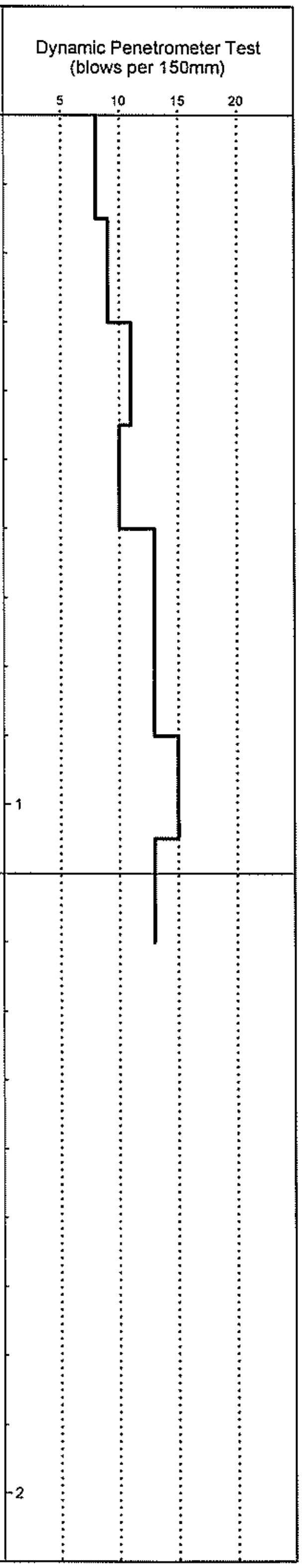
TEST PIT LOG

CLIENT: Morpeth House Pty Ltd
PROJECT: Morpeth House Estate
LOCATION: Morpeth Road, Morpeth

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 126
PROJECT No: 31995.02
DATE: 08 May 09
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - Brown fine to medium grained silty sand, trace rootlets, dry		D, PID	0.1		<1 ppm	
	0.15	SILTY SAND/SANDY SILT - Dense brown fine to medium grained silty sand/sandy silt, with some clay, dry to moist						
	0.25	SANDY CLAY - Very stiff grey mottled red fine to medium grained sandy clay, M<Wp		D, pp pp	0.5 0.9		>400 kPa >400 kPa	
-1	1.0	SANDSTONE - Extremely low strength, extremely weathered, red/grey fine to medium grained sandstone						
	1.1	Pit discontinued at 1.1m, vitual refusal						
-2								



RIG: Case 580 Super LE backhoe, 300mm bucket with teeth

LOGGED: Cairnes

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U,	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ▼ Water level

CHECKED
Initials:
Date:

Douglas Partners
Geotechnics • Environment • Groundwater

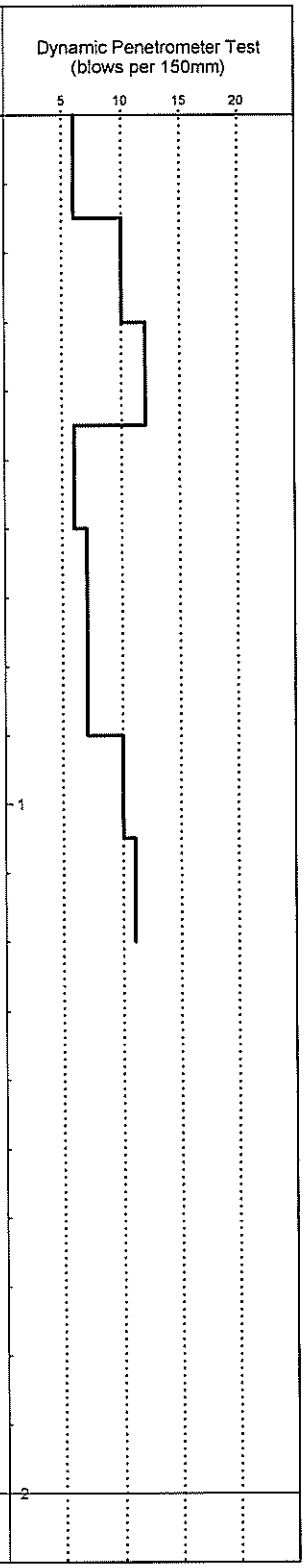
TEST PIT LOG

CLIENT: Morpeth House Pty Ltd
PROJECT: Morpeth House Estate
LOCATION: Morpeth Road, Morpeth

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 127
PROJECT No: 31995.02
DATE: 08 May 09
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - Brown fine to medium grained silty clayey sand topsoil, trace rootlets, dry to moist		D	0.1			
	0.15	SILTY SAND - Dense light brown fine to medium grained silty sand, with some fine to medium grained gravel, dry to moist		D	0.4			
	0.65	SANDY CLAY - Very stiff grey mottled red/orange fine to medium grained sandy clay, M<Wp		pp	0.7		350 - 400 kPa	
				U$_{50}$				
	1				1.1			
				D, pp	1.5		350 - >400 kPa	
				pp	1.9		>400 kPa	
	2 2.0	Pit discontinued at 2.0m, limit of investigation						



RIG: Case 580 Super LE backhoe, 300mm bucket with teeth

LOGGED: Cairnes

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U$_x$	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ≚ Water level

CHECKED
Initials:
Date:

Douglas Partners
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TEST PIT LOG

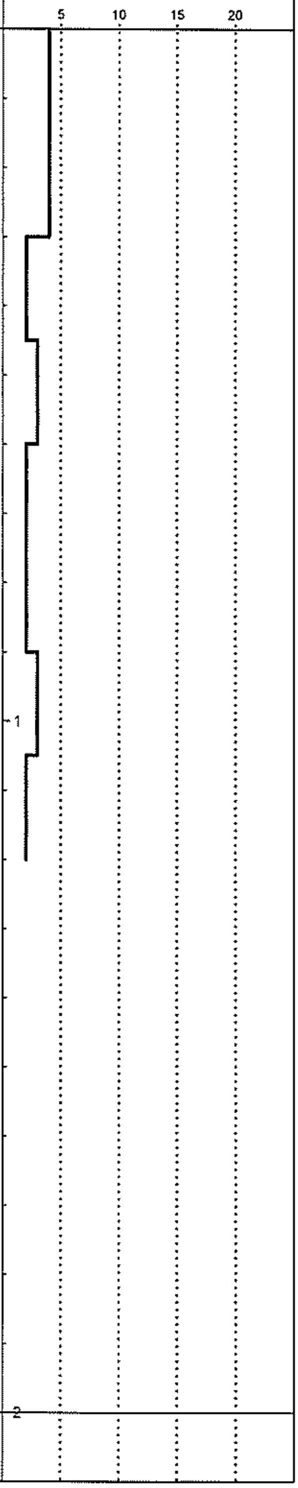
CLIENT: Morpeth House Pty Ltd
PROJECT: Morpeth House Estate
LOCATION: Morpeth Road, Morpeth

SURFACE LEVEL: --
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

PIT No: 128
PROJECT No: 31995.02
DATE: 08 May 09
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Sampling & In Situ Testing Depth	Sampling & In Situ Testing Sample	Results & Comments	Water
		FILLING - Generally comprising loose to firm brown/grey fine to medium grained silty sand, trace rootlets, dry to moist		D, PID	0.1		<1 ppm	
	0.2	FILLING - Generally comprising firm brown/grey fine to medium grained silty sand/sandy silt, with trace gravel, trace brick fragements, dry to moist		D, PID	0.5		<1 ppm	
	1							
	1.2	SAND - Loose light brown/grey fine to medium grained slightly clayey sand, wet		D	1.4			
	1.7	CLAYEY SAND - Firm brown/orange fine to medium grained clayey sand, moist		D	1.8			
	2 2.0	Pit discontinued at 2.0m, limit of investigation						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Case 580 Super LE backhoe, 300mm bucket with teeth

LOGGED: Cairnes

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U,	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ⩡ Water level

CHECKED
Initials:
Date:

Douglas Partners
Geotechnics · Environment · Groundwater

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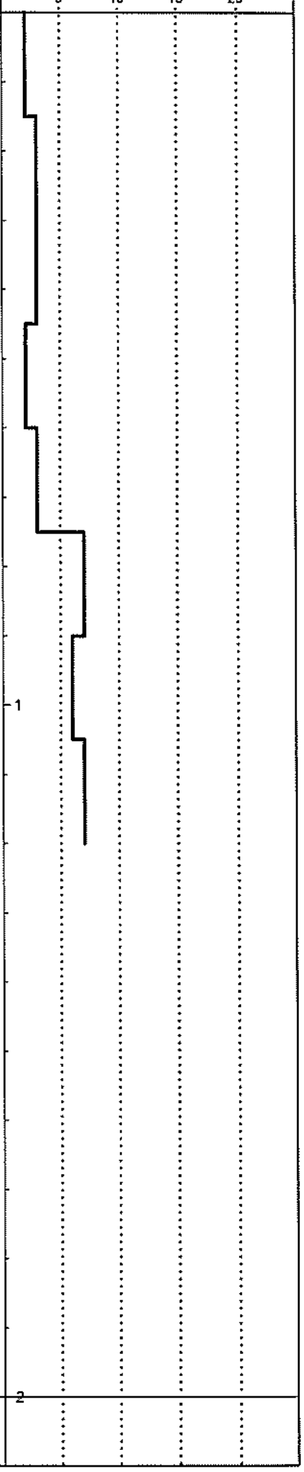
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water
		TOPSOIL - Brown/grey fine to medium grained silty sand topsoil, trace rootlets, moist						
	0.15	SILTY SAND - Loose dark brown/grey fine to medium grained silty sand, moist		D	0.3			
	0.7	SANDY CLAY - Stiff to very stiff brown mottled red/orange fine to medium grained sandy clay, M>Wp						
	1			B, pp	1.1 1.3		150 - 250 kPa	
		From 1.75m, red/grey		D, pp	1.8		>400 kPa	
	2 2.0	Pit discontinued at 2.0m, limit of investigation						

Dynamic Penetrometer Test (blows per 150mm)



RIG: Case 580 Super LE backhoe, 300mm bucket with teeth
LOGGED: Cairnes
WATER OBSERVATIONS: No free groundwater observed
REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
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U,	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ₮ Water level

CHECKED
Initials:
Date:

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Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
ABN 75 053 980 117
www.douglaspartners.com.au
15 Callistemon Close
Warabrook NSW 2304
PO Box 324
Hunter Region Mail Centre NSW 2310
Phone (02) 4960 9600
Fax (02) 4960 9601

Results of Dynamic Penetrometer Tests

Client Lend Lease Retirement Living
Project Proposed Link Road and Units
Location Closebourne Heritage Estate

Project No. 81251.21
Date 01/10/18
Page No. 2 of 2

Test Location	1011	1012	1013							
RL of Test (AHD)										
Depth (m)	**Penetration Resistance** Blows/150 mm									
0 - 0.15	10	16	25							
0.15 - 0.30	16	16	25							
0.30 - 0.45	16	13								
0.45 - 0.60	25	10								
0.60 - 0.75		6								
0.75 - 0.90		5								
0.90 - 1.05		4								
1.05 - 1.20		5								
1.20 - 1.35										
1.35 - 1.50										
1.50 - 1.65										
1.65 - 1.80										
1.80 - 1.95										
1.95 - 2.10										
2.10 - 2.25										
2.25 - 2.40										
2.40 - 2.55										
2.55 - 2.70										
2.70 - 2.85										
2.85 - 3.00										
3.00 - 3.15										
3.15 - 3.30										
3.30 - 3.45										
3.45 - 3.60										

Test Method AS 1289.6.3.2, Cone Penetrometer ☑
AS 1289.6.3.3, Sand Penetrometer ☐

Tested By DJM
Checked By MPG

Remarks Ref = Refusal, 24/110 indicates 25 blows for 110 mm penetration

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Geotechnics / Environment / Groundwater

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Client Lend Lease Retirement Living

Project Proposed Link Road and Units

Location Closebourne Heritage Estate

Project No. 81251.21

Date 01/10/18

Page No. 1 of 2

Test Location	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010
RL of Test (AHD)										
Depth (m)	**Penetration Resistance** Blows/150 mm									
0 - 0.15	2	1	-	12	11	4	2	3	4	2
0.15 - 0.30	2	2	-	9	15	3	7	13	7	3
0.30 - 0.45	7	1	-	8	7	13	15	16	13	4
0.45 - 0.60	8	2	-	7	6	14	16	20	10	7
0.60 - 0.75	8	6	-	6	5	10	22	24	10	15
0.75 - 0.90	8	6	-	4	3	14	20		7	16
0.90 - 1.05	5	9	2	7	5	20	18		7	20
1.05 - 1.20	4	10	6	9	4	20			7	
1.20 - 1.35										
1.35 - 1.50										
1.50 - 1.65										
1.65 - 1.80										
1.80 - 1.95										
1.95 - 2.10										
2.10 - 2.25										
2.25 - 2.40										
2.40 - 2.55										
2.55 - 2.70										
2.70 - 2.85										
2.85 - 3.00										
3.00 - 3.15										
3.15 - 3.30										
3.30 - 3.45										
3.45 - 3.60										

Test Method AS 1289.6.3.2, Cone Penetrometer ☑
AS 1289.6.3.3, Sand Penetrometer ☐

Tested By DJM
Checked By MPG

Remarks Ref = Refusal, 24/110 indicates 25 blows for 110 mm penetration

Appendix C

Results of Laboratory Testing

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Newcastle Laboratory
15 Callistemon Close Warabrook Newcastle NSW 2310
Phone: (02) 4960 9600
Fax: (02) 4960 9601
Email: Peter.Gorseski@douglaspartners.com.au

NATA
WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

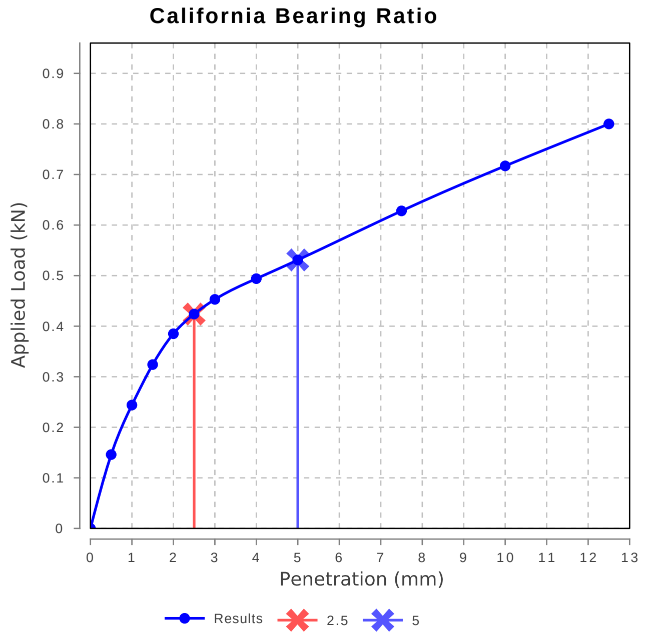
Approved Signatory: Peter Gorseski
Laboratory Manager
NATA Accredited Laboratory Number: 828

Report Number:	**81251.21-1**
Issue Number:	1
Date Issued:	31/10/2018
Client:	Lend Lease Retirement Living 53/1 Monty Place, Ngunnawal ACT 2913
Project Number:	81251.21
Project Name:	Proposed Stage 6
Project Location:	off Morpeth Road, Morpeth
Work Request:	2692
Sample Number:	18-2692A
Date Sampled:	10/10/2018
Sampling Method:	Sampled by Engineering Department
Sample Location:	**1004 (0.8 - 1.2m)**
Material:	Silty Clay

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

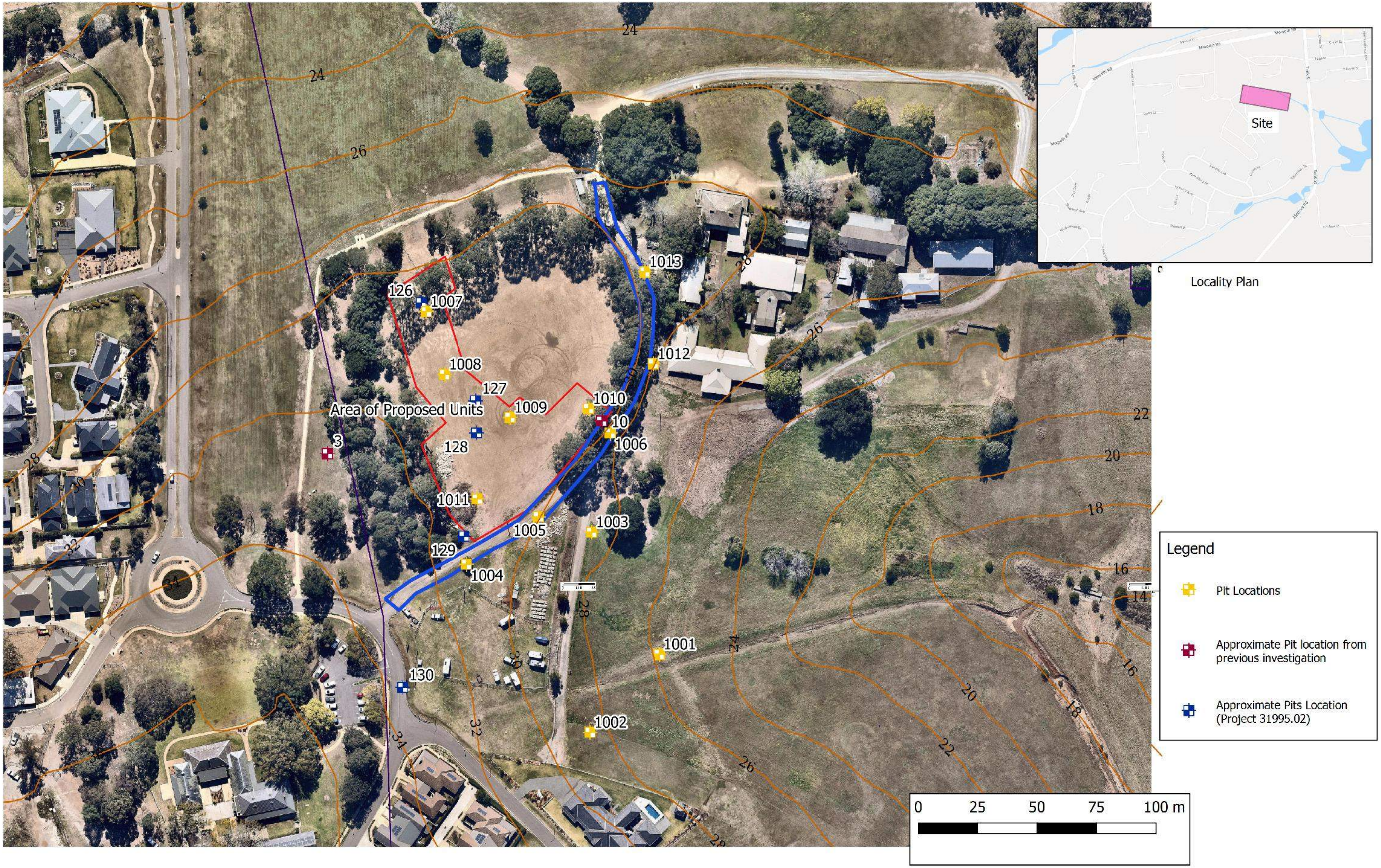
Dry Density - Moisture Relationship (AS 1289 5.1.1 & 2.1.1)	
Mould Type	1 LITRE MOULD A
Compaction	Standard
No. Layers	3
No. Blows / Layer	25
Maximum Dry Density (t/m^3)	1.72
Optimum Moisture Content (%)	18.5
Oversize Sieve (mm)	19
Oversize Material (%)	0
Method used to Determine Plasticity	Visual Assessment
Curing Hours	48

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	2.5 mm		
CBR %	**3.0**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Method used to Determine Plasticity	Visual Assessment		
Maximum Dry Density (t/m^3)	1.72		
Optimum Moisture Content (%)	18.5		
Laboratory Density Ratio (%)	99.0		
Laboratory Moisture Ratio (%)	99.0		
Dry Density after Soaking (t/m^3)	1.61		
Field Moisture Content (%)	16.6		
Moisture Content at Placement (%)	18.3		
Moisture Content Top 30mm (%)	23.5		
Moisture Content Rest of Sample (%)	19.8		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Curing Hours	48		
Swell (%)	5.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Appendix D

Drawing 1 – Test Location Plan



Drawing adapted from plan supplied by client and NearMap image

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: Lend Lease Retirement Living
OFFICE: Newcastle
DRAWN BY: MPG
SCALE: 1:1500 @ A3
DATE: 18.10.2018

TITLE: **Test Location Plan**
Proposed Link Road and Units
Closebourne Heritage Estate, Morpeth

PROJECT No: 81251.21
DRAWING No: 1
REVISION: 1