



# **Douglas Partners**

*Geotechnics | Environment | Groundwater*

Report on  
Geotechnical Investigation

Proposed  
Administration Building and Carpark  
Medowie Christian School  
Waropara Road, Medowie

Prepared for  
Medowie Christian School Limited

In Consultation with  
EPM Projects Pty Ltd

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## Executive Summary

This report presents the results of a geotechnical investigation undertaken for a proposed administration building and carpark at Medowie Christian School, Waropara Road, Medowie. It is understood the proposed development includes the partial demolition of the existing reception building and construction of a new two storey administration building as well as the construction of a new 13 space carpark.

Field work comprised the drilling of three boreholes and dynamic penetrometer testing at all borehole locations and two additional locations. Subsurface conditions encountered at the test locations included filling to depths of up to 0.2 m underlain by initially firm, then very stiff clay within the bores undertaken for the administration building, and filling to up to 0.7 m depth, underlain by silty sand then firm to stiff clay in the area of the proposed car parking. No free groundwater was observed in the bores whilst augering.

The site was classified Class P in accordance with AS2870 – 2011 with characteristic surface movements ( $y_s$ ) estimated to be approximately 45 mm to 55 mm for footings founded in the natural very stiff clay.

Shallow footings founded at least 0.5 m depth below the finished surface level and within the natural very stiff or better clay should be proportioned for a maximum allowable bearing pressure of 200 kPa. Total settlements of up to about 10 mm (independent of seasonal reactive ground movements) are anticipated for this footing configuration and loading conditions.

Bored piles would be suitable for the support of structural loads, founded in very stiff or better clay and proportion for a maximum allowable end bearing pressure of 350 kPa for a socket length of greater than four pile diameters and an allowable shaft adhesion of 20 kPa for the section of shaft within the stiff or better clay.

To minimise the effects of fluctuations of moisture content within the reactive soils present at the site, it is recommended that a cut-off drain is constructed upslope of the proposed building to intersect surface and near surface water flows. The drain should convey the collected water into the formal stormwater collection system downslope of the proposed building development.

For the car parking area a flexible pavement of 250 mm total thickness is recommended for a design traffic loading of  $4 \times 10^3$  ESA.

The results of testing indicated that the soil is moderately aggressive to buried concrete based on soil pH and non-aggressive to buried steel piles.

A hazard factor of 0.10 and a site sub-soil Class  $C_e$  – shallow soil site.

Site soils considered unsuitable for the disposal of stormwater.

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## **Report on Geotechnical Investigation and Proposed Administration Building and Carpark Medowie Christian School, Waropara Road, Medowie**

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### **1. Introduction**

This report presents the results of a geotechnical investigation undertaken for a proposed administration building and carpark at Medowie Christian School, Waropara Road, Medowie. The investigation was commissioned by Medowie Christian School Ltd and was undertaken in consultation with EPM Projects Pty Ltd, managers for the project. The investigation was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal NCL150561 dated 26 August 2015.

It is understood the proposed development includes the partial demolition of the existing reception building and construction of a new two storey administration building as well as the construction of a new 13 space carpark.

The aim of the investigation was to assess the subsurface soil and groundwater conditions and provide comments on the following:

- Subsurface conditions;
- Site classification to AS2870 with regard to the reactivity of the soil;
- Site factor to AS 1170.4 with regard to earthquake effects;
- Carpark pavement thickness design including CBR design values;
- Footing design options and parameters (shallow footings and piled footings);
- Estimated settlements including differential settlement;
- Retaining wall design parameters including temporary and long term batter slope requirements;
- Depth to groundwater (if encountered);
- Site preparation requirements including excavatability and suitability of material for reuse on site;
- Qualitative assessment of the potential for on-site disposal of stormwater; and
- Comment on soil aggressiveness (pH, EC, sulfates and chlorides).

The investigation comprised the drilling of three boreholes, dynamic penetrometer testing (DPT), laboratory testing and preparation of this report. The details are presented in this report together with comments on the items listed above.

DP is also carrying out a Preliminary Site Investigation (contamination) for the site, which will be reported under a separate cover.

## 2. Site Description

The site is located at the Medowie Christian School, Waropara Road, Medowie. The proposed development lies within two distinct areas of the school as follows:

- Proposed Administration Building Western area of the school; and
- Proposed Additional Car Parking Northern area of the school.

Figure 1, below, shows an aerial view of the school with the approximate proposed development areas.



**Figure 1: Aerial image of school showing proposed administration and car parking areas**

### **Proposed Administration Building**

The proposed administration building footprint lies within a partially developed area of the site. An existing administration block is located within the eastern part of the development footprint (refer Figure 2).





**Figure 2: View of proposed administration building footprint, looking south**

The ground surface generally falls to the south at slopes in the order of 5 to 10°.

An existing footpath is present within the development footprint, together with in-ground services (fire ring main, electricity cabling and irrigation lines).

The ground surface within the south-western area of the proposed building footprint was damp at the time of investigation (refer Figure 3).



**Figure 3: Area of damp ground in south-western corner of proposed administration building footprint, looking south**

An existing cutting of approximately 2 m in height was located to the north of the proposed building footprint. Conditions exposed within this cutting included grey mottled orange residual clay (refer Figure 4).



**Figure 4: Existing cutting to the north of proposed administration building**

A number of mature trees were present within the proposed footprint.

### **Proposed Car Parking Area**

The proposed car parking area is located within the northern area of the school grounds. It lies within an embankment batter between an existing pavement and a flat, grassed area (refer Figure 5).



**Figure 5: Area of proposed car park**

## **3. Field Work Methods**

Field work was undertaken on 23 September 2015 and comprised the following:

- Drilling of three boreholes (designated Bores 1, 2 and 5) taken to depths ranging from to 1.5 m to 8.95 m; and



- Dynamic penetrometer testing at all borehole locations and two additional locations (designated DPTs 3 and 4).

The bores were drilled using a four-wheel drive mounted rotary drilling rig equipped with 100 mm diameter solid flight augers. Standard penetration tests (SPTs) were performed at selected depths.

Test locations were set out by a geotechnical engineer from DP based on the proposed development, site features and presence of in-ground services. The engineer also logged the subsurface profile at each test location and collected samples for laboratory testing and identification purposes.

At the completion of drilling, the boreholes were backfilled with the cuttings from the drilling process.

The approximate test locations of bores and DPTs are shown on Drawing 1, in Appendix C.

## 4. Field Work Results

The subsurface conditions encountered at the bores and DPT locations are presented in the Borehole Logs and DPT results in Appendix A. These should be read in conjunction with the preceding accompanying notes which explain the descriptive terms and classification methods used in the logs.

A summary of the subsurface conditions encountered at the test locations is provided below:

### Administration Building

FILLING	Generally comprising either wood chip mulch or clayey sand to depths of 0.06 m and 0.2 m in Bores 1 and 2 respectively.
CLAY	Initially firm in Bore 2, but very stiff below 0.2 m and 0.4 m in Bores 1 and 2 respectively. Stiff clay was encountered from 4 m depth in Bore 1.

The results of dynamic penetrometer testing indicated the presence of stiff to very stiff conditions at DCP 3. Low blow counts were observed within the upper 0.45 m of DCP 4, however this location was within an existing garden and hence these blow counts are probably associated with loosened soil. Higher blow counts, indicating stiff or better conditions were recorded below 0.45 m depth.

### Car Park

FILLING	Generally comprising sandy clay and sand filling to 0.7 m depth.
SILTY SAND	Medium dense, grey silty sand to 1 m depth.
CLAY	Firm to stiff silty clay to termination of the bore at 1.5 m depth.

## Groundwater Observations

No free groundwater was observed in the bores whilst augering. It should be noted that groundwater levels are affected by factors such as climatic conditions and soil permeability and will therefore vary with time.

## 5. Laboratory Testing

Laboratory testing comprised the following:

- Two shrink-swell tests on cohesive material from the bores within the proposed administration building; and
- One California bearing ratio test on a sample of the car park subgrade.
- Two soil samples were analysed for the following analytes:
  - o pH;
  - o Electrical Conductivity (EC);
  - o Sulphate (SO<sub>4</sub>); and
  - o Chloride (Cl).

The detailed test results are presented in Appendix B and are summarised in Tables 1 to 3 below.

**Table 1: Results of Shrink Swell Testing**

Location	Depth (m)	Description	I <sub>ss</sub> (% per Δ pF)	FMC (%)
Bore 1	0.5 – 0.8	Grey mottled brown CLAY	4.3	31.0
Bore 2	0.8 – 1.0	Yellow mottled brown CLAY	3.6	23.2

Notes to Table 1:

I<sub>ss</sub> – Shrink-swell index

FMC – Field Moisture Content

**Table 2: Summary of California Bearing Ratio Testing**

Bore	Depth (m)	Description	FMC (%)	MDD (t/m <sup>3</sup> )	OMC (%)	CBR (%)	Swell During Soaking (%)
5	1.1 – 1.3	Brown grey sandy silt CLAY	18.9	1.83	15.0	11	0.1

Notes to Table 2:

FMC = Field moisture content

MDD = Maximum dry density

OMC = Optimum moisture content

CBR = California bearing ratio

**Table 3: Summary of Agressivity Testing**

Bore	Depth (m)	Description	pH	Electrical Conductivity ( $\mu\text{S/cm}$ )	Chloride (Cl)	Sulphate ( $\text{SO}_4$ )
1	1 – 1.45	Grey brown CLAY	4.7	160	220	29
2	0.5	Yellow brown CLAY	4.9	110	70	69

## 6. Proposed Development

It is understood that the proposed development comprises the following:

- Construction of a new administration building in the general location shown on Drawing 1 with the following features:
  - o The administration building will be a two storey, split level building;
  - o A 2.5 m high retaining wall is proposed at the split level interface;
  - o Column working loads in the order of 250 kN are anticipated;
- Construction of a new 15 space car parking area in the northern area of the site, as shown on Drawing 1.

## 7. Comments

### 7.1 Site Classification

Site classification to AS 2870 is not strictly applicable to this site due to it being a school development rather than a residential development. However, the principles of footing design and site maintenance presented therein should be taken into account for structures such as that proposed for the site.

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 1), the typical soil profiles revealed in the bores, and the results of laboratory testing.

Owing to the presence of existing buildings, existing filling and mature trees within the zone of influence of the proposed building, the site classification for the site is Class P in accordance with AS2870 – 2011 (Ref 1).

As a guide for footing design, the range of characteristic surface movements ( $y_s$ ) is estimated to be approximately 45 mm to 55 mm for footings founded in the natural very stiff clay under normal seasonal moisture fluctuations without the influence of the trees within the zone of influence, filling and on the understanding that new, additional filling is not proposed.

AS 2870-2011 (Ref 1) provides guidance and a method to estimate potential surface movements due to tree induced suction change for existing and possible new trees (eg extreme drying effects). The estimated additional surface movement due to drying from trees remaining on site, within a distance of 0.5 times the height of the tree, from the buildings is estimated from Appendix H4(e) of AS 2870-2011. Based on DP's experience, it is expected that additional surface movements due to swelling because of removal of trees would be of similar magnitude to that for drying. Therefore, tree induced surface movements should be added to the differential mound movement ( $y_m$ ) as defined in AS 2870-2011.

The effect of additional surface movement from suction change due to the presence of trees within close proximity of the buildings, ( $y_{t \max}$ ), is estimated to be 25 mm to 45 mm. Footings should be designed for the surface movement from suction change due to the presence of trees ( $y_{t \max}$ ), in addition to the estimated characteristic surface movement ( $y_s$ ).

Design, construction and maintenance should take into account the need to achieve and preserve an equilibrium soil moisture regime beneath and around buildings. Such measures include paved areas around structures to fall away from the building, flexible plumbing connections and service trenches to be backfilled with compacted clay. These and other measures are described in AS 2870-2011 (Ref 1) and the attached CSIRO-BTF 18 publication.

Site classification, as above, has been based on the information obtained from the bores and on the results of laboratory testing, and have involved some interpolation between data points. In the event that conditions encountered during construction are different to those presented in this report, it is recommended that advice be sought from this office.

## 7.2 Footings

### 7.2.1 Shallow Footings

It is considered that shallow pad or strip footings would be suitable for the support of structural loads associated with the proposed development. Shallow footings founded at least 0.5 m depth below the finished surface level and within the natural very stiff or better clay, as encountered below about 0.2 m to 0.4 m depth in Bores 1 and 2, should be proportioned for a maximum allowable bearing pressure of 200 kPa. Total settlements of up to about 10 mm (independent of seasonal reactive ground movements) are anticipated for this footing configuration and loading conditions.

Differential settlements would depend on the loading applied between adjacent footings and differential movements between the areas of the existing trees. Increases in footing dimensions, founding depth or applied pressure will result in non-linear increases in settlement.

For shallow footings, the structure should be designed to accommodate additional potential ground surface movements associated with abnormal moisture conditions imposed by adjacent trees (such as articulation joints to allow for differential movement). Void formers should be used below the slab to protect against heave.

Footings should not be founded in existing or proposed filling unless it has been placed and compacted under Level 1 earthworks as defined in AS 3798-2007 (Ref 2).

Footing excavations should be inspected by geotechnical engineers to confirm design parameters.

### **7.2.2 Bored Piles**

Bored piles would be suitable for the support of structural loads. The bored piles should be founded in very stiff or better clay and proportion for a maximum allowable end bearing pressure of 350 kPa for a socket length of greater than four pile diameters and an allowable shaft adhesion of 20 kPa for the section of shaft within the stiff or better clay. The upper 1 m of shaft adhesion should be ignored. For a 0.6 m diameter pile, founded in stiff to very stiff clay at 5 m depth, a maximum allowable working load of 250 kN has been estimated.

If any water collects in the base of the pile holes, this should be removed, and the base checked for potential softening and over-drilled as necessary, prior to pouring of concrete. Suitable founding strata should be confirmed during construction.

Settlement of piles is expected to be up to about 1% of the pile diameter for the end-bearing pressures provided above.

## **7.3 Site Drainage**

During the investigation it was noted that the ground surface was damp within the footprint of the proposed building. Based on discussion with school staff, it is understood that seepage regularly occurs within the area immediately upslope of, and within, the proposed administration building footprint.

To minimise the effects of fluctuations of moisture content within the reactive soils present at the site, it is recommended that a cut-off drain is constructed upslope of the proposed building to intersect surface and near surface water flows. The drain should be constructed to at least 0.6 m depth and include dual ag-line encapsulated in geofabric and surrounded by free draining gravel, with the upper 0.3 m of the trench excavation backfilled with low permeability clay soils, such as present at the site. The drains should convey the collected water into the formal stormwater collection system downslope of the proposed building development.

## **7.4 Excavation and Reuse of Excavated Material**

Excavation of the clay soils encountered at the site is anticipated to be readily achieved with the use of conventional earthmoving equipment, such as 5 tonne or larger excavators.

The residual clay soils are considered suitable for the re-use as engineered filling, provided they are placed and compacted with control of layer thickness, moisture content and compaction. Due consideration should be given to the effect on reactive soil movements should clay material won on site be used beneath the foundations for the proposed structures as it may lead to a more severe site classification.



## 7.5 Retaining Walls

### 7.5.1 Temporary Excavation

It is understood that excavation of up to 2.5 m may be required for the construction of the split level building. A retaining wall will be constructed along the split level interface. The clay encountered in the bores is generally of stiff or better consistency and would be expected to stand unsupported in the short term. However, there would be the possibility of localised dry friable lumps dislodging. This may be exacerbated by prolonged exposure and adverse weather. The risk could be reduced by ensuring a short exposure period, and undertaking the construction in sections, if feasible.

The stiff or stronger clay should be battered no steeper than 1.5H:1V.

### 7.5.2 Design Parameters

For permanent retaining walls, where the wall will be free to deflect, design may be based on “active” ( $K_a$ ) earth pressure coefficients, assuming a triangular earth pressure distribution. This would comprise any non-propped or laterally unrestrained walls (e.g. cantilever type walls). Cantilever walls should not be used to support any adjacent building foundations or underground services unless it is designed for the additional surcharge loading. Walls which are not free to move, should be designed for an at rest earth pressure coefficient ( $K_o$ ) in addition to any surcharge from the footings if support of adjacent footings is required.

The suggested long term (permanent) design soil parameters are shown in Table 4 below. Any additional surcharge loads, including those imposed by proposed footings or inclined slopes, during or after construction, should be accounted for in design.

**Table 4: Geotechnical Parameters for Retaining Structures**

Parameter	Symbol	Clay
Bulk Density	$\gamma$	18 kN / m <sup>3</sup>
Effective Cohesion	$c'$	0 kPa
Angle of Friction	$\phi'$	25°
Active Earth Pressure Coefficient	$K_a$	0.4
At Rest Earth Pressure Coefficient	$K_o$	0.6

Backfill placed behind the wall should be free-draining (20 mm single size gravel or coarser) and connected to the wall drainage system. A slotted drainage pipe should be placed at the base of the backfill which should all be encapsulated in a geotextile fabric. Alternatively, the retaining wall should be designed for full hydrostatic pressure.

A clay lining, a dish drain or impermeable surface should be formed at the top of the wall backfill to prevent stormwater overland flow surcharging the retaining wall.

The very stiff or better clay would be a suitable bearing stratum for retaining wall footings which should be proportioned for a maximum allowable bearing pressure of 100 kPa in clay.

## 7.6 Pavement Design

The following pavement thickness design is in accordance with Austroads – Guide to Pavement Technology (Ref 3).

### 7.6.1 Design Traffic

It is understood that the carpark pavement will be trafficked by predominantly light vehicles with the occasional garbage and delivery trucks. Austroads (Ref 3) provides indicative design traffic values for lightly trafficked roads. For this development a design traffic loading of  $4 \times 10^3$  ESA has been adopted. If the traffic loading is to be significantly different from the above, the pavement thickness should be reviewed.

### 7.6.2 Subgrade CBR

The results of laboratory testing on the natural clay subgrade soil from the investigation indicated a four day soaked CBR value of 11%. It is noted, however that results of the shrink swell testing of the clay soils encountered at the site indicated that they are of high plasticity and the presence of similar high plasticity soils cannot be discounted within the proposed car park and hence a design CBR of 5% has been used.

### 7.6.3 Flexible Pavement Thickness Design

The flexible pavement thickness design for the proposed car park pavement is presented in Table 5, below.

**Table 5: Flexible Pavement Thickness**

<b>Pavement Layer</b>	<b>Thickness (mm)</b>
Wearing Course	2 Coat Spray Seal
Basecourse	100
Subbase	150
Total	250

Notes to Table 5:

- 1 Where an asphaltic concrete wearing course is used a 7 mm prime seal should be placed over the basecourse prior to placement of the AC. The thickness of the AC may be deducted from the subbase layer.

The pavement thickness presented above is dependent on the provision and maintenance of adequate surface and subsurface drainage. Surface grades should be sufficient to prevent ponding of stormwater.

The recommended material quality and compaction requirements for sealed flexible pavement are presented in Table 6, below.

**Table 6: Material Quality and Compaction Requirements – Sealed Flexible Pavement**

Pavement Layer	Material Quality	Compaction Requirements
Basecourse	CBR $\geq$ 80%, PI $\leq$ 6%. Grading in accordance with SR41 (Ref 4)	Compact to at least 98% dry density ratio Modified (AS 1289.5.2.1, Ref 5)
Subbase	CBR $\geq$ 30%, PI $\leq$ 12%. Grading in accordance with SR41 (Ref 4)	Compact to at least 95% dry density ratio Modified (AS 1289.5.2.1, Ref 5)
Select Subgrade*	Soaked CBR $\geq$ 15%	Compact to 100% dry density ratio Standard (AS 1289.5.1.1, Ref 6)
Subgrade	CBR $\geq$ 5%	Compact to at least 100% dry density ratio Standard (AS 1289.5.1.1, Ref 6)

Notes to Table 6:

CBR – California bearing ratio (4 day soaked)

PI – Plasticity Index

\* If required, refer Section 7.7

## 7.7 Subgrade Preparation

The following procedure is recommended for preparation of the pavement subgrades:

- Excavate to design subgrade level;
- Remove any additional topsoil, uncontrolled filling (unless deemed suitable to remain in place by a geotechnical engineer) or deleterious materials. Tree stumps / tree roots should be removed and backfilled with approved select subgrade material;
- Proof roll the excavated surface to assess moisture content and soft zones. Remove soft zones and replace with compacted approved filling. Moisture contents should be in the range -4% (dry) to -1% (dry) OMC, for pavements where OMC is the optimum moisture content at standard compaction. If wet subgrade conditions are encountered, the material should either be tined and allowed to dry or removed and replaced with a select subgrade (CBR>15%). The depth of any excavation should be confirmed by geotechnical inspection;
- Compact the natural subgrade to a minimum dry density ratio of 100% Standard (AS 1289.5.1.1). The compacted clay subgrade should be left exposed for a minimum amount of time prior to placement of pavement layers to minimise the occurrence of desiccation cracking in dry weather, or softening in wet weather; and
- If raising of the subgrade level is required, all deleterious materials should be removed. Approved filling should then be placed in layers not exceeding 250 mm loose thickness and compacted to a minimum dry density ratio of 100% Standard at the moisture content described above.

Geotechnical inspections and testing should be undertaken during construction in accordance with AS 3798-2007 (Ref 2).

## 7.8 Soil Aggressivity

The results of the laboratory testing on the soil collected from Bore 1 and 2 were compared against exposure classification limits provided in AS2159-2009 (Ref 7). The results of the testing indicated that the soil is moderately aggressive to buried concrete based on soil pH and non-aggressive to buried steel piles.

## 7.9 Earthquake Site Factor

Using the results of test bores as well as the procedures described in AS1170.4 – 2007 (Ref 8) a hazard factor of 0.10 and a site sub-soil Class C<sub>e</sub> – shallow soil site.

## 7.10 On Site Disposal of Stormwater

Site soils generally consist of residual clay to depths of over 6 m. Such soils are of low permeability and are generally unsuitable for the disposal of stormwater.

## 8. References

1. Australian Standard AS2870 - 2011, "Residential Slabs and Footings".
2. Australian Standard AS3798-2007, "Guidelines on Earthworks for Commercial & Residential Developments", Standards Australia, March 2007.
3. Austroads, "Guide to Pavement Technology Part 2: Pavement Structural Design", Austroads AGPT02, 12 February 2012.
4. ARRB Special Report 41 "A Structural Design Guide for Flexible Residential Street Pavements", Australian Road Research Board, April 1989.
5. Australian Standard AS1289.5.2.1-2003, "Testing Soils for Engineering Purposes".
6. Australian Standard AS1289.5.1.1-2003, "Testing Soils for Engineering Purposes".
7. Australian Standard AS2159-2009, "Piling - Design and Installation".
8. Australian Standard AS1170.4-2007, "Structural Design Actions, Part 4: Earthquake Actions in Australia".

## 9. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at Medowie Christian School, Medowie in accordance with DP's proposal NCL150561 dated 26 August 2015 and acceptance received from EPM Projects Pty Ltd, acting on behalf of Medowie Christian School Ltd. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Medowie Christian School Ltd and EPM Project Pty Ltd 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 contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

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**Douglas Partners Pty Ltd**



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## **Appendix A**

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About this Report  
Sampling Methods  
Soil Descriptions  
Symbols and Abbreviations  
Borehole Logs (Bores 1, 2 and 5)  
Results of Dynamic Penetrometer Testing  
CSIRO 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.

## Copyright

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

## Borehole and Test Pit Logs

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

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

## Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;

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

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

## Reports

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

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

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

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

# *About this Report*

## **Site Anomalies**

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

## **Information for Contractual Purposes**

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

## **Site Inspection**

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



## Sampling

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

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

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

## Test Pits

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

## Large Diameter Augers

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

## Continuous Spiral Flight Augers

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

reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

## Non-core Rotary Drilling

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

## Continuous Core Drilling

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

## Standard Penetration Tests

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

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

The test results are reported in the following form.

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

# *Sampling Methods*

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.





## Description and Classification Methods

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

## Soil Types

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

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

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

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

The proportions of secondary constituents of soils are described as:

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

Definitions of grading terms used are:

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

## Cohesive Soils

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

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

## Cohesionless Soils

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

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

# *Soil Descriptions*

## **Soil Origin**

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

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

Transported soils may be further subdivided into:

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

# 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 <sub>50</sub>	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

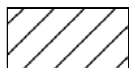
### Soils



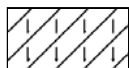
Topsoil



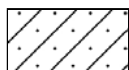
Peat



Clay



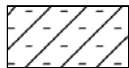
Silty clay



Sandy clay



Gravelly clay



Shaly clay



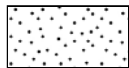
Silt



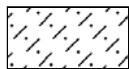
Clayey silt



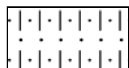
Sandy silt



Sand



Clayey sand



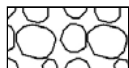
Silty sand



Gravel



Sandy gravel

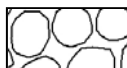


Cobbles, boulders



Talus

### Sedimentary Rocks



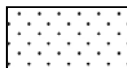
Boulder conglomerate



Conglomerate



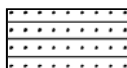
Conglomeratic sandstone



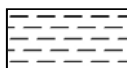
Sandstone



Siltstone



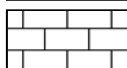
Laminite



Mudstone, claystone, shale

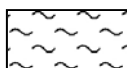


Coal

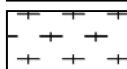


Limestone

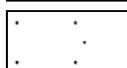
### Metamorphic Rocks



Slate, phyllite, schist

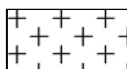


Gneiss

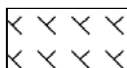


Quartzite

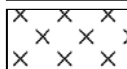
### Igneous Rocks



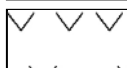
Granite



Dolerite, basalt, andesite



Dacite, epidote



Tuff, breccia



Porphyry

# BOREHOLE LOG

**CLIENT:** EPM Projects Pty Ltd  
**PROJECT:** Medowie Christian School  
**LOCATION:** Waropara Road, Medowie

**SURFACE LEVEL:** --  
**EASTING:** 392444  
**NORTHING:** 6377648  
**DIP/AZIMUTH:** 90°/--

**BORE No:** 1  
**PROJECT No:** 81808.00  
**DATE:** 23/9/2015  
**SHEET 1 OF 1**

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		
	0.2	FILLING - Generally comprising of grey brown clayey, fine to medium grained sand filling, with trace of rootlets, moist to wet		D	0.4				
				U	0.5				
		CLAY - Very stiff, grey brown clay, slightly sandy, with fine grained sand, M>Wp			0.8	50	pp = 400		
					1.0				
	1			S	1.45		3,4,4 N = 8		
		From 1.70m, grey, with trace sand and some silt			1.9		pp = 400		
	2				2.5				
				S	2.7		pp = 350-400 3,7,5 N = 12		
					2.95				
	3								
	4	From 4.0m, stiff			4.0				
				S	4.3		2,4,5 N = 9 pp = 180-200		
					4.45				
	5								
					5.5		2,3,4 N = 7 pp = 150		
				S	5.8				
	5.95	Bore discontinued at 5.95m, limit of investigation			5.95				
	6								
	7								
	8								
	9								

**RIG:** 4WD mounted FG102

**DRILLER:** FICO (S.C)

**LOGGED:** West

**CASING:** Uncased

**TYPE OF BORING:** Solid flight auger

**WATER OBSERVATIONS:** No free ground water whilst augering

**REMARKS:**

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

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)



# BOREHOLE LOG

**CLIENT:** EPM Projects Pty Ltd  
**PROJECT:** Medowie Christian School  
**LOCATION:** Waropara Road, Medowie

**SURFACE LEVEL:** --  
**EASTING:** 392435  
**NORTHING:** 6377634  
**DIP/AZIMUTH:** 90°/--

**BORE No:** 2  
**PROJECT No:** 81808.00  
**DATE:** 23/9/2015  
**SHEET 1 OF 1**

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		
	0.06	FILLING - Generally comprising of brown wood chip mulch, with some silt and some sand, moist		D	0.2				
	0.4	At 0.06m, geofabric		D	0.5				
		CLAY - Firm, grey mottled brown clay, slightly silty, with trace fine to coarse grained sand, M>Wp			0.8		pp = 350-400		
		CLAY - Very stiff, yellow brown clay, with trace silt, M>Wp		U <sub>50</sub>	1.0				
					1.2		2,4,4 N = 8		
				S	1.65				
		From 2.0m, pale grey brown			2.5		pp = 350-400 3,5,7 N = 12		
				S	2.95				
					4.0		4,6,12 N = 18		
		From 4.0m, with trace ironstained gravel up to 40mm in size		S	4.3		pp = 300-350		
					4.45				
					5.5		pp = 350-400 3,8,10 N = 18		
				S	5.7				
					5.95				
					7.0		1,7,15 N = 22 pp = 550		
		From 7.0m, grey		S	7.3				
					7.45				
					8.5		4,14,20 N = 34		
				S					
	8.95	Bore discontinued at 8.95m, limit of investigation			8.95				

**RIG:** 4WD mounted FG102

**DRILLER:** FICO (S.C)

**LOGGED:** West

**CASING:** Uncased

**TYPE OF BORING:** Hand auger to 0.2m then solid flight augering

**WATER OBSERVATIONS:** No free ground water whilst augering

**REMARKS:**

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

SAMPLING & IN SITU TESTING LEGEND			
A	Auger sample	G	Gas sample
B	Bulk sample	P	Piston sample
BLK	Block sample	U	Tube sample (x mm dia.)
C	Core drilling	W	Water sample
D	Disturbed sample	W	Water seep
E	Environmental sample	W	Water level
		PID	Photo ionisation detector (ppm)
		PL(A)	Point load axial test Is(50) (MPa)
		PL(D)	Point load diametral test Is(50) (MPa)
		pp	Pocket penetrometer (kPa)
		S	Standard penetration test
		V	Shear vane (kPa)

# BOREHOLE LOG

**CLIENT:** EPM Projects Pty Ltd  
**PROJECT:** Medowie Christian School  
**LOCATION:** Waropara Road, Medowie

**SURFACE LEVEL:** --  
**EASTING:** 392504  
**NORTHING:** 6377687  
**DIP/AZIMUTH:** 90°/--

**BORE No:** 5  
**PROJECT No:** 81808.00  
**DATE:** 23/9/2015  
**SHEET 1 OF 1**

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		
	0.05	FILLING - Generally comprising grey brown, fine to medium grained sandy clay filling, with abundant rootlets, M>Wp		B	0.3				
	0.7	FILLING - Generally comprising of grey brown silty clay filling, with trace to some fine grained sand, roots, rootlets, timber and subrounded to subangular gravel up to 10mm in size, M>Wp		B	0.5				
	1.0	SILTY SAND / SANDY SILT - Medium dense, grey, fine grained sandy silt / silty sand, moist		D	0.9				
	1.3	CLAY - (Firm to stiff), grey brown silty clay, with some fine grained sand and trace roots and rootlets, M>Wp		B	1.1				
	1.5	Bore discontinued at 1.5m, limit of investigation							
	2								
	3								
	4								
	5								
	6								
	7								
	8								
	9								

**RIG:** 4WD mounted FG102

**DRILLER:** FICO (S.C)

**LOGGED:** West

**CASING:** Uncased

**TYPE OF BORING:** 300m solid flight auger

**WATER OBSERVATIONS:** No free ground water whilst augering

**REMARKS:**

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

SAMPLING & IN SITU TESTING LEGEND					
A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	W	Water seep	S	Standard penetration test
E	Environmental sample	W	Water level	V	Shear vane (kPa)

## Results of Dynamic Penetrometer Tests

**Client** EPM Projects Pty Ltd

**Project** Medowie Christian School

**Location** Waropara Road, Medowie

**Project No.** 81880.00

**Date** 23/09/2015

**Page No.** 1 of 1

Test Locations	1	2	3	4	5				
RL of Test (AHD)									
Depth (m)	<b>Penetration Resistance</b> Blows/150 mm								
Eastings	392444	392435	392449	392445	392504				
Northings	6377648	6377634	6377655	6377631	6377687				
0.00 – 0.15	0	0	1	0					
0.15 – 0.30	2	1	4	0					
0.30 – 0.45	3	2	7	1					
0.45 – 0.60	5	4	7	4					
0.60 – 0.75	8	11	9	5					
0.75 – 0.90	11	12	9	9					
0.90 – 1.05	16	15	9	15					
1.05 – 1.20		16	12	15					
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									

**Test Method** AS 1289.6.3.2, Cone Penetrometer ☒  
 AS 1289.6.3.3, Sand Penetrometer ☐

**Tested By** DJW  
**Checked By** MPG

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



# 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; landslide; 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 perpend).

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

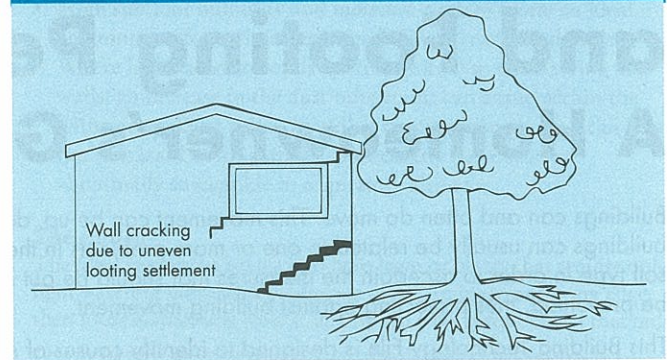
Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the 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

### Trees can cause shrinkage and damage



external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

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

#### Movement caused by tree roots

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

#### Complications caused by the structure itself

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

#### Effects on full masonry structures

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

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

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

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

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

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



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

#### Effects on framed structures

Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation 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.

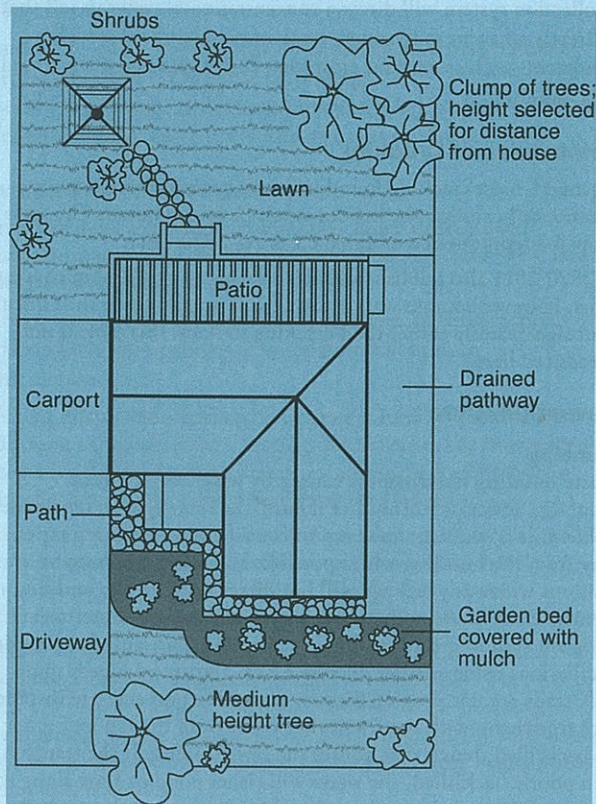
For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving should

#### 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.**

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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## Appendix B

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### Laboratory Test Results

## Result of Shrink-Swell Index Determination

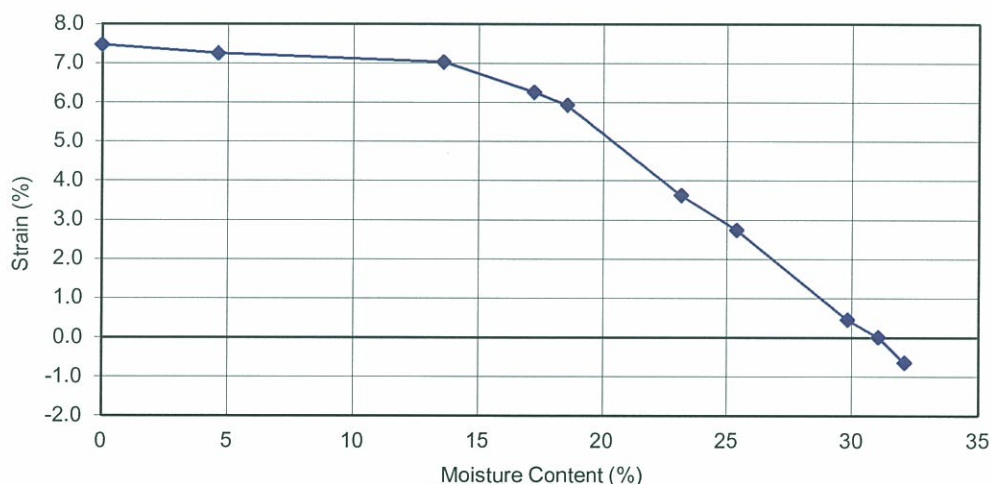
<b>Client :</b>	EPM Projects Pty Ltd	<b>Project No. :</b>	81808.00
<b>Project :</b>	Proposed Administration Building	<b>Report No. :</b>	N15-191_1
<b>Location :</b>	Waroparra Road, Medowie	<b>Report Date :</b>	08.10.2015
<b>Test Location :</b>	Bore 1	<b>Date Sampled :</b>	23.09.2015
<b>Depth / Layer :</b>	0.5 - 0.8m	<b>Date of Test:</b>	28.09.2015
		<b>Page:</b>	1 of 1

### CORE SHRINKAGE TEST

Shrinkage - air dried	7.2 %
Shrinkage - oven dried	7.5 %
Significant inert inclusions	0.0 %
Extent of cracking	SC
Extent of soil crumbling	0.0 %
Moisture content of core	31.0 %

### SWELL TEST

Pocket penetrometer reading at initial moisture content	400 kPa
Pocket penetrometer reading at final moisture content	220 kPa
Initial Moisture Content	30.1 %
Final Moisture Content	32.1 %
Swell under 25kPa	0.7 %



### SHRINK-SWELL INDEX $I_{ss}$ 4.3% per $\Delta pF$

<b>Description:</b>	Silty CLAY - Grey brown mottled red
<b>Test Method(s):</b>	AS 1289.7.1.1, AS 1289.2.1.1
<b>Sampling Method(s):</b>	Sampled by Newcastle Engineering Department
<b>Extent of Cracking:</b>	<div>UC - Uncracked</div> <div>SC - Slightly cracked</div> <div>MC - Moderately cracked</div> <div>HC - Highly cracked</div> <div>FR - Fractured</div>

### Remarks:

Note that NATA accreditation does not cover the performance of pocket penetrometer readings



NATA Accredited Laboratory Number: 828  
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

Tested:	JH
Checked:	DM

Dave Millard  
Laboratory Manager

## Result of Shrink-Swell Index Determination

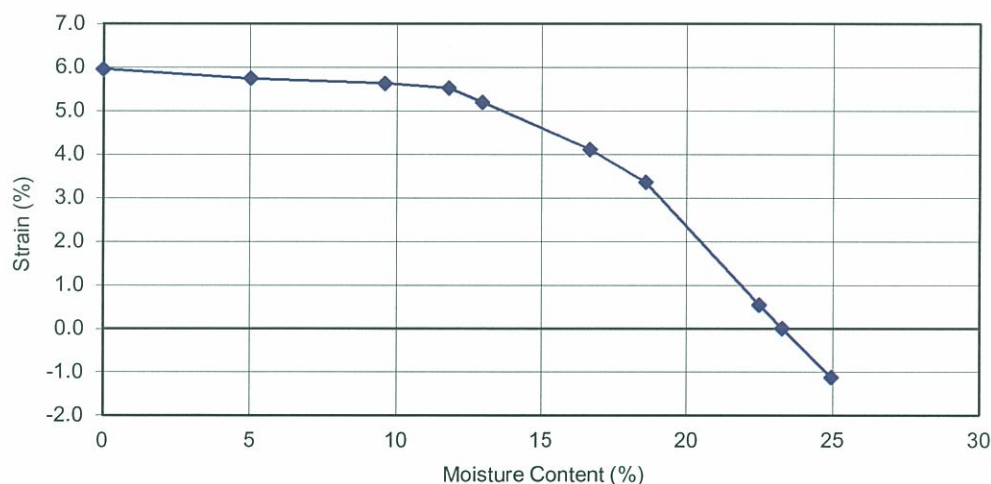
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<b>Project :</b>	Proposed Administration Building	<b>Report No. :</b>	N15-191_2
<b>Location :</b>	Waroparra Road, Medowie	<b>Report Date :</b>	08.10.2015
<b>Test Location :</b>	Bore 2	<b>Date Sampled :</b>	23.09.2015
<b>Depth / Layer :</b>	0.8 - 1.0m	<b>Date of Test:</b>	28.09.2015
		<b>Page:</b>	1 of 1

### CORE SHRINKAGE TEST

Shrinkage - air dried	5.7 %
Shrinkage - oven dried	5.9 %
Significant inert inclusions	0.0 %
Extent of cracking	UC
Extent of soil crumbling	0.0 %
Moisture content of core	23.2 %

### SWELL TEST

Pocket penetrometer reading at initial moisture content	300 kPa
Pocket penetrometer reading at final moisture content	200 kPa
Initial Moisture Content	22.8 %
Final Moisture Content	24.9 %
Swell under 25kPa	1.1 %



### SHRINK-SWELL INDEX $I_{ss}$ 3.6% per $\Delta pF$

<b>Description:</b>	Silty CLAY - Grey brown
<b>Test Method(s):</b>	AS 1289.7.1.1, AS 1289.2.1.1
<b>Sampling Method(s):</b>	Sampled by Newcastle Engineering Department
<b>Extent of Cracking:</b>	<div>UC - Uncracked</div> <div>SC - Slightly cracked</div> <div>MC - Moderately cracked</div> <div>HC - Highly cracked</div> <div>FR - Fractured</div>

#### Remarks:

Note that NATA accreditation does not cover the performance of pocket penetrometer readings



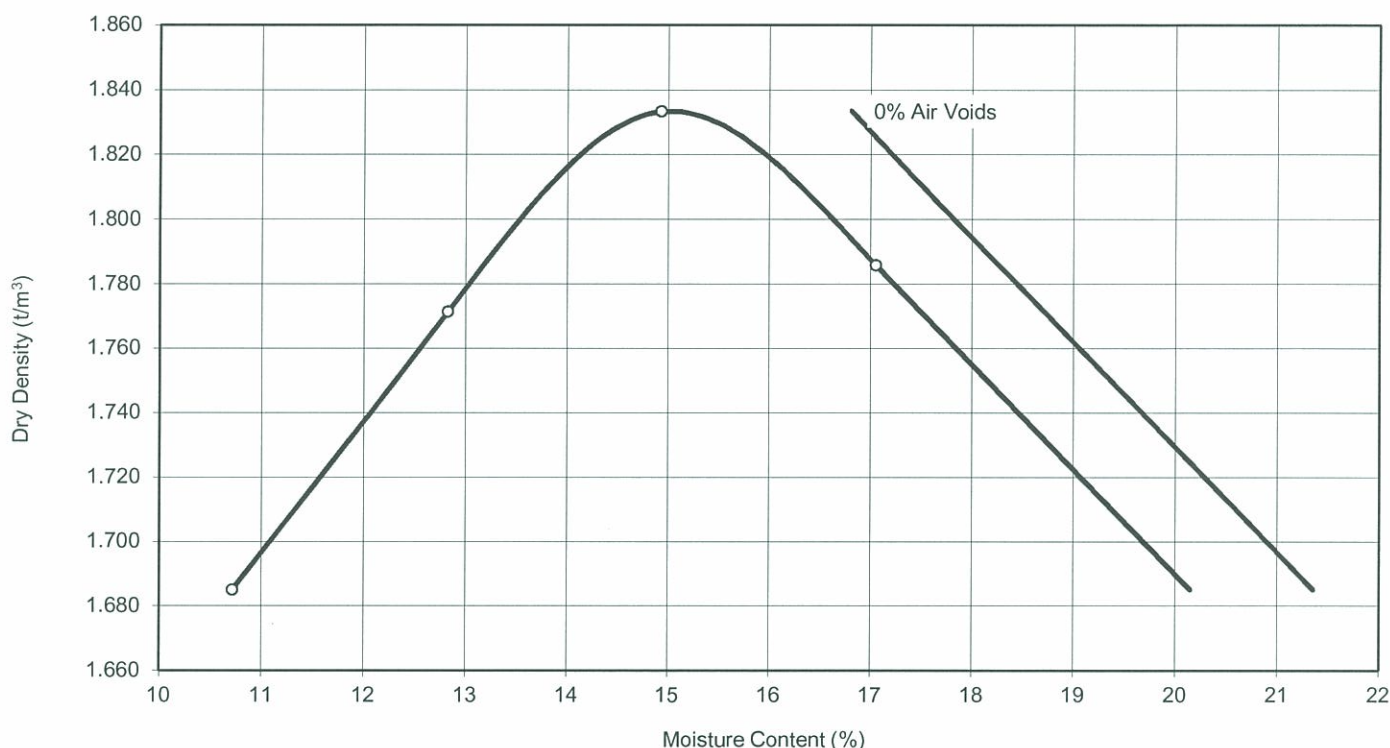
NATA Accredited Laboratory Number: 828  
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

Tested:	JH
Checked:	DM

Dave Millard  
Laboratory Manager

## Results of Compaction Test

<b>Client :</b>	EPM Projects Pty Ltd	<b>Project No. :</b>	81808
<b>Project :</b>	Proposed Administration Building	<b>Report No. :</b>	N15-191_3
<b>Location :</b>	Waroparra Road, Medowie	<b>Report Date :</b>	08.10.2015
		<b>Date of Test:</b>	29.09.2015
		<b>Page:</b>	1 of 1



**Sample Details:** Location: Bore 5  
Depth: 1.1 - 1.3m

Particles > 19mm: 0%

**Description:** Sandy Silty CLAY - Brown grey

<b>Maximum Dry Density:</b>	<b>1.83 t/m³</b>
<b>Optimum Moisture Content:</b>	<b>15.0 %</b>

**Remarks:**

**Test Methods:** AS 1289.5.1.1, AS 1289.2.1.1

**Sampling Methods:** Sampled by DP Engineering Department



NATA Accredited Laboratory Number: 828  
The results of the tests, calibrations and/or measurements included in this document are traceable to Australian/national standards. Accredited for compliance with ISO/IEC 17025

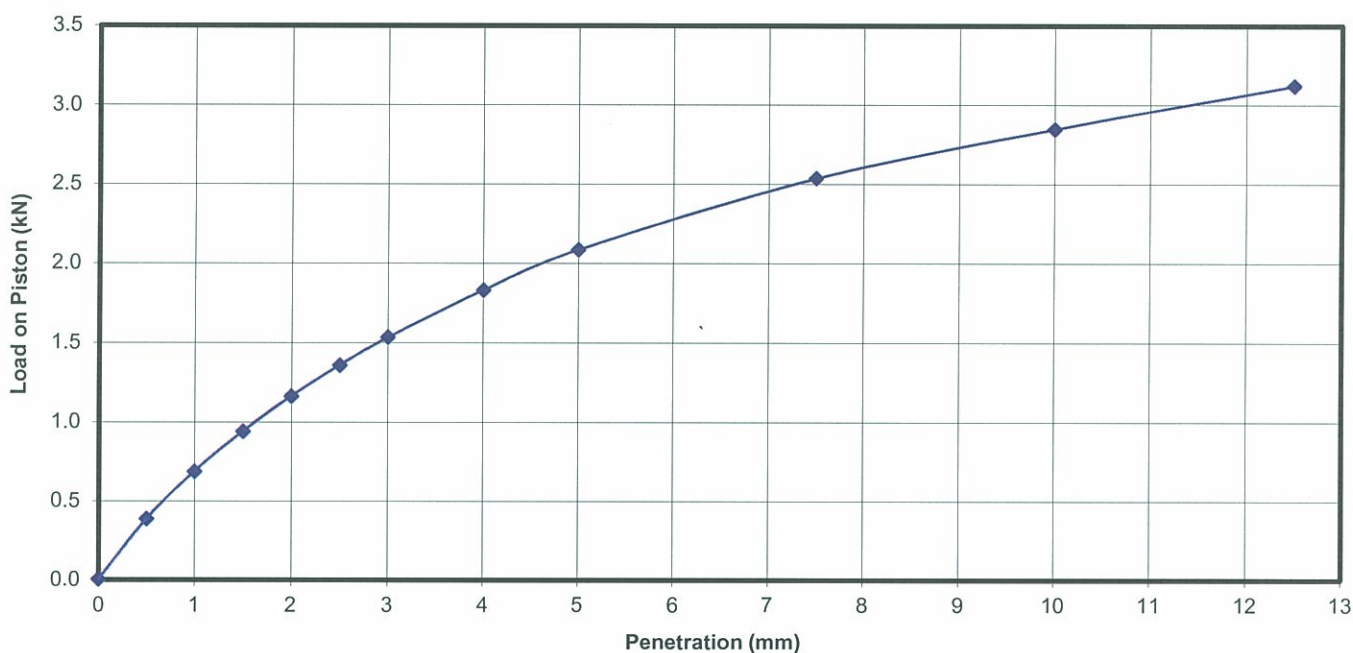
Tested:	JH
Checked:	DM

Dave Millard  
Laboratory Manager



## Result of California Bearing Ratio Test

<b>Client :</b>	EPM Projects Pty Ltd	<b>Project No. :</b>	81808
<b>Project :</b>	Proposed Administration Building	<b>Report No. :</b>	N15-191_4
<b>Location :</b>	Waraparra Road, Medowie	<b>Report Date :</b>	08.10.2015
<b>Test Location :</b>	Bore 5	<b>Date Sampled :</b>	23.09.2015
<b>Depth / Layer :</b>	1.1 - 1.3m	<b>Date of Test:</b>	06.10.2015
		<b>Page:</b>	1 of 1



**Description:** Sandy Silty CLAY - Brown grey

**Sampling Method(s):** Sampled by DP Engineering Department

**Test Method(s):** AS 1289.6.1.1, AS 1289.2.1.1

**Remarks:**

Percentage > 19mm: 0.0%

**LEVEL OF COMPACTION:** 99.5% of STD MDD

**SURCHARGE:** 4.5 kg

**SWELL:** 0.1%

**MOISTURE RATIO:** 101% of STD OMC

**SOAKING PERIOD:** 4 days

CONDITION	MOISTURE CONTENT %	DRY DENSITY t/m <sup>3</sup>
At compaction	15.1	1.82
After soaking	16.8	1.82
After test		
Top 30mm of sample	16.1	-
Remainder of sample	16.0	-
Field values	18.9	-
Standard Compaction (OMC/MDD)	15.0	1.83

RESULTS		
TYPE	PENETRATION	CBR (%)
TOP	5.0mm	11

**CERTIFICATE OF ANALYSIS**

**134939**

**Client:**

**Douglas Partners Newcastle**  
Box 324 Hunter Region Mail Centre  
Newcastle  
NSW 2310

**Attention:** Michael Gawn

**Sample log in details:**

Your Reference:	<b>81808, Medowie Christian School</b>
No. of samples:	2 Soils
Date samples received / completed instructions received	25/09/2015 / 25/09/2015

**Analysis Details:**

Please refer to the following pages for results, methodology summary and quality control data.  
Samples were analysed as received from the client. Results relate specifically to the samples as received.  
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.

***Please refer to the last page of this report for any comments relating to the results.***

**Report Details:**

Date results requested by: / Issue Date:	2/10/15 / 1/10/15
Date of Preliminary Report:	Not Issued

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Accredited for compliance with ISO/IEC 17025. **Tests not covered by NATA are denoted with \*.**

**Results Approved By:**



Jacinta Hurst  
Laboratory Manager

Misc Inorg - Soil			
Our Reference:	UNITS	134939-1	134939-2
Your Reference	-----	BH1	BH2
Depth	-----	1.0-1.45	0.5
Date Sampled		23/09/2015	23/09/2015
Type of sample		Soil	Soil
Date prepared	-	28/09/2015	28/09/2015
Date analysed	-	28/09/2015	28/09/2015
pH 1:5 soil:water	pH Units	4.7	4.9
Electrical Conductivity 1:5 soil:water	µS/cm	160	110
Chloride, Cl 1:5 soil:water	mg/kg	220	70
Sulphate, SO4 1:5 soil:water	mg/kg	29	69



MethodID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B.

**Client Reference: 81808, Medowie Christian School**

QUALITY CONTROL	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results	Spike Sm#	Spike % Recovery
Misc Inorg - Soil						Base II Duplicate II %RPD		
Date prepared	-			28/09/2015	[NT]	[NT]	LCS-1	28/09/2015
Date analysed	-			28/09/2015	[NT]	[NT]	LCS-1	28/09/2015
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	LCS-1	102%
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	LCS-1	101%
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	105%
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	108%

**Report Comments:**

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NA: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

### **Quality Control Definitions**

**Blank:** This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

**Duplicate:** This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

**Matrix Spike:** A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

**LCS (Laboratory Control Sample):** This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

**Surrogate Spike:** Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

### **Laboratory Acceptance Criteria**

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.

Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.

Spikes for Physical and Aggregate Tests are not applicable.

For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.

Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

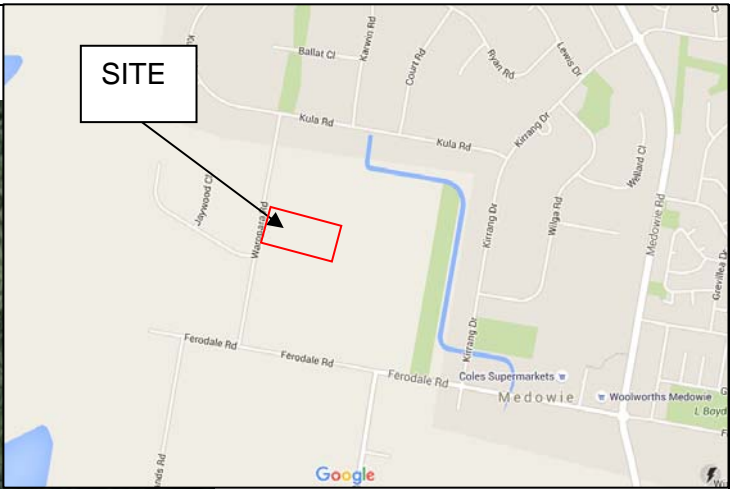
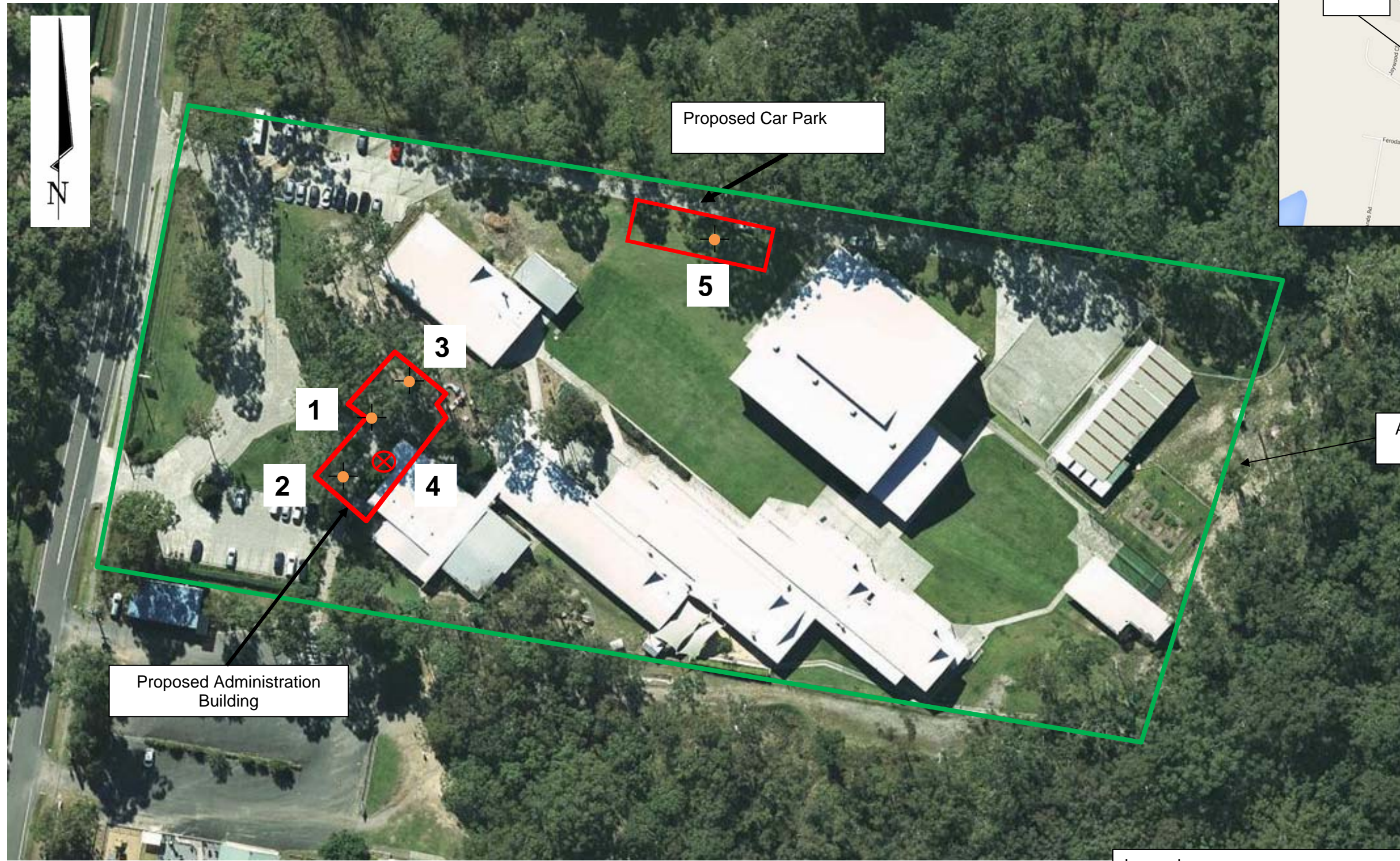
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## **Appendix C**

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Drawing 1 – Test Location Plan

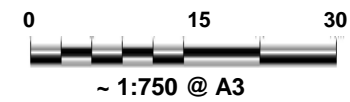





Locality of Site

Approximate boundary of school grounds

Notes:  
1. Drawing adapted from aerial image obtained from Spatial Information Exchange



Legend:	
	Approximate Test Bore Location and number
	Approximate DCP Location and number

 <b>Douglas Partners</b> <i>Geotechnics   Environment   Groundwater</i>	CLIENT: Medowie Christian School Limited		TITLE: <b>Test Location Plan</b>  <b>Proposed Administration Building</b>	PROJECT No: 81808.00
	OFFICE: Newcastle	DRAWN BY: MPG		DRAWING No: 1
	SCALE: 1:750@A3	DATE: 28.09.2015		REVISION: 0



## Memorandum

<b>To</b>	EPM Projects Pty Ltd		
<b>From</b>	Michael Gawn	<b>Date</b>	29 Feb 2016
<b>Subject</b>	Medowie Christian School	<b>Project No.</b>	81808.00

Following receipt of correspondence from Port Stephens Council dated 11 February 2016 and receipt of the latest plans for Stage 1 of the development at the Medowie Christian School, the following comments are made:

- DP was engaged to carry out a geotechnical investigation and preliminary site assessment (contamination). The results of these investigations are contained within our reports Project 81808 Documents 1 and 2;
- Reference to the Council letter indicates that comment is required as to whether the areas of environmental concern identified in our investigation are within the Stage 1 development. Reference to Drawing 1 of our preliminary site assessment should be made and indicates the following:
  - Surficial filling was identified in the area of the proposed administration building;
  - Filling associated with the pond embankments and proposed enlargement of the existing detention basin was also identified; and
  - Both of these areas appear to be within the area of Stage 1 development.
- Therefore, it can be concluded that there are identified areas of environmental concern within the proposed Stage 1 development footprint.
- As discussed in Section 9 of our report (Document 2), the presence or absence of contamination in these areas can only be confirmed by further investigation including environmental sampling and chemical testing. In DP's experience, this would be best addressed with a targeted intrusive contamination assessment with samples retrieved from the areas of environmental concern within the Stage 1 development area, for laboratory analysis for the contaminants of concern. It may be practical to carry out the Stage 2 targeted intrusive investigation during construction works.
- It is noted, as further stated in our report, the potential areas of environmental concern were generally localised and associated with near surface impacts, which would be readily addressed through appropriate investigation, and remediation (where required). Should contamination be identified during the Stage 2 investigation, DP could provide comment on suitable methods of remediation, if required.

In relation to the SEPP 55 requirements, contaminated site management and assessment in NSW is classified by the NSW EPA into the following stages:

- Stage 1 – Preliminary Site Investigation



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- Stage 2 – Detailed Site Investigation
- Stage 3 – Site Remedial Action Plan
- Stage 4 – Site Validation and Ongoing Monitoring.

A Stage 1 investigation was completed and identified a number of areas of potential contamination. The report concluded that the areas of potential contamination identified, once assessed and remediated, if necessary, will be suitable for the proposed land use.

We trust this meets your current requirements.

**Douglas Partners Pty Ltd**

Reviewed by

Michael Gawn  
**Principal**

Stephen Jones  
**Principal**