Limited Geotechnical Investigation

At

No 176 Salamander Way, Salamander Bay

For

St Philip's Christian College

25 October 2017

5QS Ref: 7209

5QS CONSULTING GROUP

25 October 2017
5QS Ref: 7209

St Philips Christian College
C/- Schreiber Hamilton Architects
224 Maitland Road
ISLINGTON NSW 2296

Attention: Mr Jonathon Dawes

Dear Sirs,

Re: Limited Geotechnical Investigation
Proposed Multi-Purpose Building
No 176 Salamander Way, Salamander Bay

The following report presents the results of a limited geotechnical investigation undertaken for the above property.

If you have any further enquiries please do not hesitate to contact the undersigned.

Yours faithfully

5QS Consulting Group

Peter Fennell
Director / Principal Geotechnical Engineer

Contents

Attachments

1. Drawing 7209/G1
2. Dynamic Cone Penetrometer Probe Logs
3. Engineering Logs
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7. Lime Types

Limited Geotechnical Investigation

Proposed Multi-Purpose Building

No 176 Salamander Way, Salamander Bay

1. Introduction

As requested, 5QS Consulting Group has prepared this report on a limited geotechnical investigation of proposed residential development at the above property. The proposed development is understood to involve construction of a new three-storey multi-purpose school building. The purpose of this report is to provide comment on:

- Geotechnical guidelines for development on the site;
- Site classification to Australian Standard AS2870–2011, 'Residential slabs and footings' [Ref 1];
- Risk of occurrence of acid sulfate soils [ASS];
- Comments on the need for an ASS management plan; and
- Suitability of on-site dispersal of stormwater.

The scope of this assessment included a desktop review of available published information, field work and preparation of this report. The following sections give the results of the assessment and comments on the above investigation scope.

2. Site Description

The site, identified as Lot 1 in DP 847022, Lots 143 and 144 in DP 715013 and Lot 1 in DP 7344433, occupies an area of approximately 3.1 hectares located on the southern side of Salamander Way, Salamander Bay. The site is bounded by Salamander Way and an existing church to the north, by existing residential development and undeveloped bushland to the east, and by undeveloped bushland to the south and west.

At the time of the investigation the area of the proposed development was occupied by existing classrooms and a grassed sporting field. Slopes on the site within the area of the proposed development are near level.

Various views of the property can be seen in Photographs P1 to P3.

Photograph P1 – View south-east through south-west, taken from near the eastern corner of the basketball courts

Photograph P2 – View south-west through north-west, taken from near the eastern corner of the Senior School Building (to be demolished)

Photograph P3 – View west through north, taken from existing sporting field to the south-east of the basketball courts

3. Background Information

3.1 Geological Setting

Reference to the ‘Newcastle 1:250 000 geological series sheet S1 56-2’, published by the Department of Mines (Ref 2) indicates that the site is underlain by sediments of Quarternary age, which typically include gravel, sand, silt, clay and “Waterloo Rock” marine and fresh water deposits.

3.2 Soil Landscape

The site lies in the Shoal Bay swamp landscape as identified on the ‘Port Stephens 1:100 000 soil landscape series sheet 9332’ and associated report, published by the NSW Department of Conservation and Land Management (Ref 3).

The Shoal Bay landscape is characterised by reedy deep organic mud swamps with open water. Slopes are less than 1 % with local relief less than 1 m. Soils typically comprise deep (greater than 300 cm) waterlogged, very poorly drained acid peats.

Limitations of the Shoal Bay swamp landscape include flood hazard, foundation hazard, permanent high watertables, waterlogging, high run-on, non-cohesive soils, deep highly plastic muds with very low wet strength.

3.3 Acid Sulfate Soil Risk

According to the Port Stephens 1:25 000 series acid sulfate soil risk map [Ref 4], the site lies within a Pleistocene aeolian swamp landform with surface levels at elevations in the order of 2 m to 4 m to the Australian height datum.

Ref 4 indicates that the site lies within an area having a low probability of occurrence of acid sulfate soils at depths between 1 m and 3 m of the ground surface.

4. Fieldwork

4.1 Methods

The fieldwork was undertaken on 4 October 2017 and consisted of a walkover assessment of the site and surrounding area by an engineer from 5QS Consulting Group, five dynamic cone penetrometer [DCP] tests, drilling of two boreholes and completion of one double-ring infiltrometer test.

4.2 Results

The subsurface profile encountered in borehole BH1 comprised sand with gravel filling to the limit of investigation at a depth of 2.1 m. The subsurface profile encountered in borehole BH2 comprised sand with gravel filling to 1.1 m depth, overlying sand to the limit of investigation at a depth of 1.9 m.

The probes at test locations DCP 1, DCP 2, DCP 3 and DCP 5 were driven to termination at depths of 6.85 m, 6.85 m, 6.9 m and 6.85 m, respectively. The probe at test location DCP 4 was driven to refusal at a depth of 0.35 m.

Free standing water levels were observed within boreholes BH1 and BH2 at depths of 2.05 m and 1.8 m, respectively.

Drawing 7209/G1 shows the approximate locations of the borehole and DCP tests.

5. Comments

5.1 Site Classification to AS 2870–2011

The site is classified as '**Class P**' (Problem site) based on the presence of sand filling at depths greater than 0.8 m within the footprint of the proposed development. Footings which are founded beneath all filling and in line with the advice given in Section 5.2, may be designed on the basis of a **Class 'S'** (Slightly Reactive) soil classification in accordance with Ref 1.

This site classification has not allowed for the effects of trees, poor site drainage, or leaking plumbing and exceptional moisture. These should be taken into consideration in the design of footing systems and the site should be maintained as outlined in the attached CSIRO Brochure BTF 18.

General information on site classification can be found in the attachment section of this report.

5.2 Geotechnical Guidelines for Site Development

5.2.1 Footings

All proposed footing systems should be designed in accordance with AS2870–2011 (Ref 1), or engineering principles. Consideration will need to be given to the required extent of excavation and filling of the site, including removal of any existing trees and site regrading, when selecting and designing the footing system.

Proposed footing systems should be designed and founded such that they are outside or below the zone of influence of all trenches/excavations in their vicinity. The zone of influence is defined by an envisaged line drawn upwards, and away, from the base of the excavation at a grade of about 2H:1V for cohesive (clay) soils, 2.5H:1V for granular (sand/gravel) soils and 1H:8V in weathered rock.

It is recommended that all footings be founded within consistent strata for the entire footprint of the proposed dwelling, ie, all footings to be founded within dense sands. It should be noted that under no circumstances should footings be founded within uncontrolled fill.

It is anticipated that deep footings founded within the natural profile of dense sands beneath all filling would be a suitable system of support for the proposed development.

Due to the high watertable encountered during the investigation and the potential risk of acid sulfate soils at likely founding depths continuous flight-auger (CFA) piles and open-bored cast-in-place concrete piles are not suitable for this site. Suitable alternate deep footing types include steel screw-piles or driven timber mini-piles. The use of driven piles will require careful consideration of the possible impacts on nearby structures from ground-induced vibrations due to the operation of piling equipment.

Unless filling of the site is to be carried out to engineering control in line with Australian Standard AS 3798–2007, ‘Guidelines on earthworks for commercial and residential developments’ (Ref 5), design of slabs and shallow footings should make no allowance for bearing capacity contribution from surface soils.

All footing installation work should be inspected by an appropriately qualified engineer who can confirm the founding levels and bearing capacities assumed for design.

5.2.2 Excavations

All permanent excavations in soil in excess of 0.8 m depth without battering on this site must be supported by engineer-designed retaining walls.

Permanent unsupported cuts in soil must be battered in accordance with the requirements of the Building Code of Australia, but in no case should be steeper than 2.5H:1V and must be protected from erosion.

Where applicable, the excavation design should incorporate surcharge loads from slopes, retaining walls, structures and other improvements within the vicinity of the excavation.

Drainage measures should be implemented above and behind all excavations to intercept both surface and subsurface water movement.

5.2.3 Filling

All fill to be placed on site to heights in excess of 1 m without battering must be supported by an engineer-designed retaining wall. Note that Council's planning guidelines may impose other restrictions. All unsupported filling should be battered in accordance with the requirements of the BCA Volume 2, but in no case should be either greater than 1 m in height or steeper than 2.5H:1V and must be protected from erosion.

Fill materials should be placed and compacted in layers of thickness and required degree of compaction to be determined in line with engineering design of proposed structures on the site.

5.2.4 Earthworks in General

Council's development guidelines should be reviewed during site planning as these might impose height limitations or support requirements on site cuts and fills.

5.2.5 Retaining Walls

All retaining walls on this site should be engineer-designed in accordance with the requirements of AS 4678–2002, 'Earth-retaining structures' (Ref 6). All retaining structures should be designed to support, where appropriate, surcharge loading due to any sloping ground surface above the retaining walls. All retaining walls should be constructed with adequate surface and subsurface drainage to the Engineer's and Council's requirements.

5.2.6 Site Drainage

The effective drainage from the site of surface and subsurface water is important to ensure the stability of the surface soil and the long-term performance of footing systems and retaining walls.

The property should be developed and maintained in accordance with the guidelines set out in Section 3 of the BCA and Appendix B of AS 2870–2011 [Ref 1]. In particular, the following measures are recommended:

- Catch/dish drains formed at the top and dish and rubble drains installed at the toe of all batters and subsoil drains installed behind new retaining walls;
- Cut areas sloped to fall away from proposed building areas and water not be allowed to pond around buildings;

- Surface stormwater and subsoil water collected and disposed of in accordance with Council's requirements; and
- Erosion control measures to be undertaken during construction to Council's requirements.

5.3 Acid Sulfate Soil Risk Assessment

5.3.1 Screening Results

Samples of the filling and the natural soil profile were recovered from each borehole and screened for the presence of actual and/or potential acid sulfate soils [ASS] in accordance with the procedure outlined in the NSW Acid Sulfate Soil Advisory Committee (ASSMAC) document, 'Acid Sulfate Soils Assessment Guidelines' (Ref 7).

The results of ASS screening are summarised in Table 1.

Table 1: Summary of results of ASS screening

Sample ID	Sample Depth [a] (m)	Sample Description	Screening Test Results			
			pH			Strength of Reaction [b]
			pH_F	pH_{FOX}	$pH_F - pH_{FOX}$	
BH1	0.35–0.4	SAND	6.05	5.46	0.59	1
	1.6–1.65	SAND	5.58	4.81	0.77	1
	2.0–2.05	SAND	5.99	4.63	1.36	1
BH2	1.1–1.2	SAND	5.21	4.85	0.36	1
	1.6–1.7	SAND	5.93	5.19	0.74	1
Guideline [e]		Sands to loamy sands	< 4[c]	< 3.5[d]	≥ 1[d]	-
		Sandy loams to light clays				
		Medium to heavy clays & silty clays				

Notes to Table 1:
a Depth below ground surface
b Strength of Reaction
  1 no or slight reaction
  2 moderate reaction
  3 high reaction
  4 very vigorous reaction
  F bubbling/frothy reaction, indicative of organics
  H heat generated

c For actual acid sulphate soils (ASS)
d Indicative value only for Potential Acid Sulphate Soils (PASS)
e ASSMAC, 'Acid Sulfate Soils Assessment Guidelines' [Ref 7]

pH_F - soil pH Test (1:5 soil:distilled water)
pH_{FOX} - soil peroxide pH Test (1:4 soil:distilled water following oxidation of soil with 30% hydrogen peroxide

5.3.2 Interpretation of Acid Sulfate Soil Risk

Based on the desktop review of published information, observations of subsurface conditions on site and the results of the screening testing of samples obtained during the fieldwork, it was interpreted that the filling and the natural sandy soils present on the site are neither actual nor potential ASS.

5.3.3 ASS Management Plan

Acid sulfate soils [ASS] in their natural state pose little problem. One of the best forms of minimising ASS impacts is to **not disturb or modify the soils from their natural state, where practicable, and to transport no excavated materials off site which have the potential to generate ASS.**

It is interpreted that soils with the potential to generate ASS conditions on site may be present at depths greater than 2.1 m below existing ground surface levels. Footing excavations and trenches for the installation of building services on the site might encounter potential and / or actual acid sulfate soils if they are taken to depths greater than 2.1 m.

Based on the above comments, it is considered that **no specific ASS management plan is required for the construction of the proposed footing system on this site.**

If, at the time of construction, excavation is required to depths greater than 2.1 m, then further investigation might be required. Where it is not practicable to limit other site excavations to a maximum depth of 2.1 m below existing ground surface levels the following strategies to manage the impact of acid sulfate soils should be adopted:

- *Minimise ASS disturbance* by, for example, placing fill to accommodate the proposed excavations such that they do not penetrate further than about 2.1 m below pre-development ground surface levels (ie, as surveyed prior to all site works).

- *Limit the use of dewatering measures on the site unless essentially required*. Lowering the ground water table, for example, by spear point extraction or pumping from open pits or trenches, has the potential to expose ASS and cause them to oxidise, as well as generating acidic soil-water leachate. When the exposed soils again contact water, the products of ASS oxidation generate acid runoff. **No dewatering is to be carried out within the natural soil profile on this site without further detailed geotechnical assessment**.

- *Minimise air exposure time of excavated soils*. The length of time that excavated acid sulfate soils are exposed to air is to be minimised so as to reduce oxidation levels. **Progressive development of excavations and regular spraying of excavation are to be used to minimise exposure times**

- *Dose excavated soils and the surfaces of site excavations using an acid-neutralising agent.* **Excavated ASS materials are to be dosed with Grade 1 Agricultural lime**, at a nominal rate of 15 kg per tonne of excavated soil (to be confirmed by the results of detailed chemical analysis), and mixed using appropriate methods to control generation and movement of acid runoff. The base and sides of excavations and trenches within ASS materials should be dosed with agricultural lime at a rate of 1 kg/m^2.

- *Control the movement of leachate from oxidised ASS on the site*. Control all leachate movement using diversion and/or containment during site excavation work. **Excavation works are not to be undertaken during periods of wet weather or if wet weather is imminent**.

- *Monitor the process of neutralising acid products*. Excavated soils, groundwater and soil-water leachate that have been dosed with acid-neutralising agents are to be tested for pH level prior to re-use on site only.

It should be noted that there are health risks associated with the use of acid-neutralising agents such as lime which need to be addressed prior to site work. Contractors should undertake a risk assessment in relation to the use of lime and obtain a Material Safety Data Sheet for the particular lime-based materials that are proposed to be used.

For descriptions of lime types, refer to the information sheet in the attachments to this report.

5.4 Stormwater Disposal by On-site Infiltration

For on-site stormwater infiltration systems that are installed in accordance with the above advice, it is recommended that a **design long-term infiltration rate of 150 mm/hr** be adopted for the proposed development at this site. A factor of safety of 2 was applied to the results of the double ring infiltrometer test in order to derive the design value.

On-site stormwater infiltration systems should be installed such that the base is founded at a nominal depth of 0.6 m below existing ground surface.

It is advised that the base of the proposed infiltration system be inspected by a suitably qualified engineer at the time of excavation to confirm that the exposed soil conditions are consistent with the geotechnical parameters used as the basis for design of the system.

6. How to Use This Report

5QS Consulting Group has prepared this report on limited geotechnical investigation for the proposed multi-purpose school building at No 176 Salamander Way, Salamander Bay, in line with 5QS Consulting Group's proposals dated 22 and 27 September 2017. The following is a guide as to the intended scope and use of this report.

- This report is provided for the exclusive use of St Philip's Christian College for the purposes as described in the report. It may not be used or relied upon for other purposes or by a third party. 5QS Consulting Group can accept no responsibility for loss or damage arising out of the use of this report beyond its purpose as stated above, or incurred by any third party relying on the report without the express written consent of 5QS Consulting Group. In preparing this report 5QS Consulting Group has necessarily relied upon information provided by the client and/or their agents.
- The extent of testing associated with this assessment is limited to the borehole and DCP probe locations and variations in ground conditions may occur. The data from the test locations have been used to provide an interpretation of the likely subsurface profile at the site of the proposed development. The interpretation may or may not faithfully represent the actual subsurface conditions at the site. 5QS Consulting Group should be contacted immediately if subsurface conditions are subsequently encountered that differ from those described in this report so that we can review and re-interpret the geotechnical model on the basis of the additional data.
- Neither this report, nor sections from this report, should be used as part of a specification for a project without review and agreement by 5QS Consulting Group. This is because this report has been written as advice and opinion rather than instructions for construction.
- This report must be read in conjunction with all of the attachments.
- The recommendations provided in this report represent a summary of our technical advice. Please discuss the recommendations with the undersigned if you require any clarification.

Yours faithfully

5QS Consulting Group

Reviewed

WMaher

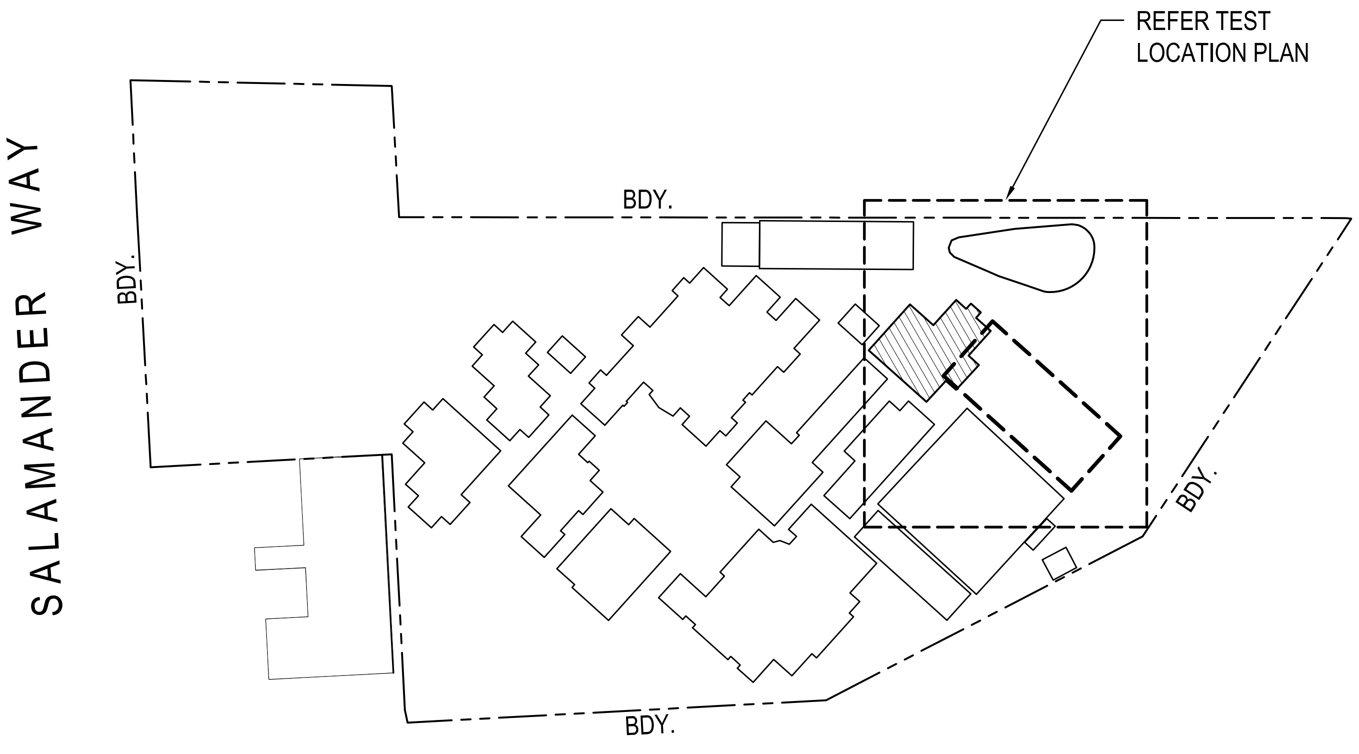
PFennell

William Maher
Professional Engineer

Peter Fennell
Director / Principal Geotechnical Engineer

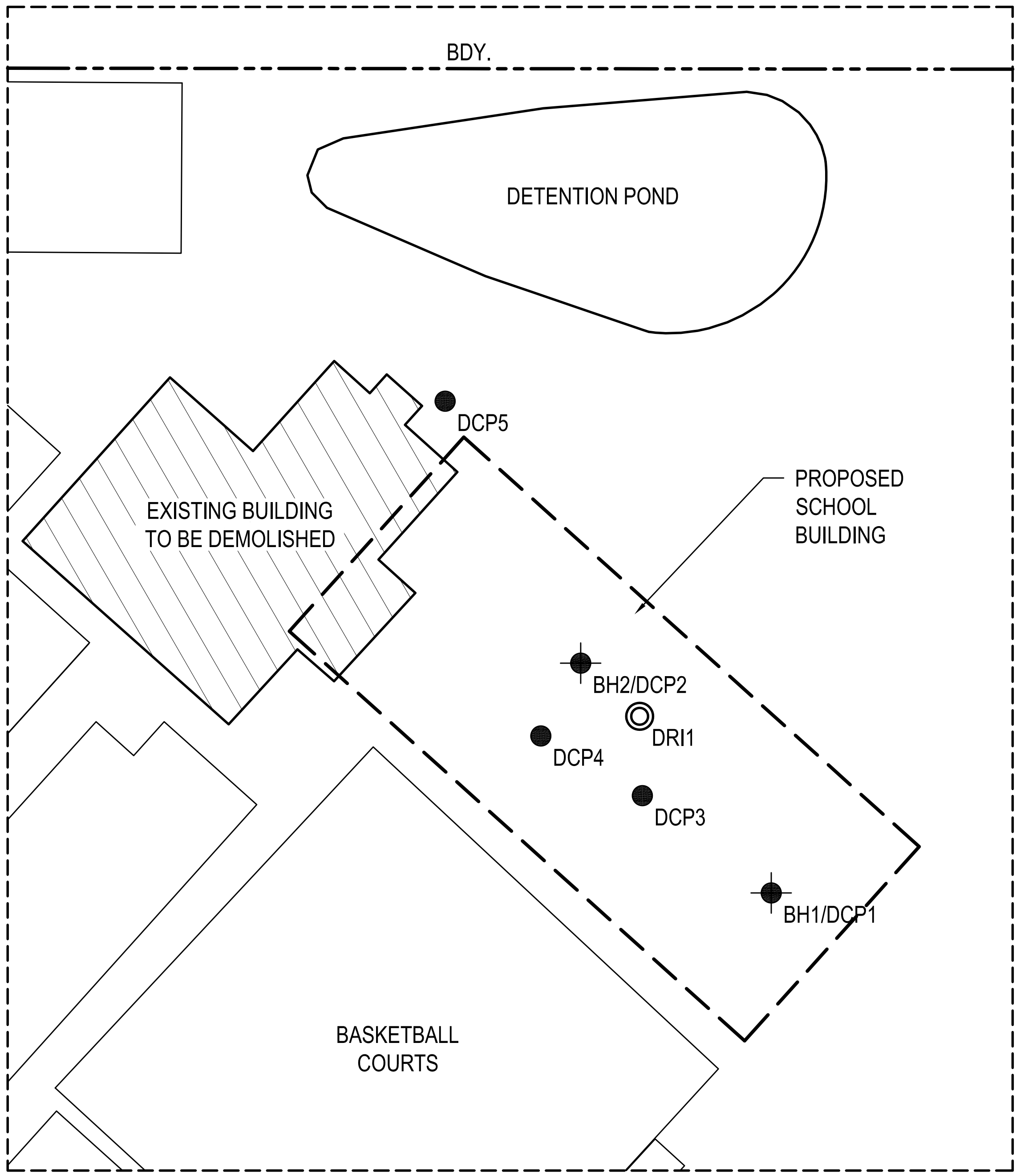
7. References

1. Australian Standard AS 2870–2011, ‘Residential slabs and footings’, Standards Australia (January 2011)
2. ‘Newcastle 1:250 000 geological series sheet S1 56-2, First Edition’, NSW Department of Mines (1966)
3. ‘Port Stephens 1:100 000 soil landscape series sheet 9332’, NSW Department of Land and Water Conservation (1995)
4. ‘Port Stephens 1:25 000 acid sulfate soil risk map – Edition Two’, NSW Department of Land and Water Conservation (December 1997)
5. Australian Standard AS 3798–2007, ‘Guidelines on earthworks for commercial and residential developments’, Standards Australia (March 2007)
6. Australian Standard AS 4678–2002, ‘Earth-retaining structures’, Standards Australia (February 2002)
7. ‘ASSMAC Acid Sulphate Soils Assessment Guidelines’, New South Wales Acid Sulphate Soil Management Advisory Committee (August 1998)



LOCALITY PLAN

SCALE 1:2000



TEST LOCATION PLAN

SCALE 1:500

LEGEND

● DCP	APPROXIMATE LOCATION OF DYNAMIC CONE PENETROMETER TEST
⊕ BH/DCP	APPROXIMATE LOCATION OF BORE HOLE AND DYNAMIC CONE PENETROMETER TEST
◎ DRI	APPROXIMATE LOCATION OF DOUBLE RING INFILTROMETER TEST

REV.	DATE	ISSUE DESCRIPTION	DESIGN	DRAWN	CHECKED
-	10.10.17	Report Issue		WJM	

Approved:

PO Box 63, Warners Bay NSW 2282
(02) 4952 1666
admin@5qs.com.au

TEST LOCATION PLAN
PROPOSED SCHOOL BUILDING
176 SALAMANDER WAY, SALAMANDER BAY
ST PHILLIPS CHRISTIAN COLLEGE

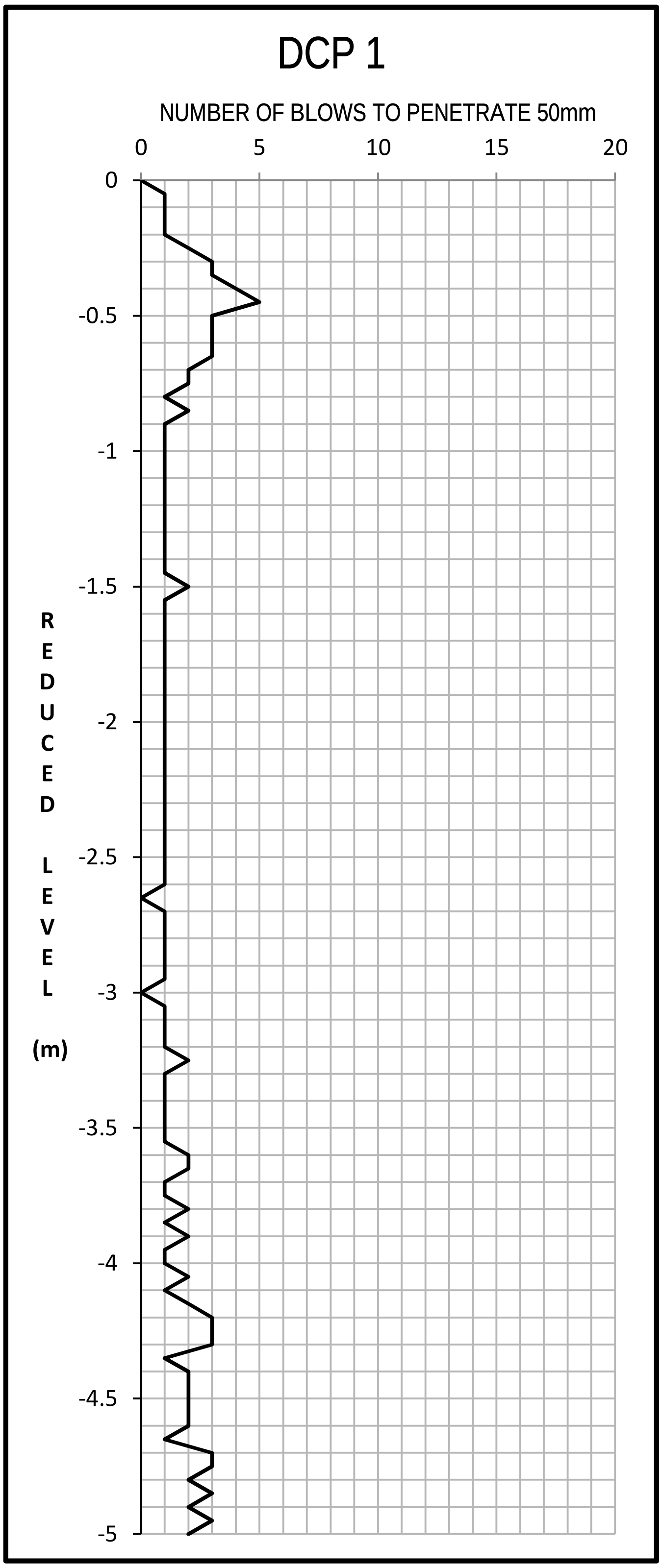
Drawing: 7209
Sheet: G1
Revision: -
Original Sheet Size: A3

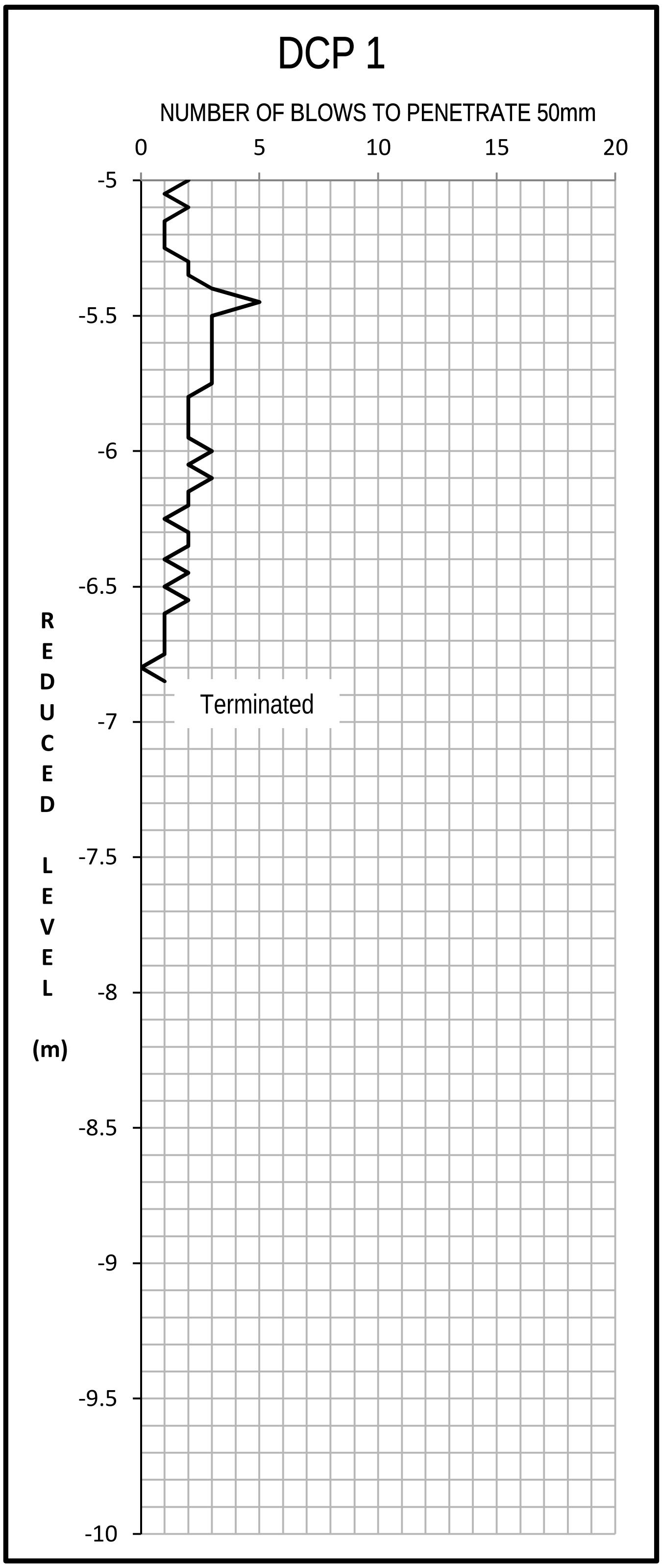
DYNAMIC CONE PENETROMETER LOG

Location:	176 Salamander Way, Salamander Bay		
Client:	St Philip's Christian College	5QS Ref:	7209
Position:	Refer to test location plan - Drawing 7209/G1	Date:	04-Oct-17
Groundwater:	Nil encountered	Logged By:	WJM

Surface RL: Not Known

Surface RL: Not Known





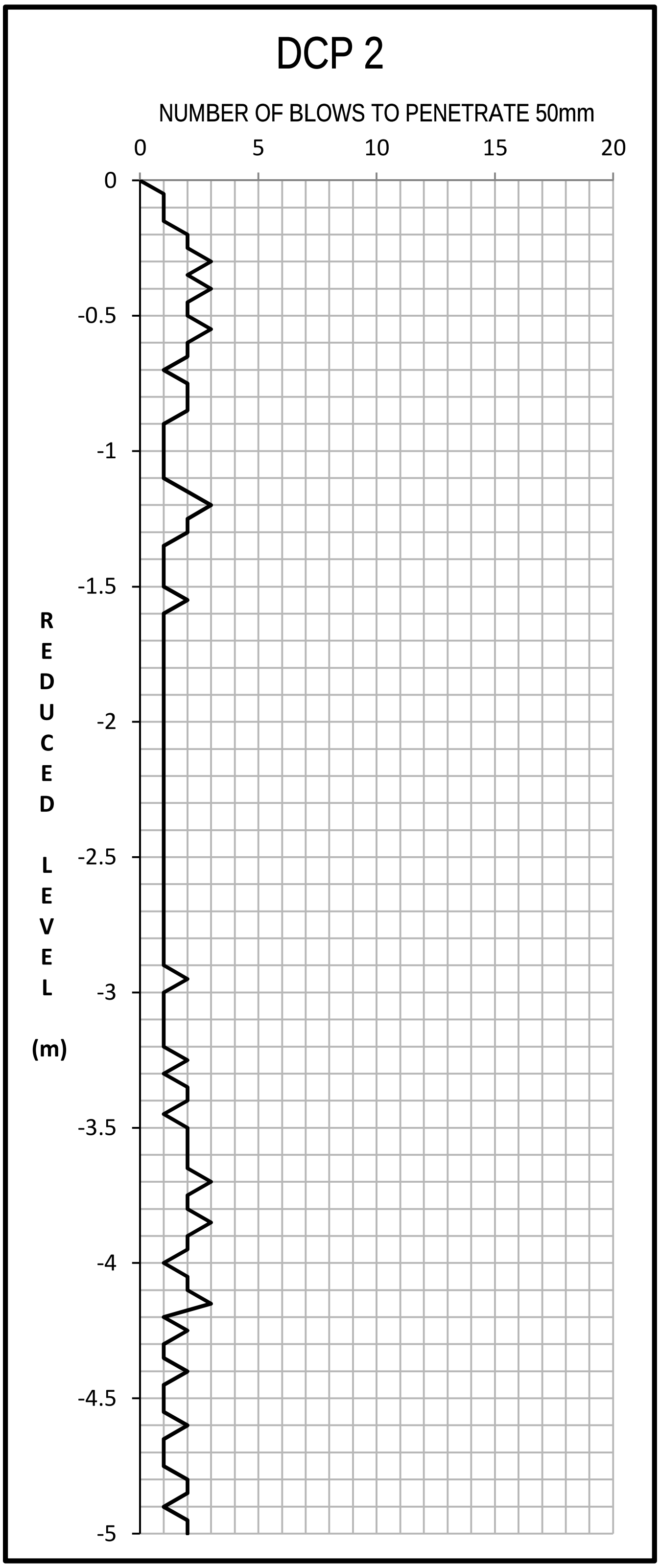
DYNAMIC CONE

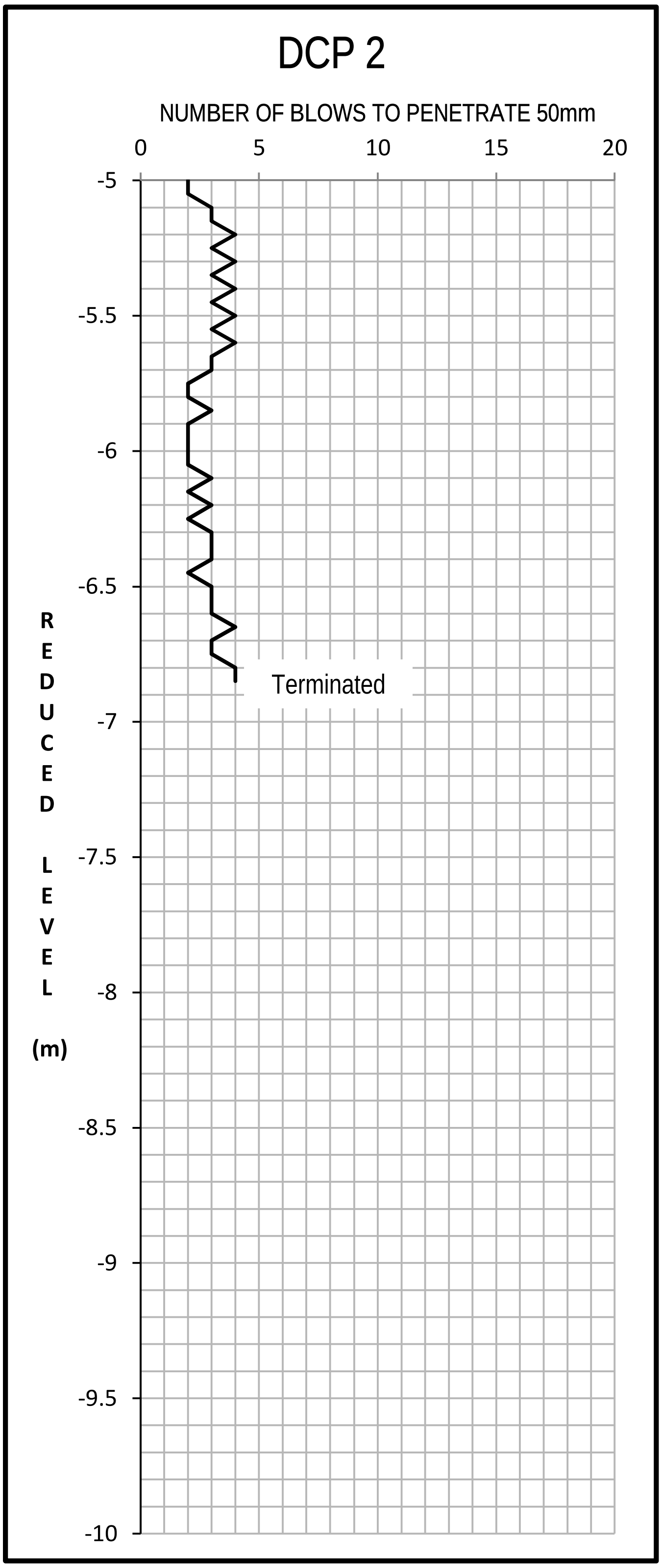
PENETROMETER LOG

Location:	176 Salamander Way, Salamander Bay		
Client:	St Philip's Christian College	5QS Ref:	7209
Position:	Refer to test location plan - Drawing 7209/G1	Date:	04-Oct-17
Groundwater:	Nil encountered	Logged By:	WJM

Surface RL: Not Known

Surface RL: Not Known





DYNAMIC CONE

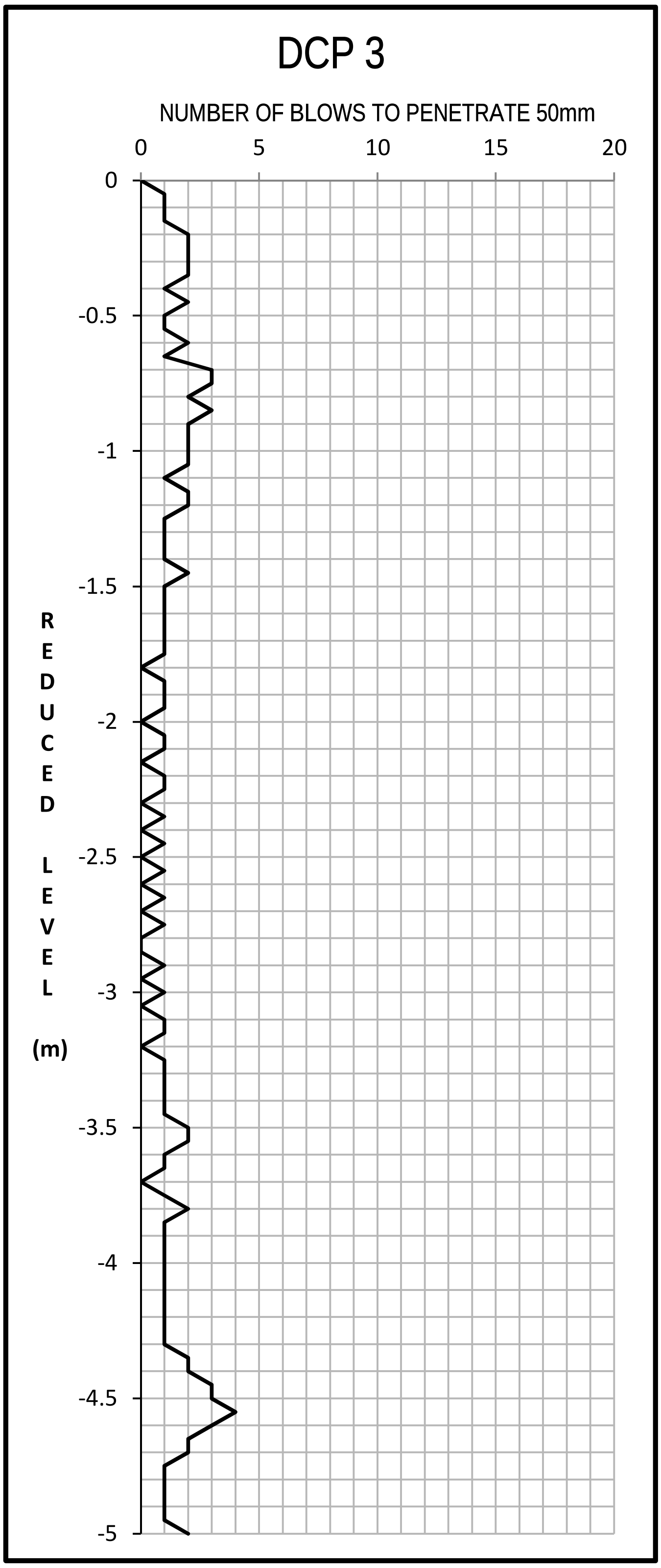
PENETROMETER LOG

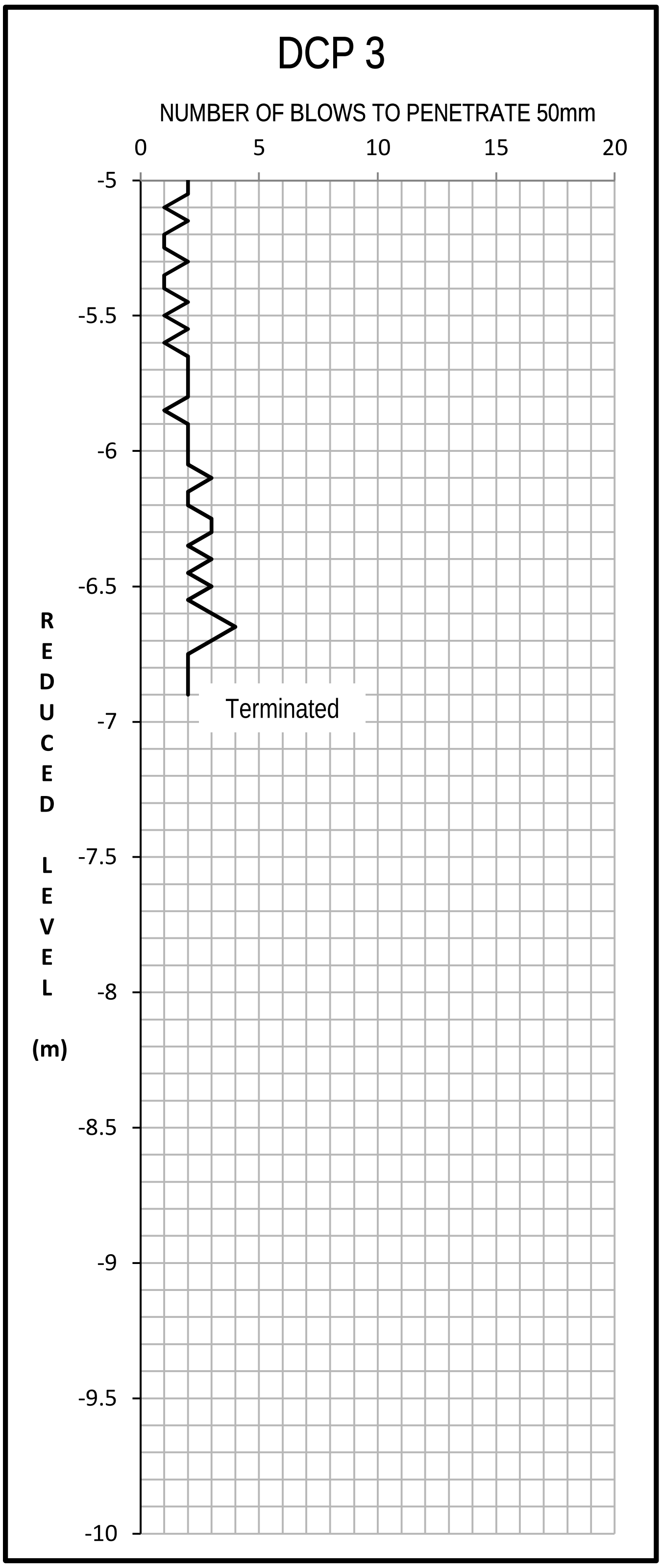
Location: 176 Salamander Way, Salamander Bay
Client: St Philip's Christian College
Position: Refer to test location plan - Drawing 7209/G1
Groundwater: Nil encountered

5QS Ref: 7209
Date: 04-Oct-17
Logged By: WJM

Surface RL: Not Known

Surface RL: Not Known



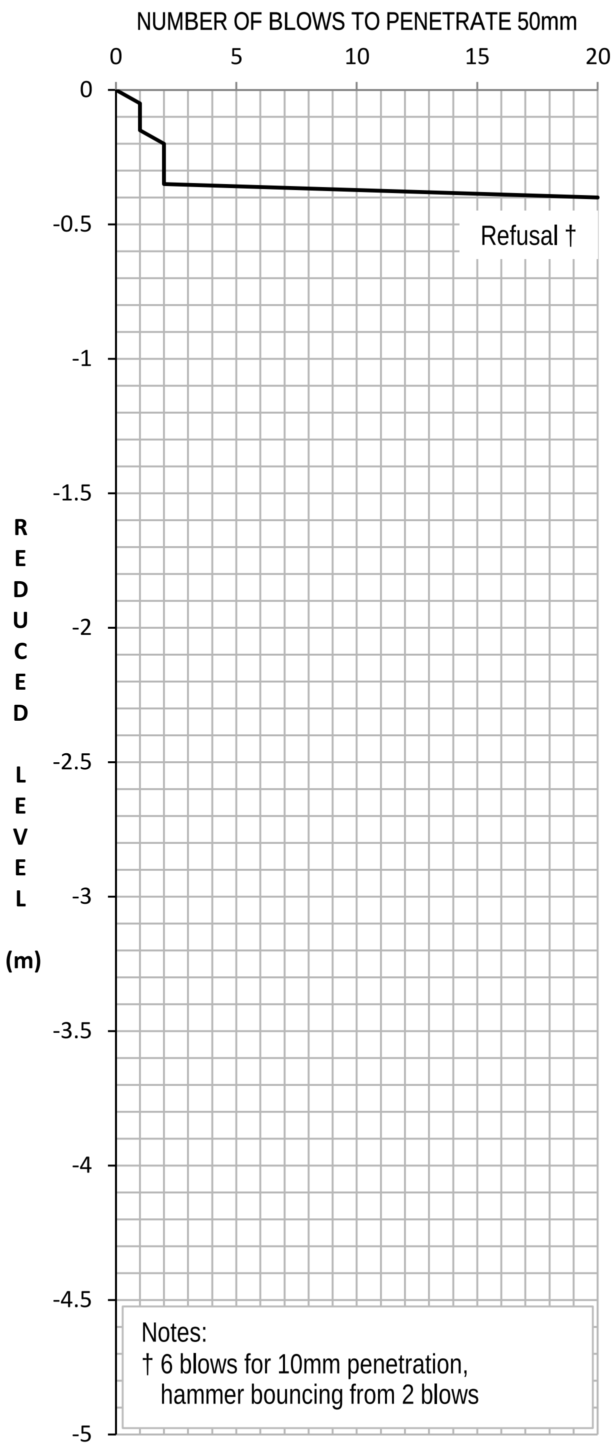


DYNAMIC CONE PENETROMETER LOG

Location:	176 Salamander Way, Salamander Bay		
Client:	St Philip's Christian College	5QS Ref:	7209
Position:	Refer to test location plan - Drawing 7209/G1	Date:	04-Oct-17
Groundwater:	Nil encountered	Logged By:	WJM

Surface RL: Not Known

DCP 4



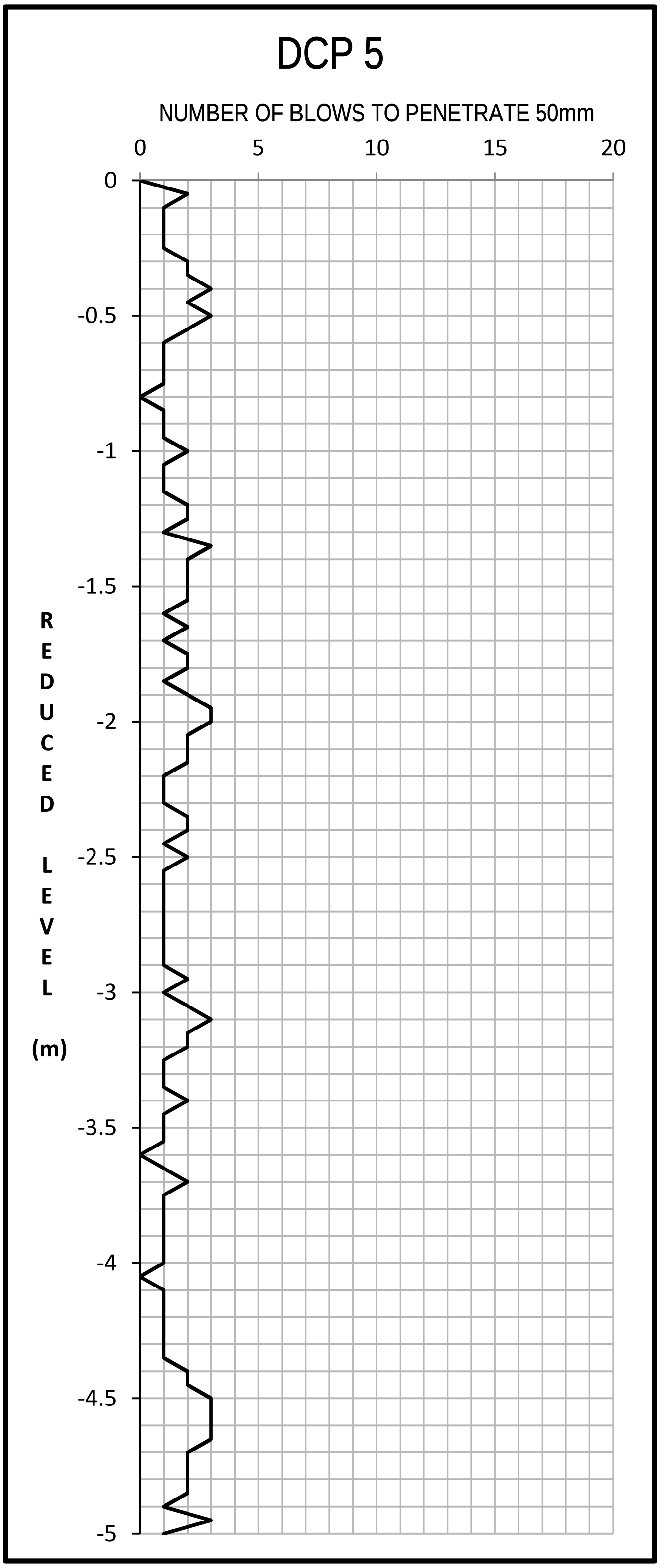
Notes:
† 6 blows for 10mm penetration,
hammer bouncing from 2 blows

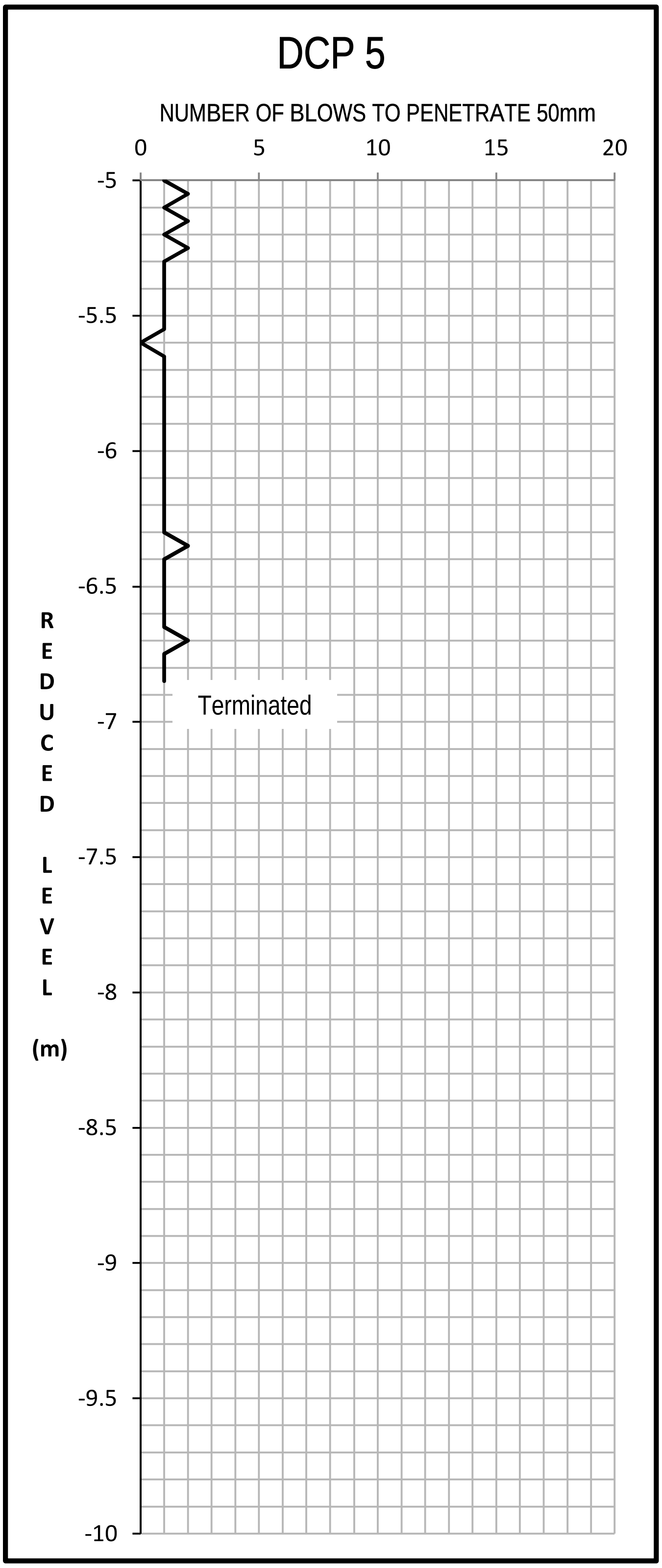
DYNAMIC CONE PENETROMETER LOG

Location:	176 Salamander Way, Salamander Bay		
Client:	St Philip's Christian College	5QS Ref:	7209
Position:	Refer to test location plan - Drawing 7209/G1	Date:	04-Oct-17
Groundwater:	Nil encountered	Logged By:	WJM

Surface RL: Not Known

Surface RL: Not Known

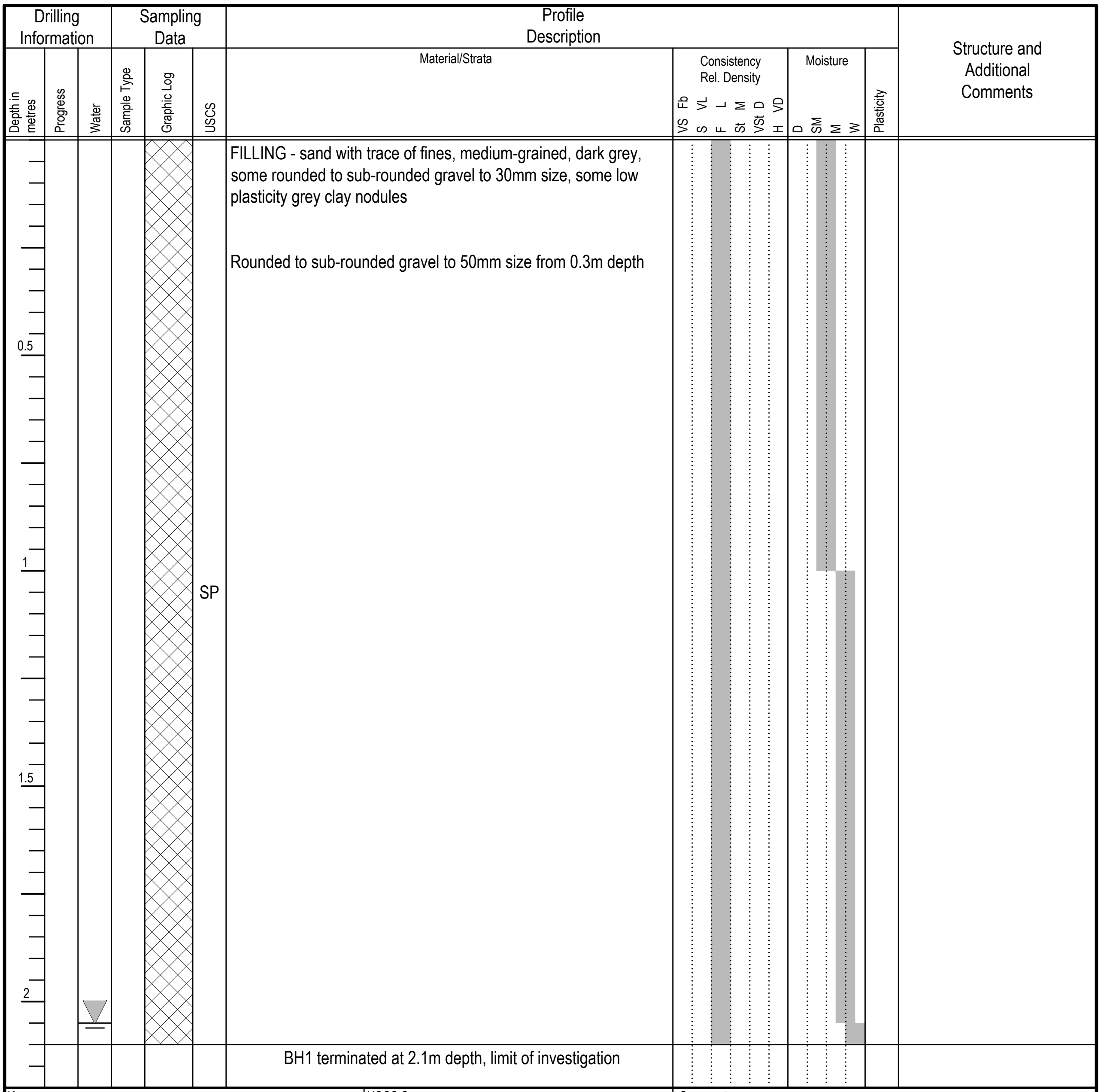




ENGINEERING LOG

Location: 176 Salamander Way, Salamander Bay
Client: St Phillip's Christian College
Position: See test location plan - Drawing 7209/G1
Surface RL: Not known
Groundwater: Freestanding water at 2.05m depth

Borehole No: BH1
Equipment: Hand Augers†
Logged By: WJM
Job No: 7209
Date: 4 Oct 2017



FILLING - sand with trace of fines, medium-grained, dark grey, some rounded to sub-rounded gravel to 30mm size, some low plasticity grey clay nodules

Rounded to sub-rounded gravel to 50mm size from 0.3m depth

BH1 terminated at 2.1m depth, limit of investigation

Key

Water
seeping
free standing

Moisture
D dry
M moist
W wet

Sampling Data
U50 undisturbed sample 50mm diameter
D disturbed sample
NC cone penetrometer
B bulk sample

Plasticity
NP Non Plastic
L Low
M Medium
H High

Consistency
Relative Density

VS	very soft		
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VSt	very dense

USCS Summary

GW	GRAVEL, well graded
GP	GRAVEL, poorly graded
GM	Silty GRAVEL
GC	Clayey GRAVEL
SW	SAND, well graded
SP	SAND, poorly graded
SM	Silty SAND
SC	Clayey SAND
ML	Low plasticity SILT
CL	Low plasticity CLAY
MH	High plasticity SILT
CH	High plasticity CLAY
OL, OH, Pt	Organic soils

Comments

† 160mm diameter clay cutter to 0.7m depth
75mm auger to limit of investigation

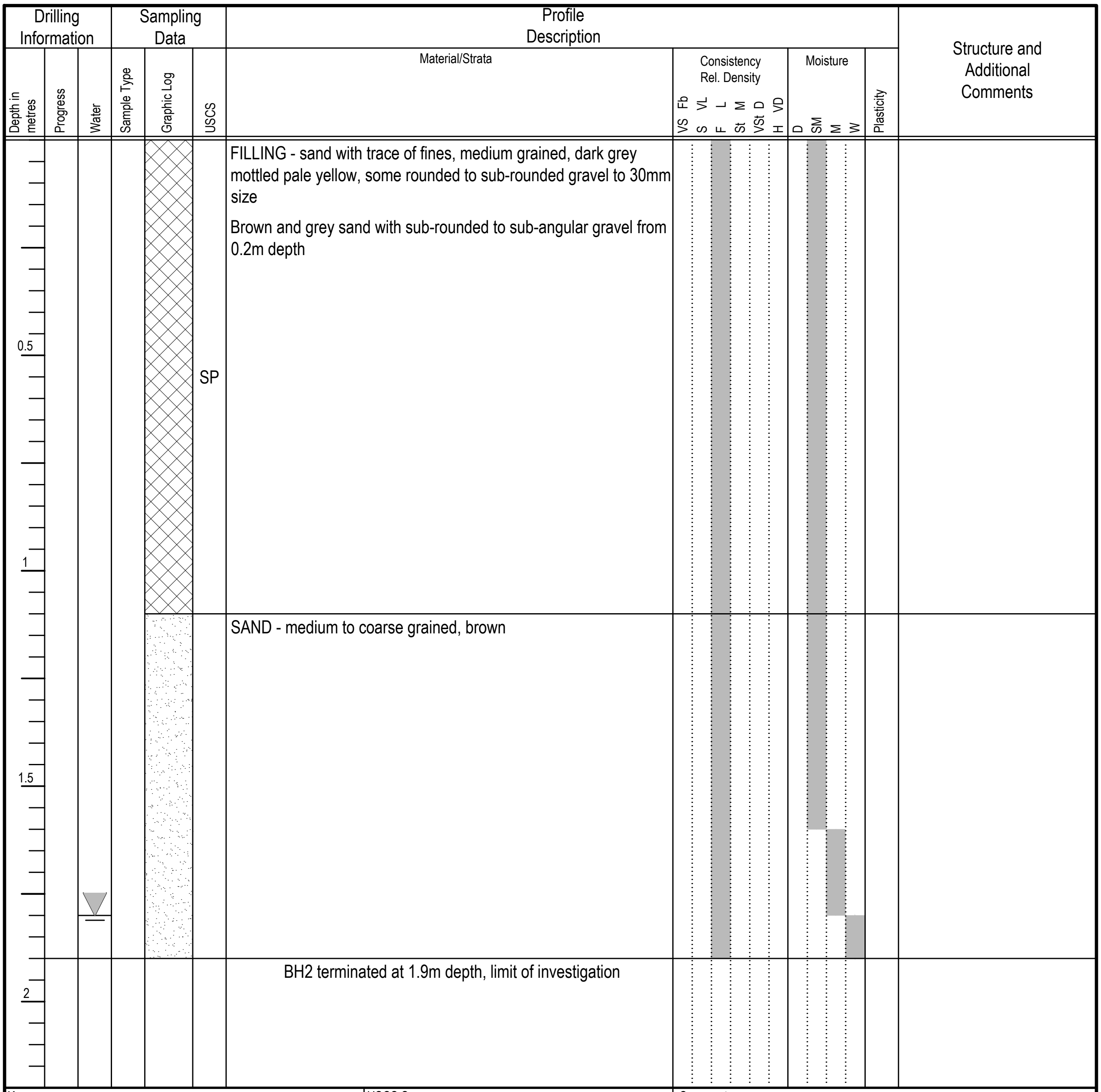
Refer to explanation sheet for description of terms and symbols used

ENGINEERING LOG

5QS CONSULTING GROUP

Location: 176 Salamander Way, Salamander Bay
Client: St Phillip's Christian College
Position: See test location plan - Drawing 7209/G1
Surface RL: Not known
Groundwater: Freestanding water at 1.8m depth

Borehole No: BH2
Equipment: Hand Augers†
Logged By: WJM
Job No: 7209
Date: 4 Oct 2017



FILLING - sand with trace of fines, medium grained, dark grey mottled pale yellow, some rounded to sub-rounded gravel to 30mm size

Brown and grey sand with sub-rounded to sub-angular gravel from 0.2m depth

SAND - medium to coarse grained, brown

BH2 terminated at 1.9m depth, limit of investigation

Key

Water
seeping
free standing

Plasticity

NP	Non Plastic
L	Low
M	Medium
H	High

Moisture

D	dry
M	moist
W	wet

Sampling Data

U50	undisturbed sample 50mm diameter
D	disturbed sample
NC	cone penetrometer
B	bulk sample

Consistency / Relative Density

VS	very soft		
S	soft	VL	very loose
F	firm	L	loose
St	stiff	M	medium dense
VSt	very stiff	D	dense
H	hard	VSt	very dense

USCS Summary

GW	GRAVEL, well graded
GP	GRAVEL, poorly graded
GM	Silty GRAVEL
GC	Clayey GRAVEL
SW	SAND, well graded
SP	SAND, poorly graded
SM	Silty SAND
SC	Clayey SAND
ML	Low plasticity SILT
CL	Low plasticity CLAY
MH	High plasticity SILT
CH	High plasticity CLAY
OL, OH, Pt	Organic soils

Comments

† 160mm diameter clay cutter to 0.4m depth
75mm auger to limit of investigation

Refer to explanation sheet for description of terms and symbols used

TERMS & SYMBOLS

Unified Soil Classification System (UCS)

COARSE-GRAINED SOILS More than half the material (by weight) is individual grains visible to the naked eye	GRAVELLY SOIL More than half of the coarse fraction is larger than 4.75mm	CLEAN GRAVEL Will not leave a stain on wet palm	Substantial amounts of all grain particle sizes	GW
			Predominantly one size or range of sizes with some intermediate sizes missing	GP
		DIRTY GRAVEL Will leave stain on wet palm	Non-plastic fines (to identify, see ML below)	GM
			Plastic fines (to identify, see CL below)	GC
	SANDY SOIL More than half of the coarse fraction is smaller than 4.75mm	CLEAN SAND Will not leave not leave a stain on wet palm	Wide range in grain size and substantial amounts of all grain particle sizes	SW
			Predominantly one size or range of sizes with some intermediate sizes missing	SP
		DIRTY SAND Will leave stain on wet palm	Non-plastic fines (to identify, see ML below)	SM
			Plastic fines (to identify, see CL below)	SC

	Ribbon	Liquid Limit	Dry crushing strength	Dilatancy reaction	Toughness	Stickiness	
FINE-GRAINED SOILS More than half the material (by weight) is individual grains not visible to the naked eye (< 0.074mm)	None	<50	None to slight	Rapid	Low	None	ML
	Weak	<50	Medium to high	None to very slow	Medium to High	Medium	CL
	Strong	>50	Slight to medium	Slow to medium	Medium	Low	MH
	Very Strong	>50	High to very high	None	High	Very high	CH
HIGHLY ORGANIC SOILS	Readily identified by colour, odour, spongy feel and frequently by fibrous texture						OL, OH, Pt

Description and classification of soils and rock in accordance with AS1726 'Geotechnical Site Investigations'

Plasticity A2.4(b)

Symbol	Descriptive term	Liquid limit (%)
NP	Non plastic	-
L	of low plasticity	< = 35
M	of medium plasticity	> 35 < = 50
H	of high plastic	> 50

Moisture Condition A2.5(a)

'Dry' (D)	Cohesive soils; hard and friable or powdery, well dry of plastic limit. Granular soils; cohesionless and free-running
'Moist' (M)	Soil feels cool, darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
'Wet' (W)	Soil feels cool, darkened in colour. Cohesive soils usually weakened and free water forms on hand when handling. Granular soils tend to cohere.

Consistency terms - Cohesive soils TA4

Term	USS (kPa)	Field guide to consistency
Very soft	< = 12	Exudes between fingers when squeezed in hand
Soft	12 - 25	Can be moulded by light finger pressure
Firm	25 - 50	Can be moulded by strong finger pressure
Stiff	50 - 100	Cannot be moulded by fingers, can be indented by thumb
Vary stiff	100 - 200	Can be indented by thumb nail
Hard	> 200	Can be indented with difficulty by thumbnail

Consistency terms - Non-Cohesive soils TA5

Term	Density Index (%)
Very loose	< = 15
Loose	15 - 35
Medium dense	35 - 65
Dense	65 - 85
Very Dense	> 85

TERMS & SYMBOLS

Symbols

Soil

Asphaltic Concrete or Hotmix
Concrete
Topsoil
Fill
Peat, Organic Clays and Silts (Pt, OL, OH)
Clay (CL, CH)
Silt (ML, MH)
Sandy Clay (CL, CH)
Silty Clay (CL, CH)
Gravelly Clay (CL, CH)
Sandy Silt (ML)
Clayey Sand (SC)
Silty Sand (SM)
Sand (SP, SW)
Clayey Gravel (GC)
Silty Gravel (GM)
Gravel (GP, GW)
Loam

Rock

Claystone (massive)
Siltstone (massive)
Shale (laminated)
Sandstone (undifferentiated)
Sandstone, fine grained
Sandstone, coarse grained
Conglomerate
Limestone
Coal
Dolerite, Basalt
Tuff
Porphyry
Granite
Pegmatite
Schist
Gneiss
Quartzite
Talus
Alluvium

Inclusions

Rock Fragments
Organic Material
Ironstone Gravel, Laterite
Shale Breccia in Sandstone

Seams

Seam >0.1m thick
Seam 0.01m to 0.1m thick

General Notes

Introduction

These notes are supplied with all geotechnical reports from **Barker Harle** and therefore may contain information not necessarily relevant to this report.

The purpose of the report is set out in the introduction section of this report. It should not be used by any other party, or for any other purpose, as it may not contain adequate or appropriate information in these events.

Engineering Reports

Barker Harle engineering reports are prepared by qualified personnel and are based on information obtained, and on modern engineering standards of interpretation and analysis of that information. 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 the design proposal or construction methods do change, **Barker Harle** request that it be notified and will be pleased to review the report and the sufficiency of the investigation work.

Geotechnical reports are based on information gained from limited subsurface test boring and sampling, supplemented by knowledge of local geology and experience. For this reason, the report must be regarded as interpretative, rather than a factual document, limited, to some extent, by the scope of information on which it relies.

***Barker Harle** cannot accept responsibility for problems which may develop if it is not consulted after factors considered in the report's development have changed.*

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

- Unexpected variations in ground conditions – the potential for this will depend partly on bore spacing and sampling frequency.
- The actions of contractors responding to commercial pressures.

If these occur, **Barker Harle** will be pleased to assist with investigation or advice to resolve the matter.

A Geotechnical Engineering Report May Be Subject To Misinterpretation

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a geotechnical engineering report. To help avoid these problems, **Barker Harle** should be retained to review the adequacy of plans and specifications relative to geotechnical issues.

Engineering Logs Should Not Be Separated From The Engineering Report.

Final engineering logs are developed by the Geotechnical Engineer based upon interpretation of field logs and laboratory evaluation of field samples. Only final engineering logs are included in geotechnical engineering reports. To minimize the likelihood of engineering log misinterpretation, *give contractors ready access to the complete geotechnical engineering report*.

Site Inspection

Barker Harle will always be pleased to provide inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit, to full time engineering presence on site.

Change In Conditions

Subsurface conditions may be modified by constantly changing natural forces. Because a geotechnical engineering report is based on conditions, which existed at the time of subsurface exploration, *construction decisions should not be based on a geotechnical engineering report whose adequacy may have been affected by time*.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes or groundwater fluctuations may also affect subsurface conditions and thus, the continuing adequacy of a geotechnical report. **Barker Harle** should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

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, **Barker Harle** requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed during construction, than at some later stage, well after the event.

Ground Water

Unless otherwise indicated the water levels given on the engineering logs are levels of free water or seepage in the test hole recorded at the given time of measuring. This may not accurately represent actual ground water levels, due to one or more of the following:

- In low permeability soils, ground water although present may enter the hole slowly, or perhaps not at all during the time it 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 prior weather changes. They may not be the same at the time of construction as indicated at the time of investigation.

Accurate confirmation of levels can only be made by appropriate instrumentation techniques and monitoring programs.

General Notes – Continued

Foundation Depth

Where referred to in the report, the recommended depth of any foundation, (piles, caissons, footings etc) is an engineering estimate of the depth to which they should be constructed. The estimate is influenced and perhaps limited by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications based upon this report should provide for variations in the final depth depending upon the ground conditions at each point of support.

Engineering Logs

Engineering logs presented in the report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on the 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 economically. In any case, the boreholes or test pits represent only a very small sample of the subsurface profile.

Interpretation of 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.

Drilling Methods

The following is a summary of drilling methods currently used by **Barker Harle**, and some comments on their use and application.

Continuous Sample Drilling: The soil sample is obtained by screwing a 75 or 100mm auger into the ground and withdrawing it periodically to remove the soil. This is the most reliable method of drilling in soils as the moisture content is unchanged and soil structure, strength, appearance etc. is only partially affected.

Test Pits: These are excavated using a backhoe or tracked excavator, allowing close examination of insitu soil if it is safe to descend into the pit. The depth of digging is limited to about 3 metres for a backhoe, and about 5 metres for an excavator. A potential disadvantage is the disturbance of the site caused by the excavation.

Hand Auger: The soil sample is obtained by screwing a 75mm Auger into the ground. This method is usually restricted to approximately 1.5 to 2 metres in depth, and the soil structure and strength is significantly disturbed.

Continuous Spiral Flight Augers: The soil sample is obtained by using a 90 – 115mm diameter continuous spiral flight auger which is withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays, and in sands above the water table. Samples, returned to the surface, are very disturbed and may be contaminated. Information from the drilling is of relatively lower reliability. SPT's or undisturbed sampling may be combined with this method of drilling for reasonably satisfactory sampling.

Hand Penetrometers

Hand Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and recording the number of blows for successive 50mm increments of penetration.

Two, relatively similar tests are used:

1. Perth Sand Penetrometer (AS 1289.5.3.3) – A 16mm flat ended rod is driven with a 9kg hammer, dropping 600mm. This test was developed for testing the density of sands and is mainly used in granular soils and loose fill.

2. Cone Penetrometer/Scala Penetrometer (AS 1289.5.3.2) – A 16mm rod with a 20mm diameter cone end is driven with a 9kg hammer dropping 510mm. The test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio (CBR) have been published by various road authorities.

Sampling

Sampling is carried out during drilling to allow engineering examination, and laboratory testing of the soil or rock.

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

Undisturbed samples are taken by pushing a think walled sample tube into the soils and withdrawing this with a sample of soil in a relatively undisturbed state contained inside. 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. Details of the type and method of sampling are given in the report.

Laboratory Testing

Laboratory testing is carried out in accordance with Australian Standard 1289 series, Methods of Testing Soils for Engineering Purposes. Details of the test procedure used are given on the individual report forms.

Site Classification Notes

General

Site classification is a method adopted in residential development for quantifying the anticipated surface movements that may occur on a site, generally due to soil reactivity. Soil reactivity is an appreciable change in soil volume due to a change in the moisture content of the soil. The extent of ground movement due to a reactive clay soil depends on the degree of reactivity of the clay, depth of clay in the soil profile, the depth of potential moisture variation in the soil and the change in soil suction that occurs from dry to wet soil conditions.

AS2870 – 2011 “Residential Slabs and Footings” classifies soil profiles in terms of their potential for shrink/swell movement due to changes in moisture content, to be slight (Class S), moderate (Class M), high (Class H1 or H2) or extreme (Class E). Sites with little or no reactivity are classified rock or sand (Class A), see table 2.1 below.

For classes; M, H1, H2 and E, further classification may be required, based on the depth of the expected moisture change. For sites with deep-seated moisture changes characteristic of dry climates and corresponding to a design depth of suction change (refer to AS 2870 – 2011, clause 2.3.3) equal to or greater than 3m, the classification shall be M-D, H1-D, H2-D, or E-D as appropriate.

AS2870 – 2011 Table 2.1 “Classification Based on Site Reactivity”

Class	Foundation	Characteristic Surface Movement
A	Most sand and rock sites with little or no ground movement from moisture changes	
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes	0 – 20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	20 – 40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes	40 – 60mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes	60 – 75mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes	> 75mm

Site Classification Notes - Continued

Problem Sites

Sites which include soft soils such as soft clay, silt or loose sands, landslip, mine subsidence, collapsing soils, soils subject to erosion or fill sites greater than 0.8m for sand and 0.4m for material other than sand are classified as Problem sites (Class P).

Classification Methods

Classification for sites other than class P sites shall be determined from at least one of the following methods:

- Identification of the soil profile based upon a visual assessment of the site and surrounding areas, excavated test pits and falling weight penetrometers probes.
- Interpretation of the current performance of existing buildings within the region that are founded on a similar soil profile.
- Site classification based on characteristic surface movement in accordance with AS2870 – 2011, clause 2.2.3, with parameters obtained from laboratory test results.

Effect of Trees

The presence of trees on a site can potentially affect the performance of the footing system by having an exaggerated effect on the moisture conditions of the soil. As a general rule, sites where trees are located within the mature height of the tree from the property boundary, will be classified as a Problem site (Class P).

There are a number of methods used to assess the potential impact of a tree on the reactive performance of a site. These include:-

- AS2870 provides a design method to account for the presence of trees within and in the vicinity of the proposed building footprint.
- The ‘Foundation and Footings Society of Victoria Method’ proposes a grading of trees with respect to the effect of their roots on nearby structures and suggests how their influence may be reduced.

A tree effect score and tree effect are determined from tables CH5.1 and CH5.2 respectively.

Foundation Maintenance and Footing Performance:

A Homeowner's Guide

CSIRO

BTF 18
replaces
Information
Sheet 10/91

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

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

Soil Types

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

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

Causes of Movement

Settlement due to construction

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

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

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

Erosion

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

Saturation

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

Seasonal swelling and shrinkage of soil

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

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

Shear failure

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

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

GENERAL DEFINITIONS OF SITE CLASSES

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

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

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

Unevenness of Movement

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

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

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

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

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

Effects of Uneven Soil Movement on Structures

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

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

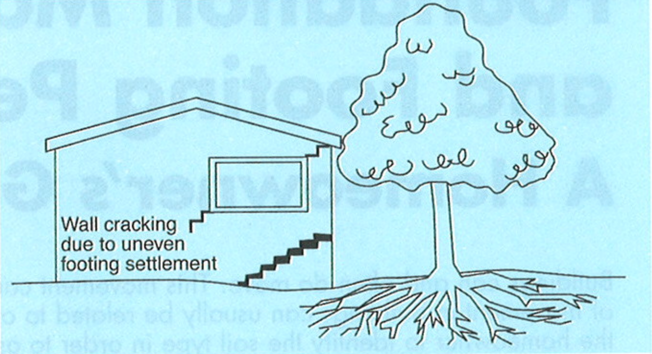
Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

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

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

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

Trees can cause shrinkage and damage



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

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

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

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

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

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

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

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

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

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

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

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

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

Water Service and Drainage

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

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

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

Seriousness of Cracking

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

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

Prevention/Cure

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

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

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

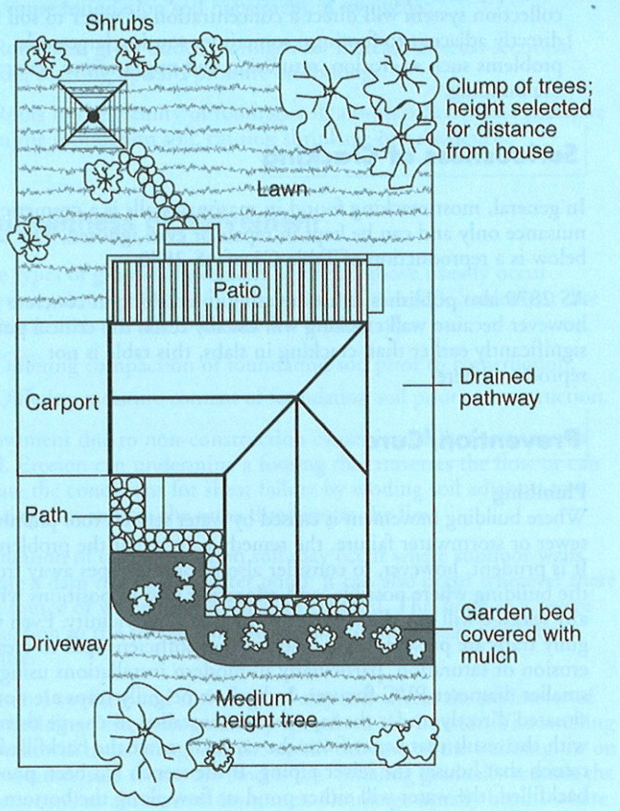
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

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

Gardens for a reactive site



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

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

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

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

Condensation

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

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

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

The garden

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

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

Existing trees

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

Information on trees, plants and shrubs

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

Excavation

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

Remediation

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

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

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

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Lime Types

Agricultural Lime

Agricultural lime products contain calcium and magnesium compounds that are capable of reducing / neutralising soil acidity. Agricultural limes are graded in terms of particle fineness and, therefore, speed of reaction with the soil. A term referred to as the effective neutralizing value (ENV) is the measure of fineness of lime.

Grade 1 Agricultural lime is specified with a minimum ENV of 80.

Hydrated Lime

"Hydrated lime" is a material, made from burnt lime, which consists essentially of calcium hydroxide or a combination of calcium hydroxide with magnesium oxide and magnesium hydroxide.

Burnt Lime

"Burnt lime" is a material made from limestone that consists essentially of calcium oxide or a combination of calcium oxide with magnesium oxide.

Quick Lime

“Quick Lime” is a material made from calcining limestone or shells, the heat driving off carbon dioxide and leaving lime. It is a white or grey caustic substance that develops great heat when treated with water, forming slaked lime.

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